

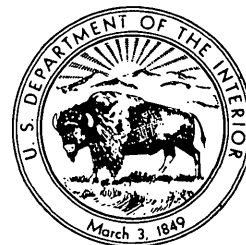
# Cretaceous and Tertiary Formations of the Book Cliffs Carbon, Emery, and Grand Counties, Utah, and Garfield and Mesa Counties, Colorado

By D. JEROME FISHER, CHARLES E. ERDMANN, and JOHN B. REESIDE, JR.

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GEOLOGICAL SURVEY PROFESSIONAL PAPER 332

*A description of 7,000 feet of  
strata ranging in age from  
Early Cretaceous to Eocene*



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# CRETACEOUS AND TERTIARY FORMATIONS OF THE BOOK CLIFFS, CARBON, EMERY, AND GRAND COUNTIES, UTAH, AND GARFIELD AND MESA COUNTIES, COLORADO

By D. JEROME FISHER, CHARLES E. ERDMANN, and JOHN B. REESIDE, JR.

## ABSTRACT

The Book Cliffs form a sinuous southward-facing escarpment that extends in a general eastward direction from the Wasatch Plateau in central Utah to Grand Mesa in western Colorado—a distance of 150 miles. The part of the Book Cliffs from the Wasatch Plateau to the Green River may be referred to as the western cliffs, the part in Utah east of the Green River as the central cliffs, and the part in Colorado as the eastern cliffs. South of the cliffs and bordering them continuously is a lowland locally bearing such names as Castle Valley and Grand Valley. South of the lowland lie three major structural features: from west to east the San Rafael Swell, the Salt Valley anticline, and the Uncompahgre uplift, which cause the sinuosity of the trend of the cliffs. At distances ranging up to 10 miles north of the Book Cliffs is another escarpment, the Roan or Brown Cliffs.

The lowland, the Book Cliffs, and the Roan Cliffs consist of Cretaceous and Tertiary strata that dip gently northward into the Uinta Basin and reach a total thickness of about 7,000 feet. The age range of the strata is from Early Cretaceous to Eocene.

The Cretaceous rocks include, at the base Lower Cretaceous units, the Cedar Mountain formation in Utah and the Burro Canyon formation in Colorado; then, in ascending order, Upper Cretaceous units, the Dakota sandstone, the Mancos shale, and the Mesaverde group. Above the Mesaverde group in the Book Cliffs are formations of undetermined age that seem to include beds which are also found in the Wasatch Plateau, where they extend from the Cretaceous into Tertiary; therefore, these formations are here called Cretaceous and Tertiary also. Above them are units considered definitely Tertiary. The Mesaverde group, because of lateral changes in character and composition, is divided into three sets of units. In the western cliffs the Star Point formation is not present as such, and the Blackhawk formation at the base of the group is overlain by the Castlegate sandstone and the Price River formation (restricted by removal of the Castlegate). In the central cliffs the much-thinned Blackhawk formation is overlain in succession by the Castlegate sandstone, the Buck tongue of Mancos shale, the Sego sandstone, the Neslen formation, the Farrer formation, and the Tuscher formation. In early reports the Sego, Neslen, and the Farrer formations have been considered members of the Price River formation, and the Tuscher formation was not included in the Mesaverde group. In the eastern cliffs the Sego sandstone is the basal unit, containing the Anchor Mine tongue of Mancos shale; the Sego is overlain by the Mount Garfield formation, containing in the lower part the "coal measures" with the Rollins sandstone member and in the upper part the "barren measures"; at the top is placed the Hunter Canyon formation. The formations

assigned to the Cretaceous and Tertiary are the North Horn and Flagstaff formations, undifferentiated, in the western cliffs and the western part of the central cliffs. The Tertiary formations are an unnamed sandstone in the eastern cliffs, the Colton formation of Eocene age in the western cliffs, the "Wasatch" formation of possible Paleocene and Eocene age in the central and eastern cliffs, and the Green River formation of Eocene age.

A comparison with standard sequence for the Rocky Mountains region indicates that the Lower Cretaceous formations are equivalent in age to the Kootenai formation (Aptian), the Dakota sandstone is early Late Cretaceous (Cenomanian), the Mancos shale includes rocks ranging in age from equivalents of the lower parts of the Bridge Creek limestone member of the Greenhorn limestone (late Cenomanian or early Turonian) to equivalents in the west perhaps of the Sharon Springs member of the Pierre shale and to equivalents in the east of the Gregory member of the Pierre shale (Campanian). The Mesaverde group generally has not yielded faunas datable more closely than very late Cretaceous.

The Lower Cretaceous rocks are nonmarine and fluviatile. The Dakota is both marine and nonmarine in Colorado and nonmarine and discontinuous in Utah. The Mancos shale is of marine origin, and the lowest parts of the Mesaverde are marine and brackish water, but the upper parts are everywhere nonmarine. The Upper Cretaceous beds record the entry into the region from the south and east of marine waters that spread rapidly; in these formed an initial deposit of sandy materials (Dakota). Then, over a long period the finer materials now composing the main body of the Mancos shale were deposited in the marine waters. These materials, though dominantly fine grained, were variable in character; notable hiatuses may be present. Deposition of the coarser grained Mesaverde group began much earlier in the west than the east and proceeded with much oscillation of the shoreline, recorded by the temporary extension of sandy marine sedimentary rocks and nonmarine rocks eastward and intervening extension of marine finer sedimentary rocks westward, though the net movement was a steady eastward retreat of the sea. The uppermost parts of the Mesaverde group are all nonmarine rocks. The post-Mesaverde rocks are terrestrial.

## INTRODUCTION

This paper is a byproduct of an examination of the mineral resources of the major part of the Book Cliffs of Utah and Colorado. The economic findings and part of the stratigraphic data resulting from the work were published in the thirties (Erdmann, 1934; Fisher, 1936). Important stratigraphic details, particularly

those concerning the relatively inaccessible higher strata, had to be left unascertained at that time, and a more detailed report on the stratigraphy was deferred in the hope that additional fieldwork could be done. It has not been possible to do this additional work, and the information available to the writers is here assembled.

#### LOCATION AND CHARACTER OF THE AREA

The Book Cliffs form a great southward-facing escarpment, at some places several escarpments, extending from east-central Utah eastward into western Colorado—a distance of some 215 miles along the cliffs, or 150 miles in a direct line. The western boundary is the Wasatch Plateau at longitude 111°, and the eastern boundary is the Colorado River, which separates the Book Cliffs from the Grand Mesa (fig. 1). If the map is held with its west edge down, these cliffs appear as a great S-shaped feature extending from Palisade, Colo., east of Grand Junction, to Castlegate, Utah. At the base of this S is the extensive area constituting the Wasatch Plateau. The Book Cliffs are a part of the Colorado Plateaus province, the southeastern part of the great Intermontane Plateaus physiographic division, which lies between the Rocky Mountains and the Sierra Nevada. Together with the Roan Cliffs they form a subsection 4–15 miles wide near the northern edge of the Canyon Lands, immediately south of the Uinta Basin. The sinuous trend of the cliffs is controlled mainly by the San Rafael Swell and the Uncompahgre uplift, two great domal structural features lying to the south, and to a lesser extent by Salt Valley, a faulted anticline. Immediately south of the Book Cliffs and underlain by the Mancos shale is an extensive lowland, parts of which at different places from west to east are known as Castle Valley, Clark Valley, Gunnison Valley, and Grand Valley. The elevation of the lowland ranges from some 4,050 feet near Green River, Utah, to about 6,500 feet north of Clark Valley (west of Sunnyside). Much of it is still mantled by remnants of gravel aprons that once extended outward from the cliffs.

From this lowland, the Book Cliffs rise majestically toward the highlands that form the southern border of the Uinta Basin and that are called the Roan Plateau. This plateau is separated into eastern and western parts by the Green River; the southern extension from the western part has been isolated by Price River and is known as the Beckwith Plateau. These features are indicated on plate 1. For convenience the Book Cliffs west of the Green River may

be called the western part; the part between the Green River and the Utah-Colorado boundary, central; and the part in Colorado, eastern. The divide at the southern margin of the Roan Plateau east of the Green River ranges in elevation between 8,000 and well over 9,000 feet. The southern margin of the Roan Plateau west of the Green River and the Beckwith Plateau, the western Book Cliffs, is relatively even and abrupt; the southern margin of the Roan Plateau east of the Green River, the central and eastern Book Cliffs, is much more irregular; and the cliff front is intricately carved into deep canyons separated by remarkable salients and headlands. The central and eastern Book Cliffs stand above the shale lowland as a double escarpment. In Utah the lower part is capped by a bench-making sandstone unit (Castlegate), and the upper part is made up of post-Castlegate formations; in Colorado the lower part is capped by the Sego sandstone, and the upper part is post-Sego formations. At distances of as much as 10 miles north of this front set of cliffs, the variegated "Wasatch" strata, capped by the Green River formation, form a second steep ascent, which is called the Roan or Brown Cliffs. The Book and Roan Cliffs consist of Cretaceous and Tertiary strata dipping in general northward into the Uinta Basin (fig. 1); to the south, beyond the shale flat, older rocks (Jurassic and Triassic in the main) form the surface, though Cretaceous strata appear again near the Henry Mountains and the La Sal Mountains.

The area is drained by the Colorado and the Green Rivers and their tributaries. Gray Canyon has been cut through the Book Cliffs by the Green River. The only second-class stream is Price River, a western tributary of the Green; the more important minor streams are shown on plate 1, but none of these is perennial throughout its entire course. Lower elevations in the region are arid, with an average rainfall of between 5 and 10 inches, which results in a sparse flora and fauna and large barren areas of well-exposed strata. The higher parts receive considerably more rainfall and support much more vegetation, even forests.

#### FIELDWORK AND ACKNOWLEDGMENTS

Fisher was engaged during the summers of 1925 and 1926 in an examination of the mineral resources of the Book Cliffs of Utah, south and east of the Sunnyside quadrangle. He was assisted by H. F. Moses and K. D. Owen in 1925 and by K. K. Landes and R. M. Leggette in 1926. Erdmann spent the summer of 1926 and part of that of 1927 in an examination

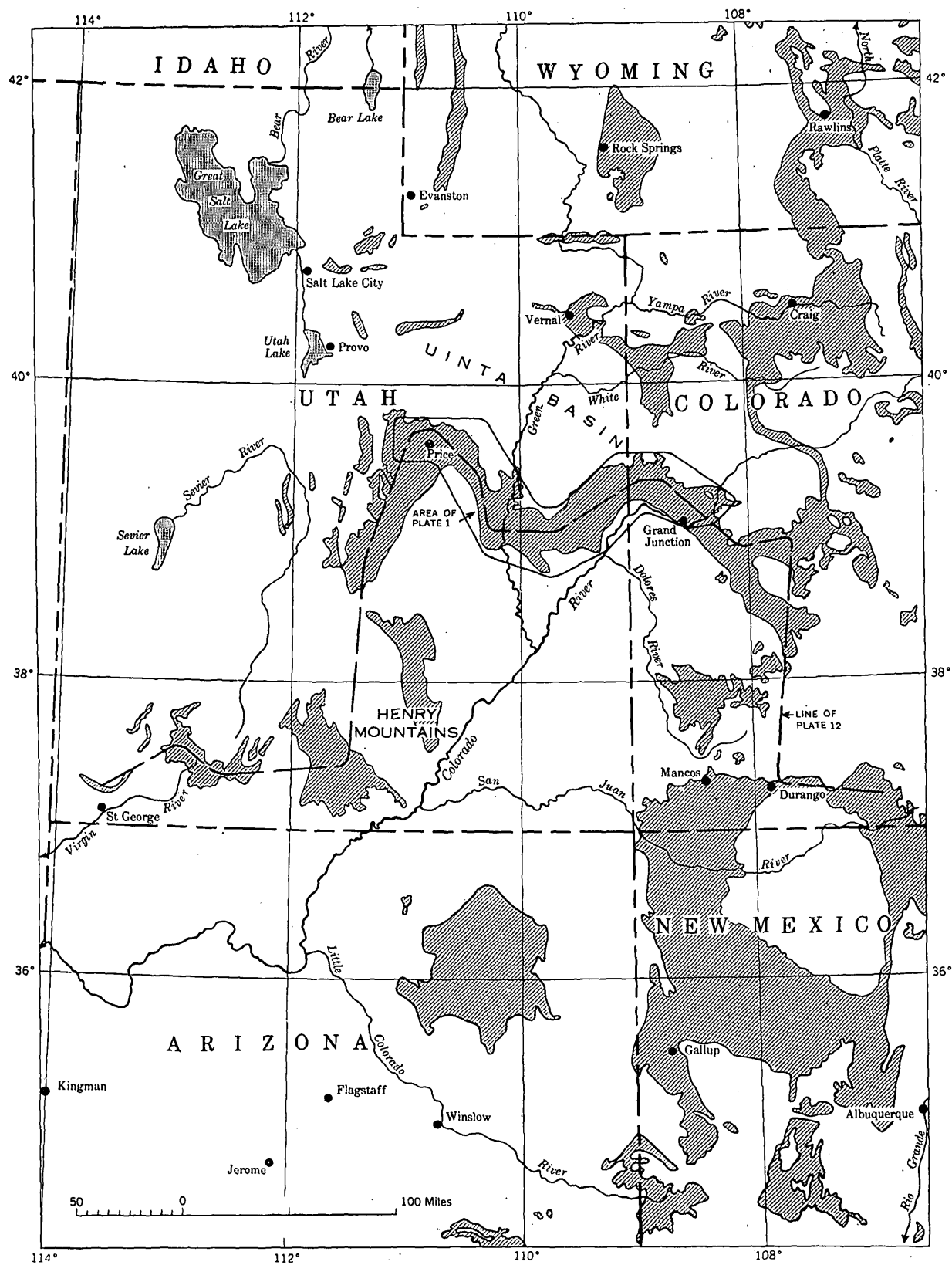


FIGURE 1.—Index map showing major outcrops of Cretaceous rocks in parts of the Rocky Mountains and Colorado Plateau regions (after Stose, 1932) and relation of the Book Cliffs of Utah and Colorado to other areas. Position of fence in plate 12 and location of plate 1 are shown.

of the mineral resources of the Book Cliffs in Colorado. He was assisted by W. D. Johnston, Jr., and W. S. Glock in 1926 and E. H. Watson in 1927. Erdmann in 1939 examined the Horse Canyon area, near Woodside, Utah. Reeside and E. M. Spieker had made reconnaissance studies of the whole Book Cliffs in 1925, and in 1926 Reeside visited both field parties. Reeside collected additional data on the basal part of the Mancos shale in 1952.

Much use has been made of earlier work in adjoining areas both east and west of that covered by the fieldwork on which this report is based. The westernmost part of the Book Cliffs was examined by F. R. Clark, and the results of his work, published in 1928, have been drawn on in this paper at several points. The region just east of the Book Cliffs was examined by W. T. Lee, and his results, published in 1912, have also supplied data. The work of E. M. Spieker (1931, 1946, 1949) on the Wasatch Plateau and other areas, chiefly west of the Book Cliffs, has supplied much help toward broad interpretations of features of the Book Cliffs. The writers are grateful to D. M. Kinney, A. D. Zapp, and W. J. Hail, Jr., for permission to use in graphic form a group of six sections in the higher beds of the western Book Cliffs.

#### PREVIOUS WORK IN THE REGION

The Franciscan friars, Dominguez and Escalante, did not enter the area during their exploration in 1776 and 1777, though they did travel around it. Later the Spanish Trail between Santa Fe and California, which crossed a small part of the district near Green River, was well used, but no scientist is known to have published any studies bearing on this part of the route. William Wolfskill's trapping party in 1830 is supposed to have been the first to follow the Spanish Trail. Perhaps the first white man to acquire a detailed acquaintance with the eastern part of the area was the trader Antoine Roubidoux, who established, probably in the 1830's, a trading post near the present site of Delta, Colo. Some of the goldseekers of 1849 probably followed the trail, but after 1850 the California-bound travelers went by way of Arizona.

In 1853 Capt. J. W. Gunnison, of the United States Army, led a party, which included Lt. E. G. Beckwith, west from Fort Leavenworth, Kans. in search of a possible railroad route between St. Louis and San Francisco near the 38th and 39th parallels. Gunnison was killed by a band of Indians in Sevier Valley, Utah, shortly after crossing the Wasatch Plateau. Beckwith (1855) and James Schiel (1855), the surgeon-geologist of the party, prepared reports de-

scribing the trip. The party descended the Gunnison River, crossed the Colorado above the mouth of the Gunnison, and traveled westward on a route some miles north of Colorado River. In Utah they approximately followed the course of the present-day U.S. Highway 50. Beckwith describes the "Roan" or "Book Mountains"; the former name is applied especially to the cliff between the Green River and the "Elk Mountains" (Grand Mesa of present usage) because of "the color of its sides." "White River" (Price River of present usage) is stated to cut through the southern point of "Little Mountain," the term applied to the Book Cliffs west of Green River, though two pages farther on it is stated that "sometimes Little Mountain from the regular appearance and variegated color of its strata, like the Roan [Mountain], is called Book Mountain." An accurate sketch of the southeast edge of the Beckwith Plateau is shown, and Beckwith describes it as follows:

The mountain wall is very irregular; deep ravines and gorges extend back into it, giving it, with its regular strata presented to us, where no sign of vegetation exists, the appearance of an unfinished fortification, on a scale which is pleasing to the imagination, and contrasts the work of men strongly with those of nature.

Schiel states (1855, p. 102):

The wearing and washing away of mountains takes place here on an immense scale, and is the more easily observed, as no vegetation of any account covers the country, hiding the destruction from the eye \* \* \* For days before we struck Green River, we travelled over a black, clayish, absolutely sterile soil, produced by the decaying mountains, and in different places, chiefly at a short distance from where we crossed Green River, we found remnants of those strata in buttes of sometimes considerable height, some of them assuming the shape of huge chimneys.

Beckwith (1855, p. 65) also notes the Spanish Trail is "but seldom used of late years."

Powell (1875), in telling of his epic trip down the Green and Colorado Rivers, briefly describes the Book and Brown Cliffs in Gray and Desolation Canyons where the strata of these cliffs cross the Green River. He refers to the shale (lower) part of the Book Cliffs as the Azure Cliffs. He does not cite and may not have been familiar with Beckwith's description of the Book Cliffs to the east. Powell's first trip down these rivers was made in 1869, the year the Union Pacific Railroad was completed.

The area east of longitude 109°30' was mapped by the Hayden Survey (Hayden, 1877) in 1875 and 1876, and that to the west by the Powell Survey (Powell, 1877) in 1876 and 1877. The Hayden maps were first published in 1877, and many data from the Powell maps appear on a hachure map of the region dated

1878 (Powell, 1879), but none of the quadrangle sheets appeared before the next decade; these show the old narrow-gage railroad line, completed in 1883. It is interesting to note that within the area here under discussion few of the names applied to the creeks or washes on these early maps are now in local use. Even the Beckwith Plateau is known locally as Elliot Mountain; indeed, it is so much dissected that it bears little resemblance to a plateau.

Gannett (1877, p. 346) states:

The Grand River Valley is limited on the north by the Roan or Book Cliffs. The first name has been given them from their prevailing color, the second from the characteristic shape of the cliff, which, with its overhanging crest and slight talus (curved shale slope), bears considerable resemblance to the edge of a bound book.

Dutton (1880, p. 161) writes that "Powell named the Tertiaries the Roan Cliffs and the Upper Cretaceous the Book Cliffs." Later Emmons (1894, p. 399) rather ingeniously invented another reason for the name "Book Cliffs," but unfortunately it applies only to the Tertiary rocks. He says:

The latter (Green River shales) are characterized by the thinness of their strata and the great definition of their bedding planes, so that their cliffs resemble the leaves of a book, whence the name "Book Cliffs."

The first geologic map and report on the Book Cliffs is by Peale (1878), who described the eastern part. Much later Eldridge (1901) published a small-scale geological map that included a little more of the Book Cliffs area. Taff's brief report (1906) covers a district mostly to the west. The first and only previous geological study of the area as a whole is by Richardson (1909); it is of reconnaissance nature. In 1909 Forrester (1918) read a paper criticizing some of Richardson's stratigraphic conclusions. Lee (1912) and Woodruff (1912) examined rocks at the eastern end of the Book Cliffs. Lupton (1914), Emery (1918), Gilluly (1929), McKnight (1940), and Baker (1946) have prepared reports which cover areas that near the Green River slightly overlap the district here discussed. Clark's short report (1914) on an area near Thompson adds nothing to the knowledge of the general stratigraphy. Campbell's railroad guidebook (1922) gives a very interesting but non-technical description of the Book Cliffs region. Winchester's study of the oil shale (1923) and the examination of bituminous sandstone beds near Sunnyside by Holmes, Page, and Averitt (1948) included the northern edge of the area. Reeside (1923), Spieker and Reeside (1925, 1926), and Spieker (1946) have published papers dealing with the Book Cliffs as part of a larger area. A very thorough description of

the westernmost part of the Book Cliffs, adjoining the area described by Fisher (1936), was published by Clark (1928), and one dealing with an area farther west and southwest in the Wasatch Plateau was published by Spieker (1931). The area of pre-Cretaceous rocks from Valley City eastward to the Colorado State line has been described by Dane (1935). Young (1955), in a paper on sedimentary facies and inter-tonguing in the Book Cliffs dealt especially with the zone of contact of the Mancos shale and Mesaverde group along the whole length of the cliffs. Stokes, Peterson, and Picard (1955) presented a column for "Salt Valley and the Book Cliffs" in a correlation chart. In the Guidebook for the Seventh Annual Field Conference of the Intermountain Association of Petroleum Geologists, held in east-central Utah in 1956, a correlation chart by Sanborn, Hill, and Arnold and papers by Mitchell, Carter, Katich, Abbott and Liscomb, Johnson, Swain, and La Rocque dealt with aspects of the stratigraphy and paleontology of the Book Cliffs. Hail, Kinney, and Zapp, (1956) discussed problems of correlation of the latest Cretaceous and earliest Tertiary of the western Book Cliffs.

#### THE FORMATIONS

This paper deals primarily with Cretaceous and lower Tertiary formations. Generally, the belt of Cretaceous rocks is wide and so also is the belt of Jurassic rocks south of them. At several places, however, folding and erosion have exposed rocks much older than Cretaceous within short distances of the Cretaceous strata. The San Rafael Swell, the Salt Valley anticline, and the Uncompahgre Plateau display these older rocks.

#### PRE-CRETACEOUS FORMATIONS

In the San Rafael Swell the exposed rocks range in age from Permian to Late Jurassic and have been divided into a long series of formations (Gilluly, 1929, p. 69-103; 1928, p. 61-110). In the Salt Valley anticline, rocks as old as Early Pennsylvanian reach the surface, and much the same sequence as in San Rafael Swell is reported (Dane, 1935, p. 24). In the Uncompahgre Plateau, Precambrian crystalline rocks are exposed, upon which rest a series of strata ranging in age from Late Triassic to Late Jurassic (Campbell, 1922; Dane, 1935; Cater, 1955).

The uppermost Jurassic rocks, the Morrison formation, form a varied series of beds—variegated shale, conglomerate, sandstone, and minor limestone. The Jurassic age of the Morrison is established primarily

by its large reptilian fauna (Baker, Dane, and Reeside, 1936, p. 58-63); that of the underlying San Rafael group by its marine fauna.

#### CRETACEOUS AND TERTIARY FORMATIONS

The formations dealt with in this paper range in age from Early Cretaceous to early Eocene and attain a maximum thickness of 7,000 feet (pl. 10). However, because of their lesser economic value, the oldest and youngest parts of this series of formations were examined much less thoroughly than the middle part.

In Utah, beds that were long considered the uppermost part of the Morrison formation and of Jurassic age are now known to belong to the middle part of the Early Cretaceous and are called the Cedar Mountain formation (Stokes, 1944, 1952; Katich, 1951). In Colorado a similar unit has been called the Burro Canyon formation (Stokes and Phoenix, 1948). Little attention was given to these beds in the fieldwork for the present paper, and the account of them is largely drawn from published sources.

The lowest unit considered in some detail in this paper has been called the Dakota sandstone. Overlying the Dakota sandstone is a great marine formation, the Mancos shale, which is succeeded in turn by a series of alternating sandstone and shale beds, in lesser part of marine origin but in greater part of nonmarine origin. To the lower part of these sandy beds has been generally applied the name Mesaverde, with the rank of either a formation or a group of formations. The relations between the Mancos shale and the overlying Mesaverde are not simple, for there is a successive loss of sandstone along the outcrop from west to east by change into shale, such that in their larger aspect the two units overlap considerably—the higher parts of the Mancos shale of the east were formed contemporaneously with the lower parts of the Mesaverde of the west. In the Book Cliffs few fossils are known from the higher parts of the sandy series, and it is not yet certain how they should be classified. In this paper they have been excluded from the Mesaverde group and viewed as units of undetermined age. Upon this undetermined zone lies a series of beds of lithology long accepted as typical of the Wasatch formation, which in its strictest sense should be of early Eocene age. Work in areas both east and west of the Book Cliffs raises some question about their age assignment, though in this paper the beds are left under the designation "Wasatch." The highest unit is the Green River formation, of Eocene age.

#### SOURCES OF THE NOMENCLATURE OF THE CRETACEOUS FORMATIONS

The nomenclature of the Cretaceous of the Book Cliffs region is purely a lithologic nomenclature. That of the major units has been carried in from other regions by a rather roundabout procedure. That of the lesser units is of local derivation.

The name Dakota has been widely used in the western interior region of the United States for sandstone that underlies the first marine Upper Cretaceous deposits, though the name originated in what is now northeastern Nebraska.

Mancos, Mesaverde, and Lewis (which name, though not used in the Book Cliffs, enters into the discussion later) were first applied in southwestern Colorado to, respectively, a marine shale unit that rests upon the basal sandstones, a succeeding series of coal-bearing sandstone and shale beds, and a second marine shale unit. The second marine shale is overlain conformably by a sequence of mainly nonmarine sandstone and shale formerly called the Laramie formation but now subdivided in northwestern New Mexico into five formations—the Pictured Cliffs sandstone, Fruitland formation, Kirtland shale, McDermott formation, and Ojo Alamo sandstone. In southwestern Colorado these names are also used, except that the McDermott is followed by the Animas formation.

In 1906 Fenneman and Gale extended the use of the names Dakota, Mancos, Mesaverde, Lewis, and Laramie to the valley of the Yampa River of northwestern Colorado, thus carrying the southwestern nomenclature in one move across the whole length of Colorado. In this usage the units concerned were strictly lithologic entities, and the succession of such units in the valley of the Yampa River matched that of southwestern Colorado very closely. Thus, though the geographic extension of the nomenclature was large, there was justification for it in the common practice of American geologists then and now. It can be shown by fossils that the units do not match well in a chronological sense, but that is equally true of many other such extensions of a lithologic nomenclature.

In 1907 and 1910 Gale applied Mancos and Mesaverde to the formations of the Danforth Hills and the Grand Hogback as far south as Colorado River, having traced the formations southward from the valley of the Yampa River. In crossing the Axial Basin anticline, Gale concluded, the Lewis and Laramie formations had disappeared and their horizons were represented by an unconformity at the top of a thickened Mesaverde formation.

Richardson in 1907 and again in 1909, for the Book Cliffs, and somewhat later Lee (1912, p. 18, 23-47), for the Grand Mesa, accepted Gale's interpretation and listed Dakota, Mancos, and Mesaverde as major Cretaceous formations, though Lee stated that the upper part of the Cretaceous section might be of Laramie age or even younger but is "referred provisionally to the Mesaverde."

Thus the nomenclature of the Book Cliffs came from the San Juan basin by way of the valley of the Yampa River, the Danforth Hills, and the exposures southward from them, all in Colorado.

Hancock in 1925 apparently accepted Gale's conclusions, but Sears, in work done also in 1925, questioned them and was led to consider that beds of the same age as those of the Lewis and Laramie formations of the Yampa valley were present in the Mesaverde sequence on the south side of Axial Basin and that the Lewis shale had passed laterally into beds predominantly of sandstone. Sears' findings have been accepted by Hancock and Eby (1930).

The present work has not shown by fossils the definite presence of strata of Lewis or post-Lewis age in the Mesaverde rocks of the Book Cliffs, but it is possible that such rocks are included in the highest beds. Spieker and Reeside (1925), in deference to the older, purely lithologic nomenclature, which was considered to be more or less well established, retained the name Mesaverde for the Book Cliffs, accepting thus the very broad significance of the term that has become customary. As commonly used, even in the San Juan basin, the name is applied to strata both much older (Pike, 1947, p. 13-16; Sears, 1936, p. 13-14) and much younger (Reeside, 1924, p. 13-16) than those of the Mesa Verde, Colorado, to which Holmes (1877) originally applied the name.

## CRETACEOUS SYSTEM

### LOWER CRETACEOUS UNITS

As noted on an earlier page, the Cedar Mountain formation is assigned to the middle part of the Lower Cretaceous (Aptian). It includes the discontinuous Buckhorn conglomerate member of Stokes at the base and a shale member above the conglomerate. The conglomerate is particularly marked by chert pebbles, and the shale is variegated and similar to the upper part of the underlying Morrison formation. The shale member is said to yield most of the "gastroliths" that have by some been considered characteristic of the Morrison formation. The Cedar Mountain formation approaches 300 feet in thickness at the north end of the San Rafael Swell but thins eastward.

In western Colorado the Burro Canyon formation occupies a position similar to that of the Cedar Mountain formation. It has a basal conglomerate, above which are beds of limestone, chert, sandstone, and some purplish and much greenish shale, the unit ranging in thickness from 150 to 250 feet. It is overlain by strata that include carbonaceous materials and that are assigned to the Dakota sandstone, and it rests upon the variegated shale beds of the upper part of the Morrison formation.

### DAKOTA SANDSTONE

*Distribution.*—The Dakota sandstone immediately underlies the Mancos shale and rests on the variegated beds of the Cedar Mountain formation or on the Burro Canyon formation. So far as is known, it forms a nearly continuous belt along the south side of the Mancos shale lowland and is absent at a few places and is interrupted by faulting at a few others. It has not actually been traced by the writers throughout the whole area, however, and was critically examined at only a few places.

*Lithologic character and thickness.*—In Utah the Dakota sandstone is remarkably variable in both thickness and lithologic character. It is composed of friable to quartzitic sandstone and conglomerate, with interbedded shale and with a very few limy layers. It contains some beds of carbonaceous material. The sandstone varies from a light-gray fine-grained sugary-textured crossbedded friable rock to hard black pebbly quartzite with a semiconchoidal fracture. The conglomerate is locally friable; elsewhere it is firmly cemented in a silica matrix. The pebbles in it are as much as 4 inches in diameter and include moderately well-rounded pieces of chert of several colors, white to red quartzite, granite, and other igneous rocks, and less well-rounded pieces of fine-textured gray limestone. A limestone pebble collected from the conglomerate  $1\frac{1}{2}$  miles south of Cedar, Utah, contained *Schuchertella chemungensis* Conrad?, a lower Mississippian species. The shale is commonly light greenish gray, but dark grays are also present. The lithologic character varies much, both laterally and vertically, but dense-textured light-gray limestone was seen at only one locality, and there as a minor lens. The thickness in the measured sections ranges from 2 to 126 feet, the thicker part lying to the east. Richardson (1909, p. 13) assigns 100 feet of massive white and buff crossbedded locally conglomeratic sandstone to this unit south of Thompson. Gilluly (1929, p. 114, 119) has published two sections of this formation in the area under discussion, and Dane



(1935, p. 113-117) has published several sections from the region east of Salt Valley. Lupton (1916, p. 27) gives a section 3 miles southwest of Mounds, near the northwest corner of the area.

In Colorado, as in Utah, the Dakota sandstone is characterized by variability as a unit and in the individual strata. Thickness at the surface ranges from 25 to 200 feet, and where penetrated by drill holes, from 120 to 200 feet, but the maximum may include some of the beds of the Burro Canyon formation.

In the older literature the Dakota sandstone was construed at many localities to show a threefold lithologic division.

The lowermost lithologic division, as so construed, is not everywhere present and is characterized by greenish sandy shale beds that closely resemble those of the underlying Morrison and by a massive brown basal sandstone, much like that at the top of the formation but at many places including lenses of chert-pebble conglomerate. This unit in recent publications has been called the Burro Canyon formation and has been removed from the Dakota.

Above the lowermost unit usually lies the middle division of carbonaceous shale containing coals of low rank and grade, some sandstone layers, and usually a basal conglomerate. The uppermost division consists of a lower part of gray marine shale 20-30 feet thick, much like the Mancos and containing some thin coarse-grained sandstone strata and more rarely basal conglomerate; this division's upper part is massive brown to buff medium-grained quartzose sandstone 20-30 feet thick. The sandstone is also of marine origin and transitional into the Mancos shale through a series of thin sandstone and shale beds that may be highly carbonaceous. The two higher divisions are now considered to constitute the Dakota sandstone.

#### MANCOS SHALE

*Distribution.*—The Mancos shale of the area is defined as consisting of all strata from the top of the Dakota sandstone to the base of the lowest sandstone unit of the Mesaverde group, which in general is the lowest sandstone cropping out in the Book Cliffs. The name Mancos was first applied by Cross (1899a) to exposures near the town of Mancos in the southwestern part of Colorado. Its use has since been extended, so that it includes the thick shale, usually in part of Colorado age and in part of Montana age, found over a large region south of the Uinta Mountains and west of the Rocky Mountains. In the present area the Mancos shale crops out in a

broad east-trending belt immediately south of the Book Cliffs. Topographically the unit makes up the lower or buttressing part of the Book Cliffs and the wide expanse of lowland or "flat" extending some miles to the south. Near the cliffs, badlands are common; locally, small box canyons greatly impede travel. Plates 2 and 3A, B show some of these features.

*Lithologic character and thickness.*—The Mancos shale is a well-marked lithologic unit at any given locality, though its content of beds, in a chronologic sense, may differ with the locality, as described below.

The thickness of the formation in the area, as far as shown by the measured sections, lies between 3,450 and 4,120 feet in Utah and between 3,908 and 4,150 feet in Colorado. There is no reason to suspect that it is thicker to the southeast in Colorado, but Clark (1928, p. 13) has reported a thickness of 5,050 feet at a locality a short distance to the west.

The Mancos is predominantly a monotonously uniform shale—drab or bluish gray on the weathered surface and very dark gray when wet. Where fresh cuts are exposed, it is dark gray, limy, and thin bedded but lacking in pronounced fissility. It weathers to a friable semipowdery mass that forms a sticky clay when wet, though water penetrates only a fraction of a foot as the wet surface quickly forms an impervious layer. The fresh apparently smooth shale feels slightly gritty to the teeth. Veinlets of gypsum and calcite are common, and patches or streaks of white "alkali" are present at many places. Throughout the area especially studied in this report and at a distance of 100-200 feet above the base of the Mancos shale is an interval containing large concretions, which are brownish on weathered surfaces and dark gray on fresh surfaces; this zone of concretions forms a conspicuous element in the sequence. Minor hogback-making sandstone beds are found at different places and horizons, and some soft sandstone beds occur.

In Utah in the northwestern part of the area, near Desert, several lenses of cuesta-forming sandstone are present about 150 feet above the base of the Mancos shale. In this same area and eastward into Colorado, an interval of hard thin platy sandstone layers in shale 50 feet or more thick and generally cuesta forming is usually construed as a relatively weak eastward extension of part of the thick Ferron sandstone member of Lupton (1916, p. 31). This interval is from 300 to 500 feet above the Dakota sandstone, and locally, as along the road south from Crescent, it forms two cuestas. Somewhat higher sandstone beds are found near Cliff and Crescent. Similar beds are found



700–900 feet below the top near Flory, in the vicinity of Sagers and Nash Washes, in the Cottonwood Creek reentrant north of Cisco, and near the Colorado line.

In Colorado an irregular group of thin-bedded and platy brown sandstone and sandy shale beds is equivalent to the sandstone beds in the lower part of the Mancos of Utah construed to be an extension of the Ferron. Unimportant showings of gas and oil have been obtained from these beds in local wells, and petroleum geologists have referred to them as the Frontier sand. Topographically the unit is expressed as a low ridge north of and parallel to the Dakota cuesta. Three other similar sandy zones occur in the lower 2,800 feet of the formation. The lowest of these is 50–200 feet thick and lies 800–900 feet above the top of the Dakota sandstone. The base of the next higher zone occurs approximately in the middle of the Mancos shale, 2,000–2,100 feet above the base. The thickness ranges from 300 to 400 feet. Six hundred feet above the top of this zone is the highest member of the group, whose thickness ranges from 100 to 200 feet. All are more or less inconspicuous topographically. Owing to weathering and disintegration of the sandy layers, the surface of the enclosing shale is usually tan or buff. Fossils seem more abundant in these beds than in the finer grained shaly layers.

In Utah the upper part of the shale is commonly sandy, more or less grading into the overlying sandstone units of the Book Cliffs. Lenticular beds and lenses of impure fine-textured gray limestone up to a foot or so thick are present in many places, especially in the upper part of the formation. The limestone weathers yellowish brown, is usually somewhat resistant, and gives rise to small hogbacks or mounds.

In Colorado the upper thousand feet of the Mancos shale is characterized by groups of thin irregular layers and overlapping lenses of calcareous sandstone, concretionary beds, and limestone. The intervals between adjacent lenses, layers, or beds of a given group are usually very regular. The thickness of the groups ranges from 4 to 15 feet; the groups are from 25 to 200 feet apart and average 90 feet apart. The groups are much more resistant than the enclosing shale beds and crop out as low brown ledges, and more rarely as a short steep cliff facing away from a short dip slope. The concretions range in size from small septaria the size of the hand to large ovoid masses 8 or 9 feet in diameter and 5 or 6 feet thick. Some beds are merely aggregates of concretions, with the intervening spaces occupied by calcareous sandstone and shale. The

fresh material in most concretions and lenses is a hard, dense dark-bluish-gray impure limestone. A few are ferruginous. Some faces of the concretions exhibit networks of small calcite veins. Upon weathering, the concretions become tan to reddish brown and disintegrate. The surface of the shale in many places is littered with small angular fragments of concretionary material. Many larger concretions have spheroidal weathering structures.

*Contact with Mesaverde group.*—Along the outcrop the upper boundary of the Mancos shale rises stratigraphically toward the east by the successive passing into shale of eastward-pointing tongues of sandstone. Between the Wasatch Plateau, Utah, and the eastern end of the Book Cliffs, at Palisade, Colo., the following parts of the Mesaverde group, in the nomenclature followed in this report, in turn form the basal unit: The Star Point sandstone, Aberdeen sandstone member of Blackhawk formation, three successively higher members of the Blackhawk formation, the Castlegate sandstone, the lower member of the Sego sandstone, and the upper member of the Sego sandstone. Accepting the local thicknesses, these steps upward are, in round numbers, 600, 150, 300, 150, 200, 300, 250, and 350 feet, respectively. According to W. W. Boyer (written communication), a few miles south of Colorado River, in sec. 18, T. 12 S., R. 99 W., the upper member of the Sego passes into shale, and the Rollins sandstone member becomes the basal Mesaverde unit.

Young (1955), in his paper on sedimentary facies and intertonguing in the Book Cliffs, has dealt particularly with the zone of contact between the main body of the Mancos shale and that of the Mesaverde group and has expanded the terminology applied to the Mesaverde sequence to designate 13 tongues or members that toward the east pass successively into the Mancos shale. A good case can be made for this procedure, but the writers have felt it more practicable to use in this paper the classification adopted during the active fieldwork.

#### MESAVERDE GROUP

The name Mesaverde was applied originally by Holmes (1877) to a series of sandstone, shale, and coal beds on the Mesa Verde in southwestern Colorado that are enclosed between what are now called the Mancos and Lewis shales and that constitute equivalents of the middle part of the Montana group. In the Book Cliffs of Colorado and Utah, the name is applied to a sequence of rocks much like that of the

typical Mesaverde—buff to yellow-brown ledge-making sandstone beds, gray shale, and coal beds. The sequence rests on the Mancos shale, but throughout the Book Cliffs there is no overlying counterpart of the Lewis shale; in fact, no later marine beds at all. The post-Mesaverde rocks are all of fresh-water origin.

In the eastern part of the Wasatch Plateau (Spieker, 1931, p. 16, 21–45) and in the western end of the Book Cliffs (Clark, 1928, p. 11, 12, 15, 16), the Mesaverde has been recognized as a group and has been divided into the following units, the highest at the top of the list and the lowest at the bottom:

Price River formation:  
 Non-coal-bearing member  
 Castlegate sandstone member  
 Blackhawk formation:  
 Coal-bearing member  
 Aberdeen sandstone member  
 Star Point sandstone:  
 Spring Canyon tongue  
 Storrs tongue  
 Panther tongue

Only the part of the Blackhawk formation above the Aberdeen member and the Price River formation of this classification extends into the parts of the Book Cliffs considered in detail in the present paper.

In the Grand Mesa in western Colorado, Lee (1912, p. 19) recognized the Mesaverde strata as a formation in which several members were named, as follows:

Undifferentiated member, at top  
 Paonia shale member, nonmarine  
 Bowie shale member, brackish-water and marine  
 Rollins sandstone member, at base

Johnson (1948) in the Paonia coal field, a part of Lee's area, continued to use Mesaverde formation, and divided it into members nearly equivalent to Lee's units but did not use the names Bowie and Paonia because of the difficulty of identifying the units by the conditions under which they were formed. Johnson's classification follows:

Barren member, at top  
 Upper coal member  
 Lower coal member  
 Rollins sandstone member, at base

Fisher (1936) did not like the term Mesaverde in the western and central Book Cliffs. Part of the Blackhawk formation is present in his area, and the Castlegate sandstone extends across the area. West of the Green River the Castlegate was considered the basal member of the Price River formation, and the remainder formed an undivided upper member. East of the Green River the Price River above the Castlegate member was divided into four named members,

including above the lower member a westward-pointing tongue of Mancos shale. This provided the following Mesaverde units:

Price River formation:  
 Farrer non-coal-bearing member  
 Neslen coal-bearing member  
 Sego sandstone member  
 Buck tongue of Mancos shale  
 Castlegate sandstone member  
 Blackhawk formation

Erdmann (1934) in the eastern Book Cliffs recognized the Mesaverde as a group. The Sego sandstone in his area formed the base of the Mesaverde, and he divided the overlying sequence into two units of formation rank. The units are—

Hunter Canyon formation  
 Mount Garfield formation  
 "Barren measures"  
 "Coal measures," including Rollins sandstone member  
 Sego sandstone  
 Upper member  
 Anchor Mine tongue of Mancos shale  
 Lower member

Young (1955), dealing particularly with the rocks between the main body of the Mancos shale and the top of the Sego from the Wasatch Plateau to the eastern Book Cliffs, did not recognize a Mesaverde unit but assigned the post-Mancos rocks to the Star Point sandstone, the Blackhawk formation, the Price River formation, and higher strata. He recognized 13 littoral marine sandstone tongues or members separated by westward-pointing tongues of Mancos shale, the whole forming a diagonal belt of littoral marine rocks, the members of which appear successively in the west and give away successively to offshore marine strata to the east. Above and to the west of this belt, he recognized a belt of lagoonal rocks cutting across the formations that in the Price River formation he designated as the Neslen facies. Above and to the west of the lagoonal facies, he recognized inland rocks that in the Price River he designated as the Farrer facies. The Castlegate he recognized as a member of the Price River that extends through the inland, lagoonal, and littoral marine facies. He shifted the Spring Canyon from the Star Point to the Blackhawk formation in the Book Cliffs. The Colorado terms Mount Garfield and Hunter Canyon he abandoned as unnecessary. Young's classification is shown in the following table. Each member of the Blackhawk and Price River formations was interpreted as consisting of a cyclical repetition of littoral marine sandstone that grades

westward and upward into lagoonal rocks, including coal-bearing strata and that is separated from the next higher and next lower sandstone by a wedge of

marine shale which fades out westward. The only names applied to these marine tongues were those already in use.

*Section of rocks exposed in the Book Cliffs (after Young, 1955)*

Section of rocks exposed in the Book Cliffs (after Young, 1906)

← WEST			EAST →	
Formation	Inland facies	Lagoonal facies	Littoral marine facies	Marine facies
Price River formation.	Farrer facies----	Neslen facies----	{ Unnamed units----- Cameo member----- Cozzette member----- Corcoran member----- Sego member, including Anchor Mine tongue----- Buck tongue of Mancos shale----- Castlegate member----- Desert member----- Grassy member----- Sunnyside member----- Kenilworth member----- Aberdeen member----- Spring Canyon member----- Storrs tongue----- Panther tongue-----	} Mancos shale.
		Castlegate member-----		
Blackhawk formation.	Inland facies----	Lagoonal facies----		
Star Point sandstone.	-----	-----		

Subsequent publications (Stokes, Peterson, and Picard, 1955; Sanborn, Hill, and Arnold, 1956; Mitchell, 1956; Katich, 1956; Abbott and Liscomb, 1956; Swain, 1956; and La Rocque, 1956) have not added material changes except that some of them show the Tuscher formation to be part of the Mesaverde group.

Because of the marked changes in the assemblage

of Mesaverde rocks over the rather long distance from the Wasatch Plateau along the Book Cliffs to Grand Mesa, particularly east of the Green River, as indicated by the differences in the nomenclatures adopted by various authors, and because the nomenclature adopted by Young does not seem particularly useful for the purposes of this paper, the writers have used the following classification for the Book Cliffs.

*Sections of the Mesaverde group at selected points in the Book Cliffs*

[All basal members are underlain by the Mancos shale]

Western Book Cliffs (Utah west of Green River)	Central Book Cliffs (Utah east of Green River)	Eastern Book Cliffs (western Colorado)
Price River formation: Bluecastle sandstone member at top. Unnamed member.	Tuscher formation Farrer formation. { Neslen formation (includes Bluecastle sandstone member in upper part). Sego sandstone	Hunter Canyon formation. Mount Garfield formation: "Barren measures." "Coal measures," containing Rollins sandstone member. Sego sandstone: Upper member. Anchor Mine tongue of Mancos shale: Lower member.
Castlegate sandstone Blackhawk formation: Upper member Middle sandstone member Middle shale member Lower sandstone member.	Buck tongue of Mancos shale. Castlegate sandstone. Blackhawk formation: Shale member. Sandstone member.	

Because of these differences in classification in the several parts of the Book Cliffs, it will be necessary in the following pages to describe the stratigraphic units in part by geographic units, though in general the order will be stratigraphic.

**BLACKHAWK FORMATION**

The Blackhawk formation was defined by Spieker and Reeside (1925, p. 443) as the coal-bearing unit

of the Wasatch Plateau. It is there as much as 900 feet thick and is enclosed by the Star Point sandstone below and the Castlegate sandstone above. Eastward along the Book Cliffs, the Star Point passes into shale and does not reach the area under consideration (Clark, 1928, p. 16), as is shown on plates 10, 11 and 12. The Blackhawk formation of the western end of the Book Cliffs consists of three eastward-pointing sandstone tongues, each of which is overlain by a west-

ward-pointing tongue of Mancos shale. The lower sandstone tongue was named the Aberdeen sandstone member by Clark (1928, p. 18). It does not extend as far east as the area under consideration, and the immediately overlying shale is therefore not differentiated from the Mancos shale. For descriptive purposes the following terminology, used by Fisher (1936) in his description of the coal beds, is here applied to the remaining parts of the Blackhawk:

- Upper member
- Middle sandstone member
- Middle shale member
- Lower sandstone member

In the part of the area west of the Green River, the Blackhawk has a thickness up to 700 feet (pl. 2C). All the contacts among these members, as well as the contacts with the enclosing beds, are conformable in the area, though to the west Spieker and Reeside (1925, p. 446) observed an erosional unconformity at the top of the formation in one place, and it is now known (Spieker, 1946, p. 122, 130-132) that the Castlegate farther west succeeds an important unconformity. The shale beds grade upward into the overlying sandstone beds, but the contacts between sandstone and overlying shale beds are at most places quite definite, though conformable.

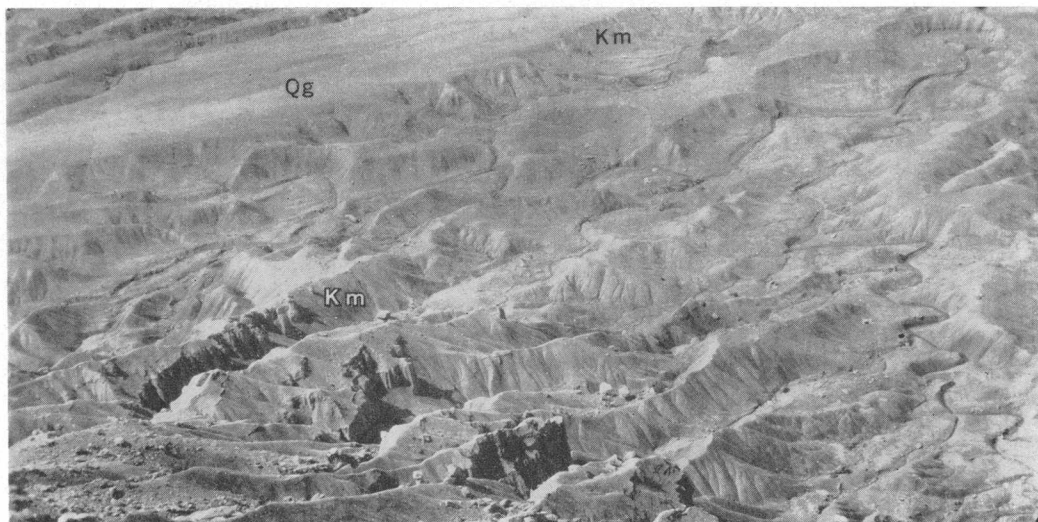
*Lower sandstone member.*—This member is found only in the northwestern part of the area and could be traced but a short distance east of the Green River. It dies out very rapidly, not by thinning but by passing into shale. This change is well shown on plate 3; along the west and south sides of the Beckwith Plateau it forms an inaccessible cliff, while at Gunnison Butte on the west bank of Green River it is split into three ledges that may be ascended easily. Its thickness is between 150 and 270 feet. Its contact with the underlying Mancos shale is gradational, but its upper surface is sharp at most places, though conformable with the overlying shale. It is medium gray, weathering buff, except for its upper part, which in most places is very light gray ("white"). It ranges from a calcareous argillaceous siltstone to a rather coarse friable sandstone. The lower part is thin bedded and crossbedded; the upper part, massive.

