gradually become less prominent in the basal part of the Cutler. The Cutler sandstones alternate with the sandy and limy shales, and are mostly less than 20 feet in thickness. The colors are pink or purplish in the coarser grits, while the finer sandstones are brick red. Cross-bedding is characteristic of many of the sandstones, and is particularly prominent in some because of the alternations of light and dark bands.

About 1450 feet above its base a series of very coarse, heavy conglomerates makes its appearance in the Cutler formation. These conglomerates contain well rounded boulders, a considerable number of which are as much as 6 to 10 inches in diameter; they consist largely of pre-Cambrian rocks, granites, schists, greenstones, and quartzites. The lower beds of conglomerate contain, however, many boulders of pitted limestone which appear to have been derived from the Ouray limestone.

TRIASSIC AND JURASSIC (?) SYSTEM

Dolores Formation

The base of the Dolores formation in the Ouray district is marked by an important unconformity, whereby the Triassic beds cut across the entire thickness of the inclined strata of the Cutler formation between the vicinity of Dexter Creek and the town of Ouray (Fig. 1). In the Amphitheatre east of Ouray the Dolores rests directly upon the Hermosa formation. It is not seen to rest upon any formation older than the Hermosa, but the structural conditions at the head of the Amphitheatre suggest that it may have rested upon much older beds, and possibly lay across the entire section of inclined Paleozoic beds.

The thickness of the Dolores formation in the district ranges from 40 to 100 feet, a difference possibly caused by the erosion which preceded the deposition of the overlying white sandstone of Jurassic age. The formation is composed of limestone-conglomerates, fine grained sandstones and shales, and impure limestones. The limestone-conglomerates lie mostly in the lower 30 feet of the formation, and comprise several beds or lenticular deposits from 1 to 10 feet in thickness. They are composed of pebbles of gray or reddish stained limestone ranging in size from 1/10 inch to 2 inches in diameter, cemented by red calcareous earthy material, and the basal conglomerate commonly contains small amounts of quartz pebbles and sand. The upper part of the formation consists of marls, sandy shales, and less commonly earthy limestones, nearly all of bright red color. Some of the limy beds near the top are variegated in red and gray colors, and in a few places a gray limy bed is present at the top, as in the lower Bachelor tunnel.

The age of the formation has been determined to be Triassic from fossils found at some localities in the limestone conglomerates in the lower part, but there is a possibility that the upper part may be Jurassic. Cross and Howe[12] state in the Ouray Folio:

> "No fossils of determinative value have been found in the Ouray quadrangle, although poorly preserved fragments of bone and teeth are abundant. Elsewhere teeth and bone fragments of a crocodile (Belodon) and of a megalosauroid dinosaur, (Palaeoctonus) have been found and are regarded by F. A. Lucas, who determined them, as of distinctly Triassic types."

JURASSIC SYSTEM

Upper (?) Jurassic Sandstone

The lower sandstone member of the "La Plata sandstone" of Cross[13] is not given a name in this report, but the correlation between the grouping now employed and that used in the Ouray folio is shown in the columnar section, Plate II-B.

This sandstone in the Ouray district ranges in thickness from 45 to 80 feet, is of a light buff or grayish color, and cross-bedding is more or less prominently developed. Except where it is locally altered to quartzite, the sandstone is soft and friable and of fine, even grain. It commonly stands in a massive or rounded cliff above the Dolores formation and in sharp contrast to the red colored rocks beneath

[12] Op. cit. p. 5.
[13] Ouray Folio, No. 153, p. 5.

it. The base of the sandstone is an important unconformity in the San Juan Mountains, although the evidence of this at Ouray is not conspicuous. Nevertheless, fragments of the Dolores are incorporated in it locally, and the variation in thickness of the Dolores formation is probably to be ascribed to erosion preceding the deposition of this sandstone. Clearer evidence of this erosion is given at Cow Creek, where the Jurassic sandstone rests directly upon the Cutler—the Dolores and probably a portion of the upper part of the Cutler having been removed by erosion.

As this formation and the beds immediately above it contain no fossils its age cannot be determined closely except by stratigraphic correlation with known sections in adjacent areas. According to a personal communication to the writer from J. B. Reeside of the United States Geological Survey, this sandstone of the Ouray district has been correlated[14] with the Entrada sandstone of southeastern Utah. The Entrada sandstone of the San Rafael Swell has been proved by Gilluly and Reeside[15], to be of Upper Jurassic age. However, until this correlation is published, the sandstone at Ouray is only tentatively assigned to the Upper Jurassic.

