RIVER RUNNERS' GUIDE TO THE

CANYONS OF THE GREEN AND COLORADO RIVERS

With Emphasis on Geologic Features

Desolation and Gray Canyons

FRONT COVER — *Desolation Canyon; view upstream from proximity of junction with Gray Canyon. Photograph by George I. Ogura, 1966.*

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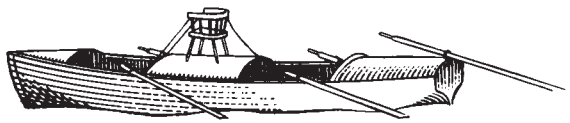
Volume IV



Desolation and Gray Canyons

By

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1869  1969

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JOHN WESLEY POWELL, 1834-1902

Foreword

ON MAY 24, 1869, MAJOR JOHN WESLEY POWELL and nine men in four wooden boats left the town of Green River, Wyoming Territory, on a voyage through the last great uncharted area in the United States—the canyons of the Green and Colorado Rivers. The historic river journey ended at the junction of the Colorado and the Rio Virgin, in Nevada, on August 29, 1869. Two years later on May 22, 1871, Powell and a party of 10, including topographers, geologists, and photographers, cast off from Green River on a second voyage through the canyons. The men of the 1871-72 expedition produced the first accurate maps of the canyons, described the exposed rock units, and made observations on archeology, ethnology, flora, and fauna. The efforts of these men represented one of the major scientific contributions of their day.

The river explorations gave Powell a unique perspective on the geologic setting and on the importance of conserving and developing equitably the scant water resources of the arid West. In 1879, Powell played a leading role in establishing the U.S. Geological Survey and the Smithsonian Institution's Bureau of Ethnology. He became the first Director of the Bureau of Ethnology, and in 1881 became the second Director of the Geological Survey. From 1888 to 1891 Powell conducted the Irrigation Surveys—forerunner of the Bureau of Reclamation.

During the hundred years since Powell's pioneer exploration, the canyons of the Green and Colorado Rivers have undergone many

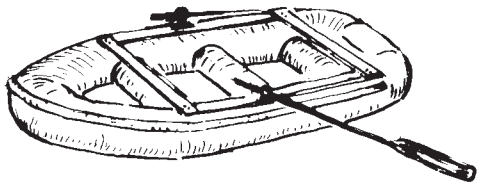
changes. Huge dams have transformed hundreds of miles of flowing river into still-water reservoirs. Farms, ranches, and towns have sprung up along the rivers wherever high cliffs open up to allow access, and uranium mines and oil wells dot the high plateaus above the canyons. However, in the depths of Desolation and Gray Canyons little has changed over the past century, and they remain the least traveled sections of the Green River.

In boating these canyons you will be reliving a part of Powell's exciting 1869 journey—passing beneath cliffs the one-armed Major climbed, running rapids that once tested the stamina of the pioneer party, and perhaps camping on a sand bar where Andy Hall, the cook, sang . . .

"When he put his arm around her,
She bustified like a forty pounder,
Look away, look away, look away in Dixie land"

George Y. Bradley's journal (Darrah, 1947, p. 48)

This river log was prepared under the auspices of the Powell Society and the United States Geological Survey as a tribute to John Wesley Powell, and is published by the Powell Society as an introduction to the rocks and landscapes you will see on *your* voyage of discovery.



Introduction

FROM OURAY TO GREEN RIVER, UTAH, the Green River follows a course through open desert and beneath lofty terraced canyon walls. Exposed on these walls are rocks recording the withdrawal of an ancient sea and the subsequent development and destruction of a large fresh-water lake. The strata dip gently upstream, so that a trip downriver is a journey back into geologic time. Successively older rocks are exposed at river level, and by studying their characteristics geologists are able to visualize the ancient environments in which the rocks formed.

At Ouray the desert dominates—the view from a bluff on a searing, windstill noon is of barren, drab rock and sand, essentially without vegetation except for a thin band of tamarisk and willow hugging the river. But afloat on the river, the shifting light of dawn or evening leads pastel shades of greenish gray, yellowish brown, cream, and brownish orange in a dance over the gentle slopes above Nine Mile Creek. Farther downriver reddish-brown cliffs rise higher, and trees appear on the uplands. At night the silent melody of stars wheeling above the dark cliffs blends with the roar of the rapids in a song of joy as old as the earth and as young as the voyageur.