*Middle shale member.*—This member was traced through the same area as the underlying sandstone. Farther east it cannot be distinguished from the Mancos shale. Its thickness ranges from 100 to 160 feet. Though it is generally composed of medium-gray shale quite like the Mancos, varying from gritty and limy to soft and laminated, it also contains local thin sandstone and siltstone layers. In places it is black and carbonaceous, and in the extreme northwest-

ern part of the area and along the southwest part of the Beckwith Plateau, a thin coal bed is present in its basal part. It crops out as a steep shale slope between vertical sandstone cliffs, but its upper part grades into the overlying sandstone and so at places constitutes the lower part of a cliff (pl. 3A).

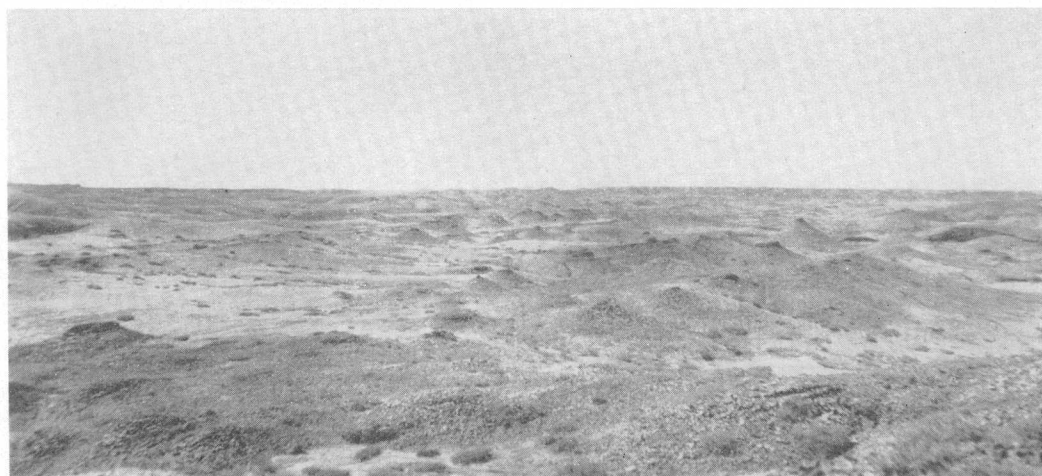
*Middle sandstone member.*—This member was traced from the western border of the area to the neighborhood of Saleratus Wash, where it passes into shale of the Mancos. Where measured, its thickness was found to range from 100 to 245 feet. Typically it appears as a massive sandstone that forms vertical cliffs (pl. 3). It is medium gray, weathering buff except for 1 to 3 zones at the top and in the upper part, which are "white." The three white sandstone zones are well shown a few miles north of the Price River; northwest of that area the middle sandstone member is commonly reddish, owing to the burning of coal beds. It is generally thin to medium bedded and even shaly in the lower part and near its eastern limits. It is commonly crossbedded, but this is not everywhere apparent. The Sunnyside coal seam was interpreted by Fisher (1936, p. 10, 13) to lie 25-75 feet below the top of this member, but Erdmann, in his section in the Horse Canyon area (see "Local sections, No. 5") found it convenient to assign the coal to the base of the upper member.

*Upper member.*—This unit ranges between 70 and 230 feet in thickness where sections were taken, although the lower figure includes only a part of the member. In the northwestern part of the area, it is mainly of shale, closely resembling in all respects the middle shale member; but near the southwestern part of the Beckwith Plateau (pls. 3A and 4B), it becomes sandy in its upper part. This sandy upper part continues as far east as the Nash Wash reentrant (northwest of Cisco), where the member within a short distance passes into shale of the Mancos. East of Saleratus Wash the lower, shale part of the member cannot be differentiated from the Mancos shale, and the upper, sandstone part in most places makes a cliff continuous with that of the overlying Castlegate sandstone, from which it is generally separated by a locally carbonaceous or coaly, minor shaly unit that is commonly present in its top part. To one somewhat casually examining the sandstone beds along the cliffs, what is here called the upper sandy part of this member would certainly be lumped with the Castlegate; but if traced carefully along the western edge of the Beckwith Plateau, particularly through the southwestern part, it can be clearly seen that the shale beds in the upper part of the member, shown in section 4 (pl. 10) and also farther to the west, grade



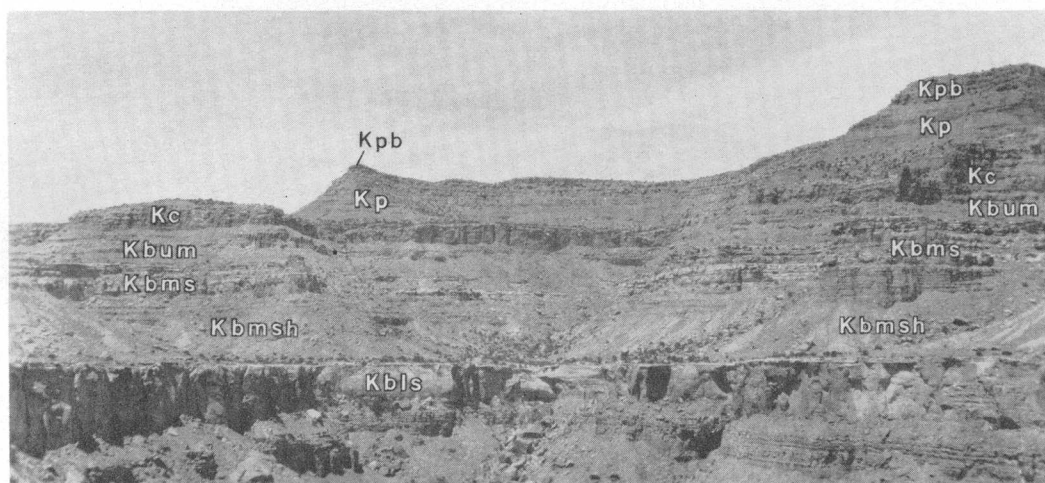
A. BOOK CLIFFS ALONG BECKWITH PLATEAU EAST OF DESERT, UTAH

Boulder-strewn shale slope showing badland character of Mancos shale, Km, near the cliffs, where it is not protected by gravel aprons, Qg.



B. MANCOS SHALE FLAT SOUTH OF BECKWITH PLATEAU, UTAH

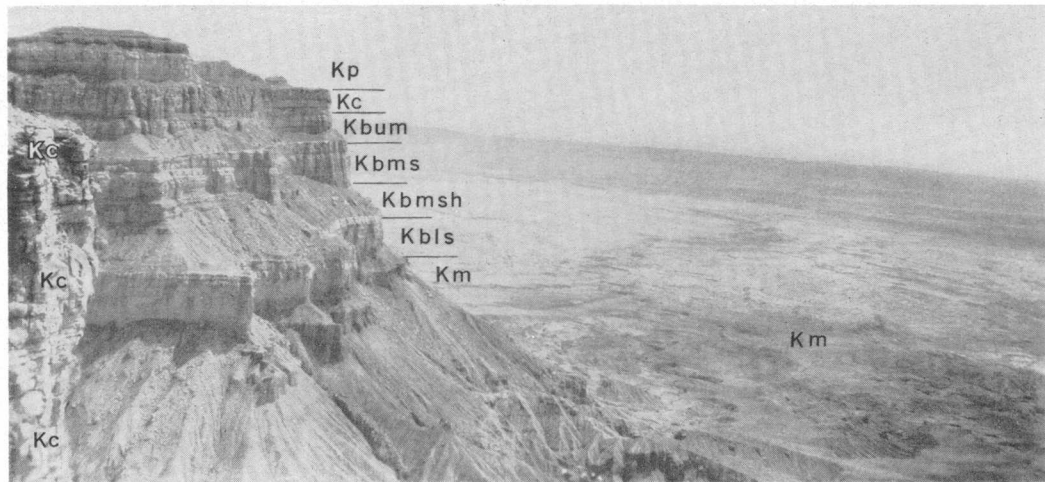
Limy and sandy layers and lenses in the shale give rise to the "beehives." Photograph by H. F. Moses.



C. VIEW WEST UP BLUECASTLE CANYON IN BECKWITH PLATEAU, UTAH

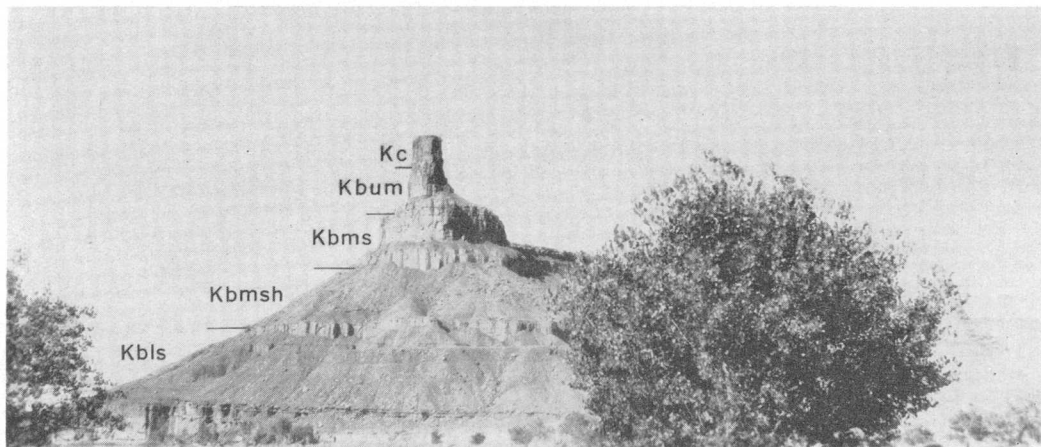
Kbls, lower sandstone member of Blackhawk formation; Kbmsh, middle shale member of Blackhawk formation; Kbms, middle sandstone member of Blackhawk formation; Kbum, upper member of Blackhawk formation; Kc, Castlegate sandstone; Kp, Price River formation, with Bluecastle sandstone member (Kpb) at top.





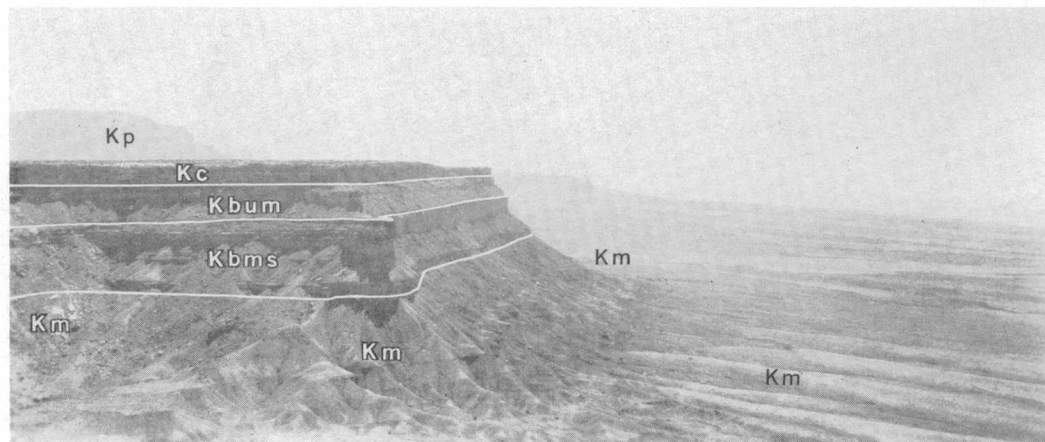
A. LOOKING SOUTH INTO SEC. 32, T. 20 S., R. 15 E., ALONG SOUTHWEST EDGE OF BECKWITH PLATEAU, UTAH

Km, Mancos shale; Kbls, lower sandstone member of Blackhawk formation; Kbmsh, middle shale member of Blackhawk formation; Kbms, middle sandstone member of Blackhawk formation; Kbum, upper member of Blackhawk formation, sandy in upper part; Kc, Castlegate sandstone, here not an important bench maker; Kp, Price River formation.



B. GUNNISON BUTTE, UTAH, FROM THE EAST

Symbols as in A.



C. BOOK CLIFFS EAST OF TUSCHER WASH (NORTHEAST OF GREEN RIVER, UTAH)

Note the wide bench surfaced by Castlegate sandstone and the replacement of the middle sandstone member of the Blackhawk formation by Mancos shale. Symbols as in A.

laterally with some rapidity into sandstone. Section 5, in "Local Sections," shows an intermediate stage, and in section 6 this upper part is markedly sandy.

Plate 3A is a view of the cliffs in the southwestern part of the Beckwith Plateau, looking south into sec. 32, T. 20 S., R. 15 E. The lower sandstone member, grading downward into the Mancos shale, makes the lowest cliff, about halfway up. Above this is the slope made by the middle shale member, grading upward into the cliff of the middle sandstone member. Above this second cliff is a minor shale slope (the lower shaly part of the upper member), which is overlain by a third sandstone cliff made up of the Castlegate sandstone resting on the upper sandy part of the upper member. The two are separated in the picture by an indistinct carbonaceous zone that appears as a notch in the cliff profile. In profile the top of the Castlegate sandstone makes a narrow bench upon which rest the younger strata.

Much of the upper member is shale, and the presence of a sandstone member in it seems somewhat incongruous. A probable explanation is that during the latter part of this stage coarser sediments from a northerly direction were being laid down over a small area, while on either side muds were being deposited. Perhaps it can be pictured best as a southward-projecting "peninsula" of sand forming in an otherwise shallow, muddy, but open sea.

#### FORMATIONS ABOVE BLACKHAWK FORMATION

The Price River formation was named by Spieker and Reeside (1925, p. 445) from exposures in Price River Canyon above Castlegate, Utah. It was described as a "succession of predominantly gray sandstones, grits, and conglomerates, with a minor amount of shale," and as including all the sedimentary rocks between the Blackhawk formation and the base of what was then called Wasatch formation, now the base of the North Horn formation. The name Castlegate was adopted by Spieker and Reeside for the lower member of the Price River formation. The thickness of the formation was given as 900—1,000 feet, and a later measurement of the type section by Spieker (1946, p. 130) shows 1,100 feet, of which about half is included in the Castlegate sandstone. The contrast between the fine grain of the underlying beds and the grit and conglomerate of the Price River beds was considered notable and together with evidence of marked unconformity on the western border of the Wasatch Plateau was considered to indicate an important hiatus in the sequence.

Clark (1928, p. 20), describing the western end of the Book Cliffs, considered the basal contact to be

conformable but described a marked erosional boundary at the top. In Clark's area the Castlegate thinned eastward, and the upper member thickened somewhat, though the total thickness did not change greatly.

Spieker (1931, p. 44) regarded the Price River of the Wasatch Plateau as of late Montana age, with an unconformable lower contact to the northwest but probably a conformable contact in the east. The best criterion for the top of the Price River was believed to be a limestone conglomerate and highly colored beds marking the Eocene. Later, Spieker (1946, p. 131) indicated that the top of the Price River is a gradational contact, placed where the coarse-grained sandstone beds of the Price River pass into the variegated finer grained beds of the North Horn formation.

Fisher (1936, p. 9, 14-30), describing the Book Cliffs east of Clark's area, subdivided the Price River formation into two members—Castlegate sandstone member and upper member. He carried this subdivision as far as the lower course of Price River, near its mouth, but beyond that he found it desirable to divide the upper member into four members—in ascending order, the Buck tongue of Mancos shale, the Sego sandstone member, the Neslen coal-bearing member, and the Farrer non-coal-bearing member.

The Castlegate sandstone, the Buck tongue of the Mancos shale, and the Price River formation were not recognized as such by Erdmann (1934, p. 22, 31-53) in the Book Cliffs in Colorado. He recognized, however, the Mesaverde group and divided it into three formations—in ascending order, the Sego sandstone, the Mount Garfield formation, and the Hunter Canyon formation.

In the present paper the name Price River formation is applied only to the beds above the Castlegate sandstone and is carried only as far east as Green River. East of the Green River the members of the Price River described by Fisher for Utah are recognized as formations, and those formations used in Colorado by Erdmann are accepted. These are shown in tabular form on page 11.

Spieker (1946, p. 122, 131) has shown recently that the Price River formation of the eastern Wasatch Plateau passes westward into a thick series of coarse-grained conglomerate beds. The series lies unconformably on beds of various ages and underlies beds that contain Late Cretaceous dinosaurs.

#### UTAH WEST OF THE GREEN RIVER (WESTERN BOOK CLIFFS)

##### CASTLEGATE SANDSTONE

*Distribution.*—The Castlegate sandstone was named from exposures in Price River Canyon about 2 miles

above the town of Castlegate. It crops out in the east face of the Wasatch Plateau and at various places within the plateau. Farther west, according to Spieker (1946, p. 131), it forms a part of a coarse-grained conglomerate series in the valley of the Spanish Fork of the Provo River. It extends eastward through the area here described to the neighborhood of the Colorado-Utah line, where it passes into the Mancos shale.

*Lithologic character and thickness.*—At the type locality it is about 400 feet thick, and a short distance to the west it thickens to about 500 feet (Clark, 1928, p. 119). In the area of this report its thickness ranges up to 190 feet, though it is somewhat thicker near its northernmost exposure in the Gray Canyon of the Green River. In the canyon of Westwater Wash it is about 70 feet thick; eastward from that locality it thins rapidly, and at the Utah-Colorado State line it is 30 feet thick, a mere "feather-edge"; at the mouth of West Salt Creek it is discontinuous. In the eastern exposures the lower part gradually becomes more shaly until a firm thin sandstone ledge at the top of the member is all that is left. Thus, along the Book Cliffs the Castlegate sandstone ranges from massive conglomeratic sandstone near Castlegate to fine-grained siltstone at the east boundary of Utah and passes entirely into shaly beds in Colorado. This change as seen along the cliffs is not entirely one of regular diminution in size of grain and thickness. (See pl. 10.) Indeed, this would not be expected unless the outcrop line marked by the cliffs happened to cut the sandstone beds in a line parallel to the direction of regular diminution in sedimentation, if perchance such a regular diminution ever existed.

For the type area Spieker and Reeside (1925, p. 445) state: "The lithologic contrast between the fine-grained, predominantly buff beds of the Blackhawk \* \* \* and the coarse, predominantly gray beds of the Price River formation is strong."

This distinction does not hold in the present area. Between Sunnyside and the Green River, the Castlegate is not pronouncedly different in any respect from the older sandstones of the Blackhawk formation; it is simply another cliff-forming sandstone, which, however, is a very definite continuous unit (pls. 2*C* and 3*A*). It makes the upper part of the highest cliff on Gunnison Butte (pl. 3*B*). East of the Green River, extending to Bitter Creek, 3 miles west of the Colorado-Utah line, however, its topographic expression is unique in that it forms the dip-slope surface capping a bench as much as 2 miles wide at the base of the second line of the Book Cliffs (pl. 4*C*).

West of the Green River then, in the present area, the Castlegate is a cliff-forming massive rather

coarse-grained (in most places) crossbedded sandstone. It is very light gray on the fresh surface but weathers to a buff to light brown, although the upper part is commonly light gray. It is friable and has a calcareous cement. Locally it contains numerous clay galls up to an inch or so in diameter, which at first sight make it appear to be conglomeratic. East of the Green River it is a cliff- and bench-forming unit that otherwise differs only in texture as it becomes progressively finer grained towards the east, especially in the extreme eastern part of the area. Its upper few feet commonly consist of more firmly cemented grains. Plate 4*B* and *C* show its appearance in some detail.

#### PRICE RIVER FORMATION (RESTRICTED)

*Distribution.*—The Price River formation, as restricted here by the removal of the Castlegate sandstone, extends eastward continuously from the type locality of the formation along the Book Cliffs as far as the Green River. South of the type locality in the Wasatch Plateau, it is widespread; and to the west it extends, according to Spieker (1946, p. 130, 131), beyond the divide between Price River and Spanish Fork of Provo River to the valley of Spanish Fork, where it forms part of a series of coarse-grained conglomerate beds.

*Lithologic character and thickness.*—The Price River formation in the western Book Cliffs is a sequence of gray and buff sandstone beds and gray shale beds, some 530 feet thick at Horse Creek. Some of the sandstone beds are locally thick and cliff-forming.

Fisher (1936, p. 18) found it useful to recognize in the Beckwith Plateau and a short distance eastward across the Green River a "Bluecastle sandstone bed" in the upper part of his "Neslen member" of the Price River formation. This unit has been recognized northwest of the area studied in detail by Fisher, in the Woodside quadrangle, by V. H. Johnson (written communication) as the uppermost 300 feet of the Price River formation and called the Bluecastle sandstone member. It is shown, therefore, to have a considerable lateral extent and assumes importance as a local unit in the area adjacent to the Green River.

#### UTAH EAST OF THE GREEN RIVER AND IN COLORADO (CENTRAL AND EASTERN BOOK CLIFFS)

In Utah east of the Green River, the Castlegate sandstone and subdivisions corresponding to the members of the Price River formation recognized by Fisher (1936, p. 9, 14-30) are used here as formations.



## CASTLEGATE SANDSTONE

This formation is described on pages 13-14.

## BUCK TONGUE OF MANCOS SHALE

An eastward-thickening tongue of Mancos shale designated by Fisher (1936, p. 10, 15) the Buck tongue, from the name of a canyon in T. 19 S., R. 23 E., overlies the Castlegate sandstone from the Beckwith Plateau to the Colorado-Utah line. Farther west it fingers into the predominantly sandy phase of the lower part of the Price River formation and is not separable. Since in mapping the Book Cliffs in Utah the formations were followed from west to east and this shale member was not recognized as a unit until the area east of the Green River was reached, it is not certain just how far west it could be traced, but the beds just above the Castlegate are very sandy north of the Price River. The thickness of the Buck tongue increases from about 100 feet in the southern part of the Beckwith Plateau to 350 feet at the Utah-Colorado line; farther east it merges with the Mancos shale, owing to the disappearance of the intervening Castlegate sandstone. Lithologically, in general, it cannot be distinguished from the Mancos shale. (See pls. 5A and 6A and 6B). The carving of a bench on the top of the Castlegate sandstone east of the Green River, and not to the west, is accounted for mainly by the greater thickness of this shale zone in this region. Its upper contact is gradational into the overlying Sego sandstone. Its origin is similar to that of the Mancos. The fossil content is shown in table 13, and the question of age and correlation is discussed with that of the Sego sandstone.

## SEGO SANDSTONE AND INCLUDED ANCHOR MINE TONGUE OF THE MANCOS SHALE

*Distribution.*—Overlying the Buck tongue, and recognizable as a unit from the Beckwith Plateau eastward into Colorado, is the marine cliff-making sandstone, the Sego, named by Fisher (1936, p. 9, 15) from the Utah settlement of that name in T. 20 S., R. 20 E.

*Lithologic character and thickness.*—In Utah the average thickness of the Sego sandstone is 175 feet, and only one section east of the Green River differs from this average by more than 40 feet. It makes from 1 to 4 minor cliffs in the basal part of the second escarpment of the Book Cliffs. In Crescent Canyon it makes 2 or 3 cliffs. Plate 6A shows a view looking northwest across the juniper-bearing Castlegate bench at Crescent Butte. The Buck tongue and Sego sandstone form the base of the escarpment,

which includes also the overlying Neslen and Farrer formations. Plate 6B shows a close view of the two lower units taken a short distance farther east. On the east side of Neslen Canyon, the Sego forms two main ledges with an intervening shaly zone containing a third minor ledge. Plate 5A shows the Buck tongue and overlying Sego sandstone in the canyon of Westwater Wash, where the former is 340 feet thick. On the whole the Sego sandstone is lithologically very similar to the Castlegate in the vicinity of the Green River. It is, however, less massive and in only a few places makes a single continuous cliff, for shaly zones that cause minor intervening slopes are generally present.

In Utah no single sandstone bed of the Sego is important enough to dignify with a special name. The shaly partings in the member appear to be fairly lenticular and exist at several or many horizons in different places; the whole is thus treated as a unit consisting predominantly of sandstone or sandy beds. The sandstone weathers buff, often very light gray at the tops of the ledge makers, and is massive to thin bedded and shaly. A peculiar detail of weathering of this quartz sandstone is shown in plate 5B; this honeycomb appearance is not untypical of the top of the member at many places. It is thought to depend upon the solvent action of water on the calcareous cement, which probably has an irregular distribution and results in the loosening of the sand grains, which are scooped out of the hollows by the abrasive action of torrential waters and possibly wind action.

In Colorado the Castlegate sandstone is not recognizable; the Buck tongue has become an integral part of the Mancos shale; and the Sego sandstone rests directly upon the Mancos shale. The upper surface of the Sego is relatively smooth and is the most persistent and easily recognizable stratigraphic horizon in the Colorado part of the Book Cliffs. The outcrop, especially toward the east, is usually a bold vertical cliff. In Colorado the Sego sandstone is subdivided into the upper sandstone member, the Anchor Mine tongue of Mancos shale, and the lower sandstone member.

*Lower member of the Sego sandstone.*—The lower member of the Sego sandstone begins to show clearly as a unit in Utah near the State boundary. Its thickness is irregular, reaching a maximum for Colorado at the mouth of the canyon of East Salt Creek, where it is 110 feet thick. At Hunter Canyon it is 90 feet thick, though between East Salt Creek and Hunter Canyon it is much less. Between Hunter Canyon and sec. 12, T. 10 S., R. 100 W., it passes into shale. Near East Salt Creek the lower member of the Sego is

typical in its lithologic character, a little less massive than it is to the west and more massive than it is to the east. Both upper and lower boundaries are markedly transitional and are more irregular than those of the upper member of the Sego. The nature of the lower boundary has been noted in some detail in connection with the Mancos shale, as has also the base of that part of the upper member that overlaps the lower member.

The general lithologic character of the lower member is given in a stratigraphic section of the unit taken at East Salt Creek. (See "Local Sections," Section 20.) Here the upper part of the member contains two massive medium-grained buff to yellow-brown sandstone beds that are 30 and 12 feet thick, respectively, and are separated by a thinner bedded sandstone that is 15 feet thick, the whole sequence being about 60 feet thick. The lower part consists of sandstone, sandy shale, and clay shale in beds up to 2½ feet thick, the whole about 50 feet thick. These lower beds are lenticular and at places contain mud pellets and fragments of carbonaceous matter.

*Anchor Mine tongue of Mancos shale.*—The general character of the Anchor Mine tongue in the western part is shown by a section at the mouth of the canyon of East Salt Creek (see "Local Sections," Section 20), where the relation of the tongue to the enclosing sandstone units is as definite and as well exposed as at any place on its outcrop. Here the tongue is 115 feet thick, the gray sandy clay shale containing in the upper 30 feet and the lower 50 feet thin beds of medium-grained gray sandstone. Where it is thinnest, near Salt Wash, the whole unit is carbonaceous and dark, the Anchor coal bed occupying a zone 5 feet thick about 11 feet above the lower member of the Sego. Near Hunter Canyon the uppermost and lowermost parts of the Anchor Mine tongue are carbonaceous and contain thin layers of coal, but most of the unit is gray sandy shale and thin-bedded sandstone. Farther east the unit resembles the Mancos shale.

*Upper member of the Sego sandstone.*—The upper member of the Sego sandstone is recognized, with considerable range in thickness, from Utah near the State boundary eastward into Colorado as far as Grand Mesa. In general, this member appears as a massive gray cliff somewhat lighter in color than the Mancos shale below. When viewed closely it consists of a great number of thin irregular or platy beds of sandstone, usually laminated and in many places crossbedded. It is more massive toward the west, and toward its eastern end contains more shale.

Near the Utah-Colorado State line, the upper mem-

ber of the Sego is about 75 feet thick, with a more massive middle zone (40 feet), a thin-bedded basal part (20 feet), and a gray-white upper part (15 feet). It maintains this general constitution to East Salt Creek, then thins to 43 feet in sec. 10, T. 8 S., R. 102 W., where it is divided into upper and lower massive beds by a stratum of carbonaceous shale and coal. At Hunter Canyon the upper bed is massive, gray white, about 25 feet thick, and the lower part is thin bedded; eastward to the Book Cliffs mine there is little change in thickness, though the unit decreases in prominence. At the Book Cliffs mine the member is 31 feet thick, massive, and gray white, but a mile north of the Book Cliffs mine there is an additional lower zone of thin sandstone and sandy shale 73 feet thick. At the Garfield mine the thickness increases abruptly to 100 feet. At the Riverside mine, near the Colorado River, the thickness is 40 feet. To the east of this locality the member becomes less prominent, and in sec. 28, T. 12 S., R. 97 W., it is a succession of platy, calcareous sandstones in shale that is hardly recognizable as a unit. It is reported by W. W. Boyer (written communication) to disappear south of Colorado River.

The sandstone of the Sego is medium grained, has a sugary texture, and is soft and friable. It is largely composed of quartz, but in some localities an abundance of ferromagnesian minerals gives it a grayish tone. Some red jasperlike grains are also present. Throughout most of its extent, the upper 10 or 15 feet is lighter than the underlying buff and brown strata. The variations in thickness that are so apparent are due to lateral changes in lithology at the base and to lack of definition of the top of the Mancos.

#### UNITS BETWEEN THE SEGO SANDSTONE AND THE TERTIARY FORMATIONS

Above the Sego sandstone different units are recognized and different names are applied in Utah and Colorado. This difference in usage has two sources—differences in the sequence of rocks, naturally expectable in exposures covering great distances at a high angle to an old shoreline; and a lack of precise information, particularly as regards significant fossils, concerning the upper part of the sequence. It has seemed more useful for practical purposes to use the boundary between Colorado and Utah as an arbitrary line of separation between the two nomenclatures, though the strata are, of course, continuous across it, and for some distance on either side the units of the respective areas might be discriminated.

In Utah the Sego sandstone is overlain, in sequence, by the Neslen formation and the Farrer formation of

definitely Late Cretaceous age and the Tuscher formation of possible Tertiary age but here arbitrarily included in the Late Cretaceous. In Colorado the Sego sandstone is overlain, in sequence, by the Mount Garfield formation, containing the Rollins sandstone member, of Late Cretaceous age, and the Hunter Canyon formation, which is essentially equivalent to the Tuscher formation. The Hunter Canyon formation is overlain in turn by a unit to which the non-committal designation Tertiary sandstone has been applied. In the southeastern part of the Grand Mesa field, Lee (1912, p. 19, 30) found the Rollins sandstone member to be the base of his Mesaverde formation and recognized above it the Bowie shale member, the Paonia shale member, and an unnamed upper member, upon which rests a conglomeratic sandstone unit correlated by Lee with the Ohio Creek conglomerate of the Crested Butte area of Colorado, but not named in this paper. Johnson (1948) adopted essentially Lee's units, but used lower and upper coal members for what Lee called Bowie and Paonia members and called the upper member the barren member. In both Utah and Colorado the next higher unit was long believed on lithologic grounds to be equivalent to the Wasatch formation, of Eocene age, but Patterson (1934, p. 99) has shown that in Colorado upper Paleocene beds are present at least locally in the lower part of it. In eastern Utah no other name than Wasatch has been used, but in Colorado the name Ruby formation was applied by Lee and others, perhaps erroneously. To the upper Paleocene part of the sequence, Plateau Valley beds has been applied by Patterson (1936).

#### NESLEN FORMATION

*Distribution.*—The Neslen formation lies between the Sego sandstone and the Farrer formation and takes its name from Neslen Canyon, in which the town of Sego is located (Fisher, 1936, p. 9, 16–19). The formation contains all the coals of importance found in the central Book Cliffs. As a unit it has not been traced west of the Green River, though all post-Sego strata of the Beckwith Plateau would fall within it. Farther to the northwest it merges into the Price River formation. To the east it appears to be equivalent to part of the Mount Garfield formation.

*Lithologic character and thickness.*—The Neslen formation is composed of alternating sandstone and shale beds that appear in outcrop as minor ledges with intervening slopes; the two are in about equal proportions. As a whole the formation is relatively light colored, contrasting therefore with the overlying somber beds of the Farrer formation. Where the

coal is not burned, the Neslen sandstone beds weather light gray to buff; and the noncarbonaceous shales, to drab or medium light gray. The strata are notably different from those of the Blackhawk formation (which contains all the coal west of the Green River) in the conspicuous absence of continuous cliff-making sandstone beds and in the inferiority of the coal beds, which are thinner and of lower rank and grade. The appearance of the unit is shown in plate 6A, in which its top is about halfway up the cliff, at the top of the light-colored zone. While in distant view its upper contact is fairly well marked, it is seen on closer inspection to be gradational. Because this upper boundary is somewhat indefinite and because of the lithologic heterogeneity of the unit, its thickness as mapped ranges over rather wide limits. Sections measured show values between 250 and 410 feet, with an average of 350 feet. Many details of its lithologic character are given in the section entitled "Local Sections."

About 200 feet stratigraphically above the base of the formation, in the Beckwith Plateau and a short distance east of it, a cliff-making sandstone bed was recognized as a unit, mainly because it forms the dip-slope surface on the top of the Beckwith Plateau (pl. 2C). It was called by Fisher (1936, p. 18, 19) the "Bluecastle sandstone bed," after the canyon of that name which nearly bisects the Beckwith Plateau, and was later called the Bluecastle sandstone member of the Neslen formation (Cobban and Reeside, 1952). It has a thickness of 100 feet, or slightly more, on the plateau but thins rapidly to the east, where it loses its identifying characteristics, as is indicated on plate 10. In the Woodside quadrangle, northwest of the area studied by Fisher, the Bluecastle member was recognized by V. H. Johnson (written communication) as the uppermost 300 feet of the Price River formation. (See section 5, p. 183–201.) It thus appears to be wedge shaped, thickening northwestward into an important unit. Aside from the characteristics already mentioned it is similar to most of the other Neslen sandstone beds—namely, it is crossbedded, medium to fine grained, and weathers buff to gray. Two other minor sandstone units (Thompson Canyon sandstone bed, Sulphur Canyon sandstone bed), together with the coal beds of the Neslen formation, were also described by Fisher (1936, p. 18, 19).

#### FARRER FORMATION

*Distribution.*—Above the Neslen formation is found a series of somber-appearing Cretaceous shale and sandstone beds grouped by Fisher (1936, p. 9, 19)

as the Farrer formation (pronounced fair-er), the name coming from a local mine of that name in the canyon of Coal Creek (T. 20 S., R. 17 E.), above which it stands as a pronounced escarpment. It also forms the upper half of the cliffs in plate 6A. It has been followed from the Green River to the Utah-Colorado line. It appears to be equivalent to the upper part of the Mount Garfield formation and possibly to part of the Hunter Canyon formation of Colorado. West of the Green River, the recognition of the Bluecastle sandstone member of the Neslen formation in the top of the Price River formation in the Woodside quadrangle and assignment of the overlying beds to the undifferentiated North Horn and Flagstaff formations suggests that the Farrer and Tuscher formations may be missing.

*Lithologic character and thickness.*—The Farrer formation was examined only at intervals, since it is not readily accessible at many places and time sufficient to make a careful study was not available. Its thickness shows notable variation; in 7 sections it ranges from 410 to 1,095 feet, averaging 690 feet. It is not sharply distinguished from either the underlying or overlying beds. It has, however, certain unifying characteristics. It is nearly non-coal-bearing although it does carry a few unimportant lenses of coal at several horizons. The sandstone beds, constituting about two-thirds of the whole, in the main weather into brown-stained blocky ledges or cliffs separated by medium-gray clay shale beds with a distinct olive-greenish tinge. This olive green of the shale beds is the best single criterion for placing the basal contact. Locally, where the shale beds are sufficiently bolstered with sandstone layers, the formation forms an impressive and unscalable cliff. The whole presents a notably somber appearance, contrasting with the enclosing lighter-colored beds. The sandstone beds show excellent crossbedding of the current type and carry lenses of clay gall "conglomerate." True pebbles are quite rare, though present. The rock consists largely of subangular to poorly rounded medium-fine quartz grains in a firm calcareous cement but contains 3–10 percent of feldspar, 2–10 percent of dark minerals, and a very small amount of white mica.

#### TUSCHER FORMATION

In Utah east of the Green River above the Farrer formation and below the varicolored, though predominantly red, "Wasatch" strata is found a series of light-colored sandstone beds separated by minor shale beds. These have been examined at only a few

localities and have never been studied in any detail. They were tentatively grouped by Fisher (1936, p. 9, 20) as a separate formation under the name Tuscher, after the canyon in T. 20 S., R. 17 E. The formation makes a continuous unit in the Book Cliffs of Utah east of the Green River.

As a unit, and at some distance, the formation stands out from the underlying somber-appearing beds and the overlying varicolored but notably red "Wasatch." The absence of interbedded varicolored shale beds was the main reason for not grouping the Tuscher formation with the "Wasatch" when the unit was established by Fisher. The positions of the actual contacts are, however, obscure in many places. The individual beds thicken and thin and cannot as a rule be traced far. On the Green River the thickness was found by Spieker (1946, p. 140) to be 215 feet; east of the Green River the thickness ranges between 267 and 600 feet. The unit is composed largely of massive sandstone beds; these are separated by thinner beds of buff to gray shale layers that in many places show a light-greenish cast. The sandstone is typically crossbedded, friable, light gray to creamy white, cliff making, weathering to rounded surfaces; but local variations were noted. The composition is largely colorless quartz in medium-sized well-rounded to angular grains generally weakly cemented by calcium carbonate. White feldspar in amounts up to 10 percent and dark minerals in amounts of 2 percent or less are present. Some layers are pronouncedly conglomeratic, carrying minor amounts of quartz and black chert pebbles up to 1 inch in diameter.

The character of the exposures and the presence of slump materials make it difficult to determine the nature of the contacts with the adjacent formations. While a pronouncedly unconformable surface has not been seen, both upper and lower contacts are thought to mark disconformities. These are indicated by the great variations in thickness of both the Tuscher formation and the Farrer formation. In places on the east side of the Nash Wash reentrant a thick basal conglomerate immediately overlies the formation.

As previously noted, Erdmann (1934, p. 33, 51) suggested that the Tuscher formation passes eastward into the Hunter Canyon formation of Colorado, and recent examination of aerial photographs by Fisher has made this correlation very probable.

Little direct evidence of the age of the Tuscher formation is available, but since it seems to be essentially equivalent to the Hunter Canyon formation and appears to be older than the undifferentiated

North Horn and Flagstaff formations, it is here assigned to the Mesaverde group and arbitrarily considered of Late Cretaceous age.

#### MOUNT GARFIELD FORMATION

*Distribution.*—The Mount Garfield formation was named by Erdmann (1934, p. 32) from Mount Garfield, about 3 miles northwest of Palisade, Colo. It is recognized along the Book Cliffs from the Utah-Colorado State boundary as far as Grand Mesa.

*Lithologic character and thickness.*—The Mount Garfield formation ranges in thickness from 970 to 1,070 feet and contains most of the coal beds in the Book Cliffs of Colorado. The lower part, ranging in thickness from 305 to 666 feet, constitutes the "coal measures"; the upper part, ranging from 405 to 665 feet, constitutes the "barren measures." In the lower part, in the vicinity of the Colorado River, a prominent sandstone bed has been designated the Rollins sandstone member, as it is believed to be the unit so named by Lee (1912, p. 30) in the Grand Mesa area. Southeast of the Colorado River the beds of the lower part of the Mount Garfield formation below the Rollins sandstone member pass into marine shales indistinguishable from the Mancos shale, and the Rollins becomes the basal unit of the Mesaverde group. The Mount Garfield formation is conformable with the Sego sandstone below and the Hunter Canyon formation above. The upper boundary is somewhat arbitrary, the Hunter Canyon formation differing chiefly in its more numerous, coarser, grayer, and more massive sandstone beds and its lack of carbonaceous shales.

*Lower part, or "coal measures."*—Erdmann (1934, p. 40-48) has described the lower part or "coal measures" of the Mount Garfield formation in detail in his report on the coals of Garfield and Mesa Counties. It consists of sandstone, shale, sandy shale, carbonaceous shale, and coal beds. Continental rocks predominate, but brackish-water rocks nearly equal them in amount. The sandstone beds are of several sorts—white, massive, apparently littoral beds; irregular but massive buff sandstone beds of fluvial origin with partings of shale and shaly sandstone; and thin irregular sandstone layers intercalated in beds of gray shale. The massive sandstone beds have grains averaging 0.25 millimeters in diameter; the thin sandstone layers in shale are hard, fine grained, and ripple marked. The clay shale beds are generally gray; the carbonaceous shale beds are generally associated with the coal beds and range from reddish brown to black.

*Rollins sandstone member.*—The most conspicuous

lithologic unit in the "coal measures" is the Rollins sandstone member. It is similar to the Sego sandstone and has been at times confused with it. The weathered surface is light yellow gray and brown; the fresh surface, grayish white to white. It is cross-bedded, coarse grained, and of sugary texture. Locally the upper part contains rusty-brown concretions as much as 30 inches in diameter, with which are at some places associated *Halymenites major* Lesquereux. No other fossils were found. The unit is not identifiable west of the Book Cliffs mine, about 10 miles northwest of Palisade.

*Upper part of "barren measures."*—Erdmann (1934, p. 44) describes these beds as follows:

The lithology of the "barren measures" of the Mount Garfield formation closely resembles that of the "coal measures." The "barren measures" contain very little coal, and the total amount of carbonaceous shale has been reduced from 15 to 6 percent. Though there is somewhat less sandstone, the beds are in general slightly more arkosic and more massive. They also show more decided characteristics of fluvial origin, especially the cross bedding. In color, structure, and size of grain (averaging 0.01 inch [0.25 mm]) the sandstones are similar to those of the "coal measures." The shaly beds in the "barren measures" are like those below, but locally they are much thicker. These deposits are considered to be of continental origin.

*Relations of the Mount Garfield formation to the Bowie and Paonia shale members of the Mesaverde formation.*—Resting on the Rollins sandstone member of the Mesaverde formation of Lee (1912, p. 32-47) in the Grand Mesa field lie in ascending order the Bowie shale member, the Paonia shale member, and the undifferentiated upper Mesaverde. Lee distinguished the Bowie shale member as of marine and brackish-water origin and the Paonia member as of fresh-water origin, both containing coal; the undifferentiated part does not contain coal. The Rollins sandstone member was said by Lee to rest on the Mancos shale throughout the Grand Mesa region. The Paonia member rests, according to Lee, on the Rollins sandstone member in the western part of the Grand Mesa area, but toward the east the Bowie member appears and gradually increases in thickness eastward. According to W. W. Boyer (written communication), Lee misidentified his units in the western part of the Grand Mesa field. The upper member of the Sego sandstone of this paper was mistaken for the Rollins, and the strata between the upper Sego and Rollins were referred to the Bowie shale member. The upper part of the "coal measures" of the Mount Garfield formation and the "barren measures" are together equivalent to the Bowie and Paonia shale members, and the

Hunter Canyon formation is equivalent to the undifferentiated upper Mesaverde.

#### HUNTER CANYON FORMATION

*Distribution.*—The Hunter Canyon formation was named by Erdmann (1934, p. 33, 48–53) and described in detail. The type locality is in Hunter Canyon, north of Grand Junction, Colo. The formation has been identified over the whole length of the Colorado part of the Book Cliffs.

*Lithologic character and thickness.*—The formation consists of massive brown-buff and gray sandstone and soft gray shale beds and ranges in thickness from 375 to 1,400 feet. It is distinguished from the Mount Garfield formation chiefly by the character of its sandstone beds, which are more numerous, coarser, grayer, and more massive than those of the Mount Garfield by the virtual absence of carbonaceous shale, and by the presence of some greenish shale beds. These differences are much like those that separate the Neslen and Farrer formations in Utah, but it is believed that the Hunter Canyon and Farrer are only in small part equivalent. The upper boundary is an evident disconformity, the erosional relief being small locally but in larger aspect attaining 1,100 feet. The overlying unit is a chert pebble conglomerate or conglomeratic sandstone.

Sandstone makes up about 60 percent of the formation, the remainder being gray shale with some thin sandstone layers. Carbonaceous shale layers constitute only about 1 percent. The sandstone beds are medium to coarse grained and in beds 10–40 feet thick but locally aggregating as much as 300 feet. The bedding is generally regular, but even thick beds may finger into shale abruptly. Crossbedding is common, and channeling fairly common. The basal parts of many beds are characterized by accumulations of mud pellets and lumps ranging in longest dimension from  $\frac{1}{4}$  to 4 inches. Gray and greenish-gray shale and sandy shale are abundant. They contain thin calcareous sandy layers and some concretions. Fossils are rare.

As noted above, the Hunter Canyon formation appears to be equivalent to the undifferentiated upper members of the Mesaverde formation of Lee (1912, p. 43) in the Grand Mesa coal field. Erdmann (1934, p. 33, 51) suggested, in proposing the name Hunter Canyon, that the unit is equivalent to part of the Farrer formation and part or all of the Tuscher formation of Utah (discussed above). Recent examination of air photographs by Fisher indicates that probably the Tuscher and Hunter Canyon are essentially equivalent units.

#### CRETACEOUS AND TERTIARY SYSTEMS

In the Wasatch Plateau the beds above the Price River formation were formerly classified as three members of the Wasatch formation. These three units are now called the North Horn formation, the Flagstaff limestone, and the Colton formation (Spieker, 1946, p. 120–122, 132–136). The lower part of the typical North Horn formation has been shown by Gilmore (1946) to contain reptiles of Late Cretaceous age, and the upper part has been shown by Gazin (1938, 1939, 1941) to contain mammals of early Paleocene age. The typical Flagstaff limestone is assigned to the late Paleocene and possibly early Eocene by La Rocque (1951) on the basis of the non-marine mollusks. In later papers La Rocque (1953, 1956) reaffirms the assignment and also definitely assigns the Colton to the Eocene.

Spieker (1946, p. 140–142) carried out a reconnaissance examination eastward from the Wasatch Plateau as far as the Green River in an attempt to trace the North Horn and other formations from the Wasatch Plateau into the Book Cliffs. The effort was not entirely successful because, with the equipment and time available, important parts of the line of outcrop could not be reached. He did, however, conclude that the Colton, North Horn, and Flagstaff formations extend into the western Book Cliffs; that certain beds which occur on the Green River represent the Colton and North Horn formations, and that below these is probably the Tuscher formation of Fisher.

In a section measured in 1925 in the canyon of Horse Creek, south of Sunnyside, Fisher assigned a thickness of 650 feet to the Price River formation above the Castlegate sandstone and thought the overlying 131-foot unit largely of sandstone might belong to the Tuscher formation. However, Reeside considered that this unit together with the overlying 655-foot largely shale unit might represent the North Horn formation. In a section measured in the same area at a later time Erdmann (written communication, 1940) assigned with doubt essentially the same sandstone bed to the Tuscher formation and suggested that it and an overlying bed might constitute the North Horn formation.

Recent reexamination of the sections in the canyon of Horse Creek and Tuscher Canyon by Hail, Kinney, and Zapp (1956 and written communication) support the correlations made by Spieker, Fisher, and Erdmann except that the beds between the Price River and Colton formations seem better assigned to an undifferentiated North Horn and Flagstaff unit and except that the Tuscher formation is not recognizable in the canyon of Horse Creek.



In Colorado a unit designated the "unnamed sandstone" was mapped by Erdmann from the Colorado-Utah boundary to the Colorado River. Though the age of this unit is dubious, it is assigned somewhat arbitrarily to the Tertiary.

#### NORTH HORN AND FLAGSTAFF FORMATIONS UNDIFFERENTIATED

According to Spieker (1946, p. 140), though the North Horn formation extends through the western Book Cliffs, the Flagstaff limestone thins eastward and does not appear to be a well-defined entity near Sunnyside. Recent examination of sections in the western Book Cliffs by Hail, Kinney, and Zapp (1956 and written communication) indicates that the North Horn and Flagstaff are not readily separable in this area, though equivalents of both are probably present. A thickness of 1,095 feet was assigned the combined unit in Willow Creek; 1,040 feet, in the canyon of Soldier Creek; and 530 feet, in the canyon of Whitmore Creek. South of Sunnyside in the Horse Canyon area, a gray unit 260 feet thick (units 175-197 of sec. 5) contains beds of gray limestone that make up about one-sixth of the thickness and become more sandy in the lower part. (See pls. 8C and D, and 9C.) Beneath it at the canyon of Horse Creek is a unit 310 feet thick (units 150-174 of sec. 5) of tan to greenish-gray shale beds and soft light-gray salt-and-pepper sandstone beds, with very minor limestone layers. (See pl. 8B.) These two units, totaling 570 feet, seem better interpreted as containing together the North Horn and Flagstaff formations. This unit has been traced by Fisher on aerial photographs into the gray unit 395 feet thick identified by Spieker (1946, p. 140) as the North Horn formation on the Green River. Beneath his North Horn, Spieker identified a possible Tuscher formation and beneath it in turn three units of sandstone and shale (his units 6, 7, and 8) that are here included in the Price River formation. East of Tuscher Canyon the terms North Horn and Flagstaff have not been used, and, if present, beds equivalent to these units have been included in the "Wasatch" formation.

#### TERTIARY SYSTEM

As indicated on page 13, the lowest part of the sequence above the Price River formation in the Wasatch Plateau is definitely of Cretaceous age, but succeeding beds are in part of Paleocene age and in part of Eocene age. Some of these units can be traced into the western Book Cliffs and perhaps beyond the Green River. The North Horn and Flagstaff formations have already been discussed. Above them, in succession, lie the Colton formation and the Green

River formation, both of Eocene age. In the central and eastern Book Cliffs, some of the higher part of the sequence is of dubious age and has been somewhat arbitrarily assigned. The Tuscher formation has been placed in the Late Cretaceous, and the unnamed sandstone has been placed in the Tertiary. A still higher part, long called Wasatch, is almost certainly all of Tertiary age. This part for convenience is called here the "Wasatch" formation and may contain both Paleocene and Eocene beds.

Patterson (1934) has demonstrated that the beds adjacent to the Colorado River near Debeque, Colo., essentially the eastern end of the Book Cliffs, that were called "Ruby" formation by Lee (1912, p. 49, 51) contain upper Paleocene deposits overlain by Eocene beds with *Coryphodon* and other vertebrates. To the Paleocene deposits, Patterson (1936, p. 397) has given the name Plateau Valley beds. Just how these beds fit into the Book Cliffs sequence has not been determined.