Cretaceous (?) System

LOWER CRETACEOUS (?) SERIES

Morrison Formation

The strata that lie between the top of the Jurassic sandstone and the base of the Dakota (?) sandstone are referred to the Morrison formation in this report, based upon the recent correlations made by Reeside, Baker, and Dane[16]. The Morrison formation is largely, if not entirely, of continental origin and in this area comprises the middle limestone and upper sandstone members of the "La Plata sandstone" of Cross and the entire thickness of the "McElmo"

[14]Baker, A. A., Dane, C. H., and Reeside, J. B., Jr., Correlation of the Jurassic formations of southeastern Utah, northeastern Arizona, northwestern New Mexico, and southwestern Colorado: U. S. Geol. Survey (report in preparation).

[15]Gilluly, James, and Reeside, John B., Jr., Sedimentary rocks of the San Rafael Swell and some adjacent areas in eastern Utah: U. S. Geol. Survey Prof. Paper 150-D, p. 78, 1928.

[16]Op. cit., personal communication from J. B. Reeside, Jr.

formation, as these two formations are defined by Cross and Howe in the Ouray Folio. (See Plate II-B). The thickness of the Morrison near Ouray ranges between 700 and 750 feet. As well as can be determined the Morrison formation at Ouray rests conformably upon the white sandstone of probably Upper Jurassic age.

Three lithologic members of the Morrison can be recognized in the district, a basal limestone, sandstone, and shale member, herein named the Wanakah member, a middle sandstone member, and an upper shale member. The stratigraphic limits of the Wanakah member are sharply defined, but the division between the sandstone and shale members is somewhat less definite. The three members will be described separately because of the economic importance of some of the beds with relation to the occurrence of ore.

Wanakah Member of the Morrison Formation

The strata that lie at the base of the Morrison formation are named the Wanakah[17] member in this report, from their exposures in the Wanakah mine. The Wanakah member is divisible into three lithologic units: a basal shale, limestone, and breccia (the "Pony Express beds"), a middle sandstone (upper sandstone member of the "La Plata sandstone" of Cross), and an upper shale division (the basal part of the "McElmo" of Cross).

"Pony Express Beds."—The "Pony Express beds" of the Wanakah member, so called from their occurrence in the Pony Express mine, are one of the important ore-bearing horizons in the sedimentary rocks, and are commonly known to the miners as the "Pony Express limestone" and the "Pony Express contact." They include all of the beds that lie between the lower and upper sandstone members of the "La Plata sandstone" of Cross. They range in thickness from one foot to 60 or 70 feet, but are commonly from 8 to 15 feet thick. The typical development in the Ouray district consists

[17]The name Wanakah has also been used for certain Middle Devonian shales in New York (Grabau, A. W., Jour. Geol., vol. 25, p. 338 (footnote) 1917), but in view of the wide geographic and geologic separation, it is believed that there will not be confusion by the use of the same name for the two units.

of a basal laminated shale and dark colored limy shales or limestones, overlain by a variable thickness of porous breccia composed largely of sharp angular shale fragments. The lower shale and limestone is always distinctly laminated in layers from less than an inch to 4 or 5 inches in thickness, and ranges in total thickness from a foot to 5 feet. Certain layers in this part are locally contorted or folded, and less commonly brecciated. Where the shales are thickest thin layers of fibrous gypsum are usually present. The finely laminated shales are black and the intercalated limy beds are dark gray or black in color and have a faint bituminous odor when broken. The upper breccia is from a few feet to 20 feet in thickness, shows an indistinct stratification at places, and commonly has been cemented by calcareous material. The limestone and shale fragments composing the breccia are small, rarely exceeding 2 inches in diameter and usually much smaller, and are sharply angular. At some places particularly where the formation is unaltered a minimum of cementing matter is present and the breccia is consequently extremely porous. This porous character of the breccia, as well as the impermeable nature of the basal beds of the member, both seem to have had an influence in the localization of ore at this horizon.

At all except two places where it was examined in the district the "Pony Express beds" have the general character described above. In at least one place they thin to a brecciated shale horizon about a foot in thickness. At one other locality about six miles north of Ouray on the east side of the Uncompahgre Valley the beds have a total thickness of 60 to 70 feet. The section of the Wanakah member measured here is shown below.

Section of the Wanakah member on the east side of the Uncompahgre Valley 6 miles north of Ouray.