This guide begins with a brief outline of the geology of the Uinta Basin, to acquaint the traveler with the geologic history and evolution of the rocks of the canyons. The body of the guide is a log describing points of interest along the river and giving the loca-

tions and ratings of rapids. A glossary of geologic terms is also included.

The course of the river and the character of the canyons from Ouray to Green River, Utah, is shown on eight topographic maps published by the U.S. Geological Survey and available from the Geological Survey at the Federal Center, Denver, Colorado 80225.

7.5-minute series
Ouray, Utah
Uteland Butte, Utah
15-minute series
Nutters Hole, Utah
Firewater Canyon, Utah
Flat Canyon, Utah
Range Creek, Utah
Gunnison Butte, Utah
Green River, Utah

The river mileages used in the log are taken from Sheets A through D of the U.S. Geological Survey topographical river survey, *Plan and Profile of the Green River, Green River, Utah to Green River, Wyoming* published in 1924. The River Survey Maps, now out of print, can usually be consulted in larger libraries, or reprints may be purchased from Leslie A. Jones, Star Route, Box 13-A, Heber City, Utah 84032. The topographic quadrangle maps are especially useful if one transcribes the mileages to them from the River Survey Maps. Four index maps (Figs. 8, 10, 17, and 21) in the log show the course of the river and the major geologic structures, and are marked at 5-mile intervals that correspond with the River Survey Maps.

I am indebted to many people for assistance in the preparation of the log which follows. William B. Cashion, John R. Dyni, David L. Gaskill, and Denise Mutschler read and criticized the manuscript. Henry W. Toll and George I. Ogura entrusted me with their assault boat, *Big Red*, for a voyage through the canyons. William B. Cashion, Ann C. Christiansen, John R. Dyni, Philip T. Hayes, and Charles W. Spencer discussed geologic problems with me afloat and around the campfire, and contributed much to the log. I am especially indebted to my "boaties" Denise, Charles, and John Mutschler, David and Gudrun Gaskill, and Charles E. Worth, who at various times shared with me the shifting panorama of cliffs, river, and sky, and the excitement of the white water rapids of Desolation and Gray Canyons.

Geologic History of the Uinta Basin

From the foothills of the Uinta Mountains to Green River, Utah, the Green River flows across sedimentary rocks which were formed tens of millions of years ago. These rocks were deposited in shallow seas, and on flood plains much like the present head of the Gulf of California, and in a large lake which sometimes teemed with a variety of organisms and at other times became as saline as Searles Lake, California.

If we could remove these rocks and examine the floor upon which they were deposited it would appear as a gigantic depression, which geologists have termed the Uinta Basin, lying against the south side of the Uinta Mountains. The Uintas are an uplifted area of the earth's crust resembling an overturned elongate relish dish. The shape of the floor of the Uinta Basin can be represented by structure contours, or lines of equal elevation, drawn on the surface of a given rock unit. Figure 1 shows a structure contour map of the Uinta Basin and its relation to the Uinta Mountains and other major uplifts.

The contours are drawn on the top of the Chinle Formation, a series of red sandstones and shales that were deposited in the Triassic Period (see Table 1) before the basin began to form. The