#### COLTON FORMATION

In Utah only the basal part of the beds above those assigned to the Price River or Tuscher formations was examined by the writers, except in the canyon of Horse Creek (section 5), where the sequence for 3,300 feet above the Price River formation was measured. Hail, Kinney, and Zapp (1956 and written communication) have examined sections in the western Book Cliffs from Willow Creek, north of Price, Utah, to the canyon of Tuscher Wash, east of the Green River. They identified the Colton formation in this area as succeeding the undifferentiated North Horn and Flagstaff formations and as intertonguing in its upper part very extensively with the Green River formation. In Willow Creek and the canyon of Soldier Creek, about 1,700 feet of beds are assigned to the Colton, with about 500 feet of interbedded Colton and Green River above it. In the canyon of Whitmore Creek the Colton is about 1,300 feet thick, but the zone of interbedding is nearly 1,700 feet thick. In the canyon of Horse Creek all of this interval is of Colton type, and the thickness of the Colton is more than 3,000 feet. Between the Green River and the Utah-Colorado State boundary, the Colton is included in the "Wasatch" formation, and the thickness is not known.

The Colton formation is described as composed of gray salt-and-pepper sandstone, greenish-buff sandstone, siltstone that commonly weathers golden brown, and shale ranging from deep red to variegated and gray. Individually, the strata are irregular and discontinuous and are of flood-plain and channel origin.

**UNNAMED SANDSTONE**

In the Colorado Book Cliffs a conglomeratic sandstone rests upon the Hunter Canyon formation and seems to be equivalent to the unit that on Grand Mesa was designated by Lee (1912, p. 48) as the Ohio Creek conglomerate. This name was taken by him from the typical Ohio Creek of Eldridge, a unit of the Anthracite-Crested Butte area farther southeast in Colorado. It was identified by Lee with the Ohio Creek largely because of its stratigraphic position and supposedly similar lithologic composition. Lee did not trace the unit, and it appears from a reconnaissance examination by W. S. Burbank and B. S. Butler (oral communication) that his use of the name is very dubious. Erdmann (1934, p. 53) did not apply a formal name to this unit in the Book Cliffs, and none is applied in this paper.

The unnamed sandstone of the eastern Book Cliffs has as its base a conglomerate or conglomeratic sandstone bed 10-40 feet thick, characterized by rounded pebbles of gray and black chert. Pebbles of other kinds of chert, quartz, and rarely jasper and limestone are also present. The pebbles range from  $\frac{1}{4}$  to 2 inches in diameter, and the matrix is gray to yellow sand. The basal conglomerate beds grade upward into a coarse-grained gray sandstone containing thin stringers and lenses of pebbles. The whole unit ranges from 155 to 370 feet in thickness. The sandstone is in beds separated by beds of shale ranging from 10 to 50 feet in thickness, predominantly gray but with a greenish tone. Clay-pellet conglomerate also occurs in the sandstone beds. The base is a major erosional unconformity, and Erdmann thinks the unit is more closely related to the overlying beds than to the underlying beds.

**"WASATCH" FORMATION**

In the western Book Cliffs the former Wasatch formation, now divided, forms the higher parts of the cliffs. From Sunnyside eastward to the Green River, the main body of the unit lies well behind the front, though "Wasatch"-capped spurs project toward the escarpment and in these areas bring the formations to a position not far back of the Book Cliffs escarpment. On the east side of Nash Wash reentrant, northwest of Cisco, the "Wasatch" again makes up the higher part of the escarpment. East of Nash Wash the formation stands up as the Roan or Brown Cliffs of the Powell maps, some miles behind (north of) the Book Cliffs.

In Utah east of the Green River the beds that are grouped as "Wasatch" are characterized by their

bright colors. The color is in the shale beds, where, besides grays, are seen brick reds, purples, yellows, and other shades. The unit contains important amounts of cliff-making sandstone, as exhibited at a locality in the Nash Wash reentrant (pl. 6C), where the lower 800 feet of the unit is present. At this locality the base of the "Wasatch" is marked by a 50-foot cliff-forming conglomerate bed (pl. 4A). A similar conglomerate is present 110 feet above the base of the unit in the canyon of Saleratus Wash. No such conglomerate was found in the Tuscher Canyon section.

In the Colorado part of the Book Cliffs the "Wasatch" formation consists of variegated clays of fluviatile or lacustrine origin, with a few sandstone and limestone layers. It is particularly susceptible to erosion and forms highly sculptured outcrops. The chief characteristic of the formation is its bright coloring, particularly reddish tints, though gray and yellow-brown and greenish tints are also present. It forms the lower part of the Roan Cliffs. Subordinate sandstone occurs as thin slabby masses and as irregular lentils and is generally fine grained. The beds of limestone are gray and fossiliferous. The thickness of the formation ranges from 280 feet at the head of West Salt Creek to 790 feet at the head of Hunter Canyon. The lower boundary is transitional from the underlying unnamed sandstone formation.

**GREEN RIVER FORMATION**

Over most of the area examined in Utah, the Green River formation lies so far behind the Book Cliffs escarpment that it was not studied. In Colorado the basal Douglas Creek member of the formation forms the upper part of the Roan Cliffs and was examined at many places. It is an assemblage of sandstone, fresh-water marlstone, and shale that reaches a maximum thickness of 1,200 feet. An abundance of calcareous material is characteristic of the member as a whole. Its aggregate color is a whitish gray.

**AGE AND CORRELATION OF THE FORMATIONS****STANDARD SEQUENCE OF THE CRETACEOUS OF THE WESTERN INTERIOR REGION**

In considering the intrarelations of the Cretaceous deposits of the western interior of the United States, it is desirable not only that they be compared within such limited regions as the Book Cliffs, but also that some sort of comparative standard be set up to which all the deposits may be referred. Cobban and Reeside (1952) have proposed such a standard reference sequence of Cretaceous formations for the western interior region



and have suggested a suite of faunal zones to accompany this standard sequence. These, with several minor emendations, are as follows:

Formations	Faunal zones
<b>Upper Cretaceous series:</b>	
Hell Creek formation.....	<i>Triceratops</i> and nonmarine invertebrates.
<b>Fox Hills sandstone:</b>	
Unnamed members.....	No zonal fossil.
Timber Lake member.....	<i>Discoscaphites nebrascensis</i> .
Trail City member.....	<i>Discoscaphites nicolletii</i> .
<b>Pierre shale:</b>	
Elk Butte member.....	No zonal fossil.
Mobridge member.....	<i>Baculites clinolobatus</i> . <i>Baculites grandis</i> . <i>Baculites baculus</i> . <i>Baculites eliasi</i> .
Virgin Creek member.....	<i>Baculites compressus</i> s. l.
Verondrye member.....	<i>Baculites corrugatus</i> s. l.
DeGrey member.....	<i>Baculites crickmayi</i> .
Crow Creek member.....	<i>Baculites scotti</i> .
Gregory member.....	<i>Baculites gregoryensis</i> .
Sharon Springs member.....	<i>Baculites</i> n. spp. <i>Baculites obtusus</i> . <i>Scaphites hippocrepis</i> . <i>Desmoscapites bassleri</i> .
<b>Niobrara formation:</b>	
Eagle sandstone equivalent.....	<i>Desmoscapites erdmanni</i> .
Telegraph Creek formation equivalent.....	<i>Clioscapites choteauensis</i> . <i>Clioscapites vermiformis</i> .
Smoky Hill chalk member.....	<i>Scaphites depressus</i> . <i>Inoceramus involutus</i> .
Fort Hays limestone member.....	<i>Inoceramus deformis</i> .
<b>Carlile shale:</b>	
Sage Breaks member.....	<i>Prionocyclus quadratus</i> . <i>Scaphites nigricollensis</i> . <i>Prionocyclus wyomingensis</i> .
Turner sandy member.....	<i>Scaphites ferronensis</i> . <i>Scaphites warreni</i> .
Blue Hill shale member.....	<i>Collignonicerias hyatti</i> .
Fairport chalky shale member.....	<i>Collignonicerias woolgari</i> .
<b>Greenhorn limestone:</b>	
Bridge Creek limestone member.....	<i>Inoceramus labiatus</i> . <i>Sciponoceras gracile</i> .
Hartland shale member.....	<i>Dunveganoceras albertense</i> . <i>Dunveganoceras conditum</i> .
Lincoln limestone member.....	<i>Dunveganoceras pondi</i> .
Belle Fourche shale.....	<i>Acanthoceras? wyomingense</i> . <i>Acanthoceras? amphibolum</i> . <i>Calyptoceras</i> sp.
<b>Lower Cretaceous series:</b>	
Mowry shale.....	<i>Neogastrolites</i> sp.
Newcastle sandstone.....	<i>Inoceramus comancheanus</i> .
Skull Creek shale.....	
Fall River sandstone.....	No zonal fossil.
<b>Gannett group:</b>	
Unnamed red shale.....	No zonal fossil.
Draney limestone.....	
Bechler conglomerate.....	<i>Protelliptio douglassi</i> .
Peterson limestone.....	
Ephraim conglomerate.....	No zonal fossil.

In terms of a commonly accepted European chronologic scheme it is believed that the zone containing *Protelliptio douglassi* and its associates is Aptian, the Skull Creek shale and the Newcastle sandstone are middle Albian, and the Mowry shale is late Albian. The Belle Fourche shale and the two lower members of the Greenhorn limestone are Cenomanian; the upper members of the Greenhorn are early Turonian. The Carlile shale is middle and late Turonian, and the Niobrara formation is Coniacian, Santonian, and early Campanian. The Pierre shale up to and in-

cluding the Virgin Creek member is middle and late Campanian, and the Mobridge and Elk Butte members of the Pierre shale and the Fox Hills sandstone are Maestrichtian. The Hell Creek is traditionally assigned to the Danian, but there is little evidence for this except position at the top of the sequence, and the usual assumption that the Danian is Cretaceous.

For comparison between the sequences of formations in the Book Cliffs and those in three other areas in the western interior region, table 1 shows the formations of these areas referred to an abbreviated form of the standard sequence.

Nonmarine faunas are found at horizons in the western interior sequence but are best characterized in the oldest and youngest beds. The equivalents of the Peterson and Draney limestones contain a considerable fauna; the fresh-water equivalents of the Skull Creek shale, such as the Bear River formation, have a varied fauna; the fresh-water equivalents of the Gregory member of the Pierre shale, such as the Judith River formation, have a somewhat smaller assemblage; and the Hell Creek formation has a large fauna, some of it, however, rather long ranging.

In the Book Cliffs region, species characteristic of some of the older zones were not noted, and these zones may be thin or missing. In the upper part of the Book Cliffs sequence, relatively few fossils are known, and these are nonmarine; satisfactory assignment may not be possible. Attention will be called to all of these features in discussing the several stratigraphic units.

Since in the Book Cliffs a given chronologic horizon may lie in strata of marine origin in the east and in strata of nonmarine origin in the west and since the contemporaneous marine and nonmarine strata may be of differing lithologic composition and hence bear differing names, it is not easy to present the picture of the relations of the zones to the lithologic units without some degree of repetition. In the following pages the fossils from the Lower Cretaceous beds and those from the Mancos shale are presented by reference to the standard units shown on preceding pages, without respect to lateral equivalents of other name or facies. Then in ascending order are given the faunas of the accepted divisions of the Mesaverde group, which chronologically overlap the upper part of the Mancos shale. The faunas from higher beds are given last.

The relations of the faunal units to the lithologic units in the Book Cliffs are shown graphically in plate 10, in a columnar diagram. The relations of the Cretaceous units over a wider area are shown in plate 11,

TABLE 1.—Correlation of Cretaceous formations in Book Cliffs and other areas

Standard sequence	Book Cliffs, Utah and Colorado		Northern San Juan basin, Colorado	Central Wyoming	Central Montana
Hell Creek formation	Nonmarine upper part of Mesaverde group; exact equivalency not known		Animas formation (part)	Lance formation	Hell Creek formation
Fox Hills sandstone			McDermott formation Kirtland shale Fruitland formation Pictured Cliffs sandstone	Lewis shale	Bearpaw shale
Pierre shale: Elk Butte member Moberg member Virgin Creek member Verendrye member DeGrey member Crow Creek member Gregory member			Lewis shale	Mesaverde group	Judith River formation
Sharon Springs member			Mesaverde group	Steele shale	Claggett shale Eagle sandstone
Niobrara formation: Smoky Hill chalk member Fort Hays limestone member				Niobrara formation	Telegraph Creek formation
Carlile shale: Sage Breaks member Turner sandy member Blue Hill shale member Fairport chalky shale member	Mancos shale in west	Mancos shale in east	Mancos shale	Carlile shale	Colorado shale
Greenhorn limestone: Bridge Creek limestone member Hartland shale member Lincoln limestone member				Frontier formation	
Belle Fourche shale	Dakota sandstone or hiatus in west	Dakota sandstone in east	Dakota sandstone equivalents not definitely determined		
Mowry shale				Mowry shale	
Newcastle sandstone Skull Creek shale	Hiatus	Hiatus		Thermopolis shale	
Fall River sandstone					
Gannett group: Unnamed red shale Draney limestone Bechler conglomerate Peterson limestone Ephraim conglomerate	Cedar Mountain formation	Burro Canyon formation		Cloverly formation	Kootenai formation

which includes the Cretaceous deposits that encircle the Canyon Lands of southeastern Utah.

#### LOWER CRETACEOUS UNITS

At or near the type locality, Cedar Mountain formation (Stokes, 1944, p. 966) has yielded dinosaur bones, the fresh-water pelecypod *Eupera onestae* (McLearn), undetermined ostracodes, and the fern *Tempskya minor* Read and Brown (Katich, 1951, p. 2049; Stokes, 1952, p. 1769). The pelecypod is widespread in the western interior region in fresh-water Lower Cretaceous deposits of Aptian age (Gannett group, and Lower Blairmore, Kootenai, and Cloverly formations), and the fern is found in the Mowry shale and equivalents. *Eupera onestae* has been found at another locality south of Thompson, Utah, together with undetermined gastropods and fish scales and with ostracodes determined by R. E. Peck (Stokes, 1952, p. 1768) as *Metacypris angularis* Peck, *Cypridea* cf. *C. brevicornis* Peck, and *C. wyomingensis* Jones and the charophyte oogonium *Clavator harrisi* Peck.

In Colorado the Burro Canyon formation has

yielded plant remains that are assigned by Brown (1950) simply to the Lower Cretaceous. These plants include the distinctive fern *Frenelopsis varians* Fontaine, and also *Cycadeoidea* sp., *Brachyphyllum crassicaule* Fontaine, and *Sphenolepis kurriana* (Dunker). The flora is marked by the absence of dicotyledonous species. Invertebrates have been reported from a single locality in the Burro Canyon formation (Reeside, 1957) and include, beside *Nippononaias asinaria* Reeside, the widespread Aptian forms *Protelliptio douglassi* (Stanton) and *Lampsilis farri* (Stanton).

#### DAKOTA SANDSTONE

The name Dakota was intended originally to apply to an introductory Upper Cretaceous sandstone unit in the Missouri Valley, and its use has been widely extended. So much confusion exists in the wide use of the name Dakota, however, that it has come to mean simply brown sandstone beds near the boundary between the Lower and Upper Cretaceous series. For a time the U.S. Geological Survey attempted to express this confusion by using a query with the name

in many regions, but even in the type area there is doubt as to what is to be included in the Dakota and as to its exact age (Tester, 1952), and the query is now omitted. The Dakota sandstone, as the name is here applied, is believed to rest unconformably on the Lower Cretaceous deposits, and it is apparently conformable with the overlying Mancos shale, which in its basal part contains a late Greenhorn fauna (early Turonian).

In Utah, determinable fossils are scarce in the Dakota. Fragmentary pelecypods were found by Fisher at one locality. Petrified wood is fairly common, and in places large tree trunks are present. Near Elgin and near Woodside, Richardson (1909, p. 14) collected fossil plants that were determined by F. H. Knowlton as typical Dakota forms; these included the ferns *Pecopteris striata* Heer? and *Gleichenia?* sp.; the conifers *Torreya oblanceolata* Lesquereux and *Pinus* sp.; and the dicotyledons *Laurus proteaefolia* Lesquereux, *L. modesta* Lesquereux?, *Liquidambar integrifolium* Lesquereux, *Andromeda linearifolia* Lesquereux?, and *Salix proteaefolia* Lesquereux. This flora, with a varied dicotyledonous element, is assigned to the early Late Cretaceous (Cenomanian). The problematical marine fossil *Halymenites major* Lesquereux is common at some places, though it has no significance in correlation. Katich (1951) reports *Inoceramus comancheanus* Cragin from the Dakota, which, if correctly determined, would be of Albian age (late Early Cretaceous). The close relationship with the Mancos shale and the fossil plants suggest strongly that, at least at most places, the Dakota sandstone in the Utah part of the region is to be placed in the Late Cretaceous (Cenomanian).

In Colorado the coal-bearing lower part of the Dakota sandstone has yielded fossil plants assigned by Brown (1950) to the early Late Cretaceous. These include the ferns *Asplenium* sp., *Matonidium americanum* Berry, and *Bolbitis coloradica* Brown, and the dicotyledons *Juglans crassipes* Heer, *Ficus daphnogenoides* (Heer), *Nelumbium* sp., *Mahonia furnaria* Brown, *Sassafras cretaceum* Newberry, *Platanus newberryana* Heer, *Celastrorhynchium stokesi* Brown, *Sterculia townieri* (Lesquereux), and *Capsulocarpus dakotensis* Berry. Brown says that these are—

chiefly species that occur in the large flora \* \* \* from the brownish Dakota sandstone of Kansas and Nebraska, in the Woodbine formation of Texas, the Dakota of the Black Hills, S. Dak., and the Upper Cretaceous rocks of Greenland.

The upper part has yielded a few marine invertebrates, notably *Inoceramus* aff. *I. prefragilis* Stephenson and an ammonite formerly called *Acanthoceras* aff. *A. rhotomagensis* (Defrance) by Reeside (1927),

but better assigned to the genus *Calycoceras*. These fossils are of early Late Cretaceous age (Cenomanian). The species found at the several localities are shown in table 2.

TABLE 2.—Invertebrate fossils from the Dakota sandstone

	USGS Mesozoic locality <sup>1</sup>						
	4198	13710	9251	9252	9253	13707	23960
<i>Inoceramus</i> sp. ....	×						
<i>Inoceramus</i> aff. <i>I. prefragilis</i> Stephenson .....							×
<i>Cymbophora?</i> sp. ....							×
Gastropod fragment .....	×						
<i>Calycoceras</i> n. sp. ....		×	×	×	×	×	×

<sup>1</sup> Descriptions of localities follow.

4198. Point between Colorado and Gunnison Rivers, near Grand Junction, Mesa County, Colo. (sec. 23, T. 1 S., R. 1 W., Ute principal meridian). Carbonaceous shale at top of coal of Dakota sandstone. Collector, W. T. Lee, 1907.
9251. One-third of a mile west and one-eighth of a mile south of SE. cor. T. 4 S., R. 3 E., 7½ miles west of Delta, Delta County, Colo. Upper 20 feet of Dakota sandstone. Collector, G. H. Stone, 1915.
9252. One-eighth of a mile southwest of loc. 9251; upper 20 ft of Dakota sandstone. Collector, G. H. Stone, 1915.
9253. Three-fourths of a mile southwest of loc. 9251; upper 20 ft of Dakota sandstone. Collector, G. H. Stone, 1915.
13707. North bank of Gunnison River, 7½ miles west of Delta, Delta County, Colo. Shale beneath uppermost sandstone of Dakota. Collector, J. B. Reeside, Jr., 1926.
13710. Highway 50, 8 miles west of Delta, Delta County, Colo.; 1 mile north of loc. 13707. Uppermost sandstone of Dakota. Collector, J. B. Reeside, Jr., 1926.
23960. Same locality as 13707.; uppermost sandstone of Dakota. Collector, J. J. Carroll and J. B. Reeside, Jr., 1952.

The fauna of the marine part of the Dakota sandstone of western Colorado, though small, resembles that of the lower part of the Graneros shale of the foothills of the Front Range of central Colorado, which has yielded from a zone 60 feet above the Dakota sandstone of that region a considerable number of species, including ammonites of the genus *Calycoceras* (Dane, Pierce and Reeside, 1937, p. 210). The difference in the horizons of the fauna in the two areas suggests that the two sandstone formations are merely homogenetic, not strictly equivalent units. The exact relation of either to the typical Dakota sandstone of northeastern Nebraska is unknown.

The present record thus leaves the Dakota sandstone in a somewhat uncertain status. The fossils of the Cedar Mountain and Burro Canyon formations are believed to indicate an Aptian age. The plants reported by Richardson and Brown and the invertebrates reported by Reeside are believed to indicate a Cenomanian age. The only indication of intermediate Albian beds is the *Inoceramus* reported by Katich, which would be of middle Albian age. Certainly at many places there would seem to be no strata to represent the Albian (including equivalents of the Mowry shale). The writers are inclined to believe that in the Book Cliffs region a Cenomanian Dakota sandstone rests unconformably on the Aptian Cedar Mountain formation or the Burro Canyon formation and that equivalents of the post-Aptian Lower Cretaceous beds

are missing. It is possible that in central Utah the discontinuous Dakota sandstone is in part equivalent to the early Greenhorn zones that in western Colorado are found in the basal part of the Mancos shale, though the evidence for this is scant, and that the Cenomanian, as well as the Albian, is poorly represented or missing.

#### MANCOS SHALE

At its type locality in southwestern Colorado, the Mancos shale was estimated by Cross (1899b) to be about 1,200 feet thick, but a measurement by Pike (1947, p. 9) shows it to be about 2,200 feet thick. The lower part contains fossils representing zones of Colorado age, whereas the upper few hundred feet contains fossils representing the lower zones of Montana age. The belt of outcrop that includes the type locality extends along the margins of the San Juan basin some distance to the east in Colorado and to the south into New Mexico (Reeside, 1924, p. 9). In all this area it is overlain by rocks assigned to the Mesaverde group. Eastward from the type locality, the lithologic boundary, by the passage of Mesaverde sandstones into marine shales, rises somewhat with respect to the faunal zones; southward from the type locality, the lithologic boundary descends by the reverse process, so much so that it passes well down into beds of Colorado age (Pike, 1947, p. 13-25; Sears, 1936, p. 13-14; Sears, Hunt and Hendricks, 1941, p. 108-110), and the Mancos includes only the older beds of Colorado age.

The Mancos shale of the Book Cliffs, though much thicker than at the type locality, nevertheless includes in the western part of the area about the same chronologic units as does the type exposure—faunal zones of Colorado age and of earlier Montana age. Eastward, younger beds are included progressively until strata are present (equivalents of the Gregory member of the Pierre shale) somewhat younger than are known in the Mancos of the San Juan basin. The equivalents of the Mancos shale in the standard sequence, so far as may be determined from available collections of fossils, are shown graphically on plate 10, and the accompanying tables list the species found.

Widespread at or near the base of the Mancos shale in eastern Utah a zone a few tens of feet thick contains an assemblage marked by *Gryphaea newberryi* Stanton; in western Colorado this species is found 60-90 feet above the Dakota sandstone. West of Green River, Utah, it has not been found. The collections from this zone available to the writers are shown in table 3. In other parts of the western interior, this species has been commonly considered of

TABLE 3.—Fossils found at various localities in the upper Greenhorn equivalent<sup>1</sup>

	USGS Mesozoic loc.							
	13255	15553	23958	3769	Lot 1	13660	9249	23962
<i>Inoceramus</i> aff. <i>I. prefragilis</i> Stephenson.....	×							
<i>Gryphaea newberryi</i> Stanton, typical form.....		×	×	×	×	×	×	
<i>Gryphaea newberryi</i> Stanton, broad form.....								×

<sup>1</sup> See list at the end of table 9 for descriptions of localities.

early Turonian age and is associated with fossils characteristic of an upper part (lower part of Bridge Creek limestone member) of the Greenhorn limestone—*Metoicoceras whitei* Hyatt, *Kanabicerias*, and *Sciponoceras gracile* (Shumard). Katich (1951) reports *Inoceramus nahvisi* McLearn in the basal part of the Mancos shale. If correctly identified, this would indicate a late Albian age and equivalence to the Mowry shale; this assignment conflicts with the apparent age of the underlying Dakota sandstone and with the accepted age of *Gryphaea newberryi*. The writers know no other evidence of the presence in the section of an equivalent of the Mowry shale.

No faunal evidence is known to the writers of the presence in the Mancos shale of the Book Cliffs region of beds equivalent to the upper part of the Belle Fourche shale and to the two lower members (Lincoln and Hartland members) and the uppermost part (upper part of Bridge Creek member) of the Greenhorn limestone. The Belle Fourche shale and the lower members of the Greenhorn limestone are generally considered equivalent to the later Cenomanian of Europe; and the upper members of the Greenhorn limestone, to the early Turonian, of Europe. In the western interior the highest member of the Greenhorn limestone contains *Inoceramus labiatus* (Schlotheim), *Thomasites*, and other ammonites. These have not been found in the Book Cliffs, but it is possible that a very thin barren representative of the rocks in the interval is present and unrecognized.

Two faunal zones, marked particularly by species of the ammonite genus *Collignonicerias* (*Prionotropis* of literature), are found in the Mancos shale above the zone containing *Gryphaea newberryi*. The species found in these zones are shown in table 4. Elsewhere these species mark the lower part of the Carlile shale. A lower zone with *Collignonicerias woollgari* (Mantell) has been recognized at localities in eastern Utah and western Colorado in the lower part of a persistent interval of rocks, marked by large concretions. The unit is as much as 50 feet thick, and its base ranges from 100 to 150 feet above the base of the Mancos shale. This zone corresponds in age to the Fairport

TABLE 4.—Fossils found at various localities in the lower Carlile equivalent <sup>1</sup>

	U.S.G.S. Mesozoic loc.														
	Collignoniceras woollgari zone														Collig- noniceras hyatti zone
	12834	23952	23953	13256	23946	3767	13254	23942	23948	23943	23949	23944	23947	23963	23422
<i>Serpula tenuicarinata</i> Meek and Hayden										?	×				×
<i>Disciniscus</i> ? n. sp.															×
<i>Lingula</i> sp.															×
<i>Membranipora</i> ? sp.															×
Bryozoan gen. and sp. undet., A															×
Bryozoan gen. and sp. undet., B															×
Bryozoan indet.											×				×
<i>Barbatia</i> n. sp.				×	×										×
<i>Pinna</i> ( <i>Atrina</i> ) aff. <i>P. (A.) lakesi</i> White.		×		×	×										×
<i>Inoceramus howelli</i> White.															×
<i>fragilis</i> Hall and Meek		×		×	×						×				×
n. sp. aff. <i>I. erectus</i> Meek					×										×
aff. <i>I. amudariensis</i> Arkhangelsky							×								×
aff. <i>I. labiatus</i> (Schlotheim)						×				×				×	×
sp.															?
<i>Pteria</i> ( <i>Phelopteria</i> ) <i>gastrodes</i> (Meek)										×		×			×
( <i>Pseudoptera</i> ) n. sp.										×	×				×
<i>Ostrea anomioidea</i> Meek										×	×				×
cf. <i>O. soleniscus</i> Meek		×			×						×				×
cf. <i>O. malachitensis</i> Stanton															?
sp.	×	×	×	×	×	×			×	×	×	×	×		?
<i>Erygyra</i> n. sp. aff. <i>E. suborbiculata</i> (Lamarck)	×	×	×	×	×	×			×	×	×	×	×		?
<i>Camptonectes platessa</i> White.		×			×						×				?
<i>Plicatula hydrotheca</i> White.											×				×
<i>Modiolus</i> n. sp. aff. <i>M. attenuatus</i> (Meek and Hayden)		×				?				×					×
<i>Pholadomya coloradoensis</i> Stanton															×
<i>Laternula</i> n. sp. aff. <i>L. doddsi</i> (Henderson)		×		×	?						×				×
<i>Liopistha</i> ( <i>Psilomya</i> ) <i>concentrica</i> Stanton		×		×	×										×
<i>Ventella mortoni</i> Meek and Hayden		×			×					?		×			×
<i>Lucina</i> ? sp.											×				×
<i>Cardium pauperculum</i> White.		×		×	×						×				×
<i>Tellina</i> ? <i>subulata</i> Meek				×	×						×				?
<i>Legumen</i> n. sp.		×		×	×						×				×
<i>Leptosolen</i> ? n. sp.											×				×
<i>Cymbophora</i> ? <i>emmonsii</i> (Meek)		×		×	?						×			?	?
<i>Corbula nematophora</i> Meek		×									×				×
<i>Chemnitzia</i> ? sp.											×				×
<i>Pseudomelania</i> ? n. sp.											×				×
<i>Cyrtodes depressa</i> Meek											×				×
<i>Lunatia</i> aff. <i>L. concinna</i> (Hall and Meek)											×				×
<i>Lunatia</i> sp.				×							×				×
<i>Amauropsis</i> ? sp.											×				×
<i>Turritella whitei</i> Stanton				×	×						×				×
<i>Lisposdites nuptialis</i> (White)				×							×				×
<i>Pyropsis</i> ? sp.				×		×					×				×
<i>Medionapus</i> ? sp. A											×				?
<i>Medionapus</i> ? sp. B											×				×
<i>Paleosephea</i> ? n. sp.											×				×
<i>Voluoderma</i> ? n. sp.										×					×
<i>Haminea</i> ? sp.											×				×
<i>Baculites</i> sp.		×		×		×					×				×
<i>Allocrioceras</i> sp.											×				×
<i>Piacenticeras pseudoplacenta</i> Hyatt		×									×				×
sp.											×				×
<i>Collignoniceras woollgari</i> (Mantell) <i>crassum</i> Haas											×			?	×
<i>woollgari</i> (Mantell) <i>typicum</i> Haas		×		×		×		×		×	×	×		?	×
cf. subsp. <i>tenuicostatum</i> Haas											×			?	×
<i>hyatti</i> (Stanton) s. s.											×				×
var. with medium sculpture and form														×	×
var. with fine sculpture and compressed form														×	×
var. with very fine sculpture														×	×
<i>Halymenites major</i> Lesquereux												×			×
Fish remains, indet.											×				×

<sup>1</sup> See list at the end of table 9 for descriptions of localities.

chalky shale member of the Carlile shale. The upper zone, with *Collignoniceras hyatti* (Stanton), has been recognized at only one locality, southeast of Price, Utah; and its stratigraphic relations to the localities cited in the lower zone are not well known.<sup>1</sup> This zone corresponds to the Blue Hill shale member of the Carlile shale. Possibly the zone with *C. hyatti* is represented in eastern Utah and western Colorado in the upper part of the persistent interval of large concretions or in the overlying shale, but the distinc-

tive fossils have not been found east of the one known locality.

Two faunal zones, marked particularly by species (see table 5) of the ammonite genus *Prionocyclus* and associated scaphites, are found in the Mancos shale above the *Collignoniceras* zones. A zone of platy calcareous sandstone beds separated by shale beds, 80-100 feet thick and referred to in some of the descriptions of the Book Cliffs region as the Ferron sandstone member of the Mancos shale, extends across eastern Utah into western Colorado, generally as a low cuesta along the outcrop. South of Crescent, Utah, there are two cuestas in this sandstone zone. The base of this

<sup>1</sup> This locality was found by Dr. P. J. Katich, who kindly permits the writers to record it here.

TABLE 5.—Fossils found at various localities in the middle Carlile equivalent<sup>1</sup>

	U.S.G.S. Mesozoic loc.																																		
	Prionocyclus macombi zone											Prionocyclus wyomingensis zone																							
	23954	23955	10276	23945	23950	3766	23957	13663	3759	3773	23964	8135	8136	8137	8138	8139	8758	8759	8760	8761	8762	8763	23956	13240	13241	13242	13257	13258	23951	13664	13665	13695	3754	9250	
<i>Leda?</i> sp.																																			
<i>Inoceramus dimidiatus</i> White		×	×		×	×		×	×	×	×												×	×					×	×		×	×		
<i>perplexus</i> Whitfield														?										×	×										
<i>howelli</i> White													×																						
<i>fragilis</i> Hall and Meek		×			×		?				?						×	×			×												?		
n. sp. aff. <i>I. labiatus</i> (Schlotheim)		×									×																								
sp.	×			×								×	×	×	×							×				×	×								
<i>Ostrea lugubris</i> Conrad						×	×	×		×	×											×					×	×		×	×			×	
sp.							×																												
<i>Anomia</i> cf. <i>A. subquadrata</i> Stanton														×									?												
<i>Cyrena?</i> sp.														×	×	×																			
<i>Cardium pauperculum</i> Meek														×	×	×			×	×		×													
<i>Tellina isonema</i> Meek														?		×				×	?		?												
<i>modesta</i> Meek												?	×	×	×	×																			
<i>Siliqua?</i> n. sp.													×	×	×	×																			
<i>Leptosolen</i> sp.														×	×	×																			
<i>Cymbophora?</i> <i>utahensis</i> (Meek)													×	×	×	?					?														
<i>Corbula kanabensis</i> Stanton													×	×	×	×						×													
<i>Teinostoma?</i> sp.														×	×	×																			
<i>Eulimella?</i> sp.														×	×	×																			
<i>Gyrodes depressa</i> Meek													×									×													
<i>Lunatia</i> aff. <i>L. concinna</i> (Hall and Meek)																																			
<i>Pugnellus?</i> sp.													×																						
<i>Volutoderma ambigua</i> (Stanton)?													×									×													
<i>gracilis</i> (Stanton)?													×																						
<i>Baculites</i> sp.			×											×										×	×										
<i>Scaphites ferronensis</i> Cobban																								×	×										
<i>whitfieldi</i> Cobban																		×	×					×	×										
<i>warreni</i> Meek and Hayden			?																					×	×										
sp.												×	×									×	×												
<i>Prionocyclus macombi</i> Meek	×			×	×	×	×			×	×		×																						
<i>wyomingensis elegans</i> Haas													×										×	×	×		×								
sp.									×																				×	×					
Fish remains, indet.								×						×	×																				

<sup>1</sup> See list at the end of table 9 for descriptions of localities.

zone of shale and sandstone lies, around the San Rafael Swell, from 600 to 400 feet above the Dakota sandstone, with the greater measurement in the west. East of the swell in both Utah and Colorado, the base is about 300 feet above the Dakota. A lower zone with *Prionocyclus macombi* Meek, *Scaphites warreni* Meek and Hayden, and their associates is found in the lower part of the shale and sandstone zone. An upper zone with *Prionocyclus wyomingensis* Meek and its associates is found in the upper part and in the overlying shale beds. *Inoceramus dimidiatus* White and *Ostrea lugubris* Conrad are very common in these zones. An equivalent of the uppermost parts of the Carlile shale has not been identified in the Mancos shale, and it is not known whether the sequence is complete but barren or whether unnoted interruptions are present.

Above the Carlile equivalents, beds that are generally more calcareous contain faunas that identify

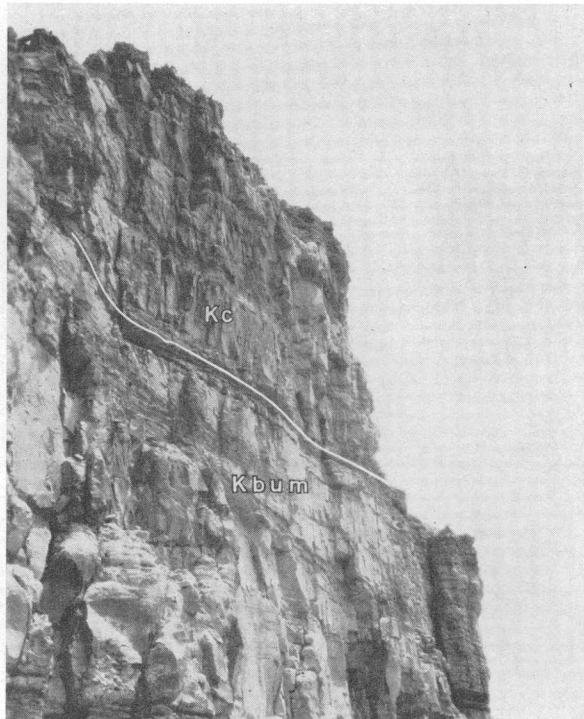
equivalents of the Niobrara formation. The typical Niobrara formation of the Great Plains has not been interpreted in the past to contain equivalents of the Telegraph Creek and Eagle formations of Montana, but recent evidence tends to support the thesis that they are present, but perhaps with a facies not indicative of an environment favorable to the faunas characteristic of the Montana formations. In the western Book Cliffs the lower and middle parts of the Niobrara equivalent below that of the Telegraph Creek are as much as 1,600 feet thick, and in the eastern Book Cliffs they are 1,000 feet. Scattered collections, shown in table 6, indicate the presence of lower Niobrara fossils (*Inoceramus exogyroides* Meek and Hayden and *I. umbonatus* Meek and Hayden, both of which may be *I. involutus* Sowerby, and *Scaphites depressus* Reeside) and lower middle Niobrara fossils (*Clisosphites vermiciformis* (Meek and Hayden) and *Inoceramus stantoni* Sokolow). Farther



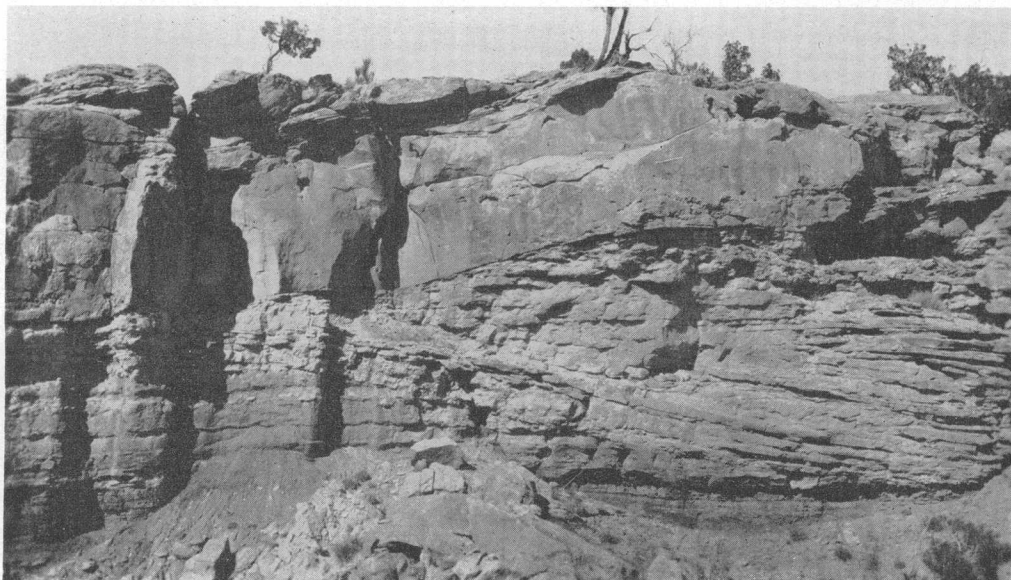


A. "WASATCH" FORMATION

Detailed view of basal conglomerate shown in plate 6C.

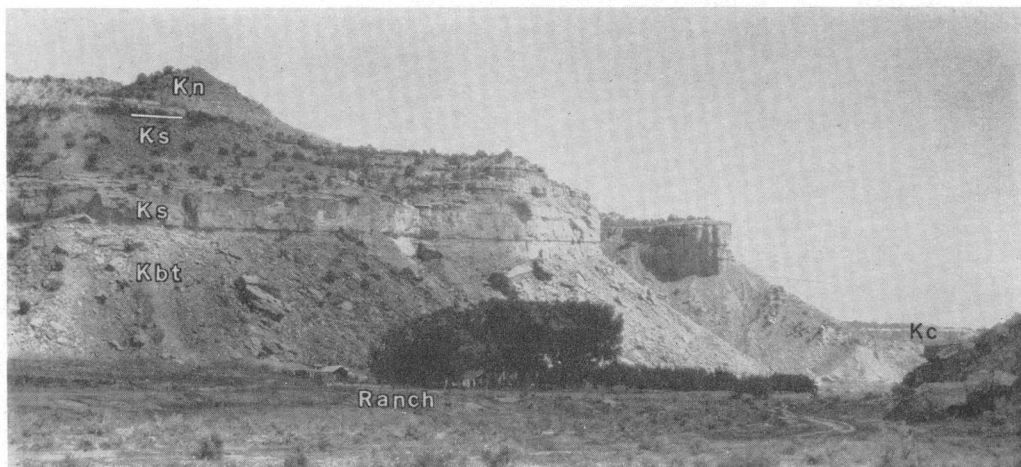


B. WEST FACE OF BECKWITH PLATEAU EAST OF DESERT, UTAH  
Castlegate sandstone, Kc; and upper, sandstone, part of upper member of  
Blackhawk formation, Kbum.



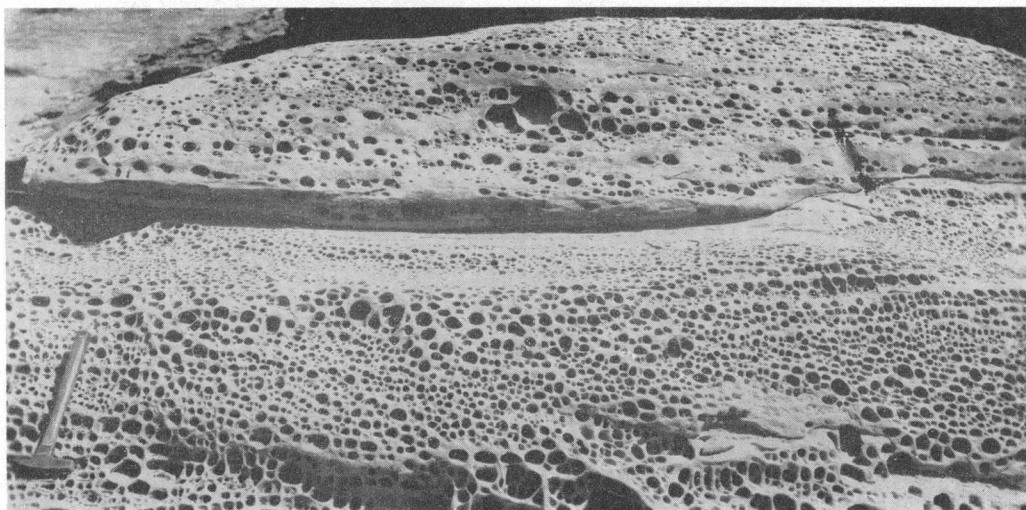
C. CASTLEGATE SANDSTONE IN A SIDE CANYON OF CRESCENT WASH, UTAH

Note irregularity of bedding. Photograph by E. M. Spieker.

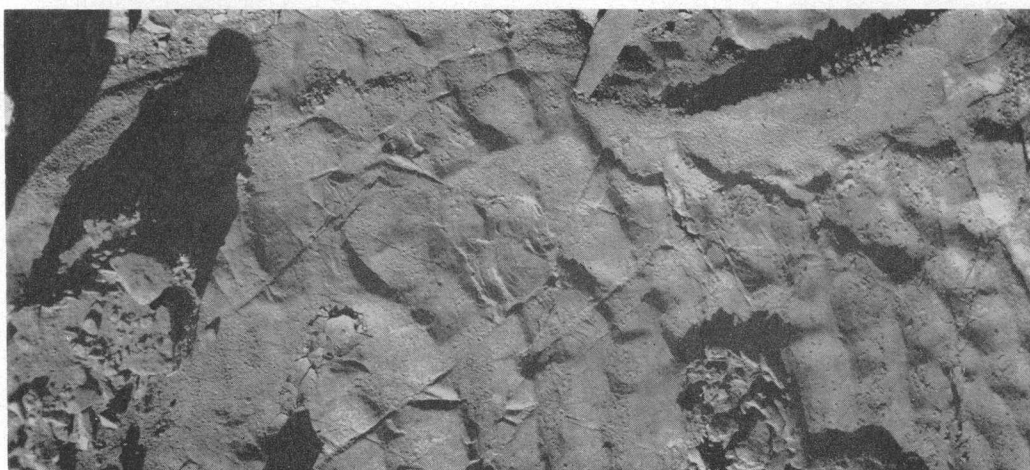


A. EAST SIDE OF CANYON OF WESTWATER WASH AT ROBERSON RANCH, UTAH

Kc, bench of Castlegate sandstone; Kbt, Buck tongue of Mancos shale; Ks, Sego sandstone; Kn, Neslen formation.



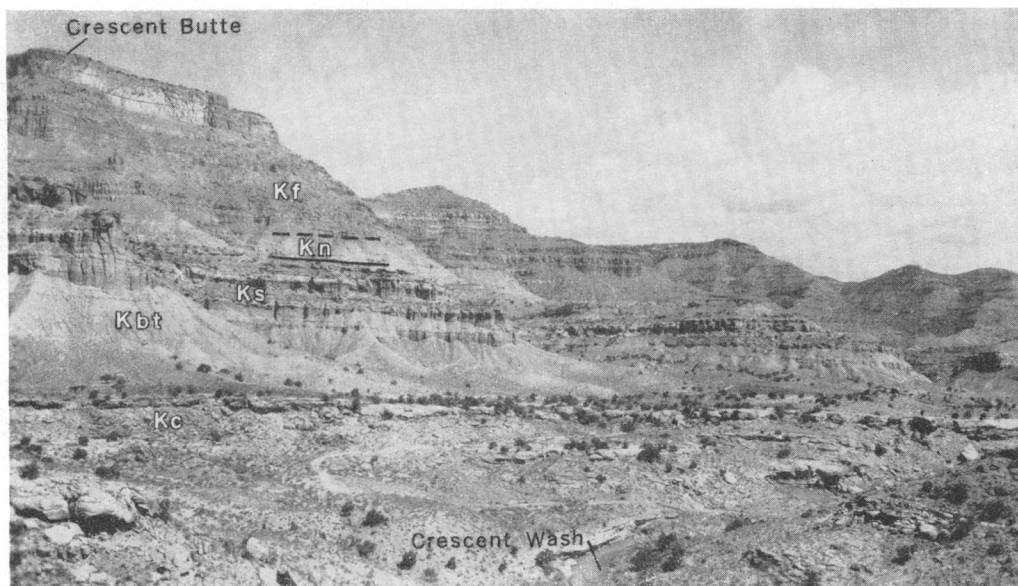
B. SEGO SANDSTONE NORTH OF CISCO, UTAH

Detailed view of weathered surface of upper, "white," part as seen in SW $\frac{1}{4}$  sec. 4, T. 19 S., R. 23 E.

C. CASTLEGATE SANDSTONE, NORTH OF CISCO, UTAH

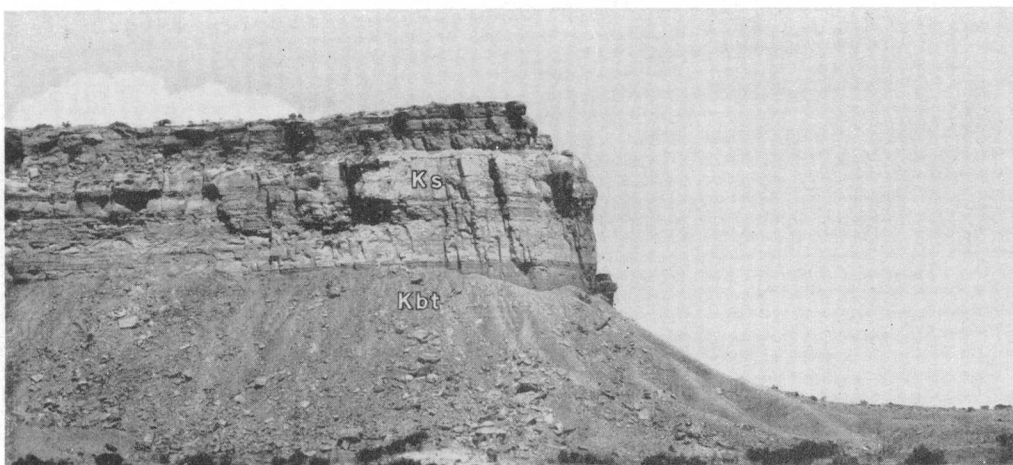
Rippled surface 4 feet below top, near southwest corner sec. 2, T. 20 S., R. 22 E. Right side of view is on the west. Average wavelength is 6 inches and average amplitude is 1 inch.





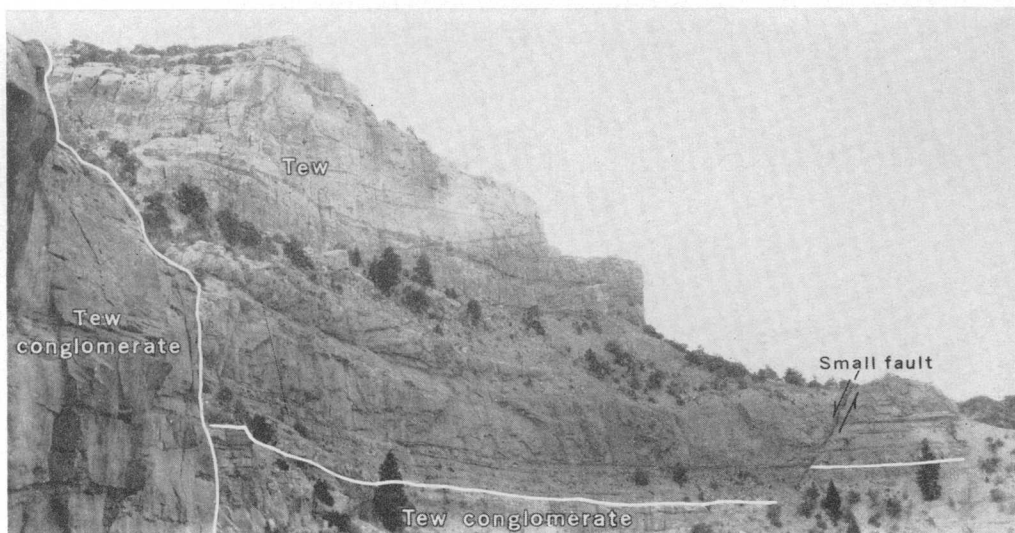
A. CRESCENT BUTTE, LOOKING NORTH ACROSS CRESCENT WASH

View of the butte in T. 20 S., R. 19 E., where it rises to 1,450 feet above the wash. Kc, bench of Castlegate sandstone, dotted with junipers; Kbt, Buck tongue of Mancos shale; Ks, Sego sandstone; Kn, Neslen formation, lower part hidden behind Sego cliff; Kf, Farrer formation.