		Feet
	Wanakah member of the Morrison formation:	
	UPPER SHALE BEDS:	
19.	Shale or mudstone; weathers to small angular fragments; color brown; weathered surface yellowish	1.5
18.	Limestone, crystalline; contains a few shale pellets; color brownish; weathers rusty brown	.5
17.	Shale or mudstone; breaks into angular fragments; color brown	1.3
16.	Limestone; lenticular bed; white and crystalline, weathering brown	.3
15.	Shale; like 17 above	.7
14.	Limestone; nodular and crystalline; color brown	.3
13.	Shale; limy and sandy layers; breaks to angular fragments; color brown, somewhat reddish or yellowish; it contains brown and gray crystalline lime nodules and lenses and a few limy layers are persistent enough to form thin limestone beds; near the top some of the calcareous nodules are partly altered to red chert and quartz	26.0
12.	Limestone; gray; dense	.6
11.	Clay shale; greenish gray	1.8
10.	Shale; sandy and brown at top grading down into fine blocky shale of greenish color at base	6.5
9.	Shale, brown	.5
8.	Shale, sandy, olive gray; impregnated with gypsum in cracks	2.4
7.	Sandstones and sandy shales, greenish and brownish colors, partly slumped	4.0
6.	Sandstone; hard; greenish gray; consists of clean quartz grains and grains of bright red chert; appears glauconitic	1.0
	Total thickness shale beds 47.4 feet	
	SANDSTONE BED:	
5.	Sandstone; soft and friable; clayey layers near top; color somewhat olive gray near top; near base color gray weathering buff	19.0
	"PONY EXPRESS BEDS":	
4.	Gypsum; banded; white with black shaly layers	1.7
3.	Gypsum; nodular; roughly bedded; with subordinate black interstitial shale and irregular shale partings	50.0
2.	Shale and limestone breccia; small angular fragments of limestone and shale partly cemented with calcite; porous	1.8
1,	Shale and limestone; thin alternations of black shale and dark limestone; some beds have a bituminous odor when struck	5.0
	Thickness "Pony Express beds" 58.5 feet	
	Total thickness of Wanakah member	124.9
	Gray cross-bedded sandstone of Jurassic age, upon which the Wanakah shale rests conformably.	

It will be seen that the "Pony Express beds" differ here from their typical development in that they are composed of three lithologic units—a basal shale and limestone, a thin breccia bed, and a thick unit of nodular gypsum with interstitial shale. This development of the formation is particularly instructive with regard to the origin of the breccia bed that commonly forms the top unit. North of the position where the section was measured the gypsum beds rapidly wedge out and entirely disappear within a few hundred feet, while the breccia within the same range increases in thickness from less than 2 feet to about 8 feet. It is apparent from the local relations that the breccia has been formed by the dissolving of the gypsum and the gradual accumulation in place of the interstitial fragments and layers of less soluble limy shale. The shape and nature of the interstitial shale masses in the gypsum beds are identical with the fragments composing the breccia.

To determine if possible whether the destruction of the gypsum deposit took place shortly following its deposition, or at a much later time during the accumulation of the overlying sediments, sections were measured at several places near the exposed gypsum beds. The sandstone which overlies the gypsum horizon was found to be of uniform thickness, regardless of whether the gypsum was present or entirely removed, and a disturbance in its dip is evident where the thick gypsum deposit wedges out. Where the gypsum was thickest, however (60 feet or more), a thinning of the upper shale beds of the Wanakah member was noticeable. There was also some evidence of the thinning of the basal beds of the overlying sandstone member of the Morrison formation. The amount of thinning seen in these beds did not however nearly account for the entire thickness of the gypsum deposit. The evidence therefore points to the beginning of destruction of the gypsum deposit after the deposition of the middle sandstone bed of the Wanakah member, and to the completion of its destruction largely after the deposition of the overlying sandstone beds. It is clear that nearly all of the gypsum had been destroyed by late Cretaceous or early Eocene time, as dikes of porphyry and fissures of this age cut through the "Pony Express beds" without showing evidence that the thick gypsum deposit was present at the time of their formation. Possibly the greatest removal of gypsum which presumably took place during the deposition of the continental beds of the Morrison formation, was accomplished by the solvent action of ground waters moving along the top of the impervious shales that lie beneath the gypsum.

Sandstone Bed (upper Sandstone of "La Plata Sandstone" of Cross)

The sandstone bed of the Wanakah member ranges between 15 and 25 feet in thickness. It consists of soft crumbly sandstone of a buff or grayish yellow color similar to the Jurassic sandstone, but it is probably on the whole more silty. It is rarely well exposed because of its soft earthy nature and because of the slumping of the shales above it. At some localities where the exposures are good, thin layers, or partings, of a very clayey shale are to be seen in its upper part. The passage to the overlying shale beds of the Wanakah member is probably fairly sharp, but this part of the section is usually not well exposed.