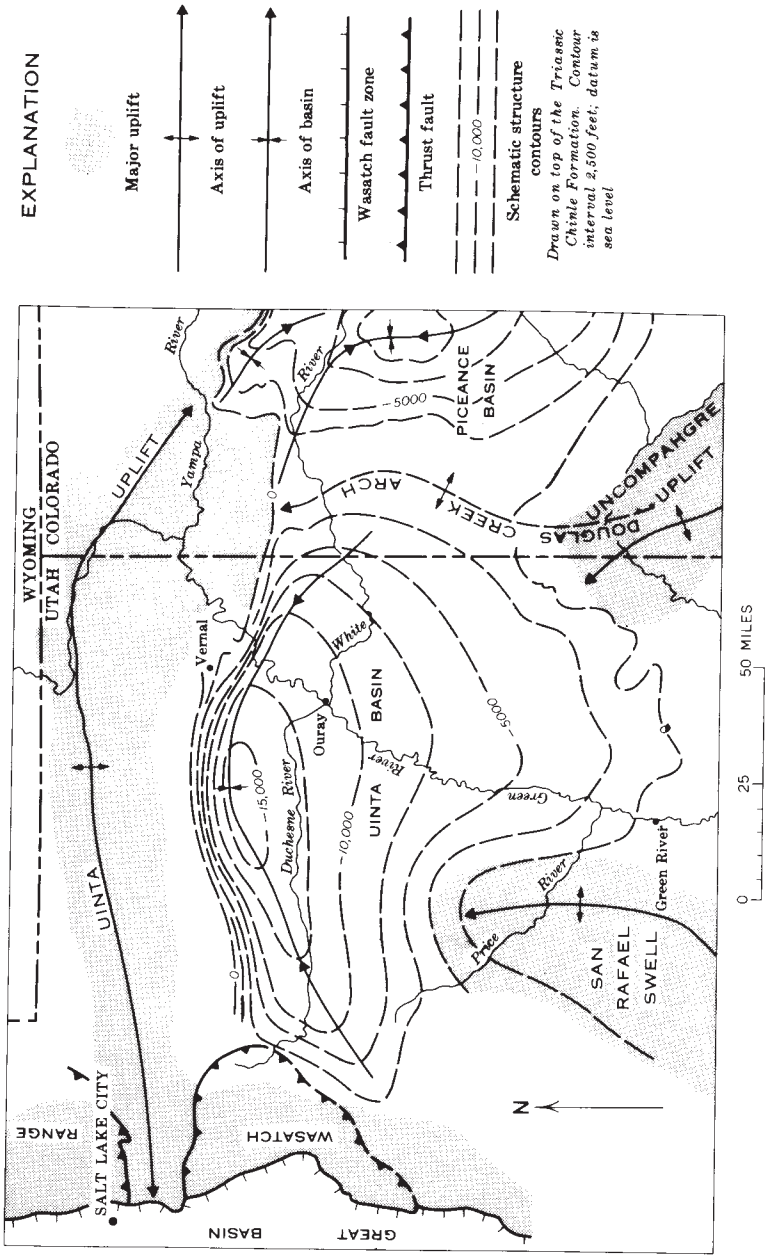


FIGURE 1 — *Tectonic sketch map of the Uinta Basin and environs.*

structure contour map shows that the Chinle Formation, which was deposited as a nearly horizontal blanket above sea level, has been warped down to more than 15,000 feet below sea level in the deepest part of the Uinta Basin. The contours also show that the basin is not a symmetrical depression, but that it has the form of a half mussel shell, with a steeper north side and a gentler south slope. The shape of the basin may also be represented on geologic cross sections, which are sketches of imaginary vertical cuts into the earth. Figure 2 is a north-south geologic cross section through the Uinta Basin that also shows the relationships between the rock layers filling the basin.

Starting at Ouray and floating down the river to Green River you will pass through successively older layers of sedimentary rocks. By studying the physical and chemical characteristics of these rocks and the fossils contained in them, geologists are able to decipher the ancient (or paleo) geography of the area and to recreate the conditions under which sediments were deposited and transformed into rocks. Arranged in chronological order, the events represented by the rocks constitute a history of this part of the earth. As chapter headings in this history we may use major divisions of geologic time (see Table 1).

The earlier parts of this history are recorded in rocks which are deeply buried beneath the Uinta Basin, but which crop out in the Uinta Mountains to the north of the basin and in the canyonlands to the south of the basin. The rocks and the geologic history of these areas are described by Baker (1946), Gilluly and Reeside (1928), Hansen (1965, 1969), Hayes and Santos (1969), McKnight (1940), Mutschler (1969), and others.

Precambrian Time (before 570 million years ago)

More than a billion years ago ancient mountain systems in the present Uinta Basin and its environs were eroded to a lowland exposing Precambrian gneisses, schists, quartzites, and granites. Marine waters then covered the lowland, and Precambrian sandstones and shales collected in a basin virtually coincident with the present Uinta Mountains. Toward the end of Precambrian time, uplift caused withdrawal of the seas and erosion of the Precambrian rocks.