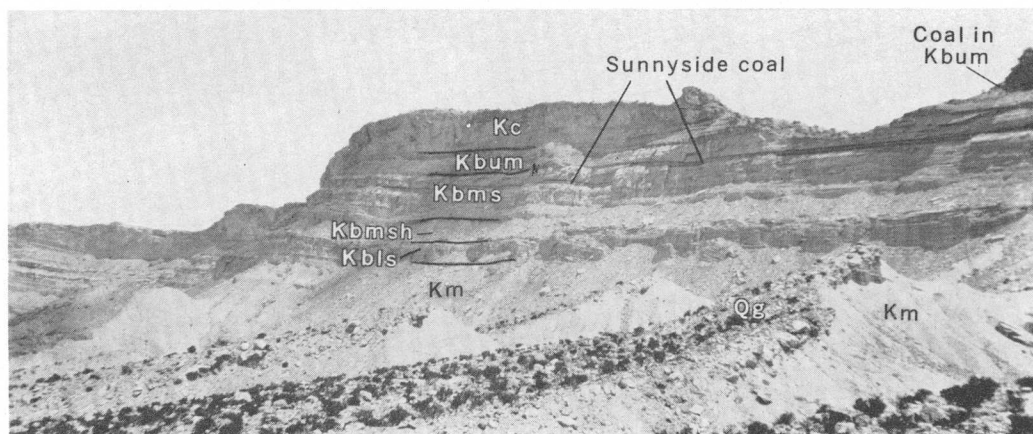
B. SEGO SANDSTONE AND BUCK TONGUE OF MANCOS SHALE

Sego sandstone, Ks, nearly 200 feet thick, in spur northwest of Thompson, Utah; Kbt, Buck tongue.



C. "WASATCH" STRATA, NORTHWEST OF CISCO, UTAH

Lower 800 feet of "Wasatch" strata, Tew, exposed on east side of Nash Wash reentrant.



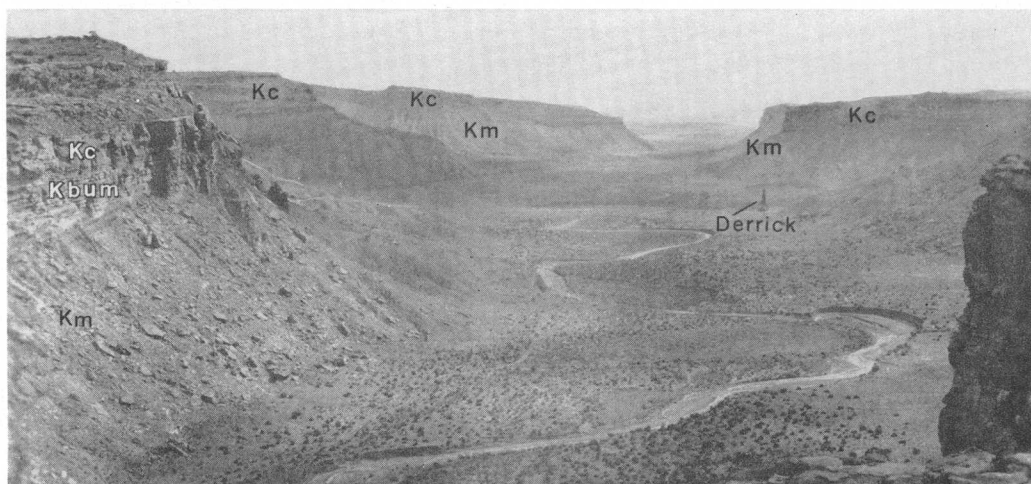
A. LOOKING NORTHEAST AT BOOK CLIFFS, 7 MILES NORTH OF WOODSIDE, UTAH

A dissected alluvial pediment cut on Mancos shale and sloping away from cliffs. Note narrow fragments of whole face of lower sandstone slumping off. Km, Mancos shale; Kbls, lower sandstone member, Blackhawk formation; Kbmsh, middle shale member, Blackhawk formation; Kbms, middle sandstone member, Blackhawk formation; Kbum, upper member, Blackhawk formation; Kc, Castlegate sandstone.



B. CASTLEGATE AND BLACKHAWK FORMATIONS, NASH WASH REENTRANT, NORTHWEST OF CISCO, UTAH

View, looking northeast from sec. 9, T. 20 S., R. 21 E., showing how large sandstone blocks from 140 feet of Castlegate and Blackhawk formations break off the cliff front. Km, Mancos shale; Kc, Castlegate sandstone and upper 50 feet of Blackhawk formation; Kp, undifferentiated formations; Tew, "Wasatch" formation.



C. WIDE ALLUVIAL FLAT, CANYON OF SALERATUS WASH, UTAH

Flat with meandering stream, owing to weakening of strata by faulting, looking down canyon, 13 miles east of Green River, Utah, from sec. 7, T. 21 S., R. 19 E. Km, Mancos shale; Kbum, sandy upper part of upper member of Blackhawk formation; Kc, Castlegate sandstone.

TABLE 6.—Fossils found at various localities in the Niobrara equivalent, to base of Telegraph Creek equivalent<sup>1</sup>

	U.S.G.S. Mesozoic loc.										
	13319	13325	13243	13244	13245	13246	13249	13260	13261	13262	13263
<i>Globigerina</i> sp.											
<i>Inoceramus stantoni</i> Sokolow		X									
<i>exogyroides</i> Meek and Haydon			X								
aff. <i>I. subquadratus</i> Schlueter			X								
<i>umbonatus</i> Meek and Haydon			X								
( <i>Haploscappha</i> ) sp.			X								
<i>Pteria</i> ( <i>Phlepteria</i> ) <i>gastrodes</i> (Meek)			X								
<i>Ostrea congesta</i> Conrad			X								
<i>Ostrea</i> n. sp.			X								
<i>Lima?</i> n. sp.			X								
<i>Lucina</i> aff. <i>L. subundata</i> Hall and Meek			X								
<i>Anchura</i> sp.			X								
<i>Phlyctiocras oregonense</i> Reeside			X								
<i>Baculites asper</i> Morton			X								
<i>codyensis</i> Reeside			X								
sp.			X								
<i>Scaphites binneyi</i> Reeside			X								
<i>depressus stantoni</i> Reeside			X								
<i>tetonensis</i> Cobban			X								
sp.			X								
<i>Clioscapphites vermiformis</i> (Meek and Haydon)			X								
<i>Gauthiericeras?</i> sp.			X								
<i>Ichthyodectes?</i> sp.			X								

<sup>1</sup> See list at the end of table 9 for descriptions of localities.

west the equivalent of the basal part of the Niobrara has yielded characteristic species such as *Scaphites impendicostatus* Cobban and *Inoceramus deformis* Meek, and equivalents of the upper middle part of the Niobrara have yielded species like *Inoceramus undulatopectatus* Roemer. It is likely that the time span of the lower and middle parts of the formation is fully represented in the Mancos shale of the Book Cliffs, but the collections are not sufficient to indicate much more than the presence of some of the various zones of the standard section.

Equivalents of the Telegraph Creek formation and of the Eagle sandstone of Montana, now thought to be of the age of the upper part of the typical Niobrara, were noted only near Green River in Utah and near Grand Junction in Colorado, though doubtless these equivalents could be identified throughout the region by a careful search for the distinctive fossils. The fossils collected by the writers are shown in tables 7 and 8. The rocks in the intervals of the equivalents of the Telegraph Creek and Eagle formations together total as much as 1,500 feet in thickness, most of which constitutes the Eagle equivalent. The Telegraph Creek formation has been considered to be the basal unit of the Montana group, but assignment to a position in the Niobrara sequence requires it to be considered part of the Colorado group.

The collections from the uppermost part of the Mancos shale are shown in table 9. The Mancos yielded few fossils west of the Green River, and in

TABLE 7.—Fossils found at various localities in the Telegraph Creek equivalent<sup>1</sup>

	U.S.G.S. Mesozoic loc.				
	13247	13248	13249	13250	13260
<i>Inoceramus lobatus</i> Goldfuss		X	X	X	X
sp.		X	X	X	X
<i>Ostrea congesta</i> Conrad		X	X	X	X
sp.		X	X	X	X
<i>Lucina</i> aff. <i>L. subundata</i> Hall and Meek		X	X	X	X
sp.		X	X	X	X
<i>Baculites aquilaensis</i> Reeside		X	X	X	X
sp.		X	X	X	X
<i>Desmophyllites mancosensis</i> (Reeside)		X	X	X	X
<i>Scaphites aquilaensis</i> Reeside		X	X	X	X
<i>lei</i> Reeside		X	X	X	X
<i>Desmoscapphites bassleri</i> Reeside		X	X	X	X

<sup>1</sup> See list at the end of this series of tables for descriptions of localities.TABLE 8.—Fossils found at various localities in the Eagle equivalent<sup>1</sup>

	U.S.G.S. Mesozoic loc.									
	13323	13324	13251	13252	13326	13340	13666	13691	13692	13697
Fresh-water species:										
<i>Mesolanistes</i> cf. <i>M. cretaceous</i> Yen						X				
Marine species:										
<i>Lingula subspatulata</i> White						X				
<i>Inoceramus</i> cf. <i>I. sagensis</i> Owen						X				
( <i>Haploscappha</i> ) sp.						X				
aff. <i>I. subquadratus</i> Schlueter						X				
<i>Ostrea congesta</i> Conrad var.						X				
sp.						X				
<i>Crenella?</i> sp.						X				
<i>Lucina subundata</i> Hall and Meek						X				
<i>Corbula</i> n. sp.						X				
<i>Teredo?</i> sp., borings in wood						X				
<i>Eutrophoceras alcesense</i> Reeside						X				
<i>Baculites</i> aff. <i>B. aquilaensis</i> Reeside						X				
<i>haresti</i> Reeside						X				
sp.						X				
<i>Haresiceras fisheri</i> Reeside						X				
sp.						X				
<i>Scaphites hippocrepis</i> (DeKay)						X				
<i>hippocrepis</i> (DeKay) <i>tenuis</i> Reeside						X				
<i>aquilaensis</i> Reeside						X				
<i>nanus</i> Reeside						X				
<i>Placenticeras</i> aff. <i>P. guadalupe</i> (Roemer)						X				
<i>Gauthiericeras?</i> sp.						X				
<i>Corax?</i> sp.						X				
<i>Lamna</i> sp.						X				
Fish remains, undet.						X				
Tooth of marine reptile, undet.						X				

<sup>1</sup> See list at the end of this series of tables for descriptions of localities.

the central Book Cliffs the fauna found is not significant. In the eastern Book Cliffs area, the few fossils collected suggest equivalence to the lowest member of the Pierre shale. Collections made by W. T. Lee around Grand Mesa, southeast of the eastern end of the Book Cliffs, are listed for the sake of completeness, and they have only a very general value for correlation. More distinctive fossils were found at equivalent horizons in the Mesaverde group.

In the tables that follow, the localities in each table are arranged in geographic order from west to east; in the locality list, however, the order is by Geological Survey Mesozoic locality number and hence roughly by date of collection.

TABLE 9.—Fossils found at various localities in equivalents of lower part of Pierre shale<sup>1</sup>

	U.S.G.S. Mesozoic loc.															
	13318	13332	13683	13693	13714	13715	4189	4206	4208	4209	4213	4216	4217	4490	4496	4498
<i>Serpula</i> sp.				X									X			
<i>Lingula nitida</i> Meek and Hayden			X	X												
<i>Nucula</i> sp.		X						X								
<i>Yoldia evansi</i> (Meek and Hayden)																
<i>Nuculana</i> sp.								X								
<i>Perissonota protezta</i> Conrad		X														
<i>Inoceramus</i> "barabini" Morton" of Meek.										X	X	X	X			
cf. <i>I. sagensis</i> Owen				X	X	?			X		X	X	X			
<i>Pteria nebrascana</i> (Evans and Shumard)								X	X	X	X	X	X			
<i>linguiformis</i> (Evans and Shumard)										X				X		
<i>sublaevis</i> Whitfield					X											
<i>Ostrea</i> cf. <i>O. plumosa</i> Morton						X										
sp.										X	X	X	X	X		X
<i>Syncyclonema halli</i> (Gabb)		X						X			X	X	X	X		
<i>Anatina</i> sp.													X			
<i>Lucina subundata</i> Hall and Meek								X								
<i>Cardium</i> ( <i>Ethmocardium</i> ) <i>whitei</i> Dall								X						X	X	X
<i>Thetis</i> ? <i>circularis</i> (Meek and Hayden)								X								
<i>Tellina</i> sp.								X							X	X
<i>Cymbophora formosa</i> (Meek and Hayden)															X	?
" <i>Mastra</i> " <i>v. arrenana</i> Meek and Hayden															X	X
<i>Corbula inornata</i> Meek and Hayden		X														
<i>Dentalium</i> sp.								X								
<i>Turritella</i> ? sp.														X		
<i>Volutoderma</i> sp.								X								
<i>Anisomyon shumardi</i> Meek and Hayden												X				
" <i>Heteroceras</i> " sp.								X								
<i>Baculites asperiformis</i> Meek	?				X							X				
<i>Acanthoscaphites</i> aff. <i>A. nodosus</i> (Owen)									X							
<i>Scaphites</i> cf. <i>S. pulcherrimus</i> Roemer					X											
<i>Placenticeras meeki</i> Boehm							X			X						
<i>intercalare</i> Meek													X	X		
Fish remains, undet.	X		X													

<sup>1</sup> See list at the end of this series of tables for descriptions of localities.

## Descriptions of localities in tables 3-9

- Lot 1. Near Home Oil Company's wells, in sec. 4, T. 19 S., R. 25 E., Grand County, Utah (Dane, 1935, p. 116)
- 3754-3773. Book Cliffs coal field, Utah and Colorado. Collected by G. B. Richardson, 1906.
3754. Bluff on south bank of Grand [Colorado] River, 1½ miles east of Grand Junction, Colo.; Mancos shale.
3759. Hill one-fourth of a mile east of reservoir near narrow gage railroad, 10 miles west of Mack, Colo.; Mancos shale.
3766. 7 miles south of Thompson, Utah; near base of Mancos shale.
3767. 2 miles southwest of Green River, Utah; base of shale bluff in Mancos shale, half a mile from top of Dakota sandstone.
3769. 2 miles east of Cisco, Utah; base of Mancos shale.
3773. Hill immediately south of D. & R. G. W. R.R., between Fruita and Mack, Colo.; near base of Mancos shale.
- 4189-4498. Grand Mesa coal field, Colo.; collected by W. T. Lee, 1907.
4189. Sec. 1, T. 11 S., R. 98 W., near Palisade; near top Mancos shale.
4206. Sec. 4, T. 14 S., R. 96 W., 9 miles northwest of Delta; near top of Mancos shale.
4208. Sec. 36, T. 13 S., R. 95 W., 10 miles northeast of Delta; 400 ft below top of Mancos shale.
4209. Sec. 21, T. 13 S., R. 95 W., 12 miles north of Delta; near top of Mancos shale.
4213. Sec. 20, T. 13 S., R. 95 W., 12 miles north of Delta; near top of Mancos shale.
4216. Sec. 30, T. 13 S., R. 95 W., west of Fairview mine, 10 miles north of Delta; about 200 ft below top of Mancos shale.
4217. Sec. 21, T. 13 S., R. 95 W., 12 miles northeast of Delta; about 400 ft below top of Mancos shale.
4490. Sec. 5, T. 14 S., R. 90 W., Minnesota Creek, 7 miles east of Paonia; near top of Mancos shale.
4496. Sec. 5, T. 14 S., R. 90 W., 7 miles east of Paonia; top of Mancos shale or base of Mesaverde formation.
4498. Sec. 8, T. 14 S., R. 90 W., 7 miles east of Paonia; top of Mancos shale.
- 8135-8139. Farnham anticline, Utah; associated with "Ferron sandstone"; collected by F. R. Clark, 1912.
8135. Sec. 15, T. 15 S., R. 11 E.; 850 ft above base of Mancos shale.
8136. Sec. 2, T. 15 S., R. 11 E.; 700 ft above base of Mancos shale.
8137. Sec. 36, T. 14 S., R. 11 E.; 700 ft above base of Mancos shale.
8138. NW¼ sec. 6, T. 15 S., R. 12 E.; 700 ft above base of Mancos shale.
8139. Center sec. 6, T. 15 S., R. 12 E.; 700 ft above base of Mancos shale.
- 8758-8763. North of Mounds, Utah; associated with "Ferron sandstone," 700-900 ft above base of Mancos shale; collected by F. R. Clark, 1913.

8758. SW¼SE¼ sec. 9, T. 15 S., R. 12 E.
8759. NE¼SW¼ sec. 4, T. 15 S., R. 12 E.
8760. SW¼ sec. 15, T. 15 S., R. 11 E.
8761. SE¼NW¼ sec. 7, T. 15 S., R. 12 E.
8762. NW¼ sec. 21, T. 15 S., R. 12 E.
8763. NW¼NW¼ sec. 6, T. 15 S., R. 12 E.
- 9249-9250. Western Colorado; collected by G. H. Stone, 1915.
9249. West of Delta; less than 50 ft above base of Mancos shale.
9250. West of Delta; 300-400 ft above base of Mancos shale.
10276. Eastern Utah; collected by J. W. Young, 1920. Railroad cut about 100 yd west of depot at Green River; thin calcareous sandstone layers in shale.
12834. Eastern Utah; collected by James Gilluly, 1924. Summerville Wash, sec. 13, T. 18 S., R. 13 E.; 150 ft above top of Dakota sandstone.
- 13240-13264. Eastern Utah; collected by E. M. Spieker and J. B. Reeside, Jr., 1925.
13240. 1 mile south of Desert (sec. 11, T. 20 S., R. 14 E.); 20 ft above "Ferron sandstone."
13241. Half a mile south of Desert. 90 ft above "Ferron sandstone."
13242. Half a mile south of Desert. 110 ft above "Ferron sandstone."
13243. Half a mile east of Desert in concretion layer about 975 ft above base of Mancos.
13244. 1 mile east of Desert in orange-brown limestone layer about 1,600 ft above base of Mancos.
13245. Same locality as 13244 and 10 ft above it.
13246. 1 mile east of Desert, in shale between 2 limestone bands, about 1,630 ft above base of Mancos.
13247. 1 mile east of Desert. Concretion in shale, 1,710 ft above base of Mancos.
13248. 1 mile east of Desert. 1,750 ft above base of Mancos.
13249. 1 mile east of Desert. 1,900 ft above base of Mancos.
13250. 1 mile east of Desert. 1,920 ft above base of Mancos.
13251. 1½ miles east of Desert. 2,200 ft above base of Mancos.
13252. 1½ miles east of Desert. In a gritty sandstone 2,175 ft above base of Mancos.
13254. 1 mile south of Green River. 100 ft above base of Mancos shale.
13255. 2 miles south of Green River, along road to Hanks-ville. Very near base of Mancos.
13256. Half a mile southwest of Desert, along Cottonwood Springs road, 100 ft above base of Mancos.
13257. 1 mile south of Desert; 60 ft above "Ferron sandstone," 380 ft above base of Mancos.
13258. 1 mile south of Desert; 80 ft above "Ferron sandstone," 400 ft above base of Mancos.
13259. Near Desert. 780 ft above base of Mancos.
13260. Half a mile east of Desert. 970 feet above base of Mancos.
13261. 1 mile east of Desert. 1,350 ft above base of Mancos.
13262. 1 mile east of Desert. 1,460 ft above base of Mancos.
13263. East of Desert. 1,525 ft above base of Mancos.
13264. East of Desert. 1,550 ft above base of Mancos.



- 13318-13340. Eastern Utah; collected by H. F. Moses, 1925.  
 13318. 6 miles northeast of Woodside (sec. 14, T. 17 S., R. 14 E.). About 500 ft below top of Mancos.  
 13319. 3 miles north of Woodside (SE $\frac{1}{4}$  sec. 29, T. 17 S., R. 14 E.). From a coarse-grained gray-brown, 6-in. limestone bed, 3,200 ft below top of Mancos.  
 13323. 4 miles southeast of Woodside (SW $\frac{1}{4}$  sec. 25, T. 18 S., R. 14 E.). 500-600 ft below top of Mancos.  
 13324. One quarter of a mile south-southwest of 13323 in the same quarter section. 500-600 ft below top of Mancos.  
 13325. 4 miles south of Woodside (NE $\frac{1}{4}$  sec. 4, T. 19 S., R. 14 E.). 2,750 ft below top of Mancos.  
 13326. 6 miles northwest of Green River (SE $\frac{1}{4}$  sec. 14, T. 20 S., R. 15 E.). About 800 ft below top of Mancos.  
 13328. 3 miles northeast of Green River (NE $\frac{1}{4}$  sec. 2, T. 21 S., R. 16 E.). 1,400 ft above base of Mancos.  
 13330. 4 miles northeast of Green River (SE $\frac{1}{4}$  sec. 28, T. 20 S., R. 16 E.). 1,950 ft above base of Mancos.  
 13331. 3 miles northeast of Green River (SW $\frac{1}{4}$  sec. 33, T. 20 S., R. 16 E.). About 1,400 ft above base of Mancos.  
 13332. East branch of Tuscher Wash (SE. cor. sec. 13, T. 20 S., R. 16 E.). 350 ft below top of Mancos.  
 13340. 4 miles northeast of Solitude (NW $\frac{1}{4}$  sec. 18, T. 21 S., R. 18 E.). About 700 ft below top of Mancos.  
 13658-13665. Western Colorado; collected by J. B. Reeside, Jr., 1926.  
 13658. North of west end of Grand Junction; lowest yellow layer, 1,800 ft beneath top of Mancos shale.  
 13659. North of west end of Grand Junction; yellow layer 1,350 ft beneath top of Mancos shale.  
 13660. 2 miles north of Whitewater; 80 ft above Dakota(?) sandstone.  
 13663. Same locality as 13660; 330 ft above Dakota(?) sandstone.  
 13664. Same locality as 13660; 400 ft above Dakota(?) sandstone.  
 13665. Same locality as 13660; 410 ft above Dakota(?) sandstone.  
 13666-13693. Eastern Utah.  
 13666. 1 $\frac{1}{2}$  miles northwest of Floy (SE $\frac{1}{4}$  sec. 32, T. 21 S., R. 18 E.). 600-700 ft below top of Mancos. Collected by D. J. Fisher, 1926.  
 13683. Sagers Canyon in sec. 5, T. 21 S., R. 21 E. About 400 ft below top of Mancos shale. Collected by R. M. Leggette, 1926.  
 13691. About 3 miles south of Sagers, near the NE. cor. sec. 7, T. 22 S., R. 21 E. From middle of Mancos shale. Collected by R. M. Leggette, 1926.  
 13692. 300 yd south of 13691 and about 75 ft lower stratigraphically. Collected by R. M. Leggette, 1926.  
 13693. 3 miles north of Sagers (sec. 4, T. 21 S., R. 21 E.). About 750 ft below top of Mancos. Collected by J. H. Hengst, 1926.  
 13695-13715. Western Colorado; collected by J. B. Reeside, Jr., 1926.  
 13695. 2 miles north of Whitewater; 453 ft above base of Mancos shale.  
 13696. 6 miles north of Grand Junction; lowest yellow layer, about 2,850 ft beneath top of Mancos shale.  
 13697. 6 miles north of Grand Junction; 2,100 ft beneath top of Mancos shale.  
 13698. 6 miles north of east end of Grand Junction; 2,200 ft beneath top of Mancos shale.  
 13714. NE $\frac{1}{4}$  sec. 31, T. 7 S., R. 102 W., on Rangely road just above Brown's lower ranch; 250 ft below top of Mancos shale.  
 13715. Same locality as 13714; 200 ft below top of Mancos shale.  
 15553. Eastern Utah; collected by A. A. Baker, 1930. About 2 $\frac{1}{2}$  miles southeast of Hanksville road, in sec. 15, T. 22 S., R. 15 E.; base of Mancos shale.  
 23422. Eastern Utah; collected by P. J. Katich and others, 1951: Highway 50, 16 miles east of Price; 330 ft above base of Mancos shale.  
 23942-23958. Eastern Utah; collected by J. B. Reeside, Jr., J. J. Carroll, and J. De A. Ramos, 1952.  
 23942. Hanksville road, half a mile south of Green River in NE $\frac{1}{4}$ SE $\frac{1}{4}$  sec. 16, T. 21 S., R. 16 E.; light-gray concretions 100 ft above base of Mancos shale.  
 23943. Same locality as 23942; base of zone of large dirty-brown concretions 130-185 ft above base of Mancos shale.  
 23944. Same locality as 23942; upper part of zone of large concretions.  
 23945. Same locality as 23942; basal part of ridge-making zone of platy sandstone 330 ft above base of Mancos shale.  
 23946. Half a mile west of Desert, in SE $\frac{1}{4}$  sec. 10, T. 20 S., R. 14 E.; sandy zone 160 ft above base of Mancos shale.  
 23947. Half a mile west of road to "Geyser" and 4 miles southeast of Green River, in center sec. 30, T. 21 S., R. 17 E.; base of concretion zone, 100 ft above base of Mancos shale.  
 23948. Hanksville road, 2 miles south of Green River, in SE $\frac{1}{4}$ SW $\frac{1}{4}$  sec. 20, T. 21 S., R. 16 E.; lowest concretions, 100 ft above base of Mancos shale.  
 23949. Same locality as 23948; base of zone of large dirty concretions 130 ft above base of Mancos shale.  
 23950. Highway 160, from Crescent to Moab, 4 miles south of Valley City, in SE $\frac{1}{4}$ SW $\frac{1}{4}$  sec. 13, T. 23 S., R. 19 E.; lower of 2 zones of platy sandstone, about 150 ft above base of Mancos shale.

23951. Same locality as 23950; upper of 2 zones of platy sandstone, about 250 ft above base of Mancos shale.  
 23952. 1 mile W. 20° N. of Cliff, in SE. cor. sec. 5, T. 19 S., R. 14 E.; basal part of zone of large dirty concretions, 115 ft above base of Mancos shale.  
 23953. Same locality as 23952; hard, cuesta-forming sandstone 165 ft above base of Mancos shale.  
 23954. Same locality as 23952; base of 30-ft zone of ridge-forming platy sandstone beds, 295 ft above base of Mancos shale.  
 23955. Same locality as 23952; middle of 30-ft zone of sandstone, 310 ft above base of Mancos shale.  
 23956. Same locality as 23952; top of 30-ft zone of sandstone, 325 ft above base of Mancos shale.  
 23957. On road to Uvanco mine, 11 miles southeast of Thompson, in NW $\frac{1}{4}$ NE $\frac{1}{4}$  sec. 25, T. 22 S., R. 21 E., projected; thin-bedded sandstone beds 300 ft above base of Mancos shale.  
 23958. 1 mile west of road to Uvanco mine, 11 miles southeast of Thompson, in NE $\frac{1}{4}$ NW $\frac{1}{4}$  sec. 26, T. 22 S., R. 21 E., projected; lowest 10 ft of Mancos shale.  
 23962. Near Highway 50, 7 miles west of Delta, western Colorado; 140 ft above base of Mancos shale; collected by P. J. Katich, 1952.  
 23963-23964. Western Colorado; collected by J. B. Reeside, Jr., J. J. Carroll, and J. De A. Ramos, 1952.  
 23963. Road north from Highway 50 to Lee Erisuma Ranch, 7 miles west of Delta; concretions 200 ft above base of Mancos shale.  
 23964. Same locality as 23963; platy sandstone beds 250 ft above base of Mancos shale.

## MESAVERDE GROUP

## BLACKHAWK FORMATION

Fossil mollusks were found in only the upper member of the Blackhawk formation. These are dominantly brackish-water forms, mostly of long range, and associated with them are a few fresh-water forms. It is probable that the mixture is wholly mechanical. The relations of the fresh-water and brackish-water faunas are discussed under the heading, "Nonmarine faunas in the sequence." The best that can be said now of the fauna is that it represents a Late Cretaceous age. However, the eastward passage of the Blackhawk into marine shale whose relative position is known affords a better dating than the brackish-water fossils. The species found are shown in table 10.

## CASTLEGATE SANDSTONE

A few fossils, as shown in table 11, were collected from the Castlegate sandstone in the area east of the Green River. The species present are indicative of brackish-water to marine conditions, except for fragments of a trionychid turtle found near Crescent Wash, which fossil may have been transported from its normal fresh-water habitat. The species do not in themselves afford an exact age assignment.

## PRICE RIVER FORMATION (RESTRICTED)

In the part of the Book Cliffs where the Price River formation, restricted by removal of the Castlegate sandstone, is recognized, few fossils were collected from the formation. The age of the formation is

fixed, however, by the passage eastward of the lower part into marine beds of Late Cretaceous age equivalent to part of the Pierre shale and by the occurrence above it, in the North Horn formation of the Wasatch Plateau, of a Late Cretaceous dinosaur fauna. The species noted are all fresh-water forms and are shown in table 12.

TABLE 10.—Fossils found at various localities in the upper part of the Blackhawk formation<sup>1</sup>

	U.S.G.S. Mesozoic loc.						
	7395	7398	7399	7397	7393	7394	13327 13333
Fresh-water species:							
<i>Unio</i> sp. ....				×		×	
<i>Viviparus</i> sp. ....				×	×	×	
<i>Campeloma</i> sp. ....			×	×			
<i>Melania insculpta</i> (Meek) ..	×		×				
<i>Goniobasis</i> aff. <i>G. conezza</i> (Meek and Hayden) ..							×
Brackish-water species:							
<i>Ostrea</i> sp. ....			×	×			×
<i>Anomia gryphorhynchus</i> Meek ..							×
<i>miconema</i> Meek ..	×	×	×	×			×
<i>Brachyodontes laticostatus</i> White ..		×	×	×			
<i>Brachyodontes regularis</i> White ..							×
<i>Corbicula cytheriformis</i> (Meek and Hayden) ..		×		×			
? sp. ....					×		×
<i>perundata</i> Meek and Hayden ..							×
<i>subtrigonalis</i> Meek and Hayden ..		×		×			
<i>undifera</i> Meek ..			×	×	×	×	
sp. ....	×						
Vertebrate:							
Turtle bone, fragments ..							×

<sup>1</sup> All localities in Utah; 7393-7399 collected by F. R. Clark, 1911; 13327 and 13333 by D. J. Fisher, 1925.

7393. 3 miles south of Sunnyside, in sec. 17, T. 15 S., R. 14 E.; 560 ft above Mancos (upper member of Blackhawk formation).  
 7394. 4 miles south of Sunnyside, in NW¼ sec. 20, T. 15 S., R. 14 E.; 560 ft above Mancos (upper member of Blackhawk formation).  
 7395. 3 miles northwest of Sunnyside, in sec. 24, T. 14 S., R. 13 E.; 520 ft above Mancos (upper member of Blackhawk formation).  
 7397. 1½ miles southeast of Sunnyside, in SE¼ sec. 5, T. 15 S., R. 14 E., from dump of Mine No. 3 in Water Canyon; 480 ft above Mancos (middle sandstone member of Blackhawk formation).  
 7398. Near tunnel of Sunnyside mine No. 1, from railroad cut in mouth of No. 2 Canyon, in sec. 32, T. 14 S., R. 14 E.; 480 ft above Mancos (middle sandstone member of Blackhawk formation).  
 7399. At Sunnyside, in SW¼ sec. 32, T. 14 S., R. 14 E.; 480 ft above Mancos (middle sandstone member of Blackhawk formation).  
 13327. North of Green River, from the SW¼ sec. 6, T. 20 S., R. 16 E.; 11 ft below top of middle sandstone member of Blackhawk formation.  
 13333. Southeast tributary of Tuscher Wash, SE. cor. sec. 13, T. 20 S., R. 16 E.; 30 ft below top of middle sandstone member of Blackhawk formation.

TABLE 11.—Fossils found at various localities in the Castlegate sandstone<sup>1</sup>

	U.S.G.S. Mesozoic loc.			
	Lot 1	13680	13684	13685
<i>Ostrea</i> sp. undet. ....		×		×
<i>Corbicula</i> sp. undet. ....		×		×
<i>Cardium</i> n. sp. aff. <i>C. whitei</i> Dall. ....		×		×
<i>Corbula subtrigonalis</i> Meek and Hayden ..			×	
<i>Baculites</i> sp., fragment ..				×
<i>Placentiaceras</i> sp., fragment ..				×
<i>Lamna</i> sp. ....	×	?		
Trionychid turtle (carapace fragments) ..	×			

<sup>1</sup> Descriptions of localities follow:

- Lot 1 (loc. 26). North of Crescent, in NW¼ sec. 16, T. 21 S., R. 19 E.; 10 ft below top; collected by D. J. Fisher, 1926.  
 13680. East wall Thompson Canyon, in sec. 15, T. 21 S., R. 20 E.; from float blocks from upper part of formation; collected by J. H. Hengst, 1926.  
 13684. West side Sagers Canyon, in NW¼ sec. 8, T. 21 S., R. 21 E.; from top of member; collected by D. J. Fisher, 1926.  
 13685. 2 miles north of Oscar Turner's ranch (Nash Wash) from the NE¼ sec. 3, T. 20 S., R. 21 E.; slump from Castlegate sandstone; collected by D. J. Fisher, 1926.

TABLE 12.—Fossils found at various localities in the Price River formation (restricted)<sup>1</sup>

	U.S.G.S. Mesozoic loc.			U.S.G.S. Mesozoic loc.	
	12247	8140		12247	8140
<i>Unio</i> cf. <i>U. priscus</i> Meek and Hayden ..		×	<i>Viviparus</i> sp. ....	×	
<i>Unio</i> cf. <i>U. amarillensis</i> Stanton ..	×	×	<i>Trilomopsis</i> sp. ....	×	×
sp. ....	×	×	<i>Campeloma</i> cf. <i>C. amarillensis</i> Stanton ..		×
<i>Sphaerium</i> cf. <i>S. planum</i> Meek and Hayden ..		×	<i>Lioplacodes</i> sp. ....	×	
<i>Valvata</i> sp. ....	×		<i>Goniobasis</i> ? <i>subtrigona</i> Stanton ..	×	

<sup>1</sup> Descriptions of localities follow.

8140. Sec. 14, T. 13 S., R. 10 E., canyon of Deadman Creek, Wellington quadrangle, Utah; base of formation; collected by F. R. Clark, 1912.  
 12247. 1 mile above Castle Gate on Price River; base of formation; collected by E. M. Spieker and J. B. Reeside, Jr., 1923.

### BUCK TONGUE OF MANCOS SHALE

The Buck tongue of the Mancos shale has yielded a marine fauna of considerable variety that is most comparable to that of the Gregory member of the Pierre shale. The species found are shown in table 13.

TABLE 13.—Fossils found at various localities in the Buck tongue of the Mancos shale<sup>1</sup>

	U.S.G.S. Mesozoic loc.						
	13239	13712	24412	13265	13266	24411	Lot 2
<i>Nucula planimarginata</i> Meek and Hayden ..		×					
<i>Yoldia evansi</i> (Meek and Hayden) ..		×					
"Arca" n. sp. ....		×					
<i>Inoceramus</i> cf. <i>I. sagensis</i> Owen ..	×	×					
cf. <i>I. vanuzemi</i> Meek and Hayden ..						×	
cf. <i>I. oblongus</i> White ..						×	
sp. ....				×			
<i>Ostrea</i> sp. ....	×			×			
<i>Synclonema</i> n. sp. ....		×					
<i>Modiolus herseyi</i> (White) ..		×					
<i>Grenella elegantula</i> Meek and Hayden ..		×					
<i>Liopistha</i> ( <i>Cymella</i> ) <i>montanensis</i> Henderson ..		×					
<i>Lucina subundata</i> Hall and Meek ..		×					
<i>Cardium</i> ( <i>Ethmocardium</i> ) <i>whitei</i> Dall. ....	×	×					
<i>Protocardia subquadrata</i> (Evans and Shumard) ..		×					
<i>Tellina</i> sp. ....	×						
<i>Leptosolen</i> n. sp. ....	×						
<i>Cymbophora formosa</i> (Meek and Hayden) ..	×						
<i>Dentalium gracile</i> Hall and Meek ..		×					
<i>Lunatia dakotensis</i> Henderson ..	×						
<i>Gyrodes depressa</i> Meek ..	×						
<i>Spironema</i> cf. <i>S. tenuilineata</i> (Meek and Hayden) ..	×						
<i>Fusus</i> sp. ....	×						
<i>Odontobasis</i> ? sp. ....		×					
<i>Cinulia</i> ( <i>Oligoptycha</i> ) <i>concinna</i> (Hall and Meek) ..		×					
<i>Tuba</i> ? sp. ....		×					
<i>Baculites asperiformis</i> Meek ..							×
aff. <i>B. aquilaensis</i> Reeside ..					×		×
aff. <i>B. aquilaensis separatus</i> Reeside ..					×		×
cf. <i>B. asper</i> Morton ..					×		×
sp. ....					×		×
<i>Placentiaceras planum</i> Hyatt ..					×		×
sp. ....	×	×					
Dinosaur femur, distal end ..							×

<sup>1</sup> Descriptions of localities follow.

- Lot 2, unnumbered. East of the Green River, Utah; about 500 ft above top of Mancos shale, in upper part of tongue; collected by G. B. Richardson, 1906; identified by J. W. Gidley.  
 13239. Green River, 20 miles above Green River, Utah, in SE¼ sec. 1, T. 19 S., R. 16 E.; 60 ft above base; collected by E. M. Spieker and J. B. Reeside, Jr., 1925.  
 13265. Canyon of Westwater Wash., Grand County, Utah, on road; 50 ft above base; collected by E. M. Spieker and J. B. Reeside, Jr., 1925.  
 13266. Canyon of Westwater Wash, Grand County, Utah, on road; 100 ft above base; collected by E. M. Spieker and J. B. Reeside, Jr., 1925.  
 13712. Diamond Canyon, north of Cisco, Grand County, Utah, in sec. 18, T. 19 S., R. 23 E.; 100 ft above base; collected by J. B. Reeside, Jr., 1926.  
 24411. 1 mile west of the Anchor mine 1, in sec. 27, T. 8 S., R. 101 W., Mesa County, Colo.; collected by P. J. Katich, 1952.  
 24412. North side of canyon, Cottonwood Creek, in sec. 18, T. 19 S., R. 23 E., Grand County, Utah; collected by P. J. Katich, 1952.

## SEGO SANDSTONE

The Sego sandstone conformably underlies the beds of the Neslen formation in Utah and the Mount Garfield formation in Colorado. At most places the contact is definite, but where the basal beds of the Neslen are sandy, the exact position is doubtful. Fossils collected from the Sego sandstone are shown in

TABLE 14.—Fossils found at various localities in the Sego sandstone<sup>1</sup>

	U.S.G.S. Mesozoic locality											
	13320	13326	13329	13336	13337	13375	13376	13377	13379	13253	13267	13268
Fresh-water species:												
<i>Viviparus</i> cf. <i>V. panguitchensis</i> White.....			X									
<i>Campelema</i> sp.....			X									
Brackish-water species:												
<i>Membranipora</i> n. sp.....	X	X	?	X	X							
<i>Ostrea glabra</i> Meek and Hayden.....	X	X										
<i>Anomia gryphorhynchus</i> Meek and Hayden.....	X	X										
<i>Brachyodontes regularis</i> White.....	X	X										
sp.....	X	X										
<i>Corbicula cytheriformis</i> (Meek and Hayden).....	X	X										
<i>subtrigonalis</i> Meek and Hayden.....	X	X										
<i>Panope</i> n. sp.....	X	X										
Marine species:												
Boring sponge ( <i>Cliona</i> ?).....												X
<i>Serpula</i> sp.....								X				
<i>Hemaster humphreysianus</i> Meek and Hayden.....												X
<i>Discina</i> n. sp.....								X				
<i>Nucula</i> sp.....								X				
<i>Yoldia evansi</i> (Meek and Hayden).....						X				?		X
<i>Barbatula</i> cf. <i>B. barbatula</i> White.....											X	X
<i>Pinna lakesi</i> White.....											X	X
<i>Inoceramus altus</i> Meek and Hayden.....								X	X		X	X
" <i>barabini</i> Morton" of Meek.....								X	X		X	X
cf. <i>I. sugensis</i> Owen.....								X	X		X	X
sp.....								X	X		X	X
<i>Pteria linguiformis</i> (Evans and Shumard).....								X	X		X	X
<i>Ostrea</i> cf. <i>O. gillulyi</i> Reeside.....								X	X		X	X
sp.....								X	X		X	X
<i>Trigonia</i> cf. <i>T. eufalestis</i> Gabb.....								X	X		X	X
<i>Camptonectes</i> n. sp.....								X	X		X	X
<i>Syncyclonema hallii</i> (Gabb).....								X	X		X	X
<i>Anomia micronema</i> Meek.....								X	X		X	X
sp.....								X	X		X	X
<i>Modiolus attenuatus</i> (Meek and Hayden).....								X	X		X	X
<i>meeki</i> (Evans and Shumard).....								X	X		X	X
<i>Crenella</i> n. sp.....								X	X		X	X
<i>Pholadomya</i> n. sp.....								X	X		X	X
<i>Laternula</i> cf. <i>L. doddsi</i> Henderson.....								X	X		X	X
<i>Liopistha montanensis</i> Henderson.....								X	X		X	X
<i>Cardium</i> ( <i>Ethmodium</i> ) <i>whitei</i> Dall.....			X	X				X	X		X	X
<i>Protocardia subquadrata</i> (Evans and Shumard).....			X	X				X	X		X	X
<i>Dostinopsis</i> sp.....								X	X		X	X
<i>Thetis</i> circularis (Meek and Hayden).....								X	X		X	X
<i>Tellina equilateralis</i> Meek and Hayden.....			X					X	X		X	X
<i>scitula</i> Meek and Hayden.....								X	X		X	X
<i>Legumen planulatum</i> (Conrad).....								X	X		X	X
<i>Leptosolen</i> n. sp.....								X	X		X	X
" <i>Mactra</i> " <i>gracilis</i> Meek and Hayden.....								X	X		X	X
<i>Mactra</i> sp.....								X	X		X	X
<i>Panope berthoudi</i> (White).....								X	X		X	X
<i>Dentalium</i> sp.....								X	X		X	X
<i>Margarita nebrascensis</i> (Meek).....								X	X		X	X
<i>Lunatia subcrassa</i> (Meek and Hayden).....								X	X		X	X
<i>Gyrodes depressa</i> Meek.....								X	X		X	X
Neritoid gastropod, undet.....								X	X		X	X
<i>Drepanochilus evansi</i> Cossman.....								X	X		X	X
<i>Anchura</i> sp.....								X	X		X	X
<i>Fusus</i> n. sp.....								X	X		X	X
sp.....								X	X		X	X
<i>Fasciolaria</i> cf. <i>F. cheyennensis</i> (Meek and Hayden).....								X	X		X	X
<i>Olivella</i> n. sp.....								X	X		X	X
<i>Cinulla</i> sp.....								X	X		X	X
<i>Anisomyon borealis</i> (Morton).....								X	X		X	X
<i>sexsulcatus</i> (Meek and Hayden).....								X	X		X	X
<i>Oryzoceras crassum</i> (Whitfield).....								X	X		X	X
<i>Baculites</i> sp.....								X	X		X	X
<i>Didymoceras</i> n. sp.....								X	X		X	X
<i>Scaphites</i> sp., aptychus.....								X	X		X	X
<i>Platoniceras</i> cf. <i>P. intercalare</i> Meek.....								X	X		X	X
<i>Lamna</i> sp.....								X	X		X	X
Fish scales, undet.....								X	X		X	X

table 14. Two facies are represented—one of chiefly brackish-water species, accompanied at some localities by a few fresh-water species; the other more strictly marine. The marine species are most comparable to those of the Gregory member of the Pierre shale, but some of the most distinctive forms of the Gregory have not been noted in the Sego. The assemblage is notable in containing an element that brings to mind the faunas of the Late Cretaceous of the gulf region, a feature noted also at certain localities in southern Wyoming (Steele shale of Laramie Basin), in the northern Front Range in Colorado (lower sandstone members of the Pierre shale), and in northern New Mexico (Mesaverde group).

## NESLEN FORMATION

A fresh-water fauna was found in the lower beds in the western exposures and in higher beds in the eastern exposures. A brackish-water fauna with a few marine species also occurs in the lower beds, particularly toward the east. Equivalents in Colorado of the middle beds of the Neslen formation are marine. The age of the Neslen faunas cannot be placed more closely than Late Cretaceous. Several plants as well as fragments of reptiles were found.

Table 15 shows the fossils collected from the Neslen formation.

## FARRER FORMATION

The fossils of the Farrer formation include the fresh-water mollusks shown in table 16, remains of a turtle found in canyon of Saleratus Wash (bed 35 of section 10), and plant remains noted in Tuscher Canyon (bed 34 of section 8) and north of Cisco (beds 51 and 53 of section 14). The fauna is of rather late Cretaceous age.

<sup>1</sup> Descriptions of localities follow.

13236. Green River, Utah, 26 miles above the town of that name, in NE¼ sec. 19, T. 18 S., R. 17 E.; about 200 ft above Castlegate sandstone (Sego horizon); collected by J. B. Reeside, Jr., and E. M. Spieker, 1925.
13237. Same locality and collectors as 13236; loose on surface above horizon of 13236.
13253. Neslen Canyon, opposite Sego schoolhouse, Utah; probably from lower part of formation; collected by J. B. Reeside, Jr., and E. M. Spieker, 1925.
13267. Canyon of Westwater Wash, Utah, on road; collected by J. B. Reeside, Jr., and E. M. Spieker, 1925.
13268. Canyon of Westwater Wash; SW¼ sec. 32, T. 17 S., R. 24 E., or NW¼ sec. 5, T. 18 S., R. 24 E., Utah; from brown limy sandstone at or near top; collected by J. B. Reeside, Jr., and E. M. Spieker, 1925.
13320. Price River, near center sec. 18, T. 18 S., R. 15 E., Utah; 115 ft above Castlegate sandstone (Sego horizon); collected by D. J. Fisher, 1925.
13329. Canyon of Tuscher Wash; SW¼ sec. 8, T. 20 S., R. 17 E., Utah; 17 ft below top; collected by D. J. Fisher, 1925.
13336. Canyon of Tuscher Wash; NW¼ sec. 9, T. 20 S., R. 17 E., Utah; 12 ft below top; collected by D. J. Fisher, 1925.
13337. Same locality and collector as 13336; 34 ft above base.
13675. West branch of Saleratus Wash; sec. 31, T. 20 S., R. 19 E., Utah; 50 ft below top; collected by D. J. Fisher, 1926.
13676. Same locality and collector as 13675; 15 ft below top.
13677. Same locality and collector as 13675; 5 ft below top.
13679. Northwest of Thompson; sec. 5, T. 21 S., R. 20 E., Utah; 53 ft below top; collected by D. J. Fisher, 1926.
13687. Canyon of Westwater Wash; SW¼ sec. 5, T. 18 S., R. 24 E., Utah; 64 ft below top; collected by D. J. Fisher, 1926.
13690. 2 miles west of Colorado; sec. 31, T. 16 S., R. 26 E., Utah; 165 ft below top; collected by D. J. Fisher, 1926.



TABLE 15.—Fossils found at various localities in the Neslen formation<sup>1</sup>

	U.S.G.S. Mesozoic loc.							
	13334	13674	13686	13689	13688	13339	13678	13709
Fresh-water species:								
<i>Unio</i> sp.	x		x	x	x			
<i>Sphaerium planum</i> Meek and Hayden	x	x	x	x	x			
<i>Campeloma amarillensis</i> Stanton	x	x	x	x	x			
sp.	x	x	x	x	x			
<i>Tulotomops laevis</i> Yan.	x	x	x	x	x			
sp.	x	x	x	x	x			
<i>Amnicola</i> sp.	x	x	x	x	x			
<i>Lioplacodes</i> sp.	x	x	x	x	x			
<i>Physa</i> sp.	x	x	x	x	x			
Brackish-water and marine species:								
<i>Membranipora</i> n. sp.	x	x	x	x	x			
<i>Ostrea glabra</i> Meek and Hayden	x	x	x	x	x			
<i>Anomia gryphorhynchus</i> Meek	x	x	x	x	x			
<i>micronema</i> Meek	x	x	x	x	x			
<i>Brachyodontes regularis</i> (White)	x	x	x	x	x			
<i>Veniella humilis</i> (Meek and Hayden)	x	x	x	x	x			
<i>Corbicula cytheriformis</i> (Meek and Hayden)	x	x	x	x	x			
sp.	x	x	x	x	x			
<i>Cardium</i> aff. <i>C. whitei</i> Dall.	x	x	x	x	x			
<i>Corbula subtrigonalis</i> Meek and Hayden	x	x	x	x	x			
<i>Fusus?</i> sp.	x	x	x	x	x			
Vertebrates and plants:								
Turtle, undet. fragments	x	x	x	x	x			
Crocodile centrum, undet.	x	x	x	x	x			
<i>Anemia elongata</i> (Newberry) Knowlton	x	x	x	x	x			
<i>Myrica torreyi</i> Lesquereux	x	x	x	x	x			
Palm, undet.	x	x	x	x	x			

<sup>1</sup> Descriptions of localities follow.

- Lot 3, unnumbered. Above Ballard's prospect in Neslen Canyon, in sec. 27, T. 20 S., R. 20 E., Utah; about 175 ft above base; collected by G. B. Richardson; identified by F. H. Knowlton, 1906.
- Lot 4, unnumbered. North of Cisco, in NW¼ sec. 3, T. 19 S., R. 23 E., Utah; loose sandstone slab 220 ft above base; collected by D. J. Fisher, 1926.
13334. Canyon of Tuscher Wash; NW¼ sec. 9, T. 20 S., R. 17 E., Utah; in lower 10 ft; collected by D. J. Fisher, 1926.
13339. Northeast of Solitude, from SW¼ sec. 6, T. 21 S., R. 18 E., Utah; about 20 ft above base; collected by D. J. Fisher, 1926.
13674. East branch from canyon of Horse Creek, SW¼ sec. 2, T. 21 S., R. 18 E.; about 25 ft above base; collected by D. J. Fisher, 1926.
13678. West side of canyon of Saleratus Wash; sec. 31, T. 20 S., R. 19 E., Utah; 35 ft above base; collected by D. J. Fisher, 1926.
13681. Northwest of Thompson; sec. 31, T. 20 S., R. 20 E., Utah; 4 ft above base; collected by R. M. Leggett, 1926.
13686. East side of Diamond Canyon; sec. 18, T. 19 S., R. 23 E., Utah; 120 ft above base; collected by R. M. Leggett, 1926.
13688. East canyon of Westwater Wash; sec. 10, T. 17 S., R. 24 E., Utah; 304 ft above base; collected by D. J. Fisher, 1926.
13689. North branch of canyon of Sulphur Wash; sec. 24, T. 18 S., R. 23 E., Utah; 325 ft above base; collected by D. J. Fisher, 1926.
13709. West side of canyon of Saleratus Wash; NW¼ sec. 32, T. 20 S., R. 19 E., Utah; 15 ft above base; collected by J. B. Reeside, Jr., 1926.