This sandstone bed is generally mineralized in areas where the "Pony Express contact" is mineralized. The physical features of this horizon which have favored the formation of ore in the sandstone above the "Pony Express contact" will be discussed in later paragraphs.

Shale Beds of the Wanakah Member

A typical section of the shale beds of the Wanakah member is given in the accompanying table (p. 174). These beds range between 40 and 75 feet in thickness where they have been measured. The basal part consists of alternations of greenish gray sandstones, and greenish and brown shales. The base of the shales in the section given was taken at a one-foot bed of medium grained sandstone that forms a comparatively hard bed resting on the soft silty sandstone of the middle unit of the Wanakah member. The sandstone has a greenish gray color and is composed of quartz grains and scattered grains of a bright red chert. The overlying sandstone layers are more calcareous and alternate with beds of green and brown shales. The upper and greater part of the shale beds consist of brown shale containing thin beds of gray crystalline limestone. The limestone near the top of these commonly occurs as rounded or flat concretions, some of which are partly altered to red chert and quartz. The red cherts are nearly always present, but are larger and more conspicuous at some places than at others, and form excellent horizon markers where the stratigraphic relations are obscured. The top of these beds is everywhere overlain by a massive basal sandstone, or quartzite, of the sandstone member of the Morrison formation.

Sandstone and Shale Members of the Morrison Formation

So far as can be determined near Ouray the sandstone member of the Morrison rests conformably upon the Wanakah member. Its base is marked by a light colored bed of sandstone or quartzite from 20 to 30 feet in thickness. Because this bed is commonly mineralized and altered to quartzite in the central part of the district it is known to the miners as the "lower quartzite." The great persistence of this bed, together with its susceptibility to pyritization makes it an important horizon marker in the section. Its mode of alteration is much like that of the Dakota(?) sandstones, and consequently it must have been originally much more porous than the majority of the sandstones in the Morrison, which do not show an equal uniformity of alteration. This quartzite can be traced from its exposures in Canyon Creek, 3½ miles southwest of Ouray, to a point 7 miles north of Ouray on the highway to Montrose where the base of the Morrison dips beneath the valley bottom.[18]

[18]The statement regarding the persistence of this bed is emphasized because of an incorrect statement appearing in the Ouray Folio, p. 17, as follows: "There is a prevailing impression in the district that there are two ore bearing quartzites, an 'upper' and a 'lower' which are readily traceable for great distances. This impression is founded on error. The Dakota quartzite alone is a prominent and constant stratum. Below this there are many other quartzite beds, and of the ore bodies in them it cannot be proved that any two occur in the same bed." The writer cannot agree with this statement since there are places where one may walk along the outcrop of the "lower quartzite" nearly without interruption for several miles.

Two lithologic members of the Morrison may be recognized in the district, although the division between them is not sharply defined everywhere. The lower division consists predominantly of sandstones, but with many intercalated shale beds and a few thin beds of limestones. In the upper part of the sandstone member there is at most places a comparatively massive sandstone bed from 60 to 70 feet thick; above this there is a gradational change into the overlying shale division of the Morrison. This change is illustrated in the columnar sections in Plate I. The greater number of massive sandstones in the lower member commonly causes it to form cliffy exposures, above which occur more gentle slopes in the shales.

The Morrison formation, as a whole, consists of alternations of sandstones, sandy shales, and fine grained dense shales, with a number of thin limestone beds that mostly lie in the lower part of the formation. Except for the basal sandstone, most of the sandstone beds are fine grained and gray in color; a few are cross-bedded. Many of the sandstone beds near the base contain flakes or pellets of a green shale. The shales possess a variety of colors ranging from nearly white to green, red, and brown. The green shales are dense and porcelain-like, and are especially prominent in the upper part of the formation. Many of the shales are limy and contain thin lenticular limestone beds, of which there are several persistent horizons near the base of the formation. These are dense and blue-gray in color, with a somewhat mottled texture. At some localities a limestone near the base contains poorly preserved shells or casts, presumably of fresh water bivalves. Except for some tube-like remains of organisms or plants in some of the limestone beds and a fossilized footprint of a dinosaur that is exposed in the "lower quartzite" near the boarding house of the American Nettie mine, no other fossils have been found.

A few of the beds mentioned above are at least locally persistent horizons, but there is great lateral variation in the character of most of the individual beds. However, a typical section is given below in order to illustrate the general character of the formation.

Section of the sandstone and shale members of the Morrison formation on the cliffs above the Amphitheatre 1 mile east of Ouray.