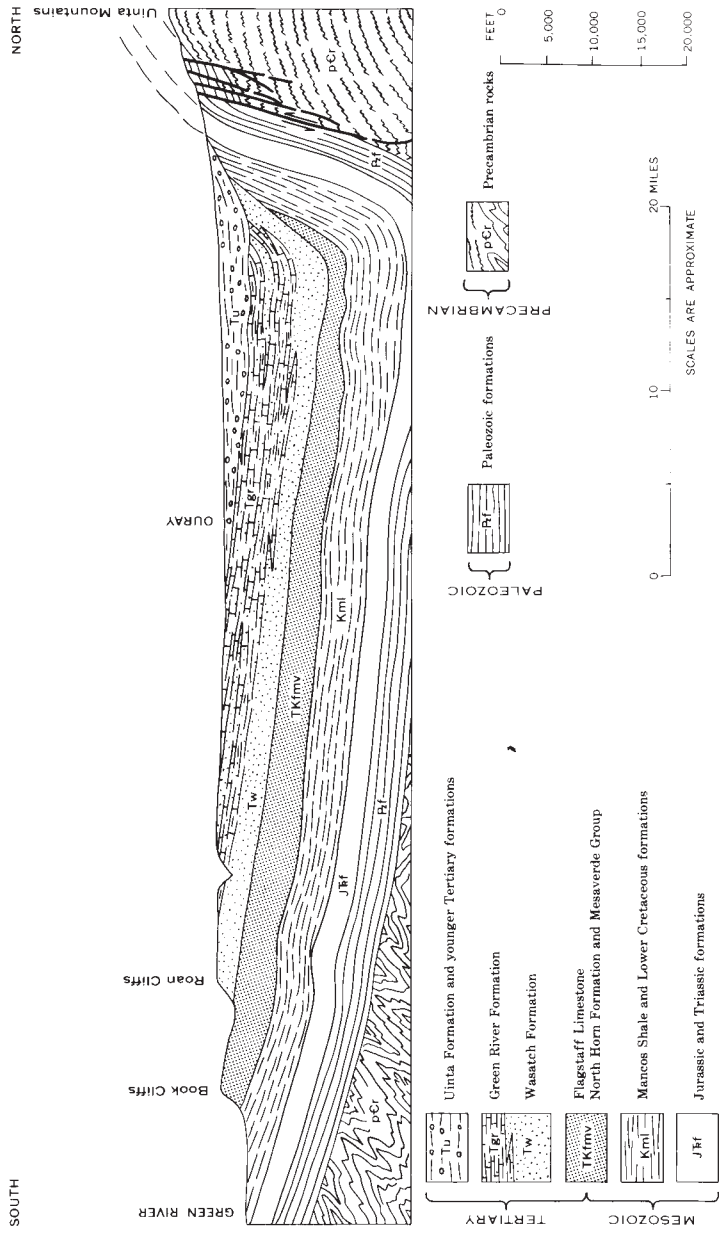


FIGURE 2 — *Generalized cross section of Uinta Basin from Green River to Uinta Mountains, Utah.*

Era	Period	Epoch	Age in millions of years
Cenozoic	Quaternary	Holocene	0.01
		Pleistocene	3
	Tertiary	Pliocene	12
		Miocene	26
		Oligocene	38
		Eocene	54
		Paleocene	65
Mesozoic	Cretaceous		135
	Jurassic		180
	Triassic		225
Paleozoic	Permian		280
	Pennsylvanian		310
	Mississippian		350
	Devonian		400
	Silurian		440
	Ordovician		500
	Cambrian		570
Precambrian			

TABLE 1 — *Divisions of geologic time.*

Paleozoic Time (570-225 million years ago)

During Middle to Late Cambrian time, seas again entered the area, and throughout the Paleozoic Era the area was either a shallow marine sea or a slightly emergent lowland.

Mesozoic Time (225-65 million years ago)

During Triassic, Jurassic, and Early Cretaceous time the site of the Uinta Basin was alternately a shallow sea, emergent tidal flats and flood plains, and wind-swept desert. The rocks that formed during this interval differ markedly in their resistance to erosion, and they show a broad spectrum of colors. Where they are exposed along the foothills of the Uinta Mountains or on the deep gorges and high mesas of the canyonlands they form some of the most spectacular and colorful scenery of the Colorado Plateau.