TABLE 16.—Fossils found at various localities in the Farrer formation<sup>1</sup>

	U.S.G.S. Mesozoic loc.		
	13673	13682	Lot 5
Mollusks:			
<i>Unio amarillensis</i> Stanton		x	
cf. <i>U. brachyopisthus</i> White		x	
cf. <i>U. brimhallensis</i> Stanton		x	
<i>Viviparus?</i> sp.	x		
<i>Campeloma amarillensis</i> Stanton		x	
<i>Tulotomops</i> sp.		x	
<i>Amnicola</i> sp.		x	
Plants:			
<i>Sabalites reichenbachii</i> (Gelnitz) Heer			x
<i>Fiscus planicostata</i> Lesquereux			x
sp.			x
<i>Malapoenna</i> sp.			x
<i>Cinnamomum affine</i> Lesquereux?			x

<sup>1</sup> Descriptions of localities follow.

- Lot 5, unnumbered. About 8 miles north of Thompson, Utah; probably from a horizon near top; collected by G. B. Richardson, 1906; identified by F. H. Knowlton.
13673. East fork of Horse Canyon, in sec. 3, T. 21 S., R. 18 E., Utah; 110 ft above base; unidentified fossil leaves also found here; collected by D. J. Fisher, 1926.
13682. North of Thompson, in SE¼ sec. 32, T. 20 S., R. 20 E., Utah; 30 ft above base, from a lens of limy sandstone in shale; collected by D. J. Fisher, 1926.

## TUSCHER FORMATION

The Tuscher formation has yielded no significant fossils. Its equivalence to the Hunter Canyon formation in Colorado does not help to date it closely, for this unit is also placed only as Late Cretaceous. It resembles the overlying "Wasatch" more in lithologic character than the underlying beds, and the nature of the contacts with both adjacent units is usually difficult to determine. It could be latest Cretaceous or earliest Tertiary, but it is here designated somewhat arbitrarily Cretaceous and part of the Mesaverde group.

## MOUNT GARFIELD FORMATION AND ROLLINS SANDSTONE MEMBER, BOWIE SHALE MEMBER, AND PAONIA SHALE MEMBER OF THE MESAVERDE FORMATION

Only a few collections of invertebrate fossils are available from the Mount Garfield formation of the Book Cliffs proper. However, from the equivalents of this formation southward and southeastward, the Rollins, Bowie and Paonia members of the Mesaverde formation, Lee (1912, p. 29-47) collected fossils noted in table 17. The lower part of the Mount Garfield yields only marine fossils. Toward the south and southeast, as stated in previous pages, most of this part passes into the upper part of the Mancos shale. The upper part of the Mount Garfield formation in the Book Cliffs has yielded only fresh-water fossils. Toward the south and southeast, however, the Bowie shale member replaces the lower beds of the upper Mount Garfield and contains both brackish-water and marine fossils. The Paonia shale member replaces still higher beds but contains dominantly fresh-water fossils. The marine fossils are of longer ranging species, as are also the brackish-water forms, but the fresh-water types are elsewhere best known in strata of very late Cretaceous age.

Lee lists fossil plants from shales of the Bowie and Paonia members and gives an analysis of the collections by F. H. Knowlton. Knowlton concludes that the fossil plants indicate an age later than the Montana epoch; that is, later than the time of deposition of the Fox Hills sandstone. Because some of the occurrences with which comparison is made are now generally accepted as very late Cretaceous (though some of them, such as the Arapahoe and Denver formations, were considered Tertiary by Knowlton), and because some occurrences are well down in the Montana sequence, it is doubtful that the plants are really distinctive of more than a general Late Cretaceous age.

The fossils of the Mount Garfield formation and equivalents are shown in tables 17 and 18.

TABLE 17.—Fossils found at various localities in the lower part of the Mount Garfield formation<sup>1</sup>

	U.S.G.S. Mesozoic loc.			
	4185	4186	4192	4203
<i>Leda</i> sp.				X
<i>Inoceramus</i> "barabini" Morton of Meek.	X		X	
<i>Ostrea</i> sp.			X	
<i>Cardium</i> ( <i>Ethmocardium</i> ) whitei Dall.		X	?	?
<i>Tellina</i> sp.		X		X
<i>Leptosolen</i> sp.		X		
<i>Maclra</i> sp.				X
<i>Corbula</i> sp.		X		
<i>Gyrodes</i> sp.		X		

<sup>1</sup> See list at the end of this series of tables for descriptions of localities.

## Descriptions of localities in tables 17 and 18

- 4184-4504. Collected by W. T. Lee, 1907.  
 4184. 3½ miles southeast of Palisade, Colo.; 250 ft above Rollins sandstone.  
 4185. 4 miles southeast of Palisade, Colo.; 25 ft above base of Mount Garfield.  
 4186. 3½ miles southeast of Palisade, Colo.; 25 ft above base of Mount Garfield.  
 4192. Same as 4186; 125 ft above base of Mount Garfield.  
 4195. 3½ miles southeast of Palisade, Colo.; 150 ft above Rollins sandstone.  
 4197. 4 miles southeast of Palisade, Colo.; 150 ft above Rollins sandstone.  
 4203. 7 miles southeast of Palisade, Colo.; 25-200 ft above base of Mount Garfield formation.

4205. Point east of Rollins mine, 75 ft above base of Paonia shale.  
 4218. 14 miles northeast of Delta, Colo.; 100 ft above base of Paonia shale.  
 4220. 4 miles northeast of Cedaredge, Colo.; 200 ft above base of Paonia shale.  
 4263. 6 miles north of Hotchkiss, Colo.; 100 ft above base of Paonia shale.  
 4264. Conine mine, 3 miles northwest of Paonia, Colo.; 40 ft above base of Bowie shale.  
 4265. 3 miles north of Paonia, Colo.; base of Bowie shale.  
 4266. Same as 4265; base of Bowie shale.  
 4268. 1 mile west of Bowie, Colo.; base of Bowie shale.  
 4269. One half of a mile north of Bowie, Colo.; base of Bowie shale.  
 4271. Same as 4269; base of Bowie shale.  
 4274. Hubbard Creek, Colo.; slide rock near top of Bowie shale.  
 4275. Same as 4274; 20 ft above base of Bowie shale.  
 4276. East side Hubbard Creek, Colo.; about 300 ft above base of Bowie shale.  
 4487. Waneta mine near Bowie, Colo.; 25 ft above base of Bowie shale.  
 4488. Near Bowie, Colo., in sec. 15, T. 13 S., R. 91 W.; 50 ft above base of Bowie shale.  
 4492. Minnesota Creek, in sec. 5, T. 14 S., R. 90 W., Colo.; base of coal.  
 4493. Same as 4492.  
 4494. Same as 4492; 90 ft higher.  
 4495. Same as 4492; 275 ft higher.  
 4497. Same as 4492; 200 ft higher.  
 4499. Same as 4492; base of Bowie shale.  
 4500. Same as 4492; near base of Bowie shale.  
 4501. Same as 4492; near top of Bowie shale.  
 4503. Coal Creek, Colo.; near top of Bowie shale.  
 4504. Same as 4503; near base of Paonia shale.  
 13970. NW. cor. SW¼ sec. 29, T. 7 S., R. 104 W., Colo.; 40 ft above highest Carbonero coal, 375 ft above top of Sego sandstone; collector, C. E. Erdmann, 1926.

TABLE 18.—Fossils found at various localities in the upper part of the Mount Garfield formation and equivalents<sup>1</sup>

U.S.G.S. Mesozoic loc. in the —																													
	Mount Garfield formation				Bowie shale member of Mesaverde formation																Paonia shale member of Mesaverde formation								
					Marine					Nonmarine																			
	13970	4184	4195	4197	4495	4497	4501	4503	4264	4265	4266	4268	4269	4271	4274	4275	4276	4487	4492	4493	4494	4499	4500	4205	4218	4220	4263	4488	4504
Fresh-water species:																													
<i>Unio pseudoendlichi</i> Yen.	X																												
<i>mesaverdensis</i> Yen.	X																												
cf. <i>U. brimhallensis</i> Stanton.		X																							X	X			
cf. <i>U. brachyopisthus</i> White.			X																										
<i>amarillensis</i> Stanton.		X																											
<i>paraholmesianus</i> Yen.		X																											
cf. <i>U. endlichi</i> White.																													
sp.	X		X																					X	X	X	X		
<i>Sphaerium</i> cf. <i>S. planum</i> Meek and Hayden.			X																					X	X				
sp.																								X		X	X		
<i>Viviparus?</i> sp.																										X	X		
<i>Campeloma</i> cf. <i>C. amarillensis</i> Stanton.		X																											
? sp.	X		X																						X	X			
<i>Tulotomops laevis</i> Yen.			X	X																					X	X			
sp.			X																						X	X			
<i>Liopacodes</i> sp.			X																										
<i>Ammicula</i> sp.			X	X																									
<i>Goniobasis</i> cf. <i>G. tenuicarinata</i> (Meek and Hayden).															X														
? sp.																													
<i>Melania wyomingensis</i> Meek.																						X							
<i>insculpta</i> (Meek).															X							?							
<i>Mesolanistes reesidei</i> (Stanton).																													
<i>Physa</i> sp.			X																										
Brackish-water species:																													
<i>Ostrea subtrigonalis</i> Evans and Shumard.						X											X			X		X							
sp.																													
<i>Anomia micronema</i> Meek.												X			X			X											
sp.													X		X														
<i>Brachydontes regularis</i> (White).													X		X		X	X			X		X						
<i>laticostata</i> (White).													X		X		X		X										
<i>Corbicula cytheriformis</i> (Meek and Hayden).									X						X		X											X	
<i>occidentalis</i> (Meek and Hayden).													X		X		X												
sp.										X			X		X		X												
<i>undifera</i> White.									X		X		X		X		X												
<i>subtrigonalis</i> Meek and Hayden.														X		X		X										X	
<i>Panope simulatrix</i> Whiteaves.			X											X	X	X	X					?	X	X			X		
Marine species:																													
<i>Inoceramus</i> "barabini" Morton" of Meek.						X																							
<i>sagensis</i> Owen.								X																					
<i>Cardium</i> ( <i>Ethmocardium</i> ) <i>whitei</i> Dall.					X	X																							
<i>Tellina</i> sp.																													
<i>Lamna</i> sp.					X			X																					

<sup>1</sup> See list at the end of this series of tables for descriptions of localities.

# HUNTER CANYON FORMATION AND UNDIFFERENTIATED MEMBER OF MESAVERDE FORMATION

The Hunter Canyon formation proper has yielded no fossils and is undated. The presumably equivalent beds to the southeast, the undifferentiated member of the Mesaverde formation, has yielded only a few invertebrates. These, as shown in table 19, are all fresh-water types and can be assigned only as Late Cretaceous. The highest beds of Lee's undifferentiated member of the Mesaverde formation are undated.

TABLE 19.—Fossils found at various localities in the undifferentiated member of the Mesaverde formation<sup>1</sup>

	U.S.G.S. Mesozoic loc.			
	4188	4191	4214	4486
<i>Unio</i> cf. <i>U. amarillensis</i> Stanton				X
cf. <i>U. brimhallensis</i> Stanton				X
cf. <i>U. priscus</i> Meek and Hayden		X		X
sp.			X	
<i>Sphaerium</i> sp.	X		X	
<i>Teredina</i> sp.				X
<i>Valvata</i> sp.	X			
<i>Mesolanistes</i> cf. <i>M. reesei</i> (Stanton)	X			
<i>Tulotomops laevis</i> Yen.			X	
sp.		X		X
<i>Campeloma</i> cf. <i>C. amarillensis</i> Stanton	X	X		
sp.			X	X
<i>Lioplacodes</i> sp.			X	
<i>Amnicola</i> sp.			X	
<i>Goniobasis</i> cf. <i>G. eulimoides</i> (Meek)	X			
sp.	X			
? <i>subtortuosa</i> (Meek and Hayden)			X	
<i>Physa</i> sp.	X			

<sup>1</sup> Descriptions of localities follow.

Collected in Colorado by W. T. Lee, 1907.

4188. Rapid Creek, 3 miles northeast of Palsade; about 1,000 ft below top of formation.

4191. 1½ miles northeast of Cameo; 800 ft below top of formation.

4214. 12 miles northeast of Delta; 600 ft below top of formation.

4486. Same locality as 4214; 300 ft below top of formation.

## NORTH HORN AND FLAGSTAFF FORMATIONS UNDIFFERENTIATED

In the Book Cliffs the North Horn and Flagstaff formations undifferentiated yielded fossils from several beds of limestone, and the species contained in them are shown in table 20. The significance of this fauna, other than that it is strictly of nonmarine origin and is probably Tertiary, is not now clear, as the ranges hitherto assumed for some of the species seem dubious.

La Rocque (1951, 1956) has expressed the opinion that the molluscan faunas of the typical North Horn formation indicate a Cretaceous to Paleocene age and the molluscan faunas of the typical Flagstaff limestone indicate a Paleocene to Eocene age. Swain (1956) has examined the ostracode faunas of parts of the Book Cliffs and seems to agree in broad terms with La Rocque. It is not yet clear, however, what the stratigraphic relations are between the North Horn and Flagstaff of the type areas and the exposures in the Book Cliffs.

TABLE 20.—Fossils found at various localities in the North Horn and Flagstaff formations undifferentiated<sup>1</sup>

	U.S.G.S. Mesozoic loc.				
	13317	Lot 6	13234	13235	13338
<i>Unio haydeni</i> Meek				X	
<i>Vitiparus paludinaformis</i> Hall			X		
<i>pangultchensis</i> White		X			
cf. <i>V. wyomingensis</i> Meek		X			
sp.	X			X	
<i>Goniobasis</i> sp.		X			
<i>Physa</i> , cf. <i>P. bridgerensis</i> Meek		X			
<i>pleromatis</i> White	X				X
<i>Helix</i> sp.				X	

<sup>1</sup> Descriptions of localities follow.

13317. West side of Horse Canyon in SE¼ sec. 28, T. 15 S., R. 14 E., Utah. Collected by D. J. Fisher, 1925.

Lot 6, unnumbered. Canyon of Horse Creek, Utah. "200 and 300 ft above base of Wasatch." Collected by G. B. Richardson; identified by W. H. Dall, 1906.

13234. Green River, 36 miles above Green River, Utah, in sec. 16, T. 17 S., R. 17 E. From gray limestone concretions in variegated shale. Collected by E. M. Spieker and J. B. Reeside, Jr., 1925.

13235. Same locality and collectors, but 312 ft higher, in gray limestone layer in shale.

13338. Soulier Mesa, north branch of Tuscher Wash, in NE¼ sec. 27, T. 19 S., R. 17 E., Utah. "265 ft above base of Wasatch." Collected by D. J. Fisher, 1925.

## UNNAMED SANDSTONE

The unnamed sandstone yielded no significant fossils, and stratigraphic importance of the unconformity at its base is unknown. It rests on the Hunter Canyon formation, whose age is also unknown. It resembles the overlying "Wasatch" formation more than the Hunter Canyon. The suggestion is strong that it is of Tertiary age, but it is here arbitrarily designated Tertiary (?).

## COLTON AND "WASATCH" FORMATIONS

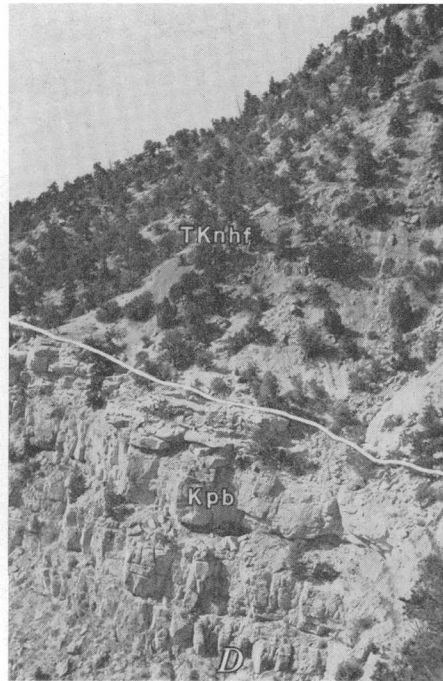
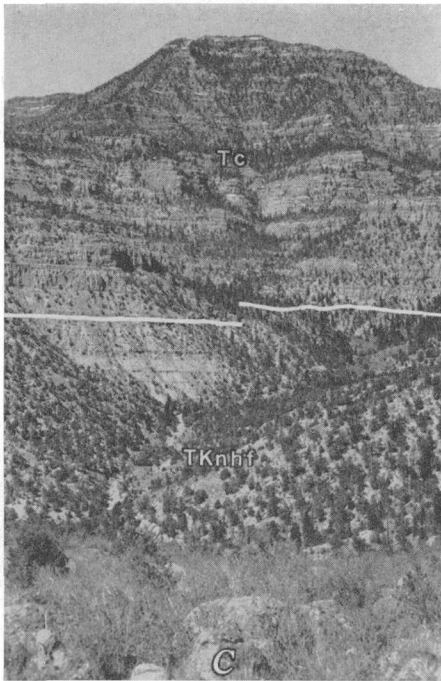
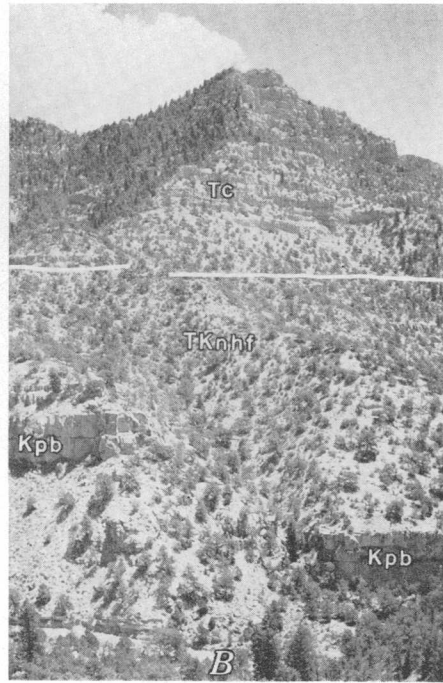
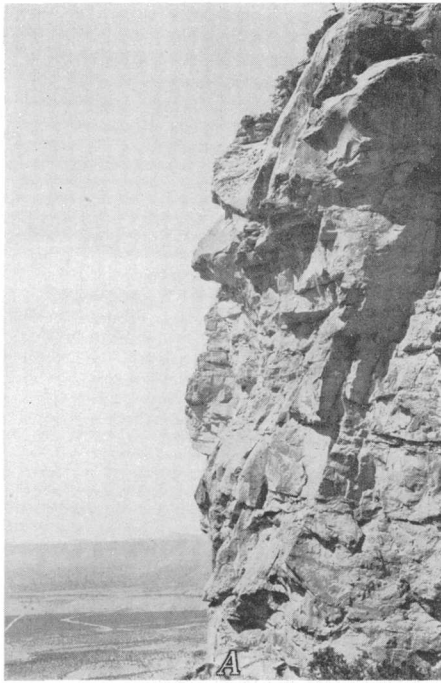
In the area examined, little direct evidence of the age of the Colton and "Wasatch" formations has been found by the writers. Not far east of the eastern end of the Book Cliffs, the beds that seem equivalent to those here called "Wasatch" have yielded vertebrates of late Paleocene and early Eocene age (Patterson, 1934). Swain (1956) in discussing the ostracodes of the general region refers to "Colton ('Wasatch') formation" and his "Colton-Green River transition beds" to the Eocene. La Rocque (1956) refers the Colton to the Eocene on the basis of the nonmarine mollusks.

## GREEN RIVER FORMATION

It is assumed here that the Green River strata of the Book Cliffs are of Eocene age, though because of lateral gradations between the fluvial facies here called "Wasatch" and the lacustrine facies here called Green River, it is possible that differing parts of the Eocene may be included in the Green River at different places.

## NONMARINE FAUNAS IN THE SEQUENCE

As may be noted in several of the preceding faunal tables, certain assemblages of species of mollusks from



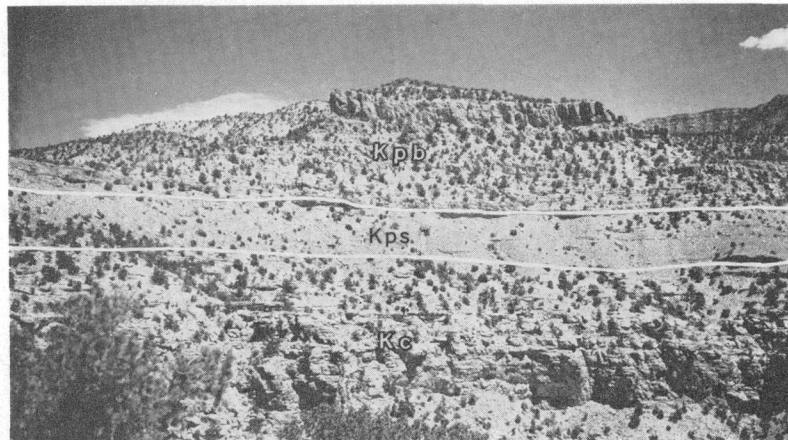
## VIEWS IN HORSE CANYON AREA, CARBON COUNTY, UTAH

- A. Castlegate sandstone cliff viewed from Bacon Culch from a point southeast of center of sec. 29, T. 15 S., R. 15 E.
- B. Fault cutting Bluecastle sandstone member of Price River formation, Kpb, just north of southeast corner of sec. 28, T. 15 S., R. 14 E.; North Horn and Flagstaff formations undifferentiated, TKnhf, in middle slope; upper sandstone cliffs in lower part of Colton formation, Tc; distance from fault to skyline is about one-half a mile.
- C. Patmos Head (elev 9,849 ft) from point just north of E $\frac{1}{4}$  corner sec. 34, T. 15 S., R. 14 E.; Colton formation, Tc, above, resting on North Horn and Flagstaff formations undifferentiated, TKnhf.
- D. Contact of North Horn and Flagstaff formations undifferentiated, TKnhf, on Bluecastle member, Kpb, of Price River formation; view north along cliff near southwest corner SE $\frac{1}{4}$ SW $\frac{1}{4}$  sec. 21, T. 15 S., R. 14 E.



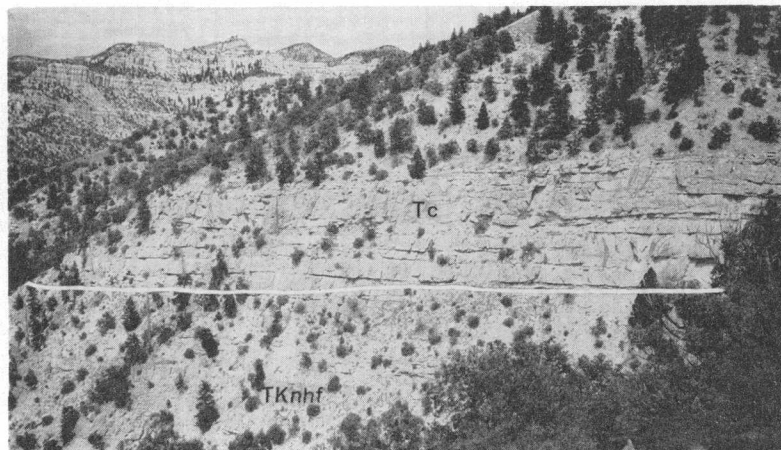
A. SHEEP CANYON, TRIBUTARY TO HORSE CREEK, CARBON COUNTY, UTAH

View looking into canyon N. 80° W. from N $\frac{1}{4}$  corner sec. 28, T. 15 S., R. 14 E. 1, Mancos shale; 2, lower sandstone member, Blackhawk formation; 3, middle shale member, Blackhawk formation; 4, middle sandstone member, Blackhawk formation; 5, Sunnyside coal zone; 6, upper shale member, Blackhawk formation; 7, Castlegate sandstone; 8, middle shale member, Price River formation; 9, Bluecastle sandstone member, Price River formation.



B. FORMATIONS IN HORSE CREEK CANYON, NEAR CENTER SEC. 4, T. 16 S., R. 14 E., EMERY COUNTY, UTAH

Lower sandstone is Castlegate sandstone, Kc; shale slope is shale member, Price River formation, Kps; upper sandstone ledges are Bluecastle member, Kpb, Price River formation.



C. COLTON, NORTH HORN, AND FLAGSTAFF FORMATIONS, IN HORSE CREEK CANYON, CARBON COUNTY, UTAH

Contact of Colton formation, Tc, on North Horn and Flagstaff formations undifferentiated, TKnhf; view looking north from point west of center sec. 35, T. 15 S., R. 14 E.



the Mesaverde group are interpreted as having lived in a brackish-water environment, and others from both the Mesaverde group and the higher zones are interpreted as having lived in fresh water. The basis for these interpretations is the assumption that various types of life have had in the past the same habits that closely similar types of the present have. Supporting evidence is generally supplied by the associated fossils and by the characteristics of the enclosing sediment. Land plants and vertebrates adapted for terrestrial life, for example, suggest a terrestrial environment, as do also such features as autochthonous coal beds and very lenticular or discontinuous bedding that is distributed through a considerable thickness of sediment.

Commonly some mixture of faunal elements is found. A dominantly brackish-water fauna may contain a few species whose normal association is with marine species; or it may contain a few species whose normal association is with fresh-water species. Similarly, a dominantly fresh-water fauna may contain a few species whose usual association is with brackish-water forms. It seems probably that this mixture is in part mechanical, the result of natural accidents that bring shells together after the death of the organisms, though it may also be partly due to the capacity of some aquatic organisms to tolerate a considerable range of salinity. In any event, the faunas as found do often contain some seemingly discordant elements.

Among the species interpreted as having lived in a brackish-water environment are *Membranipora* n. sp., *Ostrea glabra* Meek and Hayden, *Anomia gryphorhynchus* Meek, *A. micronema* Meek, *Brachydonates laticostata* White, *B. regularis* White, *Corbicula cytheriformis* (Meek and Hayden), *Corbula subtriangularis* Meek and Hayden, *C. perundata* Meek and Hayden, *C. undifera* Meek, *Panope simulatrix* Whiteaves, and *P.* n. sp. These brackish-water species are mostly rather long ranging. Some of them have been reported from the Judith River formation of Montana, considered about equal in age to the type Mesaverde group; some from the Mesaverde group of northwestern Colorado and southern Wyoming, above which is the marine Lewis shale. Most of them have been found in the Fruitland formation of the San Juan Basin of Colorado and New Mexico, above the typical Lewis shale; and in the Laramie formation of the Denver basin of eastern Colorado and the lower part of the Lance formation of the Great Plains, above the Fox Hills sandstone. This fauna probably represents an environment rather than a restricted interval of time, though all its occurrences are in beds

of rather late Cretaceous age—the middle and later parts of the Montana group and the immediately overlying beds.

Among the species interpreted as having lived in a fresh-water environment are all the species of the Unionidae, the species of *Sphaerium*, *Viviparus*, *Campeloma*, *Tulotomops*, *Lioplacodes*, *Ammicola*, *Mesolanistes*, *Melania*, *Goniobasis*, and *Physa*. The fresh-water species include both long-ranging and more restricted forms. In the work here reported, few collections were made above the Cretaceous, and the discussion pertains almost wholly to the Cretaceous forms. *Unio priscus* Meek and Hayden, *Sphaerium planum* Meek and Hayden, and *Goniobasis? subtriosa* (Meek and Hayden) have been reported from the Judith River formation and from much later zones. These species, as the brackish-water forms, do not seem to represent a very restricted interval within the Late Cretaceous, though *G.? subtriosa* is not known in the Laramie or Lance formations. The highly sculptured unionids like *Unio paraholmesianus* Yen and *U. amarillensis* Stanton, and the less ornamented species like *U. brachyopisthus* White, *U. pseudoendlichi* Yen, and *U. brimhallensis* Stanton, together with the species of gastropods like *Campeloma amarillensis* Stanton, are restricted to the higher horizons represented by the Fruitland and Kirtland formations, the Laramie formation, and the Lance formation. *Tulotomops laevibasalis* Yen is related to *T. thompsoni* (White), whose occurrences are in the Laramie and Lance formations. The reptilian faunas of the Upper Cretaceous strata of the San Juan Basin, specifically of the Fruitland, Kirtland, McDermott, and Ojo Alamo formations, and of the North Horn formation of Utah are said to be distinctly older than that of the Lance formation (C. W. Gilmore, oral communications, 1939). There is, therefore, probability of a fairly long interval within the very late Cretaceous during which these more restricted fresh-water species lived, though it is much shorter than that of the brackish-water forms and the long-ranging fresh-water forms.

At the western end of the Book Cliffs, the Blackhawk formation contains chiefly a brackish-water fauna, with but a small admixture of fresh-water species. The overlying beds have yielded only fresh-water species.

In the general vicinity of the Green River, the Blackhawk is still of brackish-water facies; and the Castlegate sandstone has yielded no fossils, but is assumed to be nonmarine. The beds immediately above the Castlegate, however, representing the landward part of the Buck tongue of the Mancos shale

have yielded a small marine fauna. The beds next above, constituting the Sego sandstone, carry a brackish-water fauna containing two fresh-water species. Immediately above it, in the lower part of the Neslen formation, occurs a fresh-water fauna, and probably all the overlying beds are of fresh-water origin. Part of the fresh-water beds of the Price River formation of the western Book Cliffs, then, pass eastward into marine and brackish-water beds.

In the vicinity of the canyon of Thompson Wash, most of the Blackhawk formation has given way to marine shales, the Castlegate sandstone contains a brackish-water fauna with one marine species, the Buck tongue is a well-defined marine unit, and the Sego sandstone has a purely marine fauna. The overlying beds have yielded only fresh-water species. The change from nonmarine to marine beds has thus proceeded farther at Thompson Wash.

In the vicinity of the canyon of Westwater Wash, most of the Castlegate sandstone has passed into marine shale, the Buck tongue is thicker, the Sego sandstone has a large and varied marine fauna, and the lower part of the Neslen formation contains a brackish-water fauna. The overlying beds are apparently all fresh-water facies.

In the vicinity of Grand Junction, the lower part of the Sego sandstone has given way to marine shale, and the lower 200 feet of the Mount Garfield formation has become marine. The upper part of the Mount Garfield and the overlying beds have yielded only fresh-water species. Farther southeast, in the Grand Mesa region, the marine part of the Mount Garfield of the Grand Junction region passes into marine shale; much of the upper part acquires marine and brackish-water facies; and only the uppermost part, together with the overlying beds, is still of fresh-water facies.

In general it may be said that in the Mesaverde group of the Book Cliffs region the fauna at a given horizon changes in facies eastward from fresh-water through brackish-water to marine and that the fresh-water fauna is restricted to progressively higher horizons eastward. Neither the fresh-water nor the brackish-water fauna changes materially in composition in the stratigraphic interval covered.

#### ORIGIN OF THE FORMATIONS

##### LOWER CRETACEOUS UNITS

By its lithologic character and its fossils, including dinosaur remains and fresh-water invertebrates, the Cedar Mountain formation appears to be a fluvial deposit. The Burro Canyon formation, with its simi-

lar composition and structure and its flora, likewise appears to be of fluvial origin.

##### DAKOTA SANDSTONE

The Dakota sandstone as recognized in Utah and the thicker equivalent in Colorado may differ somewhat in age. It appears that early in Late Cretaceous time shallow marine waters advanced from the south or east into western Colorado. The initial deposit was generally a pebble-bearing sand. The coastal belt bordering the advancing waters for a while contained swamp areas that favored the accumulation of carbonaceous materials, locally sufficient to form mineable coals. The later deposits were muds and sands laid in marine waters and now forming comparatively even and regular beds of rock. The shoreline apparently had not yet reached Utah, where rather different materials were being deposited. There the lithologic heterogeneity of the formation suggests an origin in a flood-plain area, the conglomerate and crossbedded sandstone perhaps forming in the main channels of the streams, and the shale being deposited away from the channels. Pond deposits were possibly formed locally. In early Mancos time the sea extended far to the west, beyond the Wasatch Plateau. As the Cretaceous sea advanced into Utah, some of the sand, especially that in the upper part of the Dakota, may have been deposited under marine or at least brackish conditions. That the formation is so widespread, though not everywhere preserved (the Mancos and pre-Dakota formations are locally in contact), can be explained best by assuming a relatively flat pre-Dakota surface on which it was laid down. The nature of the lower contact supports this assumption. The local presence in Utah of tree trunks up to 2½ feet in diameter, as well as other plant fossils, is also in harmony with it. The Dakota strata may consist partly of reworked Morrison material, but it seems most likely that much of the material came from the west. From Spieker's findings (1946, p. 150-152) in and near the western part of the Wasatch Plateau, it is clear that a high area not very far to the west was yielding material during at least the earlier part of Late Cretaceous time.

##### MANCOS SHALE AND MESAVERDE GROUP

Because of the large-scale interfingering of the upper part of the Mancos shale and the Mesaverde group, it is convenient here to consider these units together.



The Mancos shale of the Book Cliffs region is part of a very extensive marine shale that does not lend itself readily to division into lithologic units. By means of the series of faunal zones given under the heading, "Standard sequence of Cretaceous in the western interior region," it is possible to estimate the range in time of the formation at different places and the relative positions of individual parts of the formation in a time scale. For much of the Mancos epoch, the shoreline of the sea was west of the Book Cliffs region, but not very far west, for in central Utah a great thickness of very coarse material of Mancos age indicates proximity to land (Spieker, 1946, p. 150-152). At different times and places the accumulation of fine-grained material in parts of the great area of Mancos deposition gave way to the accumulation of dominantly coarser material, ranging from silt to sand. These bodies of coarser material are mostly thicker and coarser toward the west and extend as thinning sheets toward the east. Depending on the direction in which erosion has cut into them and on their lateral extent, many of them have been formally named as sandstone members of the Mancos shale or as tongues of some other formation.

In the Book Cliffs region the accumulation of fine-grained marine material began with the close of Dakota deposition, perhaps somewhat earlier in Colorado than in Utah, for the 60 to 90 feet of shale that are present in Colorado below the levels containing *Gryphea newberryi* Stanton appear to be lacking in Utah. As Katich has noted (1956), *Gryphaea newberryi* has not been found in the western Book Cliffs, and there may have been a brief interruption of sedimentation near the beginning of Mancos time to account for its absence from that area. A thin sequence follows that is undated, but may possibly represent the early Turonian interval, and the deposition of fine materials continued through the time of the lower Carlile units, the middle Turonian epoch.

Next follows a thin zone of sandy beds that extends across the region and far beyond it over the western interior Cretaceous area. This zone contains the middle Carlile faunas (*Prionocyclus macombi* and *P. wyomingensis* zones), though the fauna of the higher zone ranges somewhat upward into the overlying shale. Farther west and southwest a much thicker and purer unit of sandstone, at places containing coal beds and other apparently nonmarine rocks, has generally been considered the Ferron sandstone member of the Mancos shale, and the name has been applied by several authors to the thin sandstone of the Book Cliffs. Apparently the sea

waters were withdrawn somewhat toward the east, permitting the widespread accumulation of sands.

Following the deposition of the sand in middle Carlile time, there came an apparently long period of accumulation of finer material, the earlier part representing the time of the uppermost Carlile rocks and the lower and middle parts of the Niobrara formation. Some sandstones are present, but they are usually muddy and inconspicuous. West of the Book Cliffs area, however, several tongues of resistant sandstone are present, and in central Utah there is a thick conglomeratic series (Spieker, 1931, p. 18-20; 1946, p. 128; Schoff, 1951, p. 624-627). The time interval is chiefly that of chalk formation in the Great Plains, but the contemporary sedimentary rocks of the Book Cliffs are not notably more calcareous than other parts of the Mancos here. Without appreciable break fine sediment continued to accumulate through the time interval represented by the Telegraph Creek and Eagle formations. These units have not generally been considered equivalent to the uppermost part of the Niobrara formation of the Great Plains, but it now seems probable that they are. In the Wasatch Plateau the Emery sandstone member of the Mancos shale, a near-shore deposit, was formed during this interval. In the Book Cliffs region the time interval of the Niobrara is represented by the main body of the Mancos shale.

The succeeding part of Late Cretaceous time is a period of irregularly progressive restriction of the area of marine deposition, though whether this was effected by filling of the basin of deposition or by changes in relative level of land and sea is not clearly determinable. Perhaps both processes played a part. The effect on the sediment of a given place, however, is that of successive replacement of marine muds first by marine sands, then by brackish-water sands and muds, then by fresh-water sands and muds. Coal may be associated with the first of the fresh-water deposits. The process of converting the region from one of marine to one of nonmarine deposition and of extension of sand eastward was not an even one, however; for though at times the sand was carried far eastward, at times apparently the sea moved westward and the deposition of fine materials in marine water temporarily extended much farther westward than the eastward margins of the preceding nonmarine sands. Commonly the base of marine deposits is sharp, implying a rapid extension of the sea, whereas the passage into nonmarine deposits is gradational, implying a slow withdrawal of the waters. In general the succeeding sand bodies extended progressively farther eastward, and the successive areas of

fine sediment reached progressively shorter distances westward. The formation of coal beds apparently took place not far from the sea margin, for the coal beds are in the Blackhawk formation in the west and in the higher formations toward the east, but seldom far above the highest marine beds. The record of a retreating sea is shown with exceptional clearness in these deposits. The landward materials (marine sand grading westward into brackish-water and fresh-water deposits) are the Mesaverde group. The seaward materials (chiefly marine shale) are the upper part of the Mancos shale. The youngest rocks of the Mesaverde group everywhere in the region are of nonmarine origin, apparently fluvial.

Young (1955) has discussed in considerable detail this zone of intertonguing of marine and lagoonal-littoral facies, naming 1 more such unit in Utah and 3 more in Colorado than are recognized in this paper. He follows Spieker (1949, p. 61-65) in interpreting dominantly continental deposits of formations in the west to pass eastward into lagoonal deposits formed above littoral marine sands and behind offshore bar sands that grade into marine Mancos shale to the east. The intricate intertonguing is interpreted to be the result of the deposition in a shallow basin in which there were long periods of relative stability separated by sharp pulses of subsidence. Thick peat beds, formed during periods of quiet, are thought to have accumulated behind offshore bars, but little consideration is given to the differential compaction phenomena involved. Sharp subsidences preceded formation of the basal sandstone tongues and lesser pulses preceded formation of the offshore bars. A generalized cycle of four units is recognized: basal marine shale, littoral marine sandstone, lagoonal rocks, and coal.

#### POST-MESAVERDE FORMATIONS

The post-Mesaverde formations are all of nonmarine origin. Most of them, like the uppermost beds of the Mesaverde group, have the characteristics usually attributed to fluvial deposits, but the Green River formation is definitely lacustrine.

#### REGIONAL RELATIONS

It is of interest to consider briefly the relations of the Cretaceous formations of the Book Cliffs to those of the areas both southwest and southeast of the Book Cliffs. Plate 12 attempts to show these in a perspective diagram, though neither area can be connected directly with the Book Cliffs.

Thus it would seem that the Cretaceous sea reached southwestern Utah at least by early Mancos time, but

soon withdrew, though continuing to occupy the Book Cliffs area. At the end of middle Niobrara time, erosion began in southwestern Utah; marine sands were being deposited in the Wasatch Plateau area; and fine sediment was reaching the Book Cliffs area. Somewhere between southwestern Utah and the Wasatch Plateau was the shoreline of the Cretaceous sea. As time passed, this sea gradually withdrew toward the east, and the nonmarine deposits of the Mesaverde group finally extended over the whole region. Then the fluvial units, the Kaiparowits formation of the southwest, the lower part of the North Horn formation of the Wasatch Plateau, and an undetermined part of the sequence high in the Book Cliffs, possibly the Tuscher formation, closed the Cretaceous. In the southwest the next higher formation is an unconformable unit much like the "Wasatch" formation of the Book Cliffs and unlike the upper part of the North Horn formation of the Wasatch Plateau, of Paleocene age. Nothing definitely like the Flagstaff limestone of the Wasatch Plateau, Paleocene and Eocene, has been found, and it seems likely that erosion was proceeding in southwestern Utah during later North Horn and Flagstaff time. Because of uncertainty as to ages of the higher formations, the sequence of events in the Book Cliffs is still dubious.

In southwestern Utah (Gregory and Moore, 1931; Gregory, 1950) the Dakota sandstone resembles that of the Book Cliffs and is overlain by the marine Tropic shale, which is of later Greenhorn age in the basal part and of Carlile age in the remainder. Westward the Tropic passes into sandy nonmarine rocks but northeastward may be equivalent to the part of the Mancos up to and including the sandy Ferron deposits. Above the Tropic lie the dominantly sandy Straight Cliffs and Wahweap sandstones, in part nonmarine and in part marine and of Niobrara age. These pass westward into coarser nonmarine rocks, but northeastward must be equivalent to the middle part of the Mancos shale of the Wasatch Plateau and the lower middle part of the Mancos shale of the eastern Book Cliffs. At the top of the Wahweap sandstone is a hiatus that appears to represent all the formations of the Wasatch Plateau from the base of the Emery sandstone member of the Mancos shale up to the base of the North Horn formation and the upper three-fifths of the Mancos shale and most, if not all, of the Mesaverde group of the eastern Book Cliffs. Upon the Wahweap sandstone rests the Kaiparowits formation, which contains a dinosaur fauna and is like the lower part of the North Horn formation of the Wasatch Plateau. The top of the middle part of

the Niobrara equivalent is the highest stratigraphic horizon that can be carried through the region and has been made the datum for the diagram.

To the southeast of the Book Cliffs in southwestern Colorado (Reeside, 1924), the Dakota sandstone appears much like that of the Book Cliffs. It is overlain by the typical Mancos shale, which contains near the base beds of later Greenhorn age that include a calcareous unit with the latest Greenhorn fauna. Higher in the Mancos is a sandy unit with a Carlile fauna like that of the sandy beds of the lower part of the Mancos shale of the Book Cliffs area. Then follows a part of the Mancos of Niobrara age and a higher part equivalent to that of the upper part of the Mancos of the eastern Book Cliffs. In southwestern Colorado the typical Mesaverde group rests conformably upon the Mancos shale and is probably equivalent to the lower beds of the Mesaverde group of the Book Cliffs. In southwestern Colorado, however, the next higher units are the marine Lewis shale and the overlying marine Pictured Cliffs sandstone, which have no counterparts in the Book Cliffs and must be represented by some part of the nonmarine sequence. The next higher beds in southwestern Colorado, including the nonmarine Fruitland, Kirtland, and McDermott formations, and the lower part of the highly andesitic Animas formation, seem by their vertebrate and invertebrate faunas to be most nearly equivalent to the Kaiparowits formation and to the lower part of the North Horn formation.

Thus we have in the rocks to the southeast of the Book Cliffs in southwestern Colorado a record of a marine invasion like that of the Mancos of the Book Cliffs, followed by a temporary withdrawal of the sea in the time of the typical Mesaverde and a second invasion in Lewis time that did not reach the Book Cliffs nor the Wasatch Plateau. Following the second withdrawal of the sea, fluvial deposition prevailed, modified in McDermott and Animas times by an influx of volcanic detritus, partly of Cretaceous age but extending into Paleocene time. The highest beds are of Eocene age.

#### LOCAL SECTIONS

The generalized descriptions and interpretations given earlier are largely based on the local sections some of which are presented in detail below. The sections are numbered from west to east and the numbers agree with the locations shown on plates 1 and 10.

#### No. 5. Composite section in the Horse Canyon area, Carbon and Emery Counties, Utah

[Thickness of individual units by C. E. Erdmann; correlation of Flagstaff limestone and North Horn formation undifferentiated unit by J. B. Reeside, Jr.]