Dakota (?) formation:
Quartzite resting apparently conformably on the Morrison.

Morrison formation:

	Feet
SHALE MEMBER:	
Argillite (hardened clay shales); mostly green with some reddish layers; some beds cherty and others limy; interbedded with red mudstones near the base	60.0
Shale; alternating beds of red calcareous shales and greenish shales; mostly dark red	48.0
Quartzite; greenish	2.0
Earthy limestone; red and shaly with red shale at base	15.0
Sandstone; shaly and reddish	5.0
Shale; sandy, reddish	10.0
Quartzite; massive and greenish	15.0
Shales; reddish and limy with interbedded sandstones; a 2-foot lenticular bed of sandstone at base	24.0
Shale, earthy limestones, and thin sandstones; alternating beds; shales and limy beds mostly reddish brown; sandstones gray or greenish	44.0
Sandstone; gray and massive	26.0
Sandstones and shales; alternating gray sands and red shales	55.0
Shale and limy shales; reddish brown shales and earthy limestone layers	15.0
Sandstone; gray	12.0
Sandstones and red shales	19.0
Sandstone, gray with red shale layers	15.0
Shale; limy, reddish brown	2.0
SANDSTONE MEMBER:	
Sandstone; white rather massive and evenly bedded; fine grained; red shaly layers near top	61.0
Mudstones; red, break into small chips	24.0
Sandstone; gray thin bedded	10.0
Sandstone; shaly, mostly gray with reddish shaly layers	27.0
Sandstone; white	5.0
Mudstone; mostly red, some layers limy and some sandy	33.0
Sandstone; white somewhat grayish; cross-bedded	31.0
Limestone; dense, blue gray; nodular in places	5.0
Sandstones and red shales, lenticular	26.0
Quartzite; very massive, medium grain; contains pyrite and is weakly mineralized; weathered surface stained bluish black: "lower quartzite"	29.0
	618.0

Base of sandstone member conformable on shales of Wanakah member.

Age and Correlation of the Morrison Formation

Although all of the beds here included in the Morrison were assigned in the Ouray Folio[19] to the Jurassic, the Morrison at present is assigned with question to the Lower Cretaceous series by the U. S. Geological Survey. The use of the term Morrison formation in this paper, rather than retaining the local term "McElmo formation," is considered advisable, because the local name "McElmo" is practically a synonym of the older name Morrison, the only change being that the upper beds of the "La Plata sandstone" of Cross are believed to belong properly to the Morrison formation, and are so included in this report, also because of the variation in usage of the term "McElmo" by other authors, as has been pointed out by Gilluly and Reeside.[20]

CRETACEOUS SYSTEM

UPPER CRETACEOUS SERIES

Dakota (?) Sandstone

The Dakota (?) sandstone of the Ouray district, although variable in its characteristic features, commonly comprises three lithologic members. The base of the Dakota (?) formation is chosen as a bed of sandstone, at many places partly converted to quartzite, which contains round pebbles of white, red, and gray chert, gray shale, and quartz. This lies with apparent conformity upon the upper green shales of the Morrison formation. This basal bed is variable in development, being absent at some places and very conspicuous at others. The formation as a whole is composed of gray or brownish gray quartzose sandstones containing pebbly layers, with a number of thin shale partings and thicker carbonaceous shale members. The total thickness of the formation ranges between 140 and 175 feet, except where the upper shales have been eroded at the base of the Telluride conglomerate. A detailed section of the Dakota (?) formation measured near the Schofield tunnel of the American Nettie mine is given

[19] Op. cit., p. 6.
[20] Gilluly, J., and Reeside, J. B., Jr., Sedimentary rocks of the San Rafael Swell and adjacent parts of Utah: U. S. Geol. Survey Prof. Paper 150-D, p. 82, 1927.

in the accompanying table. The lower part of the formation consists of interbedded sandstones and shales with a basal chert-pebble conglomerate, the middle part of thick massive sandstones locally converted to quartzites with shale partings of variable thickness, and the upper part mainly gray and carbonaceous shales with interbedded sandstones of dark color. In places where the basal pebble bed and shales are poorly developed the massive sandstones of the middle part extend practically to the base of the Dakota(?). It is believed that the pebble bed and shales above it belong in the Dakota(?) rather than the Morrison formation, since in many places in Colorado the base of the Dakota(?) has these characteristics, and also since the shales above this bed along Dexter Creek are gray or carbonaceous, resembling the upper shales of the Dakota(?) more closely than they do the green shales of the upper part of the Morrison formation. There are, however, pebble beds in the upper part of the Morrison, about 100 feet below the Dakota(?), that closely resemble the basal sandstone of the Dakota(?) formation; but there is little chance of confusing this bed with the true base of the Dakota(?) where the overlying beds are exposed, because of the characteristic green shales in the upper part of the Morrison.