During Late Cretaceous time a shallow sea which advanced inland from the Gulf of Mexico covered most of the Western Interior of North America. On the floor of the sea, muds, which represented fine sediments that were carried long distances by currents and waves and occasional ash falls from distant volcanoes, collected to form the Mancos Shale. Fish scales, oysters, clams, ammonites (nautiloids), and other fossils indicate that the sea supported a varied fauna. To the west, in the area of the present Great Basin (Fig. 1), the Mancos Sea was bordered by a north-trending mountain range, the Cordillera, which was being actively uplifted by forces within

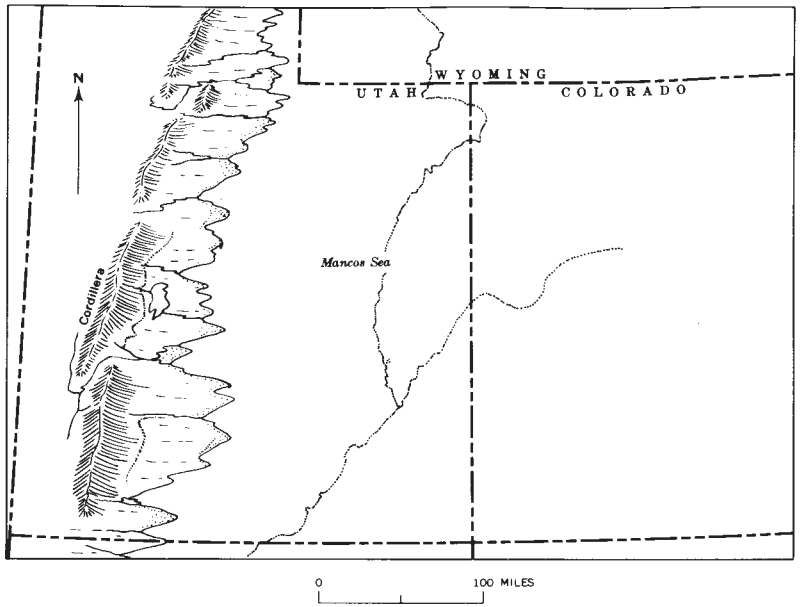


FIGURE 3 — *Paleogeographic map of the northern Colorado Plateau in Late Cretaceous (Mancos Shale in the Uinta Basin) time. Present course of the Green and Colorado Rivers dotted.*

the earth. Figure 3 is a paleogeographic map of the northern Colorado Plateau and environs at the time the Mancos Shale was being deposited in the site of the Uinta Basin.

During the remainder of the Cretaceous Period the Cordillera continued to rise, and coarse clastic sediments carried by streams from the rising mountains built a series of alluvial fans and flood plains eastward across areas formerly covered by the Mancos Sea. Locally luxuriant forests grew in swampy areas on the flood plains or around lagoons cut off from the sea by sand bars (Fig. 4). The clastic sediments that were deposited as offshore sand bars, along beaches, and on flood plains are the Mesaverde Group, and the vegetation is preserved as coal beds.

As time passed, the Mancos Sea continued to withdraw toward the southeast, and the marine, littoral, and continental sandstones of the Mesaverde Group extended farther and farther across the area formerly occupied by the Mancos Sea. The withdrawal was not,