"Wasatch" formation (part):		Feet
Upper sandstone unit, measured in SW $\frac{1}{2}$ sec. 23, T. 15 S., R. 14 E. Thicknesses estimated:		
Top of Patmos Head, elev 9,851 ft.		
237. Sandstone, gray-buff, massive; locally weathers brown; makes high vertical cliff on southeast face of mountain...		250
236. Slope, largely concealed, contains two thin sandstone beds, each about 50 ft thick.....		300
235. Sandstone, light-gray to buff, massive; makes cliff on southwest face of mountain.....		200
234. Shale, sandy.....		50
233. Sandstone.....		100
232. Shale, sandy.....		75
231. Sandstone.....		100
230. Shale, sandy, and thin sandstone beds..		175
229. Sandstone, gray-buff, arkosic, massive, medium-grained, soft, friable; feldspars weathered; elastic muscovite; contains tongues and lentils of red clay; bedding marked by clay galls; makes cliff.....		50
Thickness of unit, estimated.....		1,300
Shale unit, measured on spur of Patmos Mountain in NW $\frac{1}{4}$ sec. 26 and NE $\frac{1}{4}$ sec. 27, T. 15 S., R. 14 E.:		
228. Mudstone, maroon, especially dark in upper 10 ft; parts of grayish red owing to white sand grains in red silt; evenly bedded; some groups of beds harder and more resistant than others; weathers into small angular platy fragments that have sharp, rough edges.....		60
227. Sandstone, grayish-buff, massive; cliff-making where thick; thickens and thins, owing to irregularities on top of underlying mudstone; probably fluvial.....		0-20
226. Mudstone, maroon, like No. 228.....		15-20
225. Sandstone, grayish-buff, like No. 227; replaced by reddish shale where reduced in thickness.....		0-20
224. Mudstone, predominantly maroon; essentially like No. 228.....		100
223. Sandstone, gray-buff, medium-grained, massive, evenly bedded; upper 10 ft thin-bedded.....		40
222. Mudstone, predominantly gray, sandy, with minor amounts of maroon rock, which is in thin beds, one just below top.....		220
Thickness of unit, estimated.....		480

## No. 5 Composite section in the Horse Canyon area, Carbon and Emery Counties, Utah—Continued

## "Wasatch" formation—Continued

	<i>Feet</i>
Lower sandstone unit; upper part estimated in SE¼ sec. 22, T. 15 S., R. 14 E.; lower part measured in E½SW¼ sec. 3, T. 16 S., R. 14 E.	
221. Sandstone, massive, cliff-making	75
220. Shale, gray-green	25
219. Sandstone, massive, cliff-making	30
218. Shale, dull, maroon	15
217. Sandstone like No. 221	30
216. Shale, gray-green	40
215. Sandstone, massive, cliff-making	75
214. Mudstone, reddish; some of it very compact, platy, dull, maroon; mud-cracks	200
213. Sandstone, massive, cliff-making	50
212. Shale, gray	40
211. Sandstone, massive, cliff-making	50
210. Shale, gray	40
209. Sandstone, massive, cliff-making	50
208. Shale, gray	40
207. Sandstone	50
206. Shale, gray	50
205. Sandstone, tan, massive, cliff-making	22
(Section below this point measured.)	
204. Mudstone, light-gray-green, tan-weathering; marly, with numerous mud pellets; sharply separated from bed above, transitional below	3
203. Shale and sandy shale, with a few sandstone layers 1 ft thick; predominantly maroon, with a small amount of variegated red and green rock	65
202. Sandstone, tan, massive, cliff-forming; lentils of clay-ironstone conglomerate at base	50
201. Shale, light-gray-green	22
200. Sandstone, buff, fine-grained, massive, cliff-making	25
199. Shale, light-gray-green	35
198. Sandstone, buff- to brownish-gray, reddish-brown-weathering, fine- to medium-grained, massive, cliff-forming, crossbedded; some pellets of clay-ironstone; some subaqueous slump structures. Locally underlain by 6-in. to 1-ft layer of buff to salmon shale, with thin stringers of sand and thin clay-pellet conglomerate in sand	46

Thickness of unit, estimated 1, 128

Thickness of part of "Wasatch" formation, estimated 2, 900

North Horn and Flagstaff formations undifferentiated:  
Measured on spur between North and South Forks of canyon of Horse Creek on west side NE¼NW¼ sec. 34, T. 15 S., R. 14 E.:

197. Limestone, buff, dense, silty; lenticular mass in erosion channel at base of overlying sandstone; maximum thickness	6
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## No. 5 Composite section in the Horse Canyon area, Carbon and Emery Counties, Utah—Continued

## North Horn and Flagstaff—Continued

## Measured on spur, etc.—Continued

	<i>Feet</i>
196. Mudstone, dark-gray	12-18
195. Limestone, gray, sandy, massive	2
194. Clay, greenish-gray	5
193. Limestone, gray, dense, in layers 1½-2 ft thick; weathers into splintery fragments	7
192. Mudstone, gray, calcareous; makes slope	65
191. Limestone, gray, sandy	1½
190. Mudstone, gray	2
189. Sandstone, light-brownish-gray, medium- to fine-grained, calcareous, massive, ledge-making; the end of a lens that thickens eastward in 600 ft to 30 ft	7
188. Mudstone, gray; makes slope	6
187. Limestone, light-gray, brown-weathering, sandy	1½
186. Mudstone, light-gray, calcareous; largely concealed in slope	34
185. Limestone, light-gray, brown-weathering, sandy	1½
184. Mudstone, marly, light-gray; makes slope encrusted with layer of weathered soil about a foot thick	27
183. Limestone, light-gray, light brownish-gray-weathering, sandy; in layers 6-10 in. thick	1½
182. Mudstone, dull, maroon, weathering to purplish gray; probably variegated with gray-green	21
181. Marl, with numerous nodules of gray limestone up to 3 in. in diameter; poorly exposed, but debris covers slope below	2
180. Mudstone, dull, gray-green and drab	10
179. Sandstone, light-gray, tan-weathering, fine-grained, dense, massive, poorly sorted, with clusters of lumps of coarser grained sand	10
178. Mud-pellet conglomerate; with unit 59 makes a conspicuous ledge	1
177. Shale, clayey, light- to dark-gray; less fissile and less well consolidated than shale beds below; weathers to a tough gumbo; largely concealed in slope	30
176. Sandstone, light-gray, brownish-weathering, fine-grained, dense	1
175. Sandstone, gray-green, chalky-gray-weathering, fine-grained, dense; locally calcareous; surface littered with nodular pieces of dense dark-green sandstone that weather reddish brown or show yellow-green stains	3

## No. 5 Composite section in the Horse Canyon area, Carbon and Emery Counties, Utah—Continued

Erosional unconformity.	
Measured on spur between North and South Forks of Horse Canyon in SE¼NW¼ sec. 34, T. 15 S., R. 14 E.:	
174. Shale, tan, drab, and dark-gray; fragments of limestone concretions on surface.....	12
173. Sandstone, light-gray, weathering slightly brownish or drab; fine- to medium-grained, in 2- to 6-in. slabby layers; locally massive.....	2½
172. Shale, light-gray to tan, sandy; makes slope.....	24
171. Sandstone, slabby.....	2½
170. Sandstone, gray, salt-and-pepper, brownish-weathering, medium-grained, evenly bedded, with some crossbedding; base irregular.....	14
169. Siltstone, drab, nonfissile; makes slope.....	25
168. Sandstone, gray, fine-grained, slabby.....	2½
167. Sandstone, medium-grained, evenly bedded, noncalcareous.....	5
166. Sandstone, gray, salt-and-pepper, containing lentil of gray, reddish-weathering limestone that is dense, sandy, and about 10 ft long. With Nos. 168 and 167 locally makes a cliff.....	3
165. Sandstone, gray, medium-grained, massive, soft, friable; makes slope.....	12
164. Shale, light-gray, sandy, largely concealed by talus; makes slope.....	21
163. Sandstone, gray, medium-grained, soft, shaly.....	10
162. Sandstone, gray, medium-grained, soft; thinly and evenly bedded.....	1½
161. Shale, light-greenish-gray, with a 3-ft layer of fissile brown carbonaceous shale 6 ft above base.....	25
160. Shale, gray, fissile, slightly carbonaceous; upper 18 in. a drab shaly sandstone....	35
159. Siltstone, light-drab to greenish-gray, granular; 2-ft layer of sandstone 5 ft below top; along strike a lentil of sandstone at base.....	45
158. Sandstone, light-gray at top and gray below, medium-grained, soft, friable; base irregular; probably a lens.....	8
157. Shale, light-brownish-gray, sandy.....	8
156. Sandstone, light-gray, salt-and-pepper, medium-grained, soft, friable; upper 1 ft slabby; contains a few concretions of dense brown-weathering sandstone; about 20 percent of the sand consists of dark grains; remainder consists largely of kaolinized feldspar; quartz is a minor constituent; muscovite accessory.....	12½
155. Shale, light-gray to bluish-gray, with dark-gray at top; sandy, slightly carbonaceous; makes slope.....	27
154. Sandstone, light-gray, fine-grained, soft; thin, slabby, irregular layers.....	2

## No. 5 Composite section in the Horse Canyon area, Carbon and Emery Counties, Utah—Continued

North Horn and Flagstaff—Continued	
Measured on spur, etc.—Continued	
153. Sandstone, reddish-brown, fine-grained; thin, slabby layers in lower part, more massive above.....	2½
152. Shale, light-gray, sandy.....	3
151. Shale, dark-brown, sandy, fissile, carbonaceous.....	3
150. Shale, light-gray, sandy, granular; grades into underlying beds.....	4
Thickness of North Horn and Flagstaff formations undifferentiated.....	
	570
Disconformity.	
Price River formation:	
Upper sandstone unit, equivalent approximately to the Bluecastle sandstone member of the Neslen formation, measured on spur between the canyon of Horse Creek and tributary from east near SW. cor. sec. 34, T. 15 S., R. 14 E.	
149. Sandstone, gray-white to grayish-buff, weathering tan and rose; cement calcareous; beds 6-8 ft thick, except near top, where they are a foot thick; indistinctly crossbedded. Upper 20 ft gray white, mottled with a little darker gray sand that weathers out, leaving shallow pits. Predominantly medium grained, but with numerous irregular lentils and stringers of coarse sugary gray sand that contain a few pebbles of gray chert and quartz up to one-quarter of an inch in diameter—an arkosic grit.....	70
148. Shale, gray, sandy, poorly exposed.....	5
147. Sandstone, gray to buff, medium-grained, massive, cliff-making.....	25
146. Shale, gray; contains a few thin layers of brownish sandstone in upper part; largely concealed in slope.....	33
145. Sandstone, yellow-gray to brown, soft, silty; contains clay ironstone concretions.....	4
144. Shale, gray; largely concealed in slope....	26
143. Sandstone, buff to brown (grayer toward top and slightly mottled) medium-grained, hard, massive; cement probably calcareous; beds 1-4 ft thick; cliff making.....	40
Possible disconformity.	
142. Shale, gray; upper foot darker and more carbonaceous.....	7½
141. Sandstone, light-brown, dense, massive; thinly bedded at top; cliff-making.....	7
140. Shale, gray, with 2-ft layer of siltstone in middle.....	7
139. Sandstone, light-reddish-brown, medium-grained, hard, dense.....	2
138. Shale, gray; makes slope.....	12

*No. 5 Composite section in the Horse Canyon area, Carbon and Emery Counties, Utah—Continued*

Price River formation—Continued	Feet
137. Sandstone, buff, fine-grained, shaly, soft, in 4-in. layers, makes slope-----	7
136. Sandstone, buff, medium-grained, soft, friable; upper half massive; lower half in 6- to 12-in. layers-----	6
135. Shale, gray-----	6
134. Sandstone, light-gray, buff- to brown-weathering, soft, silty, friable, in beds 8-10 in. thick-----	5
133. Shale, dark-gray, flaky-----	8
132. Sandstone, gray-buff, medium-grained, hard, dense; makes ledge-----	2
131. Sandstone, buff, fine-grained, silty, thinly laminated, dense, hard; makes massive ledge-----	1
130. Sandstone, gray, brown-weathering, medium-grained-----	2
129. Shale, gray, flaky-----	3½
128. Sandstone, grayish-buff, brown-weathering, massive, ledge-making; base irregular-----	2
127. Shale, gray; upper part dark, carbonaceous-----	7
126. Sandstone, brown, reddish-brown-weathering, fine-grained, dense; contains carbonaceous debris; capped by 2- to 4-in. layer of orange-brown clay ironstone-----	2
125. Shale, gray-----	5
124. Sandstone, buff, brown-weathering, medium-grained, massive, ledge-making; thins northward to thickness of 1 ft-----	6½
123. Shale, gray, granular-----	11
122. Sandstone, buff, weathering brown; upper foot thinly bedded-----	4
121. Sandstone, buff, brown-weathering, medium-grained, shaly; in irregular beds 1-4 in. thick; contains a few stringers of orange-brown ironstone that are softer than the sandstone-----	5½
120. Sandstone, buff, brown-weathering, medium-grained, massive, in layers 18-24 in. thick; contains a few stringers of orange-brown clay ironstone-----	9
Thickness of unit-----	299
Lower shale unit, measured on north wall of the canyon of Horse Creek, 1,750 ft east and 850 ft north of NW. cor. sec. 3, T. 16 S., R. 14 E.	
119. Shale, gray to dark-gray, carbonaceous; fissile at base, becoming more granular at top, where it weathers into rounded forms-----	16
118. Sandstone, brown, medium-grained, hard, dense, irregularly laminated, ledge-making; contains numerous pellets of brown clay ironstone at top-----	4

*No. 5 Composite section in the Horse Canyon area, Carbon and Emery Counties, Utah—Continued*

Price River formation—Continued	Feet
Lower shale unit, etc.—Continued	
117. Sandstone, buff, brown-weathering, fine- to medium-grained, thinly and irregularly bedded; soft, friable, but grades up into harder thicker more massive layers-----	10
116. Shale, carbonaceous, dark-brown to black, thinly laminated; makes slope--	23½
115. Sandstone, brown, fine-grained; in thin irregular layers interbedded with thin layers of carbonaceous shale-----	2½
114. Shale, gray and brown; contains a few thin layers of fine-grained brown sandstone-----	4
113. Sandstone, brown, fine-grained, in thin wavy layers interbedded with grayish and brownish shale-----	18
112. Shale, dark-brown, carbonaceous-----	½
111. Coal, bony-----	1
110. Shale, black, fissile, with thin lentils of bright coal-----	1
109. Shale, dark-brown, carbonaceous-----	1
(Nos. 112 to 109 make a black band on the cliff face.)	
108. Sandstone, brown, fine-grained; in thin irregular wavy layers interbedded with thin layers of gray and brown shale---	11
107. Shale, carbonaceous, dark-brown, thinly laminated, with a few thin layers of gray-weathering sandstone-----	25
106. Sandstone, light-gray, weathering brown, medium-grained, in layers 4 to 10 inches thick; makes hard, thin, resistant ledge-----	2½
105. Shale, dark-brown, carbonaceous; weathers light bluish gray-----	3
104. Sandstone, gray, in thin wavy layers interbedded with gray carbonaceous shale-----	14
103. Shale, dark-brown, carbonaceous, fissile--	3
102. Sandstone, carbonaceous, shaly; weathers bluish gray-----	2
101. Sandstone, grayish-buff, fine-grained, thin-bedded-----	3
100. Sandstone, in thinly laminated layers 6-10 in. thick interbedded with shale, predominantly carbonaceous-----	9
99. Sandstone, light-gray, fine-grained, in 6-in. layers-----	8
98. Sandstone, light-gray, fine-grained, in slightly wavy layers up to an inch thick-----	3
97. Shale, dark-brown, carbonaceous, thinly laminated-----	3½
96. Sandstone, chocolate-brown, fine-grained, carbonaceous; top and bottom surfaces wavy; resistant ledge-----	2
95. Siltstone, carbonaceous, bluish-gray-weathering, dense, compact; layers 6-12 in. thick-----	5

## No. 5 Composite section in the Horse Canyon area, Carbon and Emery Counties, Utah—Continued

Price River formation—Continued	Feet
Lower shale unit, etc.—Continued	
94. Shale, brown to black, carbonaceous, flaky.....	1
93. Sandstone, light-gray, with bluish tone, fine-grained, slightly carbonaceous; in massive single bed.....	6
92. Siltstone, chocolate-brown, bluish-gray-weathering, carbonaceous, compact....	5
91. Sandstone, light-gray, medium-grained, in 4- to 6-in. layers; a few rusty-brown ironstone layers interbedded with shale in layers 6-8 in. thick.....	5
90. Sandstone, chocolate-brown, bluish-weathering, fine-grained, carbonaceous.....	1
89. Shale, chocolate-brown, compact; grades up into fissile carbonaceous shale.....	2
88. Sandstone, chocolate-brown, bluish-gray-weathering, dense, fine-grained, carbonaceous.....	1
87. Shale, dark-brown, carbonaceous; weathers bluish gray, compact.....	2
86. Sandstone, light-gray, fine-grained, dense, with blebs and stringers of carbonaceous material; in layers 2-8 in. thick.....	3
85. Shale, dark-brown to nearly black, carbonaceous, flaky.....	1½
84. Shale, chocolate-brown, lead-gray-weathering, compact.....	1½
83. Sandstone, light-gray, fine-grained; rock nearly white, with small amount of limonite stain; upper foot bluish with shale; in slabby layers 2-12 in. thick; intricately crossbedded, with thin lentils of gray shale between the laminae; crossbedding less in upper half.....	20½
82. Shale, gray, sandy, nonfissile.....	3
81. Sandstone, light-gray, fine-grained, in thin slabby layers.....	2½
80. Shale, light- to dark-gray, fissile, somewhat sandy.....	3½
Thickness of unit.....	234
Thickness of Price River formation.....	533

## Castlegate sandstone:

Measured on north wall of canyon of Horse Creek, near W½ cor. sec. 3, T. 16 S., R. 14 E.:

79. Sandstone, grayish-buff to light-gray, medium-grained, massive, heavy-bedded, cliff-making; white and reworked at top, which is uniform and slightly wavy; weathers dark gray to brown; bone fragments in some massive layers; lower part contains numerous pits up to three-fourths of an inch from which ferruginous concretions have weathered.....	160
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## No. 5 Composite section in the Horse Canyon area, Carbon and Emery Counties, Utah—Continued

Blackhawk formation:	Feet
Upper shale member, measured on north wall of Bacon Gulch, 2,700 ft south and 3,400 ft east of NW. cor. sec. 29, T. 15 S., R. 14 E.:	
78. Sandstone, gray, carbonaceous, in layers 1-2 ft thick with partings of coaly shale	6
77. Shale, brown to black, carbonaceous, coaly.....	6½
76. Sandstone, brown to buff, fine-grained, with contorted thin bedding, lenticular..	6½
75. Shale, gray, sandy, with thin layers of sandstone.....	3½
74. Sandstone, brown to buff, medium-grained, in beds 6 in. thick; makes low ledge....	3
73. Shale, purplish-brown to black, carbonaceous, thinly laminated, fissile.....	7
72. Sandstone, brown, fine-grained, in gnarly layers up to 4 in. thick parted by light-gray carbonaceous shale.....	5
71. Shale, gray, sandy, carbonaceous; weathers into rounded forms.....	3½
70. Shale, black, carbonaceous, fissile.....	11
69. Sandstone, brown, fine-grained, in beds up to 10 in. thick with shaly partings..	4½
68. Shale, dark-gray to black, carbonaceous, fissile.....	11
67. Sandstone, gray, reddish-brown-weathering, fine-grained, in slabby layers up to 10 in. thick with shaly partings; cliff making.....	7
66. Shale, gray, sandy, with 6-in. layer of brown-weathering sandstone in middle of bed.....	8
65. Shale, dark-gray to black, carbonaceous, fissile; somewhat coaly in middle part..	20
64. Shale, gray, sandy, with 6-in. layers of gray sandstone that weather brown....	8
63. Shale, carbonaceous.....	2
62. Sandstone, gray, brown-weathering, fine-grained, massive, crossbedded; makes low cliff; lower 5 ft soft, shaly. Shale parting 2 ft thick 6 ft below top.....	18
61. Shale, dark-gray to black, carbonaceous..	9½
60. Sandstone, gray, weathering light brown; upper 4 ft massive.....	7
59. Shale, gray, sandy.....	3
58. Sandstone, brown, fine- to medium-grained, massive, thinly laminated, friable, soft.....	7
57. Shale, gray, fissile.....	3
56. Coal, black, clean, bituminous.....	4
55. Shale, chocolate-brown, carbonaceous, fissile.....	½
54. Siltstone, drab.....	2
53. Shale, black, carbonaceous, papery.....	1½
52. Shale, gray, sandy, fissile, weathering into small chips.....	6
51. Sandstone and shale, interbedded; sandstone in 2-in. layers, nodules, and small lentils; shale in layers 4-6 in. thick.....	6½



## No. 5 Composite section in the Horse Canyon area, Carbon and Emery Counties, Utah—Continued.

Blackhawk formation—Continued		Feet
Upper shale member—Continued		
50. Sandstone, brown, fine-grained, soft, in slabby layers up to 4 in. thick; makes roof of Sunnyside coal bed.....	5	
Sunnyside coal bed:		
49. Coal.....	1	4
48. Shale, chocolate-brown, carbonaceous.....		8
47. Coal.....		9
46. Shale, gray, sandy, and thin gray sandstone.....	3	3
45. Coal.....	10	1
Total Sunnyside coal bed.....	16	
Thickness of member.....	170	
Middle sandstone member, measured at mouth of canyon of Horse Creek, in sec. 4, T. 16 S., R. 14 E.:		
44. Sandstone, light-gray to white, medium-grained, of sugary texture; top is smooth.....	24	
43. Sandstone, brown to grayish-tan, medium-grained, massive, cliff-forming; base transitional.....	82	
Thickness of member.....	106	
Middle shale member measured 1,150 ft north and 800 ft west of S $\frac{1}{4}$ cor. sec. 4, T. 16 S., R. 14 E.		
42. Shale, sandy, gray.....	1	
41. Sandstone, tan, fine-grained, compact.....	1	
40. Shale, sandy, gray.....	$\frac{1}{2}$	
39. Sandstone, tan, fine-grained, compact.....	$\frac{1}{2}$	
38. Shale, gray, fissile, in 6-in. layers interbedded with 2-in. layers of grayish-tan sandstone.....	14	
37. Sandstone, tan, fine-grained, dense, massive.....	3	
36. Shale, gray, fissile, in 6-in. layers separated by layers of tan sandstone up to 2 in. thick.....	4 $\frac{1}{2}$	
35. Sandstone, tan, fine-grained, dense; massive but thinly laminated at top.....	2 $\frac{1}{2}$	
34. Shale, blue-gray; somewhat sandy, grading toward top into alternation of 4-in. layers of brownish shaly sandstone and shale.....	22	
33. Shale, lead-gray, fissile; probably marine.....	35	
32. Limestone.....	$\frac{1}{2}$	
31. Shale, lead-gray, fissile; probably marine.....	2 $\frac{1}{2}$	
30. Limestone, dull, gray, weathering brown.....	$\frac{1}{2}$	
29. Shale, lead-gray, fissile; probably marine.....	11 $\frac{1}{2}$	
28. Shale, brown, carbonaceous.....	3	
Thickness of member.....	102	

## No. 5 Composite section in the Horse Canyon area, Carbon and Emery Counties, Utah—Continued

Blackhawk formation—Continued		Feet
Lower sandstone member, measured 1,900 ft west and 1,300 ft north of SE. cor. sec. 4, T. 16 S., R. 14 E.		
27. Sandstone, gray-white, massive, sugary, cliff-forming; evidently a reworked part of underlying unit.....	20	
26. Sandstone, brown to buff, massive, sugary, cliff-forming.....	65	
25. Siltstone, gray.....	18	
24. Sandstone, gray, tan-weathering, massive.....	2	
23. Shale, sandy, with layers of thin-bedded gray sandstone.....	2	
22. Sandstone, tan, fine-grained; lower half thin bedded.....	1	
21. Shale, gray.....	4 $\frac{1}{2}$	
20. Sandstone, orange-brown, fine-grained, ferruginous.....	$\frac{1}{2}$	
19. Shale, gray.....	1	
18. Sandstone, orange-brown, fine-grained, ferruginous.....	1	
17. Shale, gray.....	8	
16. Sandstone, gray, medium-grained, massive.....	1	
15. Shale, gray, probably marine.....	27	
14. Siltstone, gray, soft; contains several 8-in. layers of sandstone.....	7	
13. Sandstone, gray, weathering tan to grayish-tan, fine-grained, in beds 4-12 in. thick with partings of soft gray siltstone; makes broken cliff.....	7	
12. Siltstone, gray.....	2	
11. Sandstone, gray, fine-grained, tan-weathering, finely crossbedded.....	2	
10. Siltstone, gray.....	7	
9. Limestone, gray, sandy, hard, dense, thinly and evenly laminated.....	2	
8. Siltstone, gray.....	2	
7. Limestone, gray, sandy.....	$\frac{1}{2}$	
6. Siltstone, gray, with a few thin lentils of finely laminated sandstone.....	5	
5. Limestone, gray, tan-weathering, sandy.....	1 $\frac{1}{2}$	
4. Siltstone, light-gray, and fine-grained gray tan-weathering sandstone; in alternating beds 2-3 in. thick.....	5	
3. Limestone, gray, reddish-brown-weathering, sandy.....	$\frac{1}{2}$	
2. Siltstone, light-gray, nonfissile, with a few layers of more sandy rock that weathers brown.....	6 $\frac{1}{2}$	
1. Sandstone, drab, yellow- to brown-weathering, fine-grained.....	1 $\frac{1}{2}$	
Thickness of member.....	200	
Thickness of Blackhawk formation.....	578	

Mancos shale.

## No. 6. Section in the NE¼ sec. 14, T. 17 S., R. 14 E., 4 miles east of Grassy Dome

Castlegate sandstone:	Feet
15. Sandstone, massive; buff- to light-brown cliff maker; locally somewhat friable and cross-bedded.....	181
Conformable contact.	
Blackhawk formation:	
Upper member:	
14. Shale, with minor coal and sandstone; shale medium gray in main, though parts are black, carbonaceous and red, sandy; upper 7 ft carries much limy silty, nodular-weathering mudstone; thin impure sandy layers are especially common in lower part; coal mainly in upper 15 ft.....	71
Middle sandstone member:	
13. Sandstone, medium-brown, thin-bedded, platy, friable.....	5
12. Sandstone, faint-buff, massive, crossbedded, ledge-maker, light-gray, weathering faint buff, friable.....	37
11. Coal (Sunnyside), with minor shale and sandstone.....	23
10. Sandstone, very light-gray ("white").....	27
9. Sandstone, buff-brown, massive; cliff.....	42
Thickness middle sandstone member.....	134
Middle shale member:	
8. Mudstone and sandstone in alternating bands; marks gradation between lower and higher beds; mudstone (40 percent) is medium gray, limy, silty, nodular weathering; sandstone (60 percent) is buff brown and there is more of it in upper part.....	72
7. Shale, mostly concealed medium-gray slope; lower part carbonaceous, black to rich brown.....	66
Thickness middle shale member.....	138
Lower sandstone member:	
6. Sandstone, light-buff, coarse-grained, massive, crossbedded, friable; locally carries a 6-ft shaly layer.....	20
5. Sandstone, like No. 3, 75 percent; shale, like No. 4, (25 percent); sandstone more conspicuous in upper part; a local channel unconformity is present at top.....	111
4. Shale medium-dark-gray, gritty, calcareous, gypsiferous, with much carbonized wood.....	10
3. Sandstone, medium-gray, fine-grained, thin-bedded, crossbedded, very hard, calcareous cement; rich in carbonized wood fragments; some fucoidal markings.....	10
Thickness lower sandstone member.....	151
Total Blackhawk formation.....	343

## No. 6. Section in the NE¼ sec. 14, T. 17 S., R. 14 E., 4 miles east of Grassy Dome—Continued

Gradational contact.	Feet
Mancos shale:	
2. Shale, gray; not examined in detail; makes up basal part of cliffs and a wide flat expanse to west. <i>Baculites</i> sp. undet. and a fish scale found 500 ft below top. Niobrara fauna (13319) in a 6-in. gray-brown coarse-grained limestone 3,200 ft below top. Thickness measured by plane-table traverse to lower contact in sec. 3, T. 17 S., R. 13 E.....	4, 120
Conformable contact.	
Dakota sandstone:	
1. Conglomerate and other rock. Not examined in detail. Makes a pronounced dip slope. Edwin Kirk identified one of the pebbles as Madison limestone carrying <i>Schuchertella chemungensis</i> (Conrad)?	
No. 7. Section taken on north side of the upper end of Price River canyon, 3½ miles east of Woodside, Utah	
[Measured by D. J. Fisher]	
Price River formation (lower part only):	Feet
23. Shale, gray.....	25±
22. Sandstone, buff- medium-fine-grained, thin-bedded, friable; with numerous <i>Ostrea glabra</i> , Meek and Hayden, at top.....	7
21. Mudstone, medium-gray, silty, limy.....	2
20. Sandstone, buff, medium-fine-grained, friable thin-bedded; with minor shale.....	24
19. Mudstone, like No. 21; 2 in. of coal at top..	1
18. Sandstone and shale; in about equal amounts in lower part, but largely sandstone above; sandstone, buff, shale, medium gray, in places carrying carbonized wood; this unit, or at least its lower more shaly part, is correlated with the Buck tongue of Mancos shale.....	84
Part of Price River formation.....	143±

Castlegate sandstone:	
17. Sandstone, buff, massive; cliff maker; firm, weathering blocky.....	120±
Contact conformable.	
Blackhawk formation:	
Upper member:	
16. Shale, locally carbonaceous to coaly.....	2
15. Sandstone, buff, friable, round-weathering surfaces.....	10
14. Shale, medium-gray, with minor thin sandstone layers; 8 ft above base is a 4½-ft coal zone.....	26
13. Sandstone, buff, well-rounded and medium-grained; carries much carbonized wood....	12
12. Shale, coal, and a little sandstone.....	11
11. Shale, like No. 14.....	30
10. Coal and siltstone.....	2
9. Shale, like No. 14.....	9
Thickness upper member.....	102

**No. 7. Section taken on north side of the upper end of Price River canyon, 3½ miles east of Woodside, Utah—Continued**

**Blackhawk formation—Continued**

Middle sandstone member:

8. Sandstone; lower part buff; upper part grayish white.....	24
7. Coal (Sunnyside), sandstone, and shale.....	22
6. Sandstone, like No. 8.....	41
5. Shale, medium-light-gray (thins along outcrop).....	12
4. Sandstone, buff.....	59

Thickness middle sandstone member... 158

Middle shale member:

3. Shale and sandstone; lower part dominantly medium-light-gray shale forming a slope; upper part is about 60 percent of cross-bedded, buff-brown sandstone in medium (near top) to thin beds.....	158
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Lower sandstone member:

2. Sandstone, forming a pronounced cliff; separated into three distinct ledges; upper one is massive sandstone, gray white near top, but with a 2-ft brown sandstone at top; middle ledge is thinner bedded, slightly shaly; lower one is more shaly, and in lower part consists of alternating shale and sandstone beds, each about 6 in. thick.....	270
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Total Blackhawk formation..... 688

**Gradational contact**

Mancos shale:

1. Shale, bluish-medium-gray, somewhat sandy in upper part.

**No. 8. Section taken along the west side of the Beckwith Plateau in the NE¼ sec. 30, T. 19 S., R. 15 E., 4½ miles northeast of Desert, Utah**

[All beds except Dakota measured by planetable traverse. In part the descriptions are taken from studies made in sec. 8, T. 20 S., R. 15 E. By D. J. Fisher]

**Price River formation (lower part only):**

23. Sandstone (Bluecastle sandstone member), buff; ledge-making unit, forms the dip-slope surface capping the Beckwith Plateau.....	125
22. Sandstone, massive, with thin zones of carbonaceous shaly material at top and near middle.....	90 ±
21. Shale, with minor sandstone, forming slope; upper third carries much carbonaceous material; a thin coal zone in lower part.....	260 ±
20. Sandstone, like No. 18 in all essential respects, except it lacks the friable coarser grained material; may represent lower part of Sego sandstone.....	50 ±
19. Shale, medium- to light-gray, soft, fissile, gypsiferous; locally carbonaceous, probably is Buck tongue of Mancos shale....	50 ±

Part of Price River formation... 575 ±

**No. 8. Section taken along the west side of the Beckwith Plateau in the NE¼ sec. 30, T. 19 S., R. 15 E., 4½ miles northeast of Desert, Utah—Continued**

Castlegate sandstone:

18. Sandstone, very light gray, medium-buff-brown-weathering, massive, cliff-maker; in part quartzite, with grains one two-hundredths of an inch through; locally friable and coarser grained (one-fiftieth of an inch); in places beautifully cross-bedded, resembling the Navajo sandstone of the San Rafael Swell; upper part somewhat shaly at a few places; some beds carry what may be small clay galls.....

85

Contact conformable and indefinite.

Blackhawk formation:

Upper member:

17. Coal.....	½
16. Mudstone, medium-gray, silty, limy.....	4
15. Coal.....	1½
14. Sandstone, like No. 18, with minor shale and a coal lens.....	71
13. Coal.....	3
12. Sandstone, with minor shale.....	10
11. Coal.....	3
10. Shale, medium-gray, gypsiferous; minor thin sandstone layers.....	48

Thickness upper member..... 141

Middle sandstone member:

9. Sandstone, massive, indistinctly cross-bedded, friable; upper half has grains about ⅓ of an inch in diameter; rest is finer (⅓ of an inch); top 10 feet is gray-white, rest is buff.....
8. Coal (Sunnyside) in two seams, split by sandstone.....
7. Sandstone, buff, fine-grained (⅓ of an inch), cliff-maker; lower three-fourths contains about one-fourth of shale in alternating beds with sandstone.....

42

6

196

Thickness middle sandstone member..... 244

Middle shale member:

6. Shale, medium-gray, fissile, soft, powdery, gypsiferous.....

103

Lower sandstone member:

5. Sandstone, forming an unbroken, non-scalable cliff; upper 25 ft is gray white and weathers to rounded surfaces; 50 ft following is massive and light medium gray to buff and weathers into huge blocks; remainder contains more or less shale interbedded with the sandstone....

208

Total Blackhawk formation..... 696

No. 8. Section taken along the west side of the Beckwith Plateau in the NE¼ sec. 30, T. 19 S., R. 15 E., 4½ miles northeast of Desert, Utah—Continued

Gradational contact.	Feet
Mancos shale:	
Section measured between secs. 12 and 17, T. 19 S., R. 14 E.	
4. Shale, bluish-medium-gray; makes up lower part of cliffs and a flat nearly 4 miles wide; not measured in detail; 825 ft above base is a 7-ft buff sandstone bed that makes a minor hogback 1 mile east of that made by the Dakota.	3, 875

Conformable contact.

Dakota sandstone:

Section measured in NE¼ sec. 17, T. 19 S., R. 14 E.:

3. Sandstone, very light gray, fairly friable, quartzose, calcareous cement; 3- to 6-in. beds; grains about ⅛ of an inch, fairly well rounded; poorly preserved <i>Haly-menites</i> and other fossils abundant; forms top of a dip slope.	4
2. Sandstone, shaly, laminated; mostly concealed.	12½
1. Sandstone, very light-gray, crossbedded; minor ledge.	½
Total Dakota sandstone.	17

No. 9. Section measured 8 miles north of Green River, in the SW¼ sec. 6, T. 20 S., R. 16 E.

[Nos. 22 and 23 measured 1 mile to the west by alidade]

Price River formation (lower part only):	Feet
23. Sandstone, buff; ledge-making unit (Blue-castle sandstone member) capping Beckwith Plateau; massive, blocky, with minor shaly beds.	117
22. Shale and sandstone, not examined. Lower part includes equivalents of Sego sandstone and Buck tongue of Mancos shale.	378
Part of Price River formation.	495

Castlegate sandstone:

21. Sandstone, not examined in detail.	86
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Contact conformable.

Blackhawk formation:

Upper member:

20. Shale and sandstone (50 percent), interbedded.	17½
19. Sandstone, massive, cliff-forming, like No. 21.	68
18. Shale and sandstone (50 percent), interbedded.	17½
17. Sandstone, massive, ledge-making.	15½
16. Coal.	1½

No. 9. Section measured 8 miles north of Green River, in the SW¼ sec. 6, T. 20 S., R. 16 E.—Continued

Blackhawk formation—Continued	Feet
Upper member—Continued	
15. Shale, medium-gray, silty, and carbonaceous, black fissile shale.	3¾
14. Sandstone, massive to shaly, crossbedded.	6
13. Shale, like No. 15, but with seamlets of fibrous gypsum.	2¾
12. Coal, gypsiferous.	1
11. Shale, carbonaceous, fissile.	2¾
Thickness upper member.	135

Middle sandstone member:

10. Sandstone, medium- to light-buff-brown (except gray-white at top); massive, cliff-forming; lower part of sandstone is 99 percent of quartz in fairly well-rounded grains averaging ⅓ of an inch in diameter; no coal or shale at Sunnyside horizon; 11 ft below top in a slightly shaly zone get a 10-in. thin-bedded cross-bedded medium-dark-gray sandstone layer that contains abundant brackish-water fossils (13327).	65±
9. Sandstone, carrying about 40 percent of shale; gypsiferous; generally forms a slope.	50±
8. Sandstone, carrying minor shale; forms a cliff at most places.	95±

Thickness middle sandstone member. 210±

Middle shale member:

7. Shale, medium-gray, with minor sandstone; slope-former.	152
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Lower sandstone member:

(Note: This section was taken near the eastward limit of this member, which gives way to Mancos shale near here. Two miles south of here the top massive sandstone of this member is 95 ft thick.)

6. Sandstone, medium-buff-brown to light-gray (near top), ledge-making, somewhat friable with calcareous cement; upper surface weathers into rounded forms which locally make small depressions containing water; over 95 percent consists of fairly well-rounded colorless quartz grains about ⅓ of an inch in diameter; also carries grains of feldspar and of dark minerals.	20
5. Sandstone (60 percent) and shale, medium-gray, in alternating layers an inch or two in thickness; sandstone is crossbedded, light buff brown to medium gray, platy; otherwise like No. 6, though very slightly coarser grained; near top of shale occur lenticular beds up to 3-6 in. thick carrying a salty and bitter tasting powdery white mineral.	51
4. Shale, limy in upper portion; slope.	47±

No. 9. Section measured 8 miles north of Green River, in the  
SW¼ sec. 6 T. 20 S., R. 16 E.—Continued

	Feet
Blackhawk formation—Continued	
Lower sandstone member—Continued	
3. Sandstone, ledge-making, fairly firm to semi-friable, massive, crossbedded to very thin-bedded, in part platy; weathers medium gray to medium buff brown; rather fine grains ( $\frac{1}{200}$ – $\frac{1}{250}$ in.), subangular to slightly rounded; largely quartz, but with small amounts of altered feldspar	25
2. Shale, limy; would ordinarily be put with No. 1, but traced to west this unit gives way to sandstone	74±
Thickness lower sandstone member	217
Total Blackhawk formation	714±

Gradational contact.

Mancos shale:

1. Shale, forms slope about 75 ft high, underlain by limy shale capped by one or more thin beds of fine-grained buff-weathering sandstone forming cliff about 100 ft high; underlain by slope-forming shale.

No. 10. Section measured from a point near Elgin, Utah, up  
canyon of Tuscher Wash

[Lower 3,090 ft of Mancos measured by planetable; Nos. 10–22 inclusive taken by H. F. Moses in the SE¼ sec. 13, T. 20 S., R. 16 E.; Nos. 23–33 inclusive measured in secs. 8 and 9, T. 20 S., R. 17 E.; higher part of section taken in secs. 27 and 34, T. 19 S., R. 17 E. by D. J. Fisher]

“Wasatch” formation (lower part only):

	Feet
39. Sandstone; upper and lower parts are massive cliff makers and weather red brown; a hand sample from near the base is pale gray brown, has extremely fine rather angular grains $\frac{1}{400}$ – $\frac{1}{400}$ of an inch in diameter, is firmly cemented by calcareous material; though largely of quartz, some grains are of dark minerals, so that the rock has a light-colored peppery appearance; central part is crossbedded, somewhat shaly, brick red	135
38. Shale and sandstone (20–30 percent); shale mostly brick red; sandstone weathers red brown and forms three massive ledges, each 50 ft or more thick	350
“Wasatch” formation, part measured	485

North Horn and Flagstaff formations undifferentiated:

37. Shale, sandstone, conglomerate, and limestone; shale (75 percent) is reddish in upper and lower parts, but medium gray in central part; sandstone (20 percent) is variable; a sam-

No. 10. Section measured from a point near Elgin, Utah, up  
canyon of Tuscher Wash—Continued

	Feet
North Horn and Flagstaff—Continued	
ple from the base is friable, pale brownish, with grains $\frac{1}{50}$ – $\frac{1}{100}$ of an inch in diameter, with a calcareous cement, and though largely of poorly rounded quartz, contains some feldspar and about 10 percent of dark minerals occurring in limonite-stained clusters or nests; higher up, lenses of conglomerate are present; a sample shows about 10 percent of angular pebbles up to one-half of an inch in diameter mostly of red, black, and white chert and of black basalt in a matrix of sandstone as just described, but slightly coarser, which also contains small masses of pale greenish clayey material; limestone (5 percent) of medium to very light-gray to pale-brownish colors with a semilithographic texture; a 4-ft limestone bed 110 ft below top carries a few specimens of the fresh-water <i>Physa pleromatis</i> White 13338	375

Contact relations not clear.

Tuscher formation:

36. Sandstone, with minor conglomerate; massive, crossbedded, weathers into rounded domelike forms; sandstone is gray white and friable, with a little calcareous cement; grains largely of slightly rounded frosted quartz, about $\frac{1}{100}$ of an inch in diameter; less than 1 percent is of black grains, not limonite-stained; among the grains is a fine white powder; 25 ft below top is a 1-ft bed of conglomerate similar to that of No. 37, but more than 50 percent of pebbles, which show some rounding; higher in the section isolated pebbles up to three-fourths of an inch in size are found here and there	110
35. Sandstone, massive, crossbedded, making cliff unscalable at most places; sample from lower part is composed of slightly rounded grains (about $\frac{1}{75}$ of an inch) which are cemented by calcite, though the rock is quite friable; while mostly of quartz, there is present 10–15 percent of only slightly decomposed feldspar (faintly limonite stained), and 1–2 percent of black grains; though fresh surface is nearly gray white, cliffs are stained buff to rich brown	190
Total Tuscher formation	270

No. 10. Section measured from a point near Elgin, Utah, up canyon of Tuscher Wash—Continued

Contact apparently conformable, but beds are so irregular that an erosional unconformity may be present.

Farrer formation (this member as given probably also includes upper 65–70 ft of Neslen formation):

34. Shale and sandstone; generally forms a slope, but locally cliff-making where protected by Tuscher strata and properly bolstered by sandstone beds. Shale is medium gray, with a distinct olive-green tinge; makes up 85 percent of upper part and 70 percent of lower part. Much of it is not laminated, and so may more properly be called mudstone; in part is somewhat silty; carries a few limestone layers up to a foot in thickness; these vary from sandy and white to lithographic and greenish gray; in part they are nodular and limonite stained; poorly preserved leaf impressions found in limestone 525 and 545 ft below top. Sandstone occurs in ledge-making massive crossbedded layers, in units up to 50 or 60 ft thick; in part friable, but largely very firmly cemented; varies from medium gray (greenish tinge) like the shale to dirty buff owing to limonite staining and 10–15 percent dark grains; weathers light buff to rich brown; medium-fine to fairly coarse-grained; clay pellets or galls up to an inch through are common in certain layers; these are lozenge shaped and weather out readily giving exposed surfaces with a pitted appearance.-----

Feet

725

Neslen formation:

33. Sandstone, buff, massive, ledge-maker. This is the Bluecastle sandstone member that caps the undissected part of the Beckwith Plateau.----- 55
32. Shale, medium-gray (slightly bluish), weathering drab.----- 110
31. Sandstone, buff, ledge-making; carbonaceous zone in lower part.----- 50
30. Mudstone, medium-gray, silty; alternates with buff-weathering sandstone; abundant fresh-water fossils in lower 10 ft (lots 13334 and 13335).----- 30
29. Shale, velvety, black, bone, and coal (Palisade coal zone?).----- 2
28. Mudstone, medium-gray, silty.----- 3

Total Neslen formation.----- 250

Sego sandstone:

27. Sandstone, shaly, thin-bedded, buff-weathering, friable; 10 ft below top marine and brackish-water fossils of late Montana age (13336).----- 60

No. 10. Section measured from a point near Elgin, Utah, up canyon of Tuscher Wash—Continued

Sego sandstone—Continued

Feet

26. Shale, like No. 32, but somewhat sandy.----- 35

25. Sandstone, like No. 27; fossils similar to those in No. 27 5 ft below top (lot 13337).----- 45

Total Sego sandstone.----- 140

Buck tongue of Mancos shale:

24. Shale, like Mancos.----- 100

Castlegate sandstone:

23. Sandstone, massive, cliff-forming; upper part weathers light gray and forms a pronounced dip-slope surface dotted with cedars and having a few water holes and sand dunes on it.----- 120

Contact conformable.

Blackhawk formation:

Upper member:

22. Siltstone and shale in alternating layers; siltstone brown, incoherent except for a 3-ft light-gray layer 10 ft above base; shale gray, in part coaly; abundant carbonized wood.----- 26

21. Sandstone and siltstone; gray to gray-brown siltstone grading upward into sandstone that is coarse grained at top of unit; cliff forming, with poorly preserved pelecypods and with fragments of carbonized wood.----- 68

20. Siltstone, mudstone, and shale; slope-forming; poorly exposed unit; carbonized wood.----- 86

Thickness upper member.----- 180

Middle sandstone member:

19. Sandstone, brown (gray white near top), massive, with grains up to  $\frac{1}{8}$  of an inch in diameter.----- 17

18. Sandstone, shale, and siltstone; lower part consists of alternating 2- to 4-in. layers of gray-brown to muddy-brown coarse-grained sandstone and coaly shale, with 1 ft of coaly shale near middle; upper part of alternating layers of buff platy siltstone and buff silty shale, with carbonized wood; lower part carries *Anomia micronema* Meek and *Ostrea* sp. undet. (13333).----- 18

17. Sandstone, massive, crossbedded, cliff-forming; grains fairly well rounded, mostly quartz but some dark minerals and feldspar, ranging from fine in lower part to coarse at top; light buff to (at top) gray white with rounded weathering surfaces; minor lenses of sandy shale.----- 52



## No. 10. Section measured from a point near Elgin, Utah, up canyon of Tuscher Wash—Continued

Blackhawk formation—Continued	<i>Feet</i>
Middle sandstone member—Continued	
16. Siltstone, dirty-gray-brown, medium-bedded, incoherent, with carbonized wood.....	58
15. Sandstone, siltstone, and shale; weak bluff-forming unit of ash-gray shale with interbedded buff siltstone and fine-grained sandstone, the latter more important in upper part.....	45
Thickness middle sandstone member.....	190
Total Blackhawk formation.....	370
Contact gradational.	
Mancos shale:	
14. Shale, gray to black, slope-forming, probably carrying minor buff siltstone layers.....	52
13. Shale, light-yellowish-gray to gray-black; upper third carries a dozen 1- to 6-in. sandy layers that give rise to a weak bluff; lower 20 ft has 3 limestone beds ½ to 1 ft thick; these are dense textured and brecciated, with cracks filled by calcite, and weather to yellow, orange, or bright red.....	295
12. Shale, mostly ash-gray, with carbonized wood; nodular layers in upper part; top consists of lenses of red and yellow clay.....	6
11. Shale, dull, gray to bluish-gray, with carbonized wood and coaly streaks and nodules and lenses of crystalline limestone. Fauna of Montana age (lot 13332).....	½-2
10. Shale, gray-black, dense, weathering fissile; fish scales and cracks carrying gypsum needles; top consists of ash-gray shale rich in fragments of fossil wood and leaves.....	6
9. Shale, with minor limy and sandy layers; not examined in detail. Sandy zone in lower part. Niobrara fossils found at 1,400 and 1,900 ft above base (localities 13328, 13330-31).....	3,090±
Total Mancos shale.....	3,450±

Conformable contact.

Dakota sandstone:

- |   |     |
|---|-----|
| 8. Limestone, pale-brownish-gray, very fine-textured.....   | 0-½ |
| 7. Conglomerate, sandstone, and shale; extremely variable lithologically both parallel to and across the bedding; shale is light gray to gray black, sandy, with carbonized wood; sand- |     |

## No. 10. Section measured from a point near Elgin, Utah, up canyon of Tuscher Wash—Continued

Dakota sandstone—Continued	<i>Feet</i>
stone is gray white; conglomerate is very heterogeneous, with pebbles up to several inches in diameter; pebbles mostly of gray chert, but also of chert of other colors, black basalt, purple, gray, and brown quartzite, epidote(?) stained masses, hard dense limonite, graphic granite, pink granite, dense gray limestone, dark-gray porphyritic aphanite; some pebbles (not limestone) well rounded; matrix sandstone, friable to quartzitic, sandy shale, and limestone; fossil tree trunks, up to several feet long and 2½ ft in diameter.....	6-12
6. Sandstone, dense, quartzitic, limonite-stained, crossbedded.....	½
5. Shale, gray, sandy in 1- to 3-in. beds...	2-3
4. Conglomerate, as just described.....	1-3
3. Sandstone, fine-grained, quartzitic, in layers and lenses 2-4 in. thick interbedded with sandy shale.....	0-2
2. Shale; laterally gives way to conglomerate.....	2-4
1. Conglomerate as described for No. 7 grading laterally and vertically into sandstone, white to yellowish (rests on variegated limy shales of Morrison age).....	4-6
Total Dakota sandstone.....	15½-31

## No. 11. Section taken in canyon of Coal Creek, Utah

[Nos. 1-22 inclusive measured by H. F. Moses, remainder by D. J. Fisher]

Tuscher formation (lower part only):	<i>Feet</i>
55. Sandstone, friable, crossbedded; largely quartz, but a little feldspar and dark minerals.....	42+
54. Sandstone, shaly, and shale; medium-gray, weathering light gray, but dirty-brown at top; plant remains.....	20
53. Sandstone, light-buff, medium-gray-weathering, massive, crossbedded, cliff-making; very feldspathic.....	24
52. Shale and sandstone; fairly fat dark-gray clay shale layers weathering light gray; unit probably carries interbedded sandstones.....	20
51. Sandstone, light-buff, massive, crossbedded, ledge-making, friable; mostly quartz, but some feldspar (partly kaolinized and limonite-stained) and a little dark mineral matter.....	13
50. Shale and sandstone, like No. 52.....	25
49. Sandstone, like No. 51.....	22
Tuscher formation, part measured....	166+

## No. 11. Section taken in canyon of Coal Creek, Utah—Continued

Contact apparently conformable.	Feet
Farrer formation:	
48. Shale, medium-light-gray, with distinct greenish cast; carries interbedded sandstones, largely concealed by slump boulders and wash.....	160
47. Sandstone, minor light-buff ledge of coarse-grained, incoherent material; laterally merges with underlying sandstone.....	5
46. Sandstone with minor shale forming a talus slope here, a cliff there; sandstone is thin bedded, buff brown.....	21
45. Sandstone, medium-gray to buff to medium-brown, medium-grained highly cross-bedded, friable.....	23
44. Shale with minor sandstone, largely concealed by talus; shale is greenish gray and carries layers and lenses of sandstone; 150-175 ft above base is a friable nodular buff sandstone which locally forms a ledge.....	275
43. Sandstone, buff to dark-brown, fine-grained, crossbedded; rather firm; 90 percent of quartz, but with 8 percent of limonite-stained kaolinized feldspar and minor dark minerals.....	21
42. Shale, like No. 48.....	13
41. Sandstone, massive, ledge-making, like No. 43 in all respects; calcareous cement; carries clay pellets or galls which weather out readily, leaving a pitted surface.....	41
40. Shale, like No. 48.....	22
39. Sandstone, with a little shale in the lower part; makes a broken slope; sandstone is medium grained ( $\frac{1}{8}$ of an inch), buff to medium dark brown; while largely quartz, dark minerals are abundant (20 percent); in lower part are clay pellets as in No. 41.....	85
38. Shale, with minor sandstone, like No. 48; fresh shale has nodular shaped masses; a few shale layers up to 1 ft thick are dark gray, gypsiferous, and carry abundant fragments of carbonized wood.....	72
37. Sandstone, crossbedded; forms a pronounced lens, which laterally gives way to shale like No. 38 within about 100 ft.....	30
Total Farrer formation.....	768

## Neslen formation:

36. Sandstone, light-gray to buff to medium-brown, friable, ledge-making unit; mostly of slightly rounded colorless quartz grains $\frac{1}{16}$ - $\frac{1}{100}$ of an inch in diameter, but carries a little dark material and partly kaolinized feldspar.....	25
35. Shale, with minor sandstone, largely concealed; shale is medium dark gray weathering light gray, clayey, gypsiferous.....	21
34. Sandstone, massive, crossbedded; makes a minor ledge; almost entirely of well-rounded medium-fine grains of colorless quartz, loosely cemented by calcite; weathers buff to medium brown.....	12

## No. 11. Section taken in canyon of Coal Creek, Utah—Continued

Neslen formation—Continued	Feet
33. Shale, like No. 35.....	12
32. Sandstone, like No. 34; 3- to 4-ft shaly zone about 20 ft above base; locally carries a few clay pellets; upper part has birdshot-like masses that are white, giving the rock a pimpled appearance; this is probably the Bluecastle sandstone member, which caps the undissected part of the Beckwith Plateau.....	53
31. Shale, like No. 35.....	32
30. Sandstone, crossbedded, friable, with shaly lenses in the lower part; only locally a prominent ledge maker; up to one-fifth of the lower part is locally of clay pellets up to 3 in. thick; sandstone is 95 percent of fairly well-rounded 1/100-inch grains of quartz, with minor feldspar (partly kaolinized) and dark minerals.....	29
29. Shale, with minor sandstone; quite variable; shale medium-gray, silty, locally really a mudstone, to fissile, black, carbonaceous and coaly.....	13
28. Sandstone, light-gray to light-buff, cross-bedded, friable, very fine-grained quartz.....	4
27. Shale, mostly medium-gray; weathers lighter, but some nearly black carbonaceous layers; fat to silty, with one thin sandstone layer; carries irregular thin layers of sandy clay ironstone.....	28
26. Sandstone, like No. 28 except upper and lower parts are shaly.....	4
25. Shale and mudstone; mostly the latter; medium gray in the upper part; black carbonaceous shale in lower part, with four thin coal layers.....	13
24. Shale and sandstone, like above two units.....	6 $\frac{1}{2}$
23. Coal and shale (Farrer mine; probably Chesterfield seam).....	5 $\frac{1}{2}$
22. Shale with sandstone; shale medium gray in main but partly black, carbonaceous, especially near top; lower part carries about one-half fine-grained sandstone weathering thin, platy.....	58
21. Sandstone; forms a bench; medium to heavy bedded, gray to very light buff; upper part weathers into rounded masses and carries a few ironstone concretions up to 4 in. thick; a sample of the sandstone shows it to be made mainly of fine to very fine somewhat rounded quartz grains with perhaps 5 percent of slightly limonite-stained kaolinized feldspar, weakly cemented by calcite; lower 10 ft carries some interbedded sandy shale.....	34
20. Shale, with minor limestone like No. 19 in central part; lower part greenish-gray gypsiferous shale; upper part similar, but in part carbonaceous; central shales yellowish, clayey.....	23

*No. 11. Section taken in canyon of Coal Creek, Utah—Continued*

Neslen formation—Continued	Feet
19. Limestone, dark- to light-gray (weathering light yellow-brown), dense, medium-bedded.....	4
18. Sandstone, medium-coarse-grained, light-brown, weathering dark-brown.....	2
17. Shale; upper 6-8 ft dark gray, carbonaceous; rest slightly greenish gray to yellow gray to light buff.....	29
Total Neslen formation.....	408

## Sego sandstone:

16. Sandstone, yellowish-white to light-brown, medium-fine-grained, thin- to medium-bedded, crossbedded; minor ledge maker; poorly preserved pelecypods 6 ft below top.....	24
15. Sandstone and shale; slope-forming unit poorly exposed, but a few 1- to 2-ft layers of thin-bedded, dark- to light brown fine-grained sandstone crop out.....	67
14. Sandstone, gray-brown (except upper third, which is gray-white), fine-grained; thin- to thick-bedded ledge-making unit; locally somewhat shaly.....	24
Total Sego sandstone.....	115

## Buck tongue of Mancos shale:

13. Shale, with thin layers of sandstone, more important in upper part; shale brown to gray, sandy, locally coaly; sandstone platy, shaly, fine grained, yellow brown.....	138
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## Castlegate sandstone:

12. Sandstone, yellow-brown (weathering deep brown), massive crossbedded, dense, hard.....	5
11. Sandstone, white to brown, medium-grained, medium-bedded; locally shaly.....	11
10. Shale, gray, brown, and black, in part coaly.....	2½
9. Sandstone, like No. 11, but fine grained.....	1
8. Shale, like No. 10; plant remnants; changes rapidly laterally to fine-grained yellowish clayey sandstone; varies in thickness from 0 to 8 ft.; in places the two higher units are also absent; thickness where section measured.....	4½
7. Sandstone, massive, crossbedded; makes a cliff; this or No. 11 or 12 caps the pronounced Castlegate dip-slope bench; color deep buff to yellow gray; gray white in upper part; a sample from the lower part is mainly of fine to very fine slightly rounded colorless quartz grains with about 5 percent of lightly limonite-stained feldspar, cemented loosely by calcite.....	106
Total Castlegate sandstone.....	130

*No. 11. Section taken in canyon of Coal Creek, Utah—Continued*

Conformable contact.	Feet
Blackhawk formation:	
Upper member:	
6. Shale, light-gray to black, carbonaceous, coaly.....	15
5. Sandstone, tan through buff to very light-gray, massive crossbedded, thick-bedded in upper part grading downward into medium-bedded sandstone with interbedded lenses of sandy shale at the base; cliff maker.....	74
4. Shale with minor sandstone layers; more sand layers in upper part.....	93

Thickness upper member..... 182

## Middle sandstone member:

3. Sandstone, light-buff to gray-white (upper part) massive, crossbedded; cliff maker; with minor interbedded thin platy sandstone; sample from the lower part is composed mainly of very fine rounded quartz grains weakly cemented by calcite and with a little lightly limonite-stained feldspar.....	84
2. Shale and sandstone, like overlying and underlying units, and marking a gradation between the two; more sandy in upper part; forms a weak cliff at most places....	56

Thickness middle sandstone member. 140

Total Blackhawk formation..... 322

## Gradational contact.

## Mancos shale:

1. Shale, limy to clayey, with a few thin layers of limestone and of sandstone; shale dark, slightly bluish gray, weathering drab, gypsiferous.....	220+
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*No. 12. Section taken on the west side of canyon of Saleratus Wash, mainly in the southwestern part of T. 20 S., R. 19 E., Utah*

[Measured by D. J. Fisher]

"Wasatch" formation (lower part only):	Feet
66. Sandstone and shale (25 percent), variegated; sandstone, which is in part pebbly, forms massive cliff-making units 50-100 ft thick. Total thickness not measured.	
65. Conglomerate, massive, firm; ledge-making unit; consists of about 60 percent sand matrix, made up mostly of slightly rounded medium-sized quartz grains, but with about 5 percent each of feldspar and dark minerals, in a calcareous cement; carries many poorly to well rounded pebbles up to 3 in. in diameter, but averaging about 1 in.; locally has lenses of crossbedded sandstone; pebbles composed of black basalt, chert of several colors (black, light gray, jasper red, green), silicified limestone, white and lilac quartzite, lilac felsite, white vein quartz, limonite, leucophyre, and probably reddish syenite or granite....	26

No. 12. Section taken on west side of canyon of Saleratus Wash, mainly in the southwestern part of T. 20 S., R. 19 E., Utah—Continued

"Wasatch" formation—Continued	Feet
64. Shale, gray-----	12
63. Sandstone, very light-gray, crossbedded, friable; mostly of medium-coarse grains of glassy quartz with perhaps 10 percent kaolinized feldspar and 5 percent dark minerals in a calcareous cement-----	17
62. Shales, clayey; yellow, pale brick red-----	55
61. Sandstone, like No. 63, but weathers almost white and in rounded forms-----	25

"Wasatch" formation, part measured. 135

Contact relations apparently conformable, but not well exposed.