Several important ore-bearing "contacts" occur within the Dakota(?) formation, the most important of these being the upper "contact" of the American Nettie mine. The blanket ore bodies of this "contact" lie in the massive quartzite below shale No. 16 of the accompanying section. The lower "contact" of the mine lies in the basal sandstone beneath shales corresponding to No. 2 of the section. Between the lower and upper "contacts" there are others probably at different horizons within the beds represented by Nos. 10 to 14 of the accompanying section. The relative amounts of sandstone and shale within this part of the section varies considerably from place to place, so that it cannot be certain that the intermediate "contacts" are all at the same horizon.

Section of the Dakota(?) formation, showing overlying and underlying formations near the Schofield tunnel of the American Nettie mine, about 1½ miles north of Ouray.

	Feet
Quartz monzonite-porphyry; laccolithic body, 550 feet.	
MANCOS SHALE:	
Shales; marine, dark gray to black; very fissile and soft	25.0
Sandy shales with thin pebble beds; contain pebbles of quartzite, fragments of bituminous matter, and sharks' teeth; marine	2.0
	27.0
Local unconformity (?) at base of pebble bed.	
DAKOTA (?) SANDSTONE; NON-MARINE:	
25. Quartzite; very fine, light gray	1.5
24. Sandy shale; gray with black shale seams	5.0
23. Quartzite; fine grained, somewhat argillaceous	4.0
22. Shale; somewhat sandy in layers	4.0
21. Quartzite; dark gray to black, with thin black shale partings; carbonaceous	10.0
20. Shale; black and dark gray, with carbonaceous matter and leaf impressions	15.0
19. Quartzite; dark gray to nearly black; shale partings that have white markings caused by sandy lenses in carbonaceous material	5.0
18. Quartzite; gray to greenish gray; with thin black shale partings; bedding surfaces irregular caused by ripple marking or crumpling; contains marks resembling worm burrows	13.0
17. Shale; dark gray; with numerous thin quartzite and sandy shale layers; sandstones brown due to iron stain; and finely banded with gray streaks caused by shale partings	20.0
16. Shale; dark gray to black; lenticular beds of quartzite at same horizon	3.0
15. Quartzite; massive and white	25.0
14. Quartzite; gray with shale partings	1.0
13. Quartzite; white and gray	5.0
12. Shale; gray and sandy	.5
11. Quartzite; white	5.0
10. Shale, quartzite layers	.5
9. Quartzite; massive and white	18.0
8. Shale and sandstone; lenticular	5.0
7. Quartzite; gray	3.0
6. Shale; much altered; probably originally greenish or gray	1.0
5. Sandstone, shaly, quartzitic	2.0
4. Shale; greenish, bleached	1.0
3. Quartzite or sandstone; gray and brownish argillaceous	1.8
2. Sandy shale; purplish gray; greenish sandy shales at top; contains small chert pebbles	10.0
1. Sandstone, partly converted to quartzite; with round pebbles of chert, gray shale and quartz (¼ inch); upper part fine grained and greenish	17.0
Total thickness of Dakota (?)	176.3
Base of Dakota (?) sandstone resting on green shales of Morrison formation.	

Plant remains are found in the upper shales of the Dakota(?) in the vicinity of Ouray, and farther north some coal beds have been prospected. The section undoubtedly corresponds to what commonly has been referred to the Dakota on the western slope of the Rocky Mountains, but it is at such a distance from the type locality of the Dakota sandstone that absolute time equivalence cannot be definitely established with the evidence at hand, so that the name is used with a question. The Dakota(?) at Ouray is considered to belong to the early part of the Upper Cretaceous series.

Mancos Shale

Within the area included by the present survey there is preserved varying thicknesses of the Mancos shale, ranging from a total of a few feet to several hundred feet. Over most of the area in the vicinity of Ouray the greater part of the Mancos shale has been removed by the erosion that preceded the deposition of the Telluride conglomerate. As shown by the section accompanying the description of the Dakota(?) sandstone, the Mancos appears to lie unconformably upon the upper shale and sandstone member of the Dakota(?). It has not as yet been determined whether this contact represents appreciable erosion of the upper parts of the Dakota(?), or whether the Mancos sea merely reworked the top beds of the Dakota(?) as it encroached upon the land.