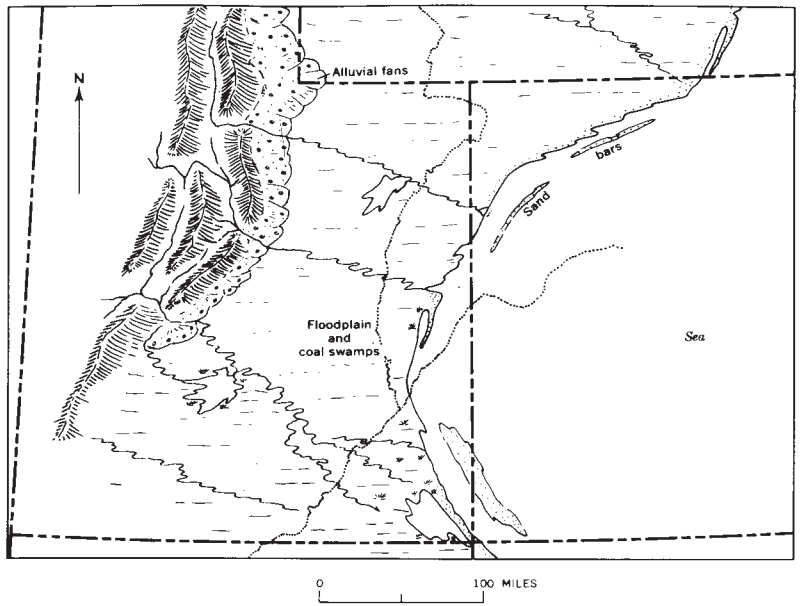


FIGURE 4 — *Paleogeographic map of the northern Colorado Plateau in Late Cretaceous (Mesaverde Group in the Uinta Basin) time. Present course of the Green and Colorado Rivers dotted.*

however, without interruptions. Minor readvances of the sea, represented by northwestward shifts of the shoreline, are recorded in the Mesaverde by marine shale sequences interbedded with sandstones.

At the close of the Cretaceous Period the site of the Uinta Basin was entirely above sea level and it was receiving coarse clastic sediments (the Tuscher Formation at the top of the Mesaverde Group) from the rising Cordillera to the west. The Uinta, Uncompahgre, and the San Rafael Swell uplifts were beginning to develop in the northern Colorado Plateau.

Cenozoic Time (65 million years ago to the present)

During Paleocene time, uplifts on the area surrounding the Colorado Plateau continued to rise and some of them shed the clastic sediments of the North Horn and Flagstaff Formations into the Uinta Basin (Fig. 5).

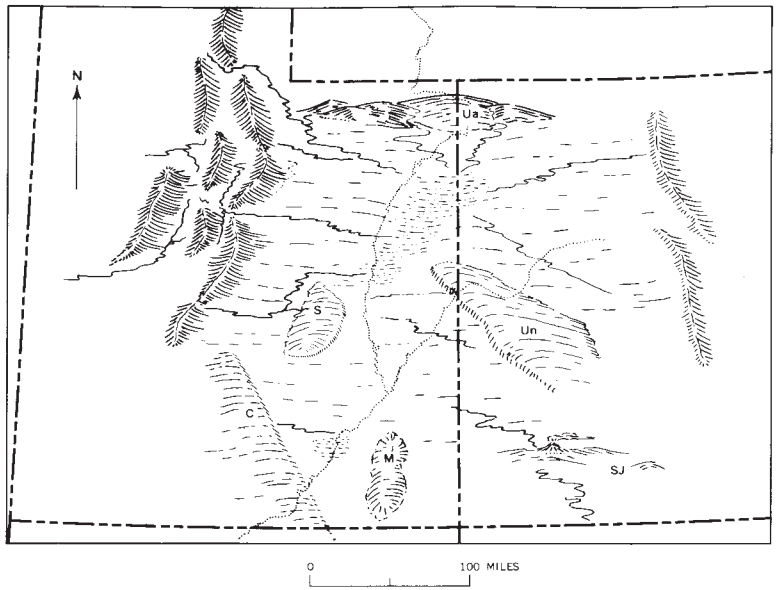


FIGURE 5 — *Paleogeographic map of the northern Colorado Plateau in early Paleocene time. Uplifts: C, Circle Cliffs; M, Monument; SJ, San Juan; S, San Rafael Swell; Ua, Uinta; Un, Uncompahgre Present course of Green and Colorado Rivers dotted.*

The Flagstaff Limestone formed in a lake lying between the Cordillera and the Uinta Basin. By the end of Paleocene time and in early Eocene time the Uinta Basin was a subsiding area, above sea level, surrounded by rising uplifts. The clastic sediments which poured into the basin from the adjacent highlands were deposited in stream channels and on floodplains. More than 2,000 feet of such material forms the main body of the Wasatch Formation (Table 3). The basin had no outlet, and water from streams and rainfall ultimately formed a major lake, Lake Uinta, in which the Green River Formation was deposited (Fig. 6).