Tuscher formation:

60. Shale, with minor sandstone; shale buff to gray-----	30
59. Sandstone, buff-weathering-----	10
58. Shale, like No. 60-----	54
57. Sandstone, like No. 49; weathers to rounded forms-----	26
56. Shale, sandy-----	36
55. Sandstone, like No. 49, except near middle carries 20 ft of shale and shaly sandstone--	81
54. Shale and sandstone-----	35
53. Sandstone, like No. 49-----	48
52. Shale-----	12
51. Sandstone, like No. 49-----	12
50. Shale, with minor sandstone layers-----	54
49. Sandstone; rich brown where cliff forming, owing to limonite stain; where it weathers to somewhat rounded surfaces it is fairly light gray; its texture at first glance is peculiar, resembling a somewhat felty aggregate; made mainly of fine-grained glassy quartz mottled with 5 percent of slightly limonite-stained feldspar and dark minerals, loosely cemented-----	38
48. Shale and sandstone making a slope-----	36
47. Sandstone, friable, crossbedded; weathers into rather light-gray rounded masses; largely of medium-fine glassy quartz grains with about 3 percent each of feldspar and dark minerals, with a little calcite cement; locally forms a cliff, stained rich brown-----	85

Total Tuscher formation----- 557

Contact apparently conformable, but not clearly exposed.

Farrer formation:

46. Shale or mudstone; poorly exposed since it is clayey and forms a slope; where it can be seen it consists of greenish-medium-gray mudstone, noncalcareous, but slightly silty-----	28
45. Sandstone, ledge, like No. 33-----	28
44. Shale and sandstone; makes a slope-----	27
43. Sandstone, minor cliff, like No. 33-----	24
42. Shale, like No. 46-----	5
41. Sandstone, like No. 33-----	10

No. 12. Section taken on west side of canyon of Saleratus Wash, mainly in the southwestern part of T. 20 S., R. 19 E., Utah—Continued

Farrer formation—Continued	Feet
40. Shale and sandstone, like No. 44-----	10
39. Sandstone, like No. 33-----	10
38. Shale, like No. 46-----	10
37. Sandstone, like No. 33-----	41
36. Shale and sandstone slope; shale like No. 46; sandstone, light gray, coarse, with dark minerals, in a bed 36 ft above base-----	57
35. Sandstone, like No. 33; with carapace of a 1-ft fresh-water turtle near base-----	46
34. Shale, sandstone, and minor limestone; probably about equal amounts of shale and sandstone, but the unit is a talus-covered slope; 10 ft above base is a 1-ft bed of greenish-gray lithographic limestone-----	72
33. Sandstone, very massive, well crossbedded, makes buff-brown cliff; subangular to well-rounded fine grains, mostly of frosted quartz but with 10 percent of limonite-stained feldspar and a little dark mineral matter; carries clay pellets or galls and a few small pebbles; friable, with calcite for cement-----	56
32. Shale and sandstone; upper part about 40 percent sandstone, with less below; sandstone interbedded with shale; 1 sandstone layer is a 10-ft ledge maker, but the rest are thinner; upper 50 ft generally forms a weak, shaly cliff, appearing greenish-medium-gray, owing to the shale-----	84
31. Sandstone, buff-brown weathering, friable, crossbedded; massive ledge, with a 1- to 2-ft shaly parting near the middle; calcareous cement-----	34
30. Sandstone and shale (40 percent) slope; lithology like two underlying units-----	32
29. Sandstone, buff-brown weathering, friable, crossbedded; massive ledge maker; mostly of fine to very fine grains of frosty quartz with some feldspar, dark minerals, and mica; calcareous cement-----	16
28. Shale, greenish-tinged medium-gray-----	51

Total Farrer formation----- 641

Neslen formation:

27. Sandstone; weathers fairly light-gray-----	29
26. Shale, with minor buff-brown sandstone in upper part; shale medium gray to buff brown-----	73
25. Sandstone; minor ledge; weathers light gray to buff brown-----	9
24. Shale with two minor coal zones 8 and 24 ft above base-----	81
23. Sandstone, buff, massive to thin-bedded, crossbedded-----	3½
22. Shale, with 2 ft of coal (Chesterfield zone)-----	9
21. Sandstone, buff, thin-bedded; minor ledge capped by an 8-in. massive gray layer-----	4
20. Shale, in part carbonaceous, with a 1-ft coal bed 61 ft above the base; carries minor interbedded sandstone-----	79

No. 12. Section taken on west side of canyon of Saleratus Wash, mainly in the southwestern part of T. 20 S., R. 19 E., Utah—Continued

Neslen formation—Continued	Feet
19. Sandstone, buff-brown; very minor ledge....	3½
18. Shale, buff to light-gray, with two carbonaceous zones.....	35
17. Sandstone, buff, crossbedded.....	1
16. Shale with minor sandstone, largely concealed; carbonaceous zone in upper part..	29
15. Sandstone, buff-brown, very limy; contains abundant shells of <i>Ostrea glabra</i> Meek and Hayden.....	2
14. Shale (presumably); concealed by slope wash.....	12
Total Neslen formation.....	370

Sego sandstone:

13. Sandstone, buff, crossbedded.....	24
12. Sandstone, shaly, with some shale, carbonaceous in upper part; gypsiferous; sandstone shows drying cracks.....	58
11. Sandstone, light-gray, fine-grained, massive, crossbedded, conspicuous; variable thickness.....	7±
10. Shale, with some sandstone (like No. 9)....	38
9. Sandstone, light-buff to buff-brown, massive, crossbedded, ledge-making; largely of very fine frosty quartz grains; some of it limonite stained, cemented loosely by calcite; carries fucoids.....	15
8. Sandstone, with shaly material in central part; buff, crossbedded, thin-bedded; locally a minor ledge-maker.....	40
Total Sego sandstone.....	182±

Buck tongue of Mancos shale:

7. Shale, gritty; dark gray weathering light medium gray; lower 60 ft concealed.....	163
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Castlegate sandstone:

6. Sandstone, mostly light-buff, but may be stained rich brown on cliff faces; carries zones of gray-white sandstone, which as a rule cannot be traced far; massive, crossbedded; a white sample is friable, nearly all fine to very fine quartz grains moderately well rounded; a brownish sample shows fine to very fine angular quartz grains, with 10 percent of brown grains, probably of limonite-stained quartz.....	132
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Conformable contact.

Blackhawk formation:

Upper member:

5. Sandstone, shaly, with some carbonaceous material; poorly exposed, but in places carries medium-gray slightly silty mudstone, and gray-brown coaly mudstone with plant fragments and specks of resin..	19
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No. 12. Section taken on west side of canyon of Saleratus Wash, mainly in the southwestern part of T. 20 S., R. 19 E., Utah—Continued

Blackhawk formation—Continued	Feet
Upper member—Continued	
4. Sandstone, buff (gray to white at top), fine to very fine-grained, crossbedded; thin bedded and shaly in lower part to massive in upper third; friable.....	111
3. Shale, medium-gray; mostly concealed by wash; about.....	100
Thickness upper member.....	230
Middle sandstone member:	
2. Sandstone, shaly; weak cliff-maker; gives way to Mancos shale a short distance to the east; about.....	110
Total Blackhawk formation.....	340

Contact gradational.

Mancos shale:

1. Shale, medium-dark-gray weathering drab, with some sandy layers in upper part; 490 ft below top is a minor sandstone that caps little buttes near Saleratus Wash; 565 feet below top is a 20-ft sandstone layer that makes a small hogback northwest of Floy.

No. 13. Section taken in canyon of Crescent Wash to the top of Crescent Butte, sec. 34, T. 20 S., R. 19 E., Utah

[Nos. 50-83 by J. B. Eby; Nos. 22-49 by R. M. Leggette; Nos. 6-8 by K. K. Landes; Nos. 1-4 by James Gilluly and C. H. Dane along Salt Creek about 6 miles south of Highway 50]

Farrer formation, in part:

	Feet
84. Sandstone, massive; reddish-brown cliff-maker; caps Crescent Butte.....	128
83. Shale.....	20±
82. Sandstone.....	10±
81. Shale.....	15±
80. Sandstone.....	20±
79. Shale.....	12
78. Sandstone.....	6
77. Shale.....	8
76. Sandstone.....	20
75. Shale and sandstone, thin-bedded.....	12
74. Shale.....	85
73. Sandstone.....	4
72. Shale.....	85
71. Sandstone.....	10
70. Shale.....	70
69. Sandstone, massive, brown; ledge maker; with clay shale, gray, in an 8-ft bed 6 ft below top and in a 2-ft bed 6 ft above base.....	32

Farrer formation, part measured... 537±

Neslen formation (top may be somewhat below top of No. 68):

68. Shale.....	40
67. Coal.....	1½
66. Shale.....	30
65. Coal.....	2½

No. 13. Section taken in canyon of Crescent Wash to the top of  
Crescent Butte, sec. 34, T. 20 S., R. 19 E. Utah—Continued

Neslen formation—Continued	Feet
64. Shale.....	40
63. Sandstone.....	8
62. Shale.....	32
61. Coal.....	1
60. Clay.....	2
59. Coal.....	1
58. Shale.....	20
57. Sandstone.....	5
56. Shale.....	10
55. Sandstone.....	15
54. Coal.....	$\frac{1}{2}$
53. Shale.....	4
52. Sandstone.....	20
51. Clay, with thin beds of coal.....	6
50. Shale, sandy, with thin-bedded sandstone layers.....	45
49. Shale and thin-bedded sandstone (25 percent); shale brown to gray, carbonaceous near base.....	25
48. Coal.....	$\frac{1}{2}$
47. Sandstone and shale, carbonaceous (20 percent) in upper part; sandstone thin bedded.....	11 $\frac{1}{2}$
46. Coal and bone.....	1 $\frac{1}{2}$
45. Shale, deep-brown, carbonaceous.....	1
44. Sandstone, thin-bedded.....	8
43. Shale, brown.....	1
42. Bone.....	$\frac{1}{2}$
41. Shale, brown.....	2
40. Sandstone and shale (10 percent); sandstone thin bedded, partly concealed; shale, carbonaceous, mainly in lower part.....	12 $\frac{1}{2}$
39. Coal and bone (Chesterfield zone).....	2
38. Sandstone, massive to medium-bedded.....	9
37. Sandstone, gray to buff, thin-bedded.....	6
36. Shale, brown to black.....	6
35. Sandstone, buff, thin-bedded.....	2 $\frac{1}{2}$
34. Coal and bone (Ballard horizon).....	1 $\frac{1}{2}$
33. Shale, brown to black, carbonaceous.....	1 $\frac{1}{2}$
32. Shale, sandy, gray to buff.....	1 $\frac{1}{2}$
31. Sandstone, thin-bedded; shaly near base..	4
30. Shale, gray; black near top.....	3
29. Sandstone, thin-bedded, gray to buff; shaly in upper part.....	10
28. Shale, brown; somewhat sandy near top..	19
27. Sandstone, thin-bedded, buff.....	7
26. Shale, brown to black, very carbonaceous near top.....	6 $\frac{1}{2}$
25. Sandstone, thin-bedded, gray to buff.....	13
24. Coal, with minor carbonaceous shale (Pali-sades coal zone).....	6 $\frac{1}{4}$
23. Shale, black to brown, carbonaceous; somewhat sandy near middle.....	22
22. Sandstone, thin-bedded, shaly, medium gray.....	35
Total Neslen formation.....	501

No. 13. Section taken in canyon of Crescent Wash to the top of  
Crescent Butte, sec. 34, T. 20 S., R. 19 E. Utah—Continued

Sego sandstone:	Feet
21. Sandstone like No. 18; rather shaly in lower part; carries fucoids; locally resembles the light-gray sandstone of No. 17.....	21
20. Sandstone, like No. 17; but less pronounced cliff maker; lower part light gray, with rounded surfaces; upper part buff brown, blocky; poorly preserved <i>Ostrea</i> zone locally present at top.....	6
19. Shale, sandy, medium-gray in all probability, but mostly concealed; carries thin beds of sandstone.....	48
18. Sandstone, friable, crossbedded, in part shaly; medium-thick-bedded and light-gray to thin-bedded and buff-brown; slightly platy near top.....	49
17. Sandstone, massive; ledge maker; upper part buff brown, blocky, with clay pellets; lower part mostly light gray, with rounded surfaces.....	16
Total Sego sandstone.....	140
Buck tongue of Mancos shale:	
16. Shale and sandstone (40 percent); shale like No. 15, but appears buff at most places owing to slope wash; sandstone, buff, crossbedded and in thin beds separated by shale.....	68
15. Shale, lower part concealed by wash; shale is medium to dark gray, gypsiferous; resembles Mancos, and carries thin brown-weathering limy layers.....	113
Total Buck tongue.....	181
Castlegate sandstone:	
14. Sandstone, light-buff to light-gray, massive, crossbedded, friable; locally contains shaly material (in part carbonaceous or even coaly) near top; elsewhere upper part is pebbly, glauconitic, with fossils (carapace of a fresh-water trionychid turtle; teeth and bones of the marine shark <i>Lamna</i> sp.; and possibly worm borings). This member is a cliff-forming unit, and its top or upper part causes a pronounced dip-slope bench....	75
Conformable contact.	
Blackhawk formation:	
Upper member:	
13. Shale, buff to medium-gray.....	5
12. Coal and bone.....	4
11. Shale, like No. 13.....	30
10. Shale, carbonaceous, with coaly streaks..	2 $\frac{1}{2}$
9. Coal, dirty.....	3
8. Sandstone, massive, very light-gray.....	34



No. 13. Section taken in canyon of Crescent Wash to the top of Crescent Butte, sec. 34, T. 20 S., R. 19 E. Utah—Continued

	Feet
Blackhawk formation—Continued	
Upper member—Continued	
7. Sandstone, massive, buff; with No. 8 constitutes a cliff-forming unit.....	36
6. Sandstone, thin-bedded, buff.....	100
Total Blackhawk formation.....	214½

Gradational contact.

Mancos shale:

5. Shale, bluish-gray; thin sandstone beds in upper part; sandy zone about 350 ft above base..... 4, 050±

Dakota sandstone:

4. Sandstone with conglomerate at base; sandstone white and light gray, carbonaceous, and heavily limonite stained; pebbles in conglomerate are of black chert; forms a strong ledge..... 9
3. Shale and sandstone; upper part gray shale with sandstone lenses up to 6 in. thick, carrying plant fragments; lower 15 ft mostly of 6-in. sandstone layers interbedded with shale; *Halymenites* common, as are plant fragments but no carbon.... 51
2. Conglomerate, crossbedded, with pebbles up to three-fourths of an inch in diameter of white, gray, yellow, and black chert.. 10

Total Dakota sandstone..... 70

Morrison formation, uppermost part:

1. Clay, light-gray; greenish gray near top; carries marly layers, limestone nodules, and some lenses of grit..... 68

No. 14. Section in canyon of Thompson Wash, Utah

[1-18 measured by J. H. Hengst; 19-45 by R. M. Leggette; 46-79 by E. M. Spieker and J. B. Reeside, Jr.]

"Wasatch" formation:

79. Varicolored beds not examined in detail.

Tuscher formation:

78. Sandstones, like No. 69, with minor inter-vening shaly beds; not examined in detail..... 200±
77. Conglomeratic sandstone; matrix like No. 69; pebbles up to 6 by 2 in., mainly quartzite and chert (black, pink, white, gray, and yellow), some igneous rock.. 20
76. Sandstone, like No. 69..... 30
75. Sandstone, gray, like No. 71..... 3
74. Shale, gray..... 5
73. Sandstone, brown-buff, crossbedded, coarse-grained, with ferruginous nodules..... 30
72. Shale, gray, granular..... 2
71. Sandstone, gray-white, calcareous..... 2
70. Shale, green-gray, granular..... 4

No. 14. Section in canyon of Thompson Wash, Utah—Continued

	Feet
Tuscher formation—Continued	
69. Sandstone, coarse-grained, friable, massive; very irregularly bedded cliff maker; weathers to a cream or buff-cream; weathered surfaces are more rounded and of lighter color than is true of lower sandstones.....	80
68. Sandstone, very coarse-grained, thin-bedded, friable, buff-weathering.....	30
Total Tuscher formation.....	406±

Farrer formation:

67. Shale, gray to green; and very coarse-grained friable brown to greenish-brown sandstone of lighter tone than beds lower in the section..... 110
66. Sandstone, brown to green, coarse-grained, friable, massive cliff maker..... 36
65. Sandstone and shale, like No. 53..... 45
64. Sandstone, like No. 66..... 60
63. Sandstone and shale, like No. 53, but sandstone somewhat coarser and greener... 130
62. Sandstone, like No. 66..... 50
61. Shale, light-gray; and brown sandstone that is fine grained and thin-bedded to coarse grained and massive..... 135
60. Sandstone and shale, much like No. 53; sandstone is finer grained and browner, but some greenish-gray sandstone is present; forms point of a long spur.... 62
59. Sandstone, like No. 57..... 15
58. Shale with some sandstone, like No. 53... 57
57. Sandstone, buff, medium-grained, massive, weathers to greenish-gray; with clay galls..... 40
56. Sandstone, massive layers like No. 52; 10-20 ft above base are fresh-water fossils of probable Fruitland age (*Tulotomops thompsoni* White; *Unio* cf. *U. baueri* Stanton, and *Unio holmesianus* White)..... 60
55. Shale, like No. 53; along outcrop this unit carries massive sandstone layers..... 100
54. Sandstone, like No. 52, massive to thin-bedded, very irregular, crossbedded, with clay galls..... 14
53. Shale and sandstone; shale in greenish-gray layers about 10 ft thick is interbedded with sandstone in beds 2-5 ft thick..... 56
52. Sandstone, green to brown to gray (coated red) medium-grained, massive; carries lenses of clay galls, and resembles the sandstones of the "Wasatch"..... 30
51. Sandstone and shale; latter in layers 4-5 ft thick; sandstone is buff, blocky; limestone layer of unknown thickness near base..... 95
- Total Farrer formation..... 1, 095

## No. 14. Section in canyon of Thompson Wash, Utah—Continued

	Feet
Neslen formation:	
50. Shale, like No. 46.....	5
49. Shale, black, carbonaceous.....	3
48. Shale (probably), and sandstone; mostly concealed, but carries layers of platy brown ferruginous sandstone.....	75
47. Sandstone, gray, medium-fine-grained; blotched with brown.....	20
46. Shale, gray, sandy.....	22
45. Sandstone, buff, medium-fine-grained, thin-bedded.....	15
44. Shale, gray to brown.....	1
43. Bone.....	2
42. Sandstone, thin-bedded (below) with carbonaceous shale; partly concealed.....	6½
41. Shale, black, carbonaceous.....	1
40. Coal and bone.....	2
39. Shale, brownish-gray.....	1
38. Sandstone, thin-bedded; largely concealed.....	5
37. Sandstone, medium-bedded.....	2½
36. Shale, carbonaceous.....	1
35. Coal (Chesterfield zone).....	4
34. Shale, brownish, carbonaceous.....	2
33. Sandstone, thin-bedded, shaly.....	6
32. Sandstone; massive, buff, ledge-forming..	18
31. Coal, bone, and carbonaceous shale (Baldard zone).....	3¼
30. Shale, carbonaceous, and a little coal....	6¼
29. Sandstone, medium-bedded.....	1
28. Shale, brown.....	18
27. Shale, carbonaceous.....	1
26. Shale, brown to black, somewhat sandy..	12
25. Shale and sandstone, thin-bedded; sandstone in upper part; unit concealed in middle; shale (gray to brown and carbonaceous in lower part).....	25
24. Sandstone and shale (25 percent); brown shale in lower part; thin-bedded shaly sandstone above.....	40
23. Coal (Palisade).....	5
22. Shale.....	3½
21. Coal and shale, carbonaceous.....	1½
20. Shale, carbonaceous, brown to black.....	4
19. Sandstone, buff, thin-bedded; concealed near middle.....	23
Total Neslen formation.....	335

## Sego sandstone:

18. Sandstone, massive, crossbedded, gray-white, coarse-grained.....	75
17. Sandstone, weathering to thin sheets and with rounded surfaces.....	25
16. Sandstone, with a little shale in thin beds; sandstone crossbedded and weathers to rounded forms; somewhat limonite stained.....	10
15. Sandstone, buff, fine-grained, massive, ledge-forming.....	60

## No. 14. Section in canyon of Thompson Wash, Utah—Continued

Sego sandstone—Continued	Feet
14. Sandstone, buff, fine-grained, limonite-stained, crossbedded; weathers into thin plates, has limonite nodules.....	30
Total Sego sandstone.....	200

## Buck tongue of Mancos shale:

13. Shale and sandstone, in alternating beds, with more shale in lower part and more sandstone above; this unit is a gradation zone between the Buck and Sego; sandstone is fine grained, crossbedded, limonite-stained.....	26½
12. Sandstone; buff, fine-grained, massive, crossbedded; ledge maker.....	4½
11. Shale, with minor thin lenses and layers of sandstone; shale is gray and gypsiferous and carries fragments of carbonized wood; lower part concealed.....	172
Total Buck tongue.....	203

## Castlegate sandstone:

10. Sandstone, buff, weathering reddish brown; massive, crossbedded; ledge maker....	40
9. Sandstone, with minor shale, nodular weathering; sandstone is a thin-bedded reddish-brown fine-grained cliff maker..	14
8. Sandstone; buff, weathering reddish brown; massive, crossbedded; cliff maker; weathered surface shows white areas the size of birdshot.....	30
Total Castlegate sandstone.....	84

## Conformable contact.

## Blackhawk formation:

## Upper member:

7. Shale and sandstone, very thin-bedded, intercalated.....	2½
6. Bone and coal.....	1½
5. Shale.....	1½
4. Sandstone and shale; sandstone is light buff, crossbedded; shale, which is in small part carbonaceous, constitutes about one-third of the unit.....	20
3. Sandstone, light-gray, fine-grained, carbonaceous; weathers buff.....	½
2. Sandstone; buff to reddish-brown, medium-grained, massive, crossbedded; cliff maker.....	95
Total Blackhawk formation.....	121

## Gradational contact.

## Mancos shale:

1. Shale, bluish-gray, limy, gypsiferous; thin beds of fine-grained sandstone in upper part.	
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No. 15. Section measured on the north side of the Nash Wash reentrant, in secs. 35 and 25, T. 19 S., R. 21 E., northwest of Cisco, Utah

[Dakota and Morrison strata measured by C. H. Dane south of Cisco on the road to Castleton, remainder by D. J. Fisher]

"Wasatch" formation (in part):

	Feet
80. Sandstone and shale (25 percent); sandstone in massive ledges and cliffs; locally stained red by wash; higher sandstone beds are light gray and weather to rounded surfaces; lower sandstone beds are buff brown, blocky; interbedded with purplish-brick-red sandy shales (to top of exposure here). (See pl. 6C.)	825
79. Conglomerate, like No. 65 in stratigraphic section 12; massive, dark-brown ledge-maker; lower two-thirds is 15 percent sandstone and 85 percent conglomerate (50 percent pebbles); upper one-third is 95 percent coarse friable quartzose cross-bedded sandstone; on next point to southeast this unit is 75 ft thick; on next point to west it is absent, and its position is occupied by red shale. (See pl. 4A and 6C.)	40

"Wasatch" formation, part measured..... 865

Contact disconformable, gently undulating; conglomerate rests on shale at point of section, but elsewhere it lies on sandstone, apparently No. 77.

Tuscher formation:

78. Shale, medium-gray with greenish tinge..	22
77. Sandstone; massive crossbedded ledge; mostly of very fine colorless quartz grains with 2 percent white feldspar and a few dark mineral grains loosely cemented to a friable mass; weathers to beautiful white rounded surfaces....	51
76. Shale, like No. 78.....	16
75. Sandstone, buff-brown, friable, medium-bedded.....	6
74. Shale and sandstone, like No. 70.....	20
73. Sandstone, white, saccharoidal; medium-fine frosted quartz grains with 10 percent feldspar and 2 percent dark grains; friable; weathers to rounded surfaces..	26
72. Shale, like No. 78.....	26
71. Sandstone, with minor shaly beds in upper half; sandstone of medium fine angular grains of frosted quartz with 5 percent buff-yellow feldspar and a very few dark grains; sugary texture, friable; weathers to very light gray rounded surfaces....	100

Total Tuscher formation..... 267

No. 15. Section measured on the north side of the Nash Wash reentrant, in secs. 35 and 25, T. 19 S., R. 21 E., northwest of Cisco, Utah—Continued

Contact apparently conformable, but not well exposed and the lithology of the units changes rapidly laterally.

Farrer formation:

70. Shale and sandstone; thin greenish sandstone beds in greenish-tinged clay shale beds.....	49
69. Sandstone, lithologically like No. 53; lower part is somber and blocky; the upper part is light gray, rounded.....	11
68. Shale and sandstone in equal amounts; like Nos. 52 and 53.....	29
67. Sandstone, like No. 55.....	11
66. Shale, like No. 54, with some medium- to thin-bedded sandstone.....	16
65. Sandstone, like No. 55.....	11
64. Shale, like No. 54.....	12
63. Sandstone, like No. 55.....	4
62. Shale, like No. 54.....	39
61. Sandstone, like No. 53, with one shaly parting.....	54
60. Shale, like No. 54.....	6
59. Sandstone, like No. 53; carries one thin shale bed.....	48
58. Shale, like No. 54; with at least 2 sandstone beds about 5 ft thick, and probably contains other thinner sandstone beds.....	96
57. Sandstone, resembling No. 53; a pronounced ledge maker.....	19
56. Shale, like No. 54.....	9
55. Sandstone, minor ledge, like No. 53.....	4
54. Shale, like No. 52; largely talus covered...	26
53. Sandstone, forms a buff-brown, semiblocky ledge, beautifully crossbedded; composed of friably cemented, fine grains, about 75 percent frosty, subangular quartz with most of the rest of slightly limonite-stained angular feldspar, but 2-3 percent dark grains; fresh surface shows a somewhat felty texture.....	14
52. Shale, light-gray, with faint but distinct greenish tinge.....	12
Total Farrer formation.....	470

Neslen formation:

51. Sandstone, light-gray to buff, massive....	8
50. Shale, medium-gray to brown.....	19
49. Sandstone, buff-gray, medium- to thick-bedded, crossbedded.....	28
48. Shale, brown to gray, in part sandy; 2-in. coal seam 6 ft above base.....	16
47. Sandstone, buff; lower 10 ft thin-bedded to thick-bedded; upper 3-4 ft medium bedded; remainder forms a semimassive ledge.....	37
46. Shale, brown.....	2
45. Coal.....	5/8
44. Shale, gray to buff, sandy.....	12

No. 15. Section measured on the north side of the Nash Wash reentrant, in secs. 35 and 25, T. 19 S., R. 21 E., northwest of Cisco, Utah—Continued

Neslen formation—Continued	Feet
43. Coal.....	¼
42. Shale, brown.....	12
41. Coal, bony.....	½
40. Shale, gray and brown.....	14
39. Coal, bony, (Chesterfield horizon).....	¼
38. Shale, gray.....	6
37. Concealed (shale or shaly sandstone).....	3
36. Sandstone, buff to light-gray, massive, crossbedded, forms ledge; mostly of fine well-rounded clear but limonite-stained quartz grains with 10 percent white feldspar and a few dark grains; more or less friable and concretionary.....	21
35. Bone, bony coal, and carbonaceous shale (Ballard coal zone).....	4
34. Sandstone, buff-gray, medium- to thick-bedded; forms ledge.....	7
33. Concealed (in main); some medium- to light-gray thin-bedded slightly shaly sandstone in upper part and some gray shale in lower part; 5 in. of bony coal 2 ft above base.....	17
32. Sandstone, buff, crossbedded; ledge maker; lower 12 ft medium bedded with a 6-in. limy layer; rest is massive, though medium bedded at top.....	33
31. Shale, medium-gray, and 20 percent buff thin-bedded sandstone; 2 in. of bony coal locally present at top.....	29
30. Sandstone and shale (40 percent), medium-gray; sandstone buff, medium- to thin-bedded.....	12
29. Shale, carbonaceous.....	1
28. Coal, bony, with bone and carbonaceous shale (Palisades zone).....	6
27. Shale, carbonaceous.....	2
26. Bone and bony coal.....	1½
25. Shale, gray; largely carbonaceous; 2 in. bone 1 ft above base.....	3
<b>Neslen formation.....</b>	<b>295</b>

#### Sego sandstone:

24. Sandstone, massive, although locally central part is thin-bedded, shaly; generally makes a cliff; upper part composed mainly of very fine frosted quartz grains with some 5 percent of kaolinized feldspar.....	53
23. Sandstone, somewhat shaly, like No. 21....	63
22. Sandstone, buff to gray, massive; ledge maker.....	12
21. Sandstone, shaly, thin-bedded, buff with some gray shale; slope maker at most places.....	29
20. Sandstone, buff-gray, medium-bedded, locally thin-bedded.....	15
<b>Total Sego sandstone.....</b>	<b>172</b>

No. 15. Section measured on the north side of the Nash Wash reentrant, in secs. 35 and 25, T. 19 S., R. 21 E., northwest of Cisco, Utah—Continued

Buck tongue of Mancos shale:	Feet
19. Shale, largely concealed by slope wash; some shaly thin-bedded sandstone layers probably present in upper part.....	188
<b>Castlegate sandstone:</b>	
18. Sandstone, buff-brown to buff-gray, medium- to thick-bedded, crossbedded; 98 percent of fairly well-rounded fine glassy quartz grains; some slightly kaolinized, limonite-stained white to flesh-colored feldspar, and a few dark grains; carries marine invertebrates (13685).....	22
17. Sandstone, largely concealed; apparently like No. 15.....	38
16. Sandstone; generally a medium- to thick-bedded ledge maker.....	26
15. Sandstone, slightly shaly, thin-bedded, buff-gray, friable; generally a slope.....	6
14. Sandstone, like No. 12.....	1
<b>Total Castlegate sandstone.....</b>	<b>93</b>

Conformable contact.

Blackhawk formation:

Upper member:

13. Sandstone and shale, lower part concealed; probably largely of thin-bedded buff-gray friable slightly shaly sandstone.....	50
12. Sandstone, buff-brown, massive, cross-bedded; forms ledge.....	1
<b>Total Blackhawk formation.....</b>	<b>51</b>

Conformable contact.

Mancos shale:

11. Shale, blue-gray; forms the wash-covered lower slope of Book Cliffs and broad flat to south; about 875 ft below top is a sandy zone, carrying two prominent sandstone beds; total thickness about...	3, 450
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Dakota sandstone:

10. Sandstone, white, sugar-textured, cross-bedded.....	13
9. Shale, light-gray, sandy.....	17
8. Sandstone, white.....	7
7. Shale, gray, sandy.....	18
6. Sandstone, white.....	6
5. Shale, gray and greenish-gray, limy.....	18
4. Sandstone, white, fine-grained, quartzitic, with biotite flakes.....	8
3. Shale, gray and green, limy.....	23
2. Conglomerate, limestone pebbles.....	4
1. Conglomerate, quartzitic, with subangular pebbles up to 4 in. in diameter of crystalline quartz; orange, brown, white, drab, red, and black.....	12
<b>Total Dakota sandstone.....</b>	<b>126</b>

No. 15. Section measured on the north side of the Nash Wash reentrant, in secs. 35 and 25, T. 19 S., R. 21 E., northwest of Cisco, Utah—Continued

Irregular wavy surface (unconformity?)	Feet
Morrison formation (part):	
Clay, variegated with subangular pebbles of quartz, all colors, and sizes up to 2 in.-----	17

No. 16. Section up the canyon of a northern tributary to Cottonwood Creek, north of Cisco in secs. 8 and 17, T. 19 S., R. 23 E., Utah

[Measured by D. J. Fisher]

Tuscher formation:	Feet
56. Sandstone and shale; sandstone like No. 55; forms massive ledges 20-100 ft high; interbedded with about equal amounts of shale and thin-bedded shaly sandstone that weathers into slopes; not examined in detail-----	600-900
55. Sandstone, massive cliff maker; lower part is friable, light brown, blocky; upper part is very light gray, with rounded surfaces; samples from lower part are light to medium light gray on a fresh surface and are composed mainly of fine to very fine, only slightly rounded grains of frosted, coated quartz with 2-4 percent white feldspar and 1-2 percent dark grains.	86
Total Tuscher formation-----	800±

Contact approximately conformable, but ill exposed.  
Farrer formation:

54. Shale and sandstone (one-third); like No. 52, but some of the sandstone is medium thick bedded-----	72
53. Sandstone; forms massive ledge containing minor shaly partings varying greatly laterally; resembles No. 51; medium light gray locally stained brown; rounded weathering surfaces; fragmentary plant remains-----	22
52. Shale and sandstone (20 percent); shale is greenish-tinged medium gray; sandstone is dirty buff, thin bedded, platy-----	34
51. Sandstone, massive, crossbedded, buff-brown to light-gray; ledge maker; mostly of angular, medium-sized grains of frosted quartz, but carries 10 percent of white feldspar, partly limonite-stained; contains petrified log 1 ft in diameter-----	19
50. Sandstone and shale; shale as in No. 52; sandstone like No. 51; locally gives way to all sandstone, in which case Nos. 51-47 inclusive form a single cliff-making unit 93 ft thick---	27
49. Sandstone, like No. 51-----	21
48. Shale, as in No. 52-----	7
47. Sandstone, like No. 51-----	19
46. Shale and sandstone (30 percent); shale as in No. 52; sandstone is medium bedded-----	65

No. 16. Section up the canyon of a northern tributary to Cottonwood Creek, north of Cisco in secs. 8 and 17, T. 19 S., R. 23 E., Utah—Continued

Farrer formation—Continued	Feet
45. Sandstone, buff; minor ledge maker---	6
44. Shale, as in No. 52; locally sandy; few medium-thin sandstone beds in upper part-----	33
43. Sandstone, buff to light-brown; minor ledge-----	14
42. Shale, medium-light-gray; with a little sandstone-----	13
41. Sandstone, friable, medium- to thin-bedded; varies from slope maker to ledge maker; some beds are light olive, but most are buff-----	24
40. Shale as in No. 44-----	10
39. Sandstone, light-buff, thin-bedded; slope maker (generally)-----	9
38. Shale, somewhat sandy, more or less concealed slope; shale in part brown with fragments of carbonized wood--	18
37. Sandstone, ledge maker, generally somber brown and blocky but locally buff gray with rounded, weathered surfaces; crossbedded; largely of fine to very fine grains of quartz, but carries 10 percent limonite-stained feldspar-----	6
Total Farrer formation-----	419

Neslen formation:

36. Shale, with minor sandstones; in small part concealed; shale is medium light gray to brown-----	19
35. Sandstone, buff, medium- to thin-bedded, shaly-----	12
34. Shale, medium-gray; locally carries minor sandstones; 4-in. coal lens 20 ft above base-----	30
33. Sandstone, gray to buff to brown, massive; cliff maker-----	54
32. Sandstone, shaly, gray; locally forms a single cliff with overlying and underlying units-----	4
31. Sandstone, thin- to medium-bedded---	31
30. Shale; sandy in lower part-----	49
29. Coal, carbonaceous shale, and bone----	2
28. Shale, buff-gray; sandy in upper part; limy in lower part-----	23½
27. Sandstone, buff; lower part massive and crossbedded; upper part medium bedded-----	7
26. Bone, coal, and shale, brown (Chesterfield coal zone)-----	4
25. Shale, brown to gray-----	1½
24. Sandstone, buff-brown, medium-bedded.	3
23. Shale, gray and brown, carbonaceous; 5 in. of bone 1 ft above base-----	7½
22. Sandstone, like No. 24-----	7
21. Sandstone, buff, medium-bedded to thin-bedded, shaly-----	18
20. Shale, sandy, with 8 in. of bony coal in middle-----	6

*No. 16. Section up the canyon of a northern tributary to Cottonwood Creek, north of Cisco in secs. 8 and 17, T. 19 S., R. 23 E., Utah—Continued*

Neslen formation—Continued		Feet
19. Sandstone, like No. 21.....		22
18. Coal, slightly bony.....		1
17. Shale, brown to gray, with some thin-bedded buff sandstone.....		24
16. Sandstone, buff to brown massive.....		4
15. Shale and 40 percent sandstone; like No. 17.....		36
14. Coal, carbonaceous shale, and bone (Palisade zone).....		8¾
13. Shale, brown.....		4½
12. Sandstone, buff, thin- to medium-bedded.....		6
11. Shale, brown, weathering gray; upper part limy.....		17½
10. Sandstone, buff, thin-bedded, shaly.....		10½
Total Neslen formation.....		413

**Sego sandstone:**

9. Sandstone; massive cliff-maker; lower 11 ft is buff brown; upper 19 ft is very light gray, crossbedded, friable; composed of poorly rounded fine grains of frosted and coated quartz with 1 percent of somewhat limonite-stained white feldspar and a trace of dark minerals.....	30
8. Shale and sandstone, like No. 6.....	67
7. Sandstone, buff, medium-bedded, forms ledge.....	3
6. Shale and 30 percent sandstone; shale like Mancos; sandstone, shaly, thin to medium bedded.....	48
5. Sandstone, buff, crossbedded; forms ledge; in beds mainly between 1 and 6 in. thick, with some shale.....	23
Total Sego sandstone.....	171

**Buck tongue of Mancos shale:**

4. Shale, sandy in upper part; carries a few lenses of fine-textured, buff weathering limestone.....	267
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**Castlegate sandstone:**

3. Sandstone; very massive resistant layer capping a pronounced dip slope; cross-bedded, fine grained; weathers light gray to buff to brown; varies notably in thickness.....	4
2. Sandstone and 40 percent shale in alternating beds; sandstone crossbedded, fine grained, medium gray and weathers buff; in beds 1-8 in. thick; limy lenses present in upper part; fucoids.....	52
Total Castlegate sandstone.....	56

**Conformable contact.**

**Mancos shale:**

1. Shale, gray; upper part limy, silty with some very thin siltstone beds.

*No. 17. Section measured in and near canyon of Westwater Wash, Utah*

[Nos. 1-37 taken at Dry Canyon in secs. 5, 7, and 8, T. 18 S., R. 24 E., by D. J. Fisher; Nos. 38-56 by E. M. Spieker and J. B. Reeside, Jr., on the east side of canyon of Westwater Wash]

"Wasatch" formation, not examined in detail.

Tuscher formation:	<i>Feet</i>
55. Sandstone, with minor shale; like Nos. 48-54; conglomeratic at top (like No. 77 of section 14); not examined in detail....	250 ±
54. Sandstone, like No. 50, though possibly browner; causes several irregular benches and contains many ferruginous bands....	56
53. Sandstone, like No. 50, but softer.....	45
52. Sandstone, like No. 50.....	80
51. Shale.....	30
50. Sandstone, massive, coarse-grained, more reddish than No. 48; forms rounded outcrop; carries partings of blue shale.....	70
49. Sandstone and shale, slope-forming unit....	25
48. Sandstone, gray, massive, crossbedded, coarse-grained; has an angular outcro ...	35

**Farrer formation:**

47. Sandstone, like No. 44, with two layers of gray shale; slope-forming unit.....	63
46. Sandstone, like No. 44, making 7 ledges 40, 25, 100, 45, 70, 42, and 28 ft thick.....	350
45. Sandstone, much like No. 44, with a hard ferruginous concretion layer at top.....	60
44. Sandstone, light-buff, friable; some harder layers weathering dark-brown; forms slope capped by ledge.....	70
43. Sandstone; lower part brown buff; upper part gray green; weathers dark brown; very hard and calcareous; forms bench.....	27
42. Sandstone, friable, greenish-gray weathering brown or buff; in part with clay galls; forms long slopes.....	40
41. Sandstone, brown; clay galls near top.....	30
40. Sandstone; ledge maker; shale at base.....	32
39. Sandstone, buff; ledge maker; like No. 38; top ledge carries poorly preserved fossil plants.....	45
38. Sandstone, buff, friable, medium-grained, irregularly bedded; forms ledge.....	22
Total Farrer formation.....	739

**Neslen member:**

37. Shale, gray; a very small part is carbonaceous; carries a minor amount of thin-bedded sandstone and a 2-ft lens of greenish-buff-gray fine-textured limestone.....	59
36. Sandstone, buff to gray thin-bedded.....	2½
35. Shale, gray, in large part carbonaceous; 3 ft above base is 6 in. of bone.....	33½
34. Sandstone, gray to buff, thin-bedded.....	10
33. Shale, brown to gray.....	6½
32. Sandstone, buff, medium-bedded, cross-bedded.....	5½



## No. 17. Section measured in and near canyon of Westwater Wash, Utah—Continued

Neslen member—Continued		Feet
31. Shale, brown to gray; carries three thin layers of bone.....	16	
30. Sandstone, buff, massive; locally highly crossbedded; ledge maker; upper part medium bedded; basal part contains a little intercalated carbonaceous shale; carries poorly preserved fossil plant fragments, carbonized wood, worm borings, and fragments of fossil bones.....	21½	
29. Bone, coal, and carbonaceous shale (Carbonera? coal zone).....	9	
28. Shale, medium- to dark-gray, limy, locally sandy; partly carbonaceous.....	11	
27. Sandstone, buff, medium- to thin-bedded, crossbedded.....	28	
26. Bone (Chesterfield horizon).....	1¼	
25. Sandstone, medium-bedded to massive; forms ledge; buff in lower part; light gray near top.....	17	
24. Shale, medium-gray; upper 3-4 ft very sandy.....	23	
23. Sandstone, buff, medium to thin bedded, in small part shaly.....	36	
22. Bone, carbonaceous shale, and coal.....	1¾	
21. Sandstone, buff to gray; shaly in lower part..	15	
20. Sandstone, buff to light-gray, massive, cross-bedded, forms ledge.....	2	
19. Shale and sandstone, variable; shale, medium-gray to brown, carbonaceous; sandstone, thin-bedded, buff to gray; locally carries 6-in. bone layer 15 ft below top.....	21	
18. Sandstone, buff to gray, thin- to medium-bedded; lower part limy and shaly.....	11	
17. Bone.....	½	
16. Sandstone, limy and shaly, buff to gray....	6	
15. Shale, carbonaceous, with a little bone and coal (Palisades zone).....	6	
14. Sandstone, massive and light gray to thin-bedded and buff yellow; upper 6 ft shaly..	15	
13. Bone.....	¾	
12. Shale, medium-gray.....	3½	
11. Sandstone, gray, buff, and brown, medium- to thin-bedded, crossbedded; upper part varies from firm to shaly sandstone.....	15	
10. Shale, carbonaceous, black to brown, with a little bone.....	2½	
9. Sandstone, buff to gray, medium- to thin-bedded; locally shaly in upper part.....	6	
Total Neslen formation.....	386	

## Sego sandstone:

8. Sandstone, buff to light-gray, thin-bedded to massive, crossbedded.....	30
7. Sandstone, buff to brown, massive; forms minor ledge.....	8
6. Sandstone, shaly, thin-bedded; forms slope; brackish-water and marine invertebrate fossils in limy layers 38 ft above base (13687).....	64

## No. 17. Section measured in and near canyon of Westwater Wash, Utah—Continued

Sego sandstone—Continued		Feet
5. Sandstone, massive.....	66	
4. Sandstone, buff-gray, thin-bedded; partly concealed.....	44	
Top Sego sandstone.....	212	

## Buck tongue of Mancos shale:

3. Shale, gray; largely concealed by wash; carries a few lenses of limestone and limy sandstone.....	338
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## Castlegate sandstone:

2. Siltstone, buff, crossbedded; in beds 2-8 in. thick separated by gray shale (20 percent); upper 2-4 ft consists of very fine-grained buff to brown crossbedded massive sandstone forming narrow dip-slope bench; lower beds carry a few limestone lenses.....	72
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## Gradational contact.

## Mancos shale:

1. Shale, gray; upper part largely concealed by debris.	
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## No. 18. Stratigraphic section from the top of the Mancos shale to base of Green River formation near West Salt Creek, Colo.

(From top of Mancos shale to top of Sego sandstone by C. E. Erdmann, near Carbonera, Colo.; section from top of Sego sandstone to top of highest Carbonera coal by G. B. Richardson (1909, p. 34-35), near Carbonera, Colo., from top of highest Carbonera coal to base of Green River formation by C. E. Erdmann. This latter section begins at N.E. cor. SW¼ sec. 18, T. 7 S., R. 103 W., and ends in sec. 4, T. 7 S., R. 103 W.)

## Tertiary

Green River formation:		Feet
Douglas Creek member:		
124. Sandstone, buff, limy; bears an abundance of ostracodes and algal structures, interbedded with gray-green lacustrine shales, which predominate..	50	

## "Wasatch" formation:

123. Shale, clay, sandy, dark, greenish, tough. Breaks into cleavage pieces one-fourth of an inch in diameter.....	10
122. Shale, clay, variegated red and gray....	20
121. Slope, concealed. Probably underlain by gray clay shale.....	30
120. Shale, clay, variegated greenish-gray and red; hackly cleavage flakes ¼-½ in. in diameter.....	35
119. Shale, clay, brick-red, dull.....	20
118. Shale, clay, gray.....	25
117. Sandstone, gray, fine-grained, micaceous with some black minerals; thin-bedded, ½-1 in. Some slabs covered with limonite pseudomorphs after pyrite. Ferruginous concretions present. Irregular bedding causes apparent unconformity with bed below.....	4

No. 18. Stratigraphic section from the top of the Mancos shale to base of Green River formation near West Salt Creek, Colo.—Continued

"Wasatch" formation—Continued	Feet
116. Conglomerate, limestone pebble; pebbles $\frac{1}{8}$ –1 in. diameter (average one-fourth of an inch), well rounded. Matrix is gray fine-grained sandstone of sugary texture; estimated composition: quartz, 60–70 percent; limy material, as cement (?), 30 percent; dark minerals, mica, jasper (?), pyrite..... $\frac{1}{8}$ –1	
115. Shale, clay, soft gray-green and olive....	45
114. Shale, clay, light gray-green.....	47
113. Shale, clay, green, dull; cleaves into platy pieces $\frac{1}{8}$ – $\frac{1}{4}$ in. in diameter.....	15
112. Shale, clay, drab-green to gray. Contains few pebbles.....	20
111. Shale, clay, light-green.....	15
110. Shale, clay, slate-colored.....	25
[Note: The 145 ft of soft shale above makes a slope that is in large part covered with red soil wash from above.]	
109. Shale, clay, soft, yellow-brown and green variegated. There is no sharp line of division between any of these beds.....	25
Total "Wasatch" formation.....	340
Tertiary(?)	