The Mancos consists of dark gray or lead-gray shales with thin beds and concretions of calcareous shale and limestone. The limy parts of the shale commonly contain numerous invertebrate fossils, and at places the basal sandy beds contain many sharks teeth. The fossils found in the lower part of the formation have been pronounced to be of Benton age[21]. The whole formation, which is about 1200 feet in thickness, corresponds to the Colorado group and part of the Pierre shale of the Montana group.

The Mancos shale has had a considerable influence on the nature of the intrusive masses of late Cretaceous or early Tertiary age, as many of these intrusions spread into laccol-

[21]Ouray Folio, No. 153, p. 6.

ithic bodies at horizons near the base of this formation. The blanketing effect of these shales is also clearly reflected in the character of the ore deposits that accompanied this early igneous activity. These effects will be discussed in more detail in the sections on igneous rocks and ore deposits.

Tertiary System

EOCENE SERIES

Telluride Conglomerate

The Telluride conglomerate underlies the San Juan tuff and was deposited after a period of great erosion in early Tertiary (Eocene) time. It rests upon a peneplained surface. The formation transgresses all of the older sedimentary rocks and certain of the monzonitic intrusions in the Mancos shale. It is composed of detritus of schist, granite, granite porphyry, Algonkian quartzite and slate, monzonite porphyry, and smaller amounts of the Paleozoic sedimentary rocks, such as the Ouray limestone and the Paleozoic "red beds." The formation has considerable variation both in its thickness and composition. At most places in the vicinity of Ouray the conglomeratic facies is the most common, but at several places sandstones, shales, and limestones make up part of the formation. At many places it is entirely absent and the San Juan tuff rests directly upon the older sedimentary or igneous rocks. Its absence is undoubtedly due at places to non-deposition on the higher land areas that surmounted the Eocene peneplain, but erosion was active between the time of its deposition and the formation of the overlying San Juan tuff. Commonly it is not more than 40 to 50 feet in thickness, but the thickness increases southward toward the Telluride quadrangle, where it is developed to a thickness of a thousand feet in Mount Wilson.

Near Ouray the peneplained surface upon which the formation rests is surmounted by a number of ridges and hills composed either of the hard Algonkian quartzites or of the monzonite-porphyry intrusions that had penetrated the Mancos shale. On Dexter Creek southeast of the Bachelor

Mine an early Tertiary hill of monzonite porphyry rises nearly 1500 feet above the local base of the Telluride formation, which laps against the base of the hill. Near this hill and to the north of it the formation contains a considerable proportion of angular blocks and weathered boulders of the porphyry.

Revisions of Areal Mapping

Except for the addition of more detail made possible by the larger scale of the map employed, only a few important areal revisions in the sedimentary formations have been found necessary to the geology of the Silverton folio published in 1905, and to that of the Ouray folio published in 1907. The most important revision is to the formations exposed along the upper part of Canyon Creek in the northwest corner of the Silverton folio, where the sedimentary rocks underlying the Telluride conglomerate and the San Juan tuff had been mapped entirely as the Hermosa formation. As is shown by the revised mapping, however, the Hermosa formation near the lower part of Canyon Creek and west of the Mineral Farm mine strikes northwestward and dips southwestward about 15° to 20°, and about two miles up Canyon Creek it dips beneath the canyon bottom and the overlying Cutler formation occupies the lower sides and bottom of the canyon (see Plate I and Section BB′). Along the sides of the canyon between the Cutler formation and the Telluride conglomerate, there is a band of the flat-lying Triassic and Jurassic rocks, lying with angular unconformity upon the Cutler formation. These rocks range from 125 to 250 feet in thickness, and include the red Dolores formation, the white cross-bedded Jurassic sandstone, and all or part of the Wanakah member of the Morrison formation. At the southwest where the sedimentary rocks disappear beneath the volcanic rocks in the narrow canyon about a mile below the Camp Bird mill, the "lower quartzite" and about 100 feet of the sandstone member of the Morrison formation are also present beneath the Telluride conglomerate.

The presence of these beds preserved from erosion this far southwest of Ouray indicates that they continue farther west and southwest beneath the San Juan tuff toward Sneffels and Telluride. These beds are also present beneath the Telluride conglomerate near the town of Telluride, but two or three miles east of Telluride near Ingram Creek, the Telluride folio shows them to be cut out by erosion at the base of the "San Miguel formation" (Telluride conglomerate). They are not known to be present at Ironton Park between Ouray and Silverton, where only the lower Paleozoic beds are preserved. It appears then that although these Triassic and Jurassic beds are probably continuous between their exposures in Canyon Creek and Ingram Creek, they probably do not extend a great distance southeastward from this line. North of Canyon Creek it is presumed that the Triassic and Jurassic rocks extend indefinitely northwestward beneath the volcanic rocks, except where their position may be broken or interrupted by intrusive rocks.