Unnamed sandstone:

108. Sandstone, gray, medium-grained, impure, arkosic.....	13
107. Sandstone, gray, medium-grained, impure, arkosic. Contains lenses of clay, and chert pebble conglomerate like those below, ranging from 3 in. to 1 ft in thickness.....	7
106. Shale, clay, gray-green to black. Cleaves into small hackly fragments ( $\frac{1}{4}$ – $\frac{1}{2}$ in.). Makes slope. Beds generally concealed.	27
105. Sandstone, gray, becoming lighter toward top; much of unit is splotted with light greenish yellow; massive, beds 5–10 ft thick; crossbedded, false bedding surfaces dip 0°–20°; medium grained; average diameter 0.01 in.; arkosic. Estimated composition: quartz, 65 percent; weathered feldspar, 20 percent; dark minerals, some probably hornblende, 15 percent. Small pimply, concretionary structures on weathered surfaces, finer and more numerous, and with the same relation to the bleached spots as in the rocks below. At 31½ ft above base is a zone of very hard, compact, oblate, spheroidal fine-grained sandstone concretions, the fresh surfaces of which show many small flashing points. Estimated composition of concretions: quartz, 60 percent; undecomposed feldspar, 25 percent; dark minerals, 15 percent (small fragments of hornblende, larger brownish fragments of chert; and a few red and green grains of jasper or chert).....	70

No. 18. Stratigraphic section from the top of the Mancos shale to base of Green River formation near West Salt Creek, Colo.—Continued

Unnamed sandstone—Continued	Feet
104. Shale, clay, sandy, gray. A few thin 1-in. layers of platy sandstone 30 ft above base. Slope surface washed over with sand from above.....	43½
103. Shale, clay, gray, with slight greenish cast toward top; marked by splotches of yellow ferruginous sand $\frac{1}{8}$ –1 in. in diameter; cleavage fragments small, irregular and friable; 45 ft above base is 3-ft ledge of buff arkosic sandstone, with pronounced pimply concretionary structure on weathered surfaces; 20 ft above base is a 2-ft ledge of massive brown fine-grained arkosic sandstone.....	48
102. Sandstone, massive, 10- to 15-ft beds, brown to buff; lower 20 ft is lighter than upper part; medium-sized poorly rounded grains average 0.01–0.02 in. in diameter; arkosic; friable, crossbedded. Estimated composition: quartz, 60 percent; weathered feldspar, 30 percent; dark minerals, 10 percent; a few flakes of muscovite. Pronounced pimply, concretionary surface on weathered faces, the small gray pimples about one-eighth of an inch in diameter and standing out as bleached spots against the brown background....	60
101. Brush-covered slope. Probably formed on thin sandstone beds alternating with shale layers.....	27
100. Shale, clay, sandy, gray. Passes eastward into conglomeratic sandstone that is gray buff slightly mottled with white, massive, coarse grained, arkosic, soft, and friable. Ferruginous concretions $\frac{1}{4}$ –1½ in. in diameter. Pimply concretions on weathered surfaces. Estimated composition: quartz, 60 percent; weathered feldspar, 30 percent; dark minerals, 10 percent; small amount of clastic mica. Upper 3 ft is thin bedded and platy.....	18
99. Sandstone and mud-ball conglomerate, sandstone predominating; conglomerate tends to overlie sandstone; both facies change laterally rapidly into shale.....	0–2
98. Shale, clay, sandy, soft, gray-brown.....	11
97. Sandstone, brown to buff, hard, medium-grained, arkosic. Two feet thick where section was taken. Grades east into 3- to 4-ft massive bed of brown sandstone at 50 ft; to west into mud-ball conglomerate of underlying bed.....	1–4
96. Shale, clay, sandy, gray-brown, soft; breaks into cleavage fragments, $\frac{1}{4}$ – $\frac{1}{2}$ in. long. Grades upward into fine-cleaving yellow shale, and laterally (50 ft to west) into hard mud-ball conglomerate.	10
95. Sandstone, brown, soft; gray on weathered surfaces.....	2

No. 18. *Stratigraphic section from the top of the Mancos shale to base of Green River formation near West Salt Creek, Colo.—Continued*

Unnamed sandstone—Continued		Feet
94. Conglomerate, mud-ball; matrix light brown to gray, with mottled red and yellow spots (clay balls); some carbonaceous matter present; rock compact and hard. Clay balls make up 20 percent of mass, diameter $\frac{1}{4}$ –1 in.; a few well-rounded chert and quartz pebbles, $\frac{1}{8}$ – $\frac{3}{4}$ in. in diameter and numerous ferruginous concretions. Casts of unios abundant, especially at top, occurring in all positions and at all angles with respect to horizontal; external casts of shells generally deformed.....		2½
93. Sandstone, brown, slightly streaked with gray, medium-grained. Estimated composition: quartz, stained by iron oxide, 70 percent; chert, 20 percent; weathered feldspar, 10 percent.....		4½
92. Shale, clay, gray, concealed.....		5
91. Sandstone, buff to brown, massive, soft, fine-grained. Estimated composition: quartz, 80 percent; feldspar, often concealed, 10 percent; dark minerals, 10 percent.....		20
90. Conglomerate, chert pebble, massive, coarse, compact, strong; mottled gray, yellow, and black; cement yellow fine-grained ferruginous sandstone. Varies considerably from place to place; at one locality it was a medium-coarse-grained sandstone. Estimated composition: quartz, 70 percent; chert, 30 percent. Pebbles all well rounded, from $\frac{1}{4}$ to $1\frac{1}{2}$ in.; a very few 6-in. quartzite cobbles. General composition: chert predominant, black, blue, gray, green, white and banded; quartz common; clay or shale, common; white limestone, rare; jasper, one example.....		9
Total unnamed sandstone.....		380

Unconformity.

Upper Cretaceous—Mesaverde group

Hunter Canyon formation:

89. Sandstone, brown, massive, medium- to coarse-grained. Estimated composition: quartz, subangular grains stained brownish-yellow, 80–90 percent; small amount of chert and coaly matter present. Small ( $\frac{1}{8}$ – $\frac{1}{4}$ in.) white pimply concretionary structures on weathered surfaces.....	5
88. Shale, clay, gray. Largely concealed on slope. Thin ledge of sandstone 24 ft above base.....	44

No. 18. *Stratigraphic section from the top of the Mancos shale to base of Green River formation near West Salt Creek, Colo.—Continued*

Hunter Canyon formation—Continued		Feet
87. Sandstone, massive, cliff-forming; grayish brown on weathered surfaces; gray (salt-and-pepper) on fresh surfaces; medium to coarse grained, diameter of grains averaging 0.01–0.03 in.; arkosic; beds 1–6 ft thick. Estimated composition: quartz, 70 percent; feldspar, 15 percent; dark minerals, 15 percent. Pimply concretions on weathered surfaces very numerous and larger than those rocks below, maximum diameter being 0.01 in.; roughly outline false bedding laminae, which slope at angles of 15°–20° between the true beds. Some ferruginous concretions scattered irregularly.....		40
86. Shale, clay, gray-purple; gray towards top; largely concealed.....		23
85. Sandstone, gray-buff, medium-fine-grained, massive, arkosic. Small pimply concretions on surface.....		13
84. Shale, clay, gray. Concealed.....		28
83. Sandstone, massive; weathered surface brown to buff, with numerous small pimply concretions in relief; fresh surface light gray (salt-and-pepper); medium fine grained averaging 0.01 in. in diameter; arkosic. Estimated composition: quartz, 65 percent; feldspar, 20 percent; dark minerals, 15 percent. False bedding laminae dip as much as 20°.....		10
82. Shale, sandy, gray, fine-grained.....		12
81. Sandstone, buff, massive. Pimply concretions on weathered surfaces.....		10
80. Shale, clay, gray, with some carbonaceous material; contains thin interbedded gray sandstone beds. Largely concealed on slope.....		15
79. Sandstone, brown to buff, medium-grained, massive, crossbedded, arkosic; contains large ferruginous concretions. Small pimply concretions on weathered surfaces.....		33
78. Shale, clay, interbedded with thin sandstone beds; some carbonaceous material. Largely concealed on slope.....		60
77. Sandstone, massive, brown to buff; medium-grained, 0.01 to 0.02 in. in diameter; arkosic. Some low-angle false bedding. Pimply concretions on weathered surfaces.....		50
76. Sandstone, brown to buff, medium-grained, arkosic. Largely concealed.....		10
75. Sandstone, brown to buff, medium-grained, massive, with some false bedding. Small pimply concretions on weathered surfaces.....		14
Total Hunter Canyon formation.....		367

No. 18. Stratigraphic section from the top of the Mancos shale to base of Green River formation near West Salt Creek, Colo.—Continued

Mount Garfield formation:	Feet
74. Shale in slope; largely concealed and probably interbedded with thin-bedded sandstone.....	25
73. Sandstone, buff, fine-grained, massive but thinly laminated; dark grains conspicuous.....	13
72. Shale, gray; interbedded with thin-bedded sandstone beds. Largely concealed on slope.....	8
71. Sandstone, buff, thin-bedded (1-2 in.), fine-grained, arkosic, micaceous.....	5
70. Sandstone, buff, medium-grained (0.2 in. average diameter), massive, arkosic. Grains all well rounded. False bedding marked by small pimply concretions on weathered surfaces. True beds 2 in. to 1 ft thick. Estimated composition: quartz, 70 percent; feldspar, 15 percent; dark minerals, 15 percent; some mica; less iron oxide than in beds below, only a few ferruginous concretions present..	9
69. Shale, clay, gray, containing thin lenses of sandstone. Largely concealed on slope.....	51
68. Sandstone, yellow-buff, medium- to fine-grained, arkosic, massive, soft, with fluviatile crossbedding. Brown weathered surfaces covered with small pimply concretions.....	12
67. Shale, clay, containing thin lenses of sandstone; slightly carbonaceous. Largely concealed on slope.....	100
66. Sandstone, buff, medium-grained (0.01 in. in diameter), massive, arkosic, cross-bedded; contains ferruginous concretions.....	12
65. Shale, clay, purplish-gray; interbedded with thin irregular buff sandstone beds; often several layers finger together to form a single massive bed; slightly carbonaceous. Generally concealed on slope.....	46
64. Sandstone, buff, very fine-grained (averaging diameter 0.003-0.004 in.), massive. Basal bed is 15 ft thick; asymmetric current and ripple markings; crossbedding, some much contorted, probably owing to subaqueous slumping. Ferruginous concretions (1 in.) on bedding surfaces. Estimated composition: quartz, 60 percent; weathered feldspar, 30 percent; dark minerals, 10 percent.....	50
63. Shale, clay, gray, largely concealed on slope.....	20

No. 18. Stratigraphic section from the top of the Mancos shale to base of Green River formation near West Salt Creek, Colo.—Continued

Mount Garfield formation—Continued	Feet
62. Sandstone, buff, medium- to fine-grained, arkosic, massive, locally crossbedded. Shaly partings and thin-bedded sandy layers occur between heavier beds. A 5-ft shale lens occurs near middle. More iron oxide and fewer dark minerals in bed below. Mud lumps (1-2 in.) near base. Changes laterally from very massive to thin-bedded sandstone..	46
61. Shale, carbonaceous, gray. Thin band (3-4 in.) of coaly material occurs 1 ft 6 in. from base, and contains a 1-in. layer of shaly sandstone. Seamed with irregular secondary veins of gypsum....	4¾-7
60. Sandstone, buff, massive; dark minerals concentrated in bunches.....	6
59. Shale, gray, clay.....	9½
58. Sandstone, buff, arkosic, platy and thin-bedded.....	2
57. Sandstone, buff, arkosic, massive. Four feet from base is 2-ft 3-in. zone of calcareous sandstone containing some carbonaceous matter.....	10
56. Shale, clay, gray. Two sandstone layers (2-3 ft) occur at 10 and 20 ft above base, and from 20-35 ft above base is a bed of gray carbonaceous clay shale..	44
55. Sandstone, gray-buff, medium-fine-grained arkosic, massive. Estimated composition: quartz, 50 percent; feldspar, 35 percent; dark minerals (hornblende?), 15 percent.....	5
54. Shale, gray, clay, slightly carbonaceous. Makes slope and weathers to gray-brown soil.....	8
53. Sandstone, massive (beds 2-3 ft thick, with thin clay partings), medium-grained (0.01 in. in diameter), arkosic..	10
52. Shale, gray, clay.....	32
51. Sandstone, buff to brown, arkosic, massive (beds 3-6 ft); contains some clastic mica. Grain slightly coarser than in beds below, and rock is more ferruginous, with nodules of iron carbonate along bedding and base.....	18
50. Shale, gray, clay.....	10
49. Sandstone, buff to brown, medium-fine-grained, arkosic, micaceous, ferruginous, massive; some crossbedding.....	9½
48. Shale, gray, clay.....	10
47. Sandstone, brown to buff, massive. Like those above and below, only more crossbedded.....	13
46. Shale, gray, clay.....	2

No. 18. Stratigraphic section from the top of the Mancos shale to base of Green River formation near West Salt Creek, Colo.—Continued

Mount Garfield formation—Continued	Feet
45. Sandstone; brown to buff on weathered surfaces; light buff on fresh surfaces; medium fine grained; massive; contains carbonaceous matter and small carbonate nodules scattered indiscriminately; crumpled crossbedding near top. Estimated composition: quartz, stained with limonite, 50 percent; weathered feldspar, 30 percent; hornblende, 20 percent..	13
44. Shale, gray, clay.....	7
43. Sandstone, fine-grained, arkosic, thin-bedded.....	4
42. Shale, gray, clay, slightly carbonaceous..	10
41. Sandstone, light-brown, fine-grained, slightly ferruginous, arkosic, thin-bedded; contains casts of plant stems and mud balls.....	4½
40. Shale, clay, carbonaceous.....	3
39. Shale, chocolate-gray, clay; contains some carbonaceous matter.....	25
38. Sandstone, buff (with thin white streaks), fine-grained, arkosic; massive (with some thin-bedded layers). At the horizon near Carbonera, Richardson collected <i>Unio</i> sp., <i>Vivipara</i> sp., <i>Goniobasis</i> sp., and <i>Tulotomops thompsoni</i> .....	13½
37. Shale, clay, carbonaceous, locally sandy. A 10-in. bed of ferruginous sandstone occurs 12 ft above base.....	39%
36. Sandstone, buff, fine-grained, arkosic, thin-bedded (4–6 in.).....	5
35. Sandstone, buff, fine-grained, arkosic, massive (2 ft beds).....	5
34. Shale, clay, ferruginous.....	4½
33. Sandstone, buff, fine-grained, arkosic, massive (in 3 beds with thin shaly partings).....	15
32. Sandstone, buff, somewhat clayey, medium-grained, arkosic, thin-bedded....	2
31. Sandstone, buff, medium-grained, arkosic, massive.....	8
30. Shale, carbonaceous, platy and thin-bedded; a few seams of bony coal and mineral charcoal; less carbonaceous and more sandy toward top.....	3½
29. Carbonera coal group (Richardson's section down to top of Sego sandstone):	
Coal.....	3½
Shale, carbonaceous.....	2
Sandstone, buff.....	10
Coal.....	3½
Shale, carbonaceous.....	3
Sandstone, buff.....	8
Coal and bone.....	2
28. Sandstone, buff, thin-bedded, and shale..	35
27. Sandstone, buff.....	5
26. Sandstone, buff, thin-bedded, and shale..	20
25. Cameo coal horizon (?). Coal.....	2

No. 18. Stratigraphic section from the top of the Mancos shale to base of Green River formation near West Salt Creek, Colo.—Continued

Mount Garfield formation—Continued	Feet
24. Shale, carbonaceous.....	2
23. Shale, dark, sandy.....	10
22. Sandstone, buff.....	5
21. Shale, carbonaceous.....	15
20. Sandstone, buff.....	2
19. Shale, drab.....	3
18. Sandstone, buff.....	7
17. Shale, carbonaceous.....	18
16. Sandstone, buff.....	7
15. Shale, drab.....	3
14. Sandstone, buff.....	10
13. Shale, carbonaceous.....	2
12. Sandstone, buff.....	25
11. Shale, carbonaceous.....	3
10. Sandstone, shaly.....	5
9. Shale, carbonaceous.....	5
8. Sandstone, buff.....	10
7. Shale, drab.....	15
6. Sandstone, shaly.....	10
5. Palisade coal zone:	
Coal.....	½
Shale, carbonaceous.....	2
Sandstone, shaly.....	20
Shale, carbonaceous.....	3
Coal.....	½
Shale, carbonaceous.....	1
Coal.....	½
Shale, carbonaceous.....	1
Sandstone, buff, shaly.....	2
Shale, carbonaceous.....	4
Coal.....	2
Shale, carbonaceous.....	5
Total Mount Garfield formation..	1, 047
Sego sandstone:	
Upper unit:	
4. Sandstone, gray, white, thin-bedded, with partings of sandy shale.....	10
3. Sandstone, brown to buff, massive; some crossbedding present. Small oval ferruginous concretions are conspicuous....	55
2. Anchor Mine tongue of Mancos shale: Sandstone, brown to light-buff, thin-bedded (1–4 in.), irregularly bedded. Partings between sandstone beds are drab shale. Films of carbonaceous matter conspicuous; mud pellets plentiful. Shaly character so typical along front of cliffs is largely lost.....	67
Lower unit:	
1. Sandstone, massive, buff to brown.....	60
Total Sego sandstone and Anchor Mine tongue.....	192
Mancos shale.	

No. 20. Stratigraphic section from the base of the top of Mancos shale to the Green River formation in canyon of Salt Wash, Colo.

[Section begins in secs. 7 and 8, T. 7 S., R. 101 W., and extends to NE. corner sec. 12, T. 8 S., R. 102 W. From Cameo coal downward, section was measured in sec. 30, T. 8 S., R. 101 W. From top of Mancos to top of sandy member of "Wasatch" measurements by hand levelling; from base of "Wasatch" to base of Green River formation measurements by aneroid barometer. Measured by C. E. Erdmann]

## Tertiary

## Green River formation:

## Douglas Creek member:

117. Clay shale, greenish-gray-----	10+
116. Limestone, gray-white, sandy; some layers thinly laminated, others crystalline; contains a few ostracodes---	10

## "Wasatch" formation:

115. Shale, clay, light-gray-----	55
114. Shale, clay, varigated red, dull, brick-red and gray. Thickness of beds ranges from 5 to 30 ft-----	380
113. Sandstone, gray-buff, soft and friable, like No. 106-----	18
112. Clay, gray, washed over with dull red--	10
111. Limestone, gray, fresh-water; weathers brown. Coiled gastropods and <i>Unio</i> fragments common-----	1
110. Shale, clay, brick-red, dull-----	30
109. Shale, clay, drab-gray; some red-----	30
108. Shale, clay, brick-red, dull-----	30
107. Shale, clay, drab-gray, washed over by dull brick-red-----	40

Total "Wasatch" formation---- 594

## Tertiary(?)

## Unnamed sandstone:

106. Sandstone, coarse-grained, thin-bedded; pockets of clay-pellet conglomerate totaling 3 ft in thickness, containing pebbles of limestone. Casts of <i>Unio</i> shells abundant-----	6
105. Sandstone, gray-buff; fresh surface tan; soft and friable, medium grained; weathers into rounded forms; makes cliff. Estimated composition: quartz, 65 percent; weathered feldspar, 20 percent; dark minerals, 15 percent---	15
104. Shale, clay, gray, dull, gray-green with a few purplish-gray bands; some dull maroon clay-----	25
103. Shale, clay, purplish with red streaks--	2
102. Shale, clay, light-gray with greenish tinge-----	23
101. Shale, clay, gray-green to field-gray; dull; contains a few thin layers of platy sandstone-----	35
100. Sandstone, gray, coarse-grained; grades downward into bed below-----	20
99. Sandstone, gray-brown; contains pockets of conglomerate, with limestone pebbles more numerous than in beds below; ferruginous concretions common-----	6

No. 20. Stratigraphic section from the base of the top of Mancos shale to the Green River formation in canyon of Salt Wash, Colo.—Continued

## Unnamed sandstone—Continued

Feet

98. Sandstone, coarse-grained, conglomeratic; carries stringers and layers of chert pebbles. Some crossbedding of torrential type; false laminae dip E. 10° ±-----	20
97. Conglomerate-----	0-½
96. Conglomerate and conglomeratic sandstone; lower layer has matrix of coarse-grained gray sand, in which are embedded smooth, well-rounded pebbles of black, gray, yellow, and reddish chert, not exceeding 2 in. in diameter; also flattened pebbles of white limestone, lumps of gray and dull green clay, lenses of coarse-grained brown sandstone; grades upward into a sandstone whose channeled top carries lenses of brown conglomeratic sandstone-----	4

Total unnamed sandstone----- 156

## Unconformity.

## Upper Cretaceous—Mesaverde group

## Hunter Canyon formation:

95. Sandstone; weathered surface cream tan; fresh surface light gray, coarse grained (0.02 in.), massive, cliff-forming; contorted crossbedding; thin layer clay-ball conglomerate at top, some balls being 4 in. long, 2 in. thick. Estimated composition: quartz, 50 percent; feldspar, 30 percent; dark minerals, 30 percent-----	15
94. Shale, gray-purplish; carbonaceous; top channeled-----	1±
93. Sandstone, buff, soft-----	5
92. Sandstone, gray, thinly bedded; some shale-----	25
91. Sandstone, gray-drab, thinly bedded (one-fourth of an inch), platy, shaly; grades up into sandy, platy gray shale, with films of carbonaceous matter on bedding surfaces-----	20
90. Sandstone, gray, coarse-grained, soft--	10
89. Sandstone, gray-tan, soft, friable, massive, cliff-forming; grain diameter averages 0.01 in. Estimated composition: quartz, 75 percent; feldspar, 18-20 percent; dark minerals, 0-8 percent, usually gathered in clusters. Small concretionary forms weather into relief on exposed faces, maximum diameter 0.08 in.; distribution averages 60-75 per square inch of surface; appear white (light gray) on freshly broken surfaces, giving rock a mottled appearance, probably owing to local cementation by silica-----	18



No. 20. Stratigraphic section from the base of the top of Mancos shale to the Green River formation in canyon of Salt Wash, Colo.—Continued

Hunter Canyon formation—Continued		Feet
88. Shale; weathered surface clayey; gray at top; dull green to olive-drab near base.....		44
87. Coal, platy black lignite 6 in. thick, underlain by 6-in. carbonaceous shale.....		1
86. Shale, clay, green to olive-drab, dull.....		25
85. Sandstone, massive, cliff-forming; as a whole gray buff with some buff and red browns, fresh surfaces grayish; upper few feet are thinly bedded (6-8 in.) and irregular, contain pockets of coarse-grained brown to greenish-drab sand, which exhibit stem impressions, and rounded lumps of chocolate-brown to black carbonaceous clay; remainder is coarse grained (diameter averaging 0.02 in.); rock soft and friable; much loose sand on outcrops. Estimated composition: quartz, grains subangular and dull, 70 percent; feldspar, grains broken along cleavages, dull white to tan, 20 percent; dark minerals (hornblende?) irregularly distributed, some cleavage fragments, 5-10 percent; a few grains of a red jasperlike material. Joint blocks on vertical cliff assume rounded forms on weathering. Vertical cliff on north wall of head of second west tributary to Salt Wash above Buniger ranch shows an erosional unconformity near middle of unit.....		58
84. Shale, drab to dark-gray; contains some beds of thin sandstone and sandy shale; weathers to slope with clayey surface.....		81
83. Sandstone, weathered surface gray buff with some browns and reds; fresh surface brownish gray; medium to coarse grained, soft and friable, arkosic. Lower 10 ft concealed; joint blocks in upper 35-ft cliff weather into rounded forms; solution cavities also present....		50
82. Shale, gray, with some soft thin-bedded sandstone; makes slope.....		55
81. Sandstone, gray, arkosic, massive. Like No. 80.....		56
80. Shale, gray; makes slope; mostly covered..		20
79. Sandstone, gray, arkosic, massive; makes ledge, and weathers into rounded mushroom forms.....		20
[Note: In general the sandstone beds above and including bed No. 79 appear to be somewhat lighter in color than those below. The difference seems to be due chiefly to the lack of red browns, yellows, and their combinations form the weathered surfaces.]		

No. 20. Stratigraphic section from the base of the top of Mancos shale to the Green River formation in canyon of Salt Wash, Colo.—Continued

Hunter Canyon formation—Continued		Feet
78. Slope, covered; probably thin-bedded sandstone and shale.....		15
77. Sandstone, gray-buff, coarse-grained, massive.....		10
76. Sandstone, thin-bedded, platy, intercalated with gray shale; makes slope; mostly concealed.....		30½
75. Sandstone, massive, cliff-forming; weathered surfaces buff to reddish brown; fresh surfaces gray (salt-and-pepper); crossbedding conspicuous, torrential type common; upper part weathers into mushroom forms. Some layers thickly speckled with small spherical ferruginous concretions (⅛-¼ in.), which may or may not conform with bedding. Locally the partings between the layers are more coarsely grained and contain numerous flattened mud-pellets whose maximum dimensions are 3 in. long, ¼ in. thick; these partings are very irregular; included beds thicken and thin and sometimes pass into a pocket filled with coarse sand and lumps of clay; carbonaceous matter and plant stems common on bedding surfaces. Across the gulch to the north, this sandstone is broken by a shale parting about 30 ft thick whose top is about 20 ft below top of this unit.....		115
74. Shale, gray, sandy.....		25
73. Sandstone, buff to yellow, medium-grained, impure, arkosic, cliff-forming; contains some mud pellets.....		8
72. Shale, gray, sandy.....		32½
71. Sandstone, buff to yellow-brown, medium-grained, thinly laminated, soft and friable, locally crossbedded, massive, cliff-forming; small concretions (by cementation) arranged parallel to bedding; less massive at top.....		25½
70. Shale, sandy, dull; color when fresh, lead gray with slight brownish tone; weathers into thin irregular flakes; bedding very thin at top; locally contains thin lenses of sandstone.....		55
69. Sandstone, buff to brown, massive, cliff-forming.....		21
68. Shale, sandy; ranges from light to dark gray; in thin irregular beds breaking into thin-edged hackly pieces.....		30
67. Sandstone, buff to brown, soft and friable, massive, cliff-forming, weathering into rounded forms.....		25½
66. Sandstone, gray, irregularly bedded, platy; lenses out into buff sandstone along outcrop.....		7

*No. 20. Stratigraphic section from the base of the top of Mancos shale to the Green River formation in canyon of Salt Wash, Colo.—Continued*

Hunter Canyon formation—Continued	Feet
65. Sandstone, massive, cliff-forming; weathered surface as a whole light yellow brown, in detail shows many shades of dark red brown, orange, and yellow; medium to coarse grained; thick bedded; thinly laminated; many irregularities in bedding. Large oval concretionary masses of fine- to medium-grained hard and dense gray sandstone in pockets on bedding surfaces; larger ones may be 8 ft long and 3 ft thick; weathers dark brown. A few lenses of soft gray sand fill shallow channels on bedding surfaces.....	52
64. Sandstone and sandy clay with lumpy forms; dull; bluish gray with greenish cast; some lead gray; in irregular and alternating beds; sandstone breaks with hackly fracture.....	10-15
63. Sandstone, massive, cliff-forming, coarse-grained; pinkish buff at base on weathered surfaces; some orange and yellow; irregular, thinly laminated false bedding. Ferruginous concretions (by cementation) up to 1½ in. diameter on bedding surfaces. Small pimply concretionary forms on weathered surfaces.....	21
62. Shale, sandy, clayey; weathered surfaces dull, lead gray and greenish gray; weathers into rounded, lumpy forms; locally contains thin lenses of sandstone and calcareous, concretionary material.....	7
61. Sandstone, massive, cliff-forming; weathered surfaces gray buff to brownish red; top noticeably gray; some yellow tones at base; fresh surfaces gray (salt-and-pepper); bedding heavy at base, less so toward top; individual beds thinly laminated, weathering into rounded forms; fluviatile crossbedding; pockety structures; coarse subangular grains, averaging 0.02 in. in diameter. Estimated composition: quartz, 80 percent; feldspar, 12 percent; dark minerals, 8 percent. Flattened mud pellets up to three-fourths of an inch in diameter. Small pimply concretionary forms on some weathered surfaces. In places along base, is 6-in. layer grading up into coarse-grained brown sandstone, containing numerous mud lumps and irregularly shaped hard limonitic concretions.....	18
Total Hunter Canyon formation.....	1, 012

*No. 20. Stratigraphic section from the base of the top of Mancos shale to the Green River formation in canyon of Salt Wash, Colo.—Continued*

Mount Garfield formation:	Feet
60. Shale, clay, gray; thin-bedded clayey sandstone in lower 5 ft.....	27
59. Sandstone, gray-buff, medium-grained, arkosic; thinner bedded at top; makes massive ledge.....	10
58. Shale, clay, gray.....	15
57. Sandstone, brown, massive.....	2
56. Shale, clay, gray.....	10
55. Sandstone, in thin beds (1 in to 1 ft); the hard massive layers are separated by the softer.....	11
54. Calcareous concretionary layer, gray to buff, hard, dense, with conchoidal fractures.....	1
53. Shale, clay, gray.....	1
52. Sandstone, light-brown, medium-grained, arkosic; a massive thinly laminated ledge; some false bedding; current marks.....	3½
51. Shale, clay, gray.....	44½
50. Shale, clay, gray; contains thin lenses of brownish sandstone that show current markings on bedding surfaces. Nearby a 5-ft lens of thin-bedded sandstone caps this unit.....	40
49. Sandstone, brownish-buff, medium-grained, thin-bedded.....	2
48. Shale, clay, gray.....	25
47. Sandstone, buff, medium-grained (maximum diameter 0.01 ± in.), massive, impure, arkosic, soft; thickness of beds ranges from 6 in. to 6 ft; weathers into rounded forms, and makes broken cliff; estimated composition: quartz, 75 percent; feldspar, 20 percent; others, 5 percent.....	33
46. Shale, clay, gray.....	20
45. Sandstone, buff, thin and platy; grades rapidly into massive ledge.....	7
44. Shale, clay, gray.....	15
43. Sandstone, light-brown, medium-grained, arkosic, crossbedded.....	2½
42. Shale, clay, gray, with a few thin sandstone lenses in lower half.....	55
41. Sandstone, gray, medium-grained, very thin-bedded (one-fourth of an inch), platy and irregular.....	1½
40. Calcareous concretionary layer, gray to buff, hard and dense with conchoidal fracture.....	½
39. Shale, clay, carbonaceous, dark gray....	2
38. Sandstone, light-brown, fine- to medium-grained, massive, thinly laminated; contains clastic mica; some carbonaceous material on bedding surfaces; current marks.....	2½
37. Shale, clay.....	6½

No. 20. *Stratigraphic section from the base of the top of Mancos shale to the Green River formation in canyon of Salt Wash, Colo.—Continued*

Mount Garfield formation—Continued		Feet
36. Shale, clay, gray; near middle of bed there is layer of coaly, chocolate-brown carbonaceous clay shale containing some woody and vegetable material; local burning at this horizon extends into the heavier burned area to the east.	15	
35. Sandstone, gray, medium-grained, cross-bedded.	2	
34. Shale, clay, gray, slightly sandy, locally carbonaceous; weathers into angular granules and making slope.	48	
33. Sandstone, massive, cliff-making; weathers buff; fresh color gray (salt-and-pepper) with slight brownish tone; medium grained (average diameter 0.01 in.); thinly laminated, with fluvatile crossbedding. Upper 5 ft thin bedded (8 in.). Estimated composition: quartz, 20 percent; light-gray weathered feldspar, 52 percent; weathered brown grains, probably feldspar, 20 percent; dark minerals, 8 percent. Small mud lumps rare.	15	
32. Shale, clay, dark-gray; weathers purplish gray; carbonaceous, somewhat sandy; contains a few thin, platy, brown sandstone beds near middle.	25½	
31. Sandstone, brown, slightly burned, thin-bedded; contains mud lumps. A few hundred feet to the east the burning extends upward about 75 ft.	5	
30. Sandstone beds, burned dull brick red.	2	
29. Shale, clay, gray, with layer of platy brown sandstone at middle.	20	
28. Clinker of burned sandstone and shale.	145	
27. Sandstone, bluish-gray to red, partly burned, fine-grained, dense, clayey; grades upward into clinker-covered slope. Top taken at approximate base of upper bench. Cameo coal, now burned out.	10	
26. Lower bench of Cameo coal bed, partly burned, very sooty, with hard bony layers.	8	
25. Sandstone and shale in thin, platy, irregular alternating layers.	5	
24. Shale, sandy, light-ash-gray, platy.	2	
23. Sandstone, brown, thin and platy.	3	
22. Shale, carbonaceous, gray, platy.	3	
21. Shale, carbonaceous, black, platy.	2	
20. Sandstone, gray-white, quartzose, slightly carbonaceous, usually massive, but may have gray shale parting near middle.	20	
19. Sandstone and shale in alternating beds; sandstone usually light gray (salt-and-pepper) to buff, medium grained; shale clayey, frequently carbonaceous, like		

No. 20. *Stratigraphic section from the base of the top of Mancos shale to the Green River formation in canyon of Salt Wash, Colo.—Continued*

Mount Garfield formation—Continued		Feet
that below, much of it sandy, or containing thin lenses of sandstone.		
Massive sandstone at base.		300
18. Palisade coal zone:		
Shale, highly carbonaceous, black and chocolate, with a few thin sandstone partings.		6¾
Shale, with sandstone nodules.		1½
Shale, clay, gray; sandy at top.		4½
Sandstone.		¾
Shale, carbonaceous, chocolate; contains seams of charcoal.		4½
Shale, clay, light-gray.		1½
Sandstone, shaly.		1½
Shale, gray, with sandstone nodules at top.		5½
Bone.		¾
Coal.		1½
Clay, white.		½
Coal.		1½
Shale, carbonaceous, chocolate.		1
Sandstone, gray.		¾-1
Shale, carbonaceous, chocolate.		¾
Total Mount Garfield formation.		1, 002
Sego sandstone:		
Upper sandstone member:		
17. Sandstone, brown, medium-grained, thin-bedded. Makes cliff.		20
Anchor Mine tongue of Mancos shale:		
16. Shale, chocolate, highly carbonaceous.		¾
15. Shale, light-chocolate, carbonaceous.		5
14. Sandstone, light-gray.		1
13. Shale, chocolate, carbonaceous.		5¾
12. Concretionary layer, calcareous and ferruginous.		1
11. Shale, carbonaceous, chocolate color.		11
10. Sandstone lens, gray, massive.		3¾-10
9. Shale, gray to brown, carbonaceous, mineral charcoal.		2¾
8. Clay, with sandstone nodules at top.		3
7. Anchor coal:		
Bone.		¾
Coal.		2½
Shale, carbonaceous, chocolate color.		¾
Bone.		¾
Coal.		1
6. Shale, carbonaceous, chocolate; weathers gray. Hard and dense, highly jointed. Grades laterally into sandy layer.		5
5. Shale, highly carbonaceous, laminated, chocolate; plant remains.		1
4. Shale, carbonaceous; seams of mineral charcoal.		¾
3. Shale, carbonaceous, light-chocolate; weathers gray.		6¾

*No. 20. Stratigraphic section from the base of the top of Mancos shale to the Green River formation in canyon of Salt Wash, Colo.—Continued*

	Feet
Sego sandstone—Continued	
Lower sandstone member:	
2. Sandstone, light-gray, fine-grained; massive beds with thin shaly partings----	25
1. Sandstone, light-gray, thin irregular beds.	15
Total Sego sandstone and Anchor Mine tongue.....	113

Mancos shale.

*No. 21. Type section of Hunter Canyon formation in Hunter Canyon, in secs. 20, 29, and 32, T. 8 S., R. 100 W., Colorado*  
[Measured by C. E. Erdmann]

Tertiary(?):

  Unnamed sandstone.

Unconformity.

Cretaceous:

  Hunter Canyon formation:

	Feet
28. Shale, gray, sandy, soft, containing thin beds (1-2 ft) of sandstone, which become thicker toward base.....	143
27. Sandstone, massive, medium-grained, gray	10+
26. Shale, gray, sandy, platy, but irregularly bedded, slightly calcareous. Bedding surfaces show current markings. Contains thin lenticular beds of sand, which have same general character.....	28
25. Sandstone, gray-white, medium-grained, massive. Bedding fairly uniform, but locally is cut by thin lenses of a more brownish sandstone.....	26
24. Sandstone (similar to bed next above) and lead-gray shale containing thinner lenses of sandstone, in alternating beds which vary in thickness from 25 to 40 ft. Just below highest sandstone bed, shale is dull and greenish-gray and contains a thin layer of chocolate-brown to black carbonaceous shale and about 4 in. of coal.....	144
23. Sandstone, gray (salt-and-pepper), medium-grained, cliff-forming, massive...	46
22. Shale, clay, gray.....	10
21. Sandstone, gray (salt-and-pepper), coarse-grained.....	15
20. Shale, clay, gray. Contains thin beds (1-3 ft.) of coarse-grained gray sandstone. About 120 ft. above base is a massive cliff-forming bed of medium-grained gray (salt-and-pepper) sandstone, 20-25 ft thick, which lenses out rapidly. Just below the sandstone bed shale is somewhat carbonaceous, but most is typically gray.....	235
19. Sandstone in thin beds (maximum 2 ft) interbedded with thin, platy sandy shale.....	30
18. Sandstone, massive. Upper 30 ft lighter in color and slightly coarser-grained than lower part, thinly laminated; cross-	

*No. 21. Type section of Hunter Canyon formation in Hunter Canyon, in secs. 20, 29, and 32, T. 8 S., R. 100 W. Colorado—Continued*

	Feet
Cretaceous—Continued	
Hunter Canyon formation—Continued	
bedding well developed. Lower 10 ft composed of medium-grained gray-buff quartz-feldspar sand with an admixture of ferruginous minerals; characterized by small mud pellets, and also contains many small spherical ferruginous concretions, whose maximum diameter is about 2 in. Near top are lenses or channels of varying shapes filled with a coarser grayer sand.....	40
17. Shale, sandy, lead-gray, with layer of black carbonaceous shale containing fragments of mineral charcoal on top..	6
16. Sandstone, thin-bedded, gray. These beds strike N. 45° W. and dip 5° NE., beds immediately below strike N. 75° W. and dip 3° N. This discordance is probably local and due to large scale crossbedding.....	3
15. Sandstone, gray to buff, massive, composed of impure quartz-feldspar sand. Some clastic mica over 0.02 in. in diameter. At base average size grain is about 0.01 in. Bedding uniform in general, though there is local crossbedding. Basal part contains large irregular fragments of poorly laminated sandy shale.....	34
14. Shale, sandy, gray; carbonaceous at top. Lenses out rapidly.....	2
13. Sandstone, thin-bedded, and sandy shale, intercalated. The rapid interchange of sandstone and shale is characteristic. Toward the base the beds of sandstone become thinner and more regular.....	93
12. Sandstone, light gray, massive, cliff-forming, impure, feldspathic. Near middle is thin layer of finely laminated dark-brown carbonaceous sandstone, with thin lenses of normal sandstone. Base is intricately crossbedded.....	17
11. Shale, lead-gray, thin, platy, carbonaceous. Contains woody remains and thin lenses of sandstone. Passes downward into thin-bedded sandstone.....	9-11
10. Shale, clay, gray.....	15
9. Sandstone, gray, coarse-grained, crossbedded, thin-bedded 11 in. at top. Shows a few thin limy layers.....	15
8. Shale, sandy, gray; contains many small irregular channels filled with a medium impure feldspathic sand, which is seamed with thin films of carbonaceous material.....	15
7. Sandstone, buff, coarse-grained, massive, cliff-forming. Contains thin layers of gray-green and crimson shale. Weathers into rounded forms, smooth pedestals, and turrets.....	30

No. 21. *Type section of Hunter Canyon formation in Hunter Canyon, in secs. 20, 29, and 32, T. 8 S., R. 100 W. Colorado—Continued*

Cretaceous—Continued	Feet
Hunter Canyon formation—Continued	
6. Shale, sandy, gray to gray-black. Nodular structure. Contains ferruginous concretions.....	30
5. Sandstone, coarse-grained, gray with rusty specks; weathers brownish black. Beds 12-16 in. thick, each uniformly cross-bedded, tangential type, dipping north.....	30
4. Shale, grayish to black; contains numerous thin irregular and lenticular layers of medium-grained grayish sandstone. Some are finer grained, dense, calcareous.....	35
3. Sandstone, gray, medium- to coarse-grained, specked with black and brown; weathered surfaces black to brown. Contains thin layers and lenses of greenish-gray sandy shale.....	25
2. Shale, gray to greenish-gray; contains thin lenticular gray sandstone which weathers brown. Just above base, 6-8 ft of greenish-gray shale is parted by a thin lens of crimson clay shale.....	40
1. Sandstone, gray to buff, medium-grained; in massive lenticular beds 30-50 ft thick, separated by partings of gray to gray-green sandy shale 2-6 ft thick. Some of these shale beds contain plant remains. Crossbedding is rare in basal part but common in upper third, where beds are less massive and are most intricately interbedded with the shale in channels, lenses, and pockets. In many parts, isolated lumps of shaly material appear to be enclosed in sandstone. Lateral irregularity of beds very marked. Weathered surfaces of crossbedded parts are alveolated. Base of strata of probably post-Laramie age is placed at base of this sandstone.....	300
Total Hunter Canyon formation.....	1,427

Mount Garfield formation:

No. 22. *Stratigraphic section from top of Mancos shale upward to crest of Book Cliffs at Book Cliff mine, SW¼ sec. 8, T. 10 S., R. 99 W., Colorado.*

[Upper 1,000 ft measured by aneroid barometer; lower beds measured by hand leveling. Measured by C. E. Erdmann]

Upper Cretaceous—Mesaverde group:

Hunter Canyon formation (part):

60. Sandstones, light-gray to buff, thick-bedded, massive, cliff-forming; lenticular, pinching and swelling along outcrop; make up 85 percent of unit; intercalated light-gray shale constitutes remaining 15 percent.....	163
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No. 22. *Stratigraphic section from top of Mancos shale upward to crest of Book Cliffs at Book Cliff mine, SW¼ sec. 8, T. 10 S., R. 99 W., Colorado—Continued*

Upper Cretaceous—Continued	Feet
Hunter Canyon formation—Continued	
59. Alternating series of sandstone and shale; sandstone making up about 70 percent of unit. Sandstone massive, cliff forming, becoming more so toward top where sandstone is 40 feet thick; buff on weathered surfaces; light gray (salt-and-pepper) on fresh surfaces, medium grained, feldspathic; some thin layers of reddish carbonaceous sandstone and shaly sandstone with white or greenish spots. Gray clay shale more abundant at base where sandstone is thinner bedded. All beds are lenticular and vary considerably in thickness along strike.....	437
Total Hunter Canyon formation, part measured.....	600

Mount Garfield formation:

58. Non-coal-bearing rocks ("barren measures"): An alternating series. Sandstone, sandy shale, and clay shale, with 2 thin layers of brown carbonaceous shale near the middle and 1 near the top. Five principal beds of sandstone form massive ledges. They are about equally spaced, and lowest is at the base of the unit. Relatively thin-bedded in detail, layers being separated by thinner softer beds or by shaly partings. Some cross-bedding. Weathered surfaces reddish brown and have many solution pockets. Fresh surfaces gray to buff. Medium-grained throughout; grains are chiefly quartz, but some weathered feldspar and some ferromagnesian minerals are present. A few layers of arkosic sand present. Shale beds predominantly gray and contain varying amounts of sand and carbonaceous material, but only three beds contain much carbonaceous material. Many shale beds have a sharply defined base where they rest upon sandstone but grade upward into overlying sandstone.....	410
57. Coal-bearing rocks ("coal measures"):	
Shale, purplish-gray carbonaceous.....	5½
Sandstone, sandy shale, and gray shale.....	12
Shale, carbonaceous, with thin seam of bony coal 4 in. below top.....	28
Sandstone, medium-grained, massive, ledge-forming. Weathered surface buff; fresh surface gray. Small spherical ferruginous concretions. Some carbonaceous material. Crossbedding, in beds 2-4 ft thick, separated by thinner layers.....	15

No. 22. Stratigraphic section from top of Mancos shale upward to crest of Book Cliffs at Book Cliff mine, SW¼ sec. 8, T. 10 S., R. 99 W., Colorado—Continued

Upper Cretaceous—Continued		Feet
Mount Garfield formation—Continued		
56. Shale, clay, gray-----		21½
55. Shale, carbonaceous, with some bony coal-----		1
54. Shale, gray. Limy concretions at base, and large channel sandstone lenses toward top-----		11½
53. Shale, carbonaceous, with bony coal in middle-----		7½
52. Sandstone, light-gray, fine-grained; massive at base; thinner bedded and softer at top-----		9½
51. Shale, carbonaceous-----		6¾
50. Coal, bony-----		1½
49. Shale, carbonaceous-----		½
48. Sandstone, buff, thin-bedded, medium-grained, soft. Grades up into light-gray sandy shale-----		12
47. Shale, brown, carbonaceous-----		1¾
46. Coal, bony-----		¾
45. Shale, brown, carbonaceous-----		4¾
44. Coal-----		½
43. Shale, brown, carbonaceous-----		¾
42. Coal, bony-----		1½
41. Shale, carbonaceous, purplish- and chocolate-brown. Contains some gray shale and thin lenses of sandstone-----		44½
40. Concretionary layer, calcareous; red brown on weathered surface; bluish gray on fresh surface. Hard, dense, conchoidal fracture. Rests unevenly on shale surface below-----		2-3
39. Shale, clay, gray-----		13
38. Sandstone, medium-grained, massive; reddish brown on weathered surface; lighter on fresh surface. Contact with underlying shale uneven-----		4
37. Shale, purplish-brown, carbonaceous. Sandy lenses at top-----		14
36. Sandstone, brown, medium-grained; in thin irregular beds; crossbedded on small scale-----		4
Cameo coal zone:		
35. Coal, bony, with a few thin layers of carbonaceous shale-----		19¾
34. Shale, carbonaceous, with carbonaceous sandstone at top-----		1
33. Coal, bony, with few thin seams of good coal-----		1½
32. Shale, carbonaceous-----		8
31. Coal, bony-----		3¾
30. Shale, dark-brown to black, carbonaceous-----		1½
29. Coal, bony-----		4¾
28. Shale, purplish-gray, carbonaceous-----		1¾
Rollins sandstone member:		
27. Sandstone, massive, cliff-forming. Fresh surfaces grayish white to white; weathered surfaces light yellow gray and		

No. 22. Stratigraphic section from top of Mancos shale upward to crest of Book Cliffs at Book Cliff mine, SW¼ sec. 8, T. 10 S., R. 99 W., Colorado—Continued

Rollins sandstone member—Continued		Feet
brown, locally stained red or purplish by wash from Cameo clinker. Coarse grained and sugary in texture; 80-90 percent quartz and 10-20 percent dark minerals. Bedding thickest toward top. Crossbedding present throughout. Locally, at both top and bottom, are thin bands and lenses of purplish-brown carbonaceous shale containing fragments of carbonized wood and mud pellets. Upper part may also contain semispherical concretions of white sandstone 10-30 inches in diameter. Associated with them are numerous casts of <i>Halymenites major</i> -----		71
26. Slope, strata concealed. Probably shale or soft thin-bedded sandstone-----		14
25. Sandstone, medium-grained, crossbedded, massive, thin-bedded near base-----		10½
24. Shale, gray, interbedded with soft thin-bedded sandstone-----		44
23. Sandstone, light-reddish-brown, thin-bedded, flaggy. Plant remains-----		3
22. Shale, gray, carbonaceous. Some thin-bedded brown sandstone near base-----		30
21. Coal, subbituminous-----		1
20. Sandstone, grading up into purplish-gray carbonaceous sandstone-----		2½
19. Shale, purplish gray, carbonaceous. Grades into bed above-----		8½
18. Sandstone, micaceous. Grades upward into thin-bedded purplish-gray sandy carbonaceous shale-----		3¾
17. Sandstone; upper part cream colored; lower part buff; gray-white on fresh surfaces. Thin bedded, somewhat irregular. Crossbedding in upper part, which is separated from lower part by false bedding surface. Medium-grained, sugary texture. Solution pits, rounded forms on weathered surface-----		33
16. Sandstone, purplish-brown, dull, carbonaceous, in thin, irregular, gnarly beds, with some calcareous concretions near base. Thin lenses and stringers of gray crossbedded sandstone appear near top, and finally lenses of channel sandstones predominate. Lenses are ½ in. to 3 ft thick, width in proportion-----		29
15. Sandstone, medium-grained massive, arkosic, cliff-making; buff to tan on weathered surfaces, which have a corroded appearance. Evenly bedded, but a crossbedded layer appears 14 ft above base. Numerous irregular ferruginous concretions at top. Grades into overlying bed-----		33



No. 22. *Stratigraphic section from top of Mancos shale upward to crest of Book Cliffs at Book Cliff mine, SW $\frac{1}{4}$  sec. 8, T. 10 S., R. 99 W., Colorado—Continued*

Rollins sandstone member—Continued

- |  | Feet |
|--|------|
| 14. Sandstone, gray on fresh surfaces, in beds ranging from 10 in. to 5 ft in thickness, with shaly parting $5 \pm$ in. thick. Much of shale is carbonaceous. Sandstone laminae may be a quarter of an inch thick or more; shale laminae much thinner. All layers swell and pinch along outcrop. Topmost bed consists of intertongued sandstone and shale, locally channeled and filled by sands of overlying bed..... | 34   |
| 13. Shale, sandy; grades into bed above.....   | 9    |
| 12. Shale, carbonaceous, purplish. Contains sandy lenses, which become thicker and more numerous near top....  | 16   |

Palisade coal zone:

- |  |    |
|--|----|
| 11. Coal, subbituminous.....   | 2½ |
| 10. Shale, chocolate-brown, carbonaceous....   | 4  |
| 9. Coal.....   | 1½ |
| 8. Shale, gray. Limy lens near bottom....  | 14 |
| 7. Sandstone, gray, weathering tan, medium-grained, soft, friable, crossbedded; thin; irregularly bedded with shale, becoming more massive toward top..... | 13 |
| 6. Shale, light-gray, flaky.....   | 3½ |
| 5. Coal, subbituminous.....  | 1½ |
| 4. Shale, yellow-brown, sandy, carbonaceous, platy. Plant remains. Locally nodular. Becomes less sandy and more carbonaceous toward top.....               | 22 |
| 3. Coal, subbituminous.....  | ½  |
| 2. Shale, dark-brown to black, carbonaceous. Contains carbonized vegetal remains; resin, peppered with many small white grains of quartz sand.....         | ½  |

Total Mount Garfield formation.. 1,053

Sego sandstone:

- |   |    |
|---|----|
| 1. Sandstone, massive in general appearance, but thin-bedded on closer examination; some crossbedding developed on moderate scale; whitish gray with a buff tone, medium grained, of sugary texture, soft, friable. Largely quartz; gray tone given by ferromagnesian minerals; some red jaspery grains. Upper half corroded into small holes and niches. A few small ferruginous concretions near top..... | 31 |
|---|----|

Mancos shale.

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