IGNEOUS FORMATIONS

Extrusive Volcanic Rocks

San Juan Tuff

The earliest surface deposits of volcanic origin preserved in the Ouray region consist of a very thick accumulation of water-laid tuff, breccia, and agglomerate, which was named the San Juan tuff by Whitman Cross in 1901. This formation attains a maximum thickness of nearly 3000 feet at the head of the Amphitheatre east of Ouray. Except for the lower few hundred feet the formation is composed almost exclusively of volcanic rock fragments of andesitic and latitic composition. The basal part of the formation contains boulders and pebbles of granitic and siliceous pre-Tertiary rocks similar to those composing the Telluride conglomerate.

In the vicinity of Canyon Creek, Sneffels, and Ouray, two lithologic members of the San Juan tuff are recognizable (Plate II, C). The lower member, which is here named the *Canyon Creek member,* as it may be a restricted facies of the San Juan tuff, is from 300 to 1200 feet in thickness, and comprises the most important cliff-forming part of the formation. The textural varieties of the Canyon Creek member range from fine sandy tuffs to coarse agglomerate and breccia, with interbedded conglomeratic beds. The conglomeratic beds differ from the others by being composed partly or largely of distinctly rounded water-worn boulders of the volcanic rocks. It is mainly on the basis of the presence of these conglomerate beds and their character that the twofold division of the San Juan tuff has been made; the Canyon Creek member contains many interbedded conglomerate layers, whereas the upper part of the San Juan tuff is comparatively free of them. The fragments of the rocks composing the Canyon Creek member comprise a great variety of lavas, many of which are porphyritic andesites and latites. The size of the fragments range from microscopic particles composing the tuffs to large boulders and angular blocks 2 to 3 feet in diameter. The characteristic color of most of the beds of the Canyon Creek member is dull greenish gray, although some beds are reddish or purplish in color, while the individual fragments possess a wide range in color and tone. The coarse agglomerates are commonly chaotic, and exhibit bedding only when viewed at a distance, but the tuffs, conglomerates, and conglomeratic beds with which they are interbedded form distinct layers and give a bedded appearance to the whole formation.

The upper part of the tuff, which is here named the *Sneffels member* of the San Juan tuff, is characterized in the lower part by the uniform nature of the lava fragments of which it is composed. The fragments are mostly of finely porphyritic lava which contains numerous small phenocrysts of feldspar. Conglomerate beds are much less common than in the Canyon Creek member and are essentially absent in the lower part of the Sneffels member. The Sneffels member is about 1500 feet in thickness, and becomes more heterogeneous in the upper part as the base of the Silverton series is approached. At many places the breccia at the base of the Sneffels member is of reddish color, and composed of small angular fragments of oxidized lava, but this color change is not of sufficient persistence to be used as a horizon marker. On the whole, however, the member is characterized by many light colored beds of reddish or pinkish tone, as is especially noticeable northeast of Ouray, where the normal colors are less affected by hydrothermal alterations.

Ranging in different localities from 700 to 900 below the base of the Silverton series there is an andesitic flow or several flows interbedded in the Sneffels member of the San Juan tuff. These flows range from 25 to 50 feet or more in thickness, are of dark gray or reddish color, and characterized by amygdaloidal and scoriaceous tops. These flows appear to be of local development in the vicinity of Sneffels on the south slope of Potosi Peak, and in the ridges south of the Camp Bird mill, and comprise the only known interruption in the accumulation of clastic material that forms the San Juan tuff. The source and entire extent of these flows has not as yet been determined.

It was found possible to trace the division between the two members of the San Juan tuff from the vicinity of Sneffels eastward to the ridges beyond the Uncompahgre river, but the present extent of the survey gives no indication as to the significance of this change. The bulk of the production from the Tertiary veins between Ouray and Telluride has come from the upper or Sneffels member of the San Juan tuff.

The variation in thickness of the Canyon Creek member of the San Juan tuff is the result of the uneven or hilly surface upon which it was deposited. Along Canyon Creek just below the Camp Bird mill the lower member is normally from 1100 to 1200 feet in thickness, but above the monzonite-porphyry intrusion on the north side of the canyon the thickness attained is only 600 to 700 feet, a difference accounted for by the height to which the eroded monzonite extended above the regional peneplain of the western San Juan mountains, upon which the Telluride conglomerate rests. Above the monzonite body on Cascade Mountain northeast of the