During middle Eocene time the lake was bounded on the west by a highland on the eastern margin of the present Great Basin, on the north by the Uinta Mountains, on the east by uplifts in Colorado, and to the south probably by the Circle Cliffs and Monu-

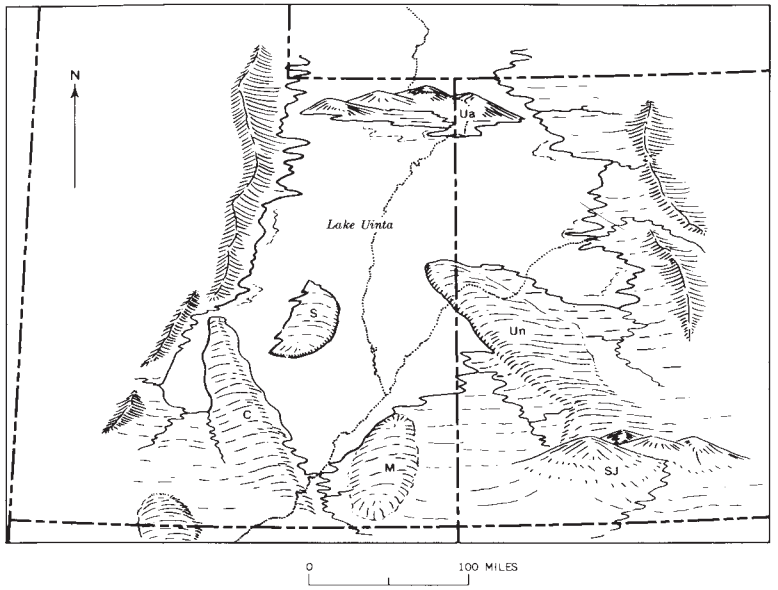


FIGURE 6 — *Paleogeographic map of the northern Colorado Plateau in middle Eocene time. Uplifts lettered as in Figure 5. Present course of Green and Colorado Rivers dotted.*

ment uplifts. Within the lake, marlstones, siltstones, sandstones, oil shales, and tuff beds accumulated. The marlstones represent calcium carbonate precipitated by chemical and organic means. Locally algae built up sizeable calcium carbonate reefs near the lake shore. The siltstones and sandstones represent sediment transported to Lake Uinta by streams, and they occur as beach, offshore bar, and lakebottom deposits. Oil shales are marlstones containing a very high percentage of organic matter which will yield oil when heated. Much of the organic matter in the oil shales may have been concentrated in fecal pellets, or excrement, of ostracods and other small animals who foraged on algae. The tuff beds represent "fallout" of ash from volcanic eruptions in areas outside the Uinta Basin. Locally in the deeper parts of the Uinta Basin the Green River Formation includes black shale that contains sodium, calcium, magnesium, barium carbonate, bicarbonate, borosilicate, and sul-

fate minerals (Milton, 1957; Milton and Eugster, 1959). These minerals were precipitated from concentrated brines formed when evaporation of the lake greatly exceeded the inflow of fresh stream and river water.

Many of the Green River lacustrine strata are very thin bedded, and individual beds may persist over large areas. Some geologic sections show a cyclic repetition of very thin beds or laminae which may represent seasonal differences in sedimentation. These strata, called varves, are one of the most striking aspects of the Green River Formation. Although it covered a large area (Fig. 6), Lake Uinta was probably never more than 100 feet deep at its deepest point, and many of the Green River strata show mud cracks, ripple marks, crossbedding, raindrop impressions, and other features indicative of very shallow water deposition. That Lake Uinta and its shores teemed with life is indicated by the abundance and variety of fossils found in the Green River Formation. Among the organisms represented by fossils are turtles, fish, crocodiles, birds, mollusks, ostracods, algae, a myriad of insects and larvae, and plants.

At the same time that the Green River Formation was being deposited in Lake Uinta, the sandstones and siltstones of the Wasatch Formation were collecting in stream channels and on flood plains surrounding the lake. The shoreline of Lake Uinta was not static, but shifted frequently toward or away from the center of the lake in response to variations in the rate of subsidence of the Uinta Basin, changes in the amount of sediment being transported toward the lake from the surrounding uplifts, and climatic factors. This shifting action produced an intertonguing between Green River lacustrine strata and Wasatch fluvial strata that records the shifting shoreline of Lake Uinta (Fig. 7).

In a given area the wedge edge of each tongue of Wasatch strata represents a maximum advance of the shoreline into the lake, and the wedge edge of each Green River tongue represents a maximum expansion of the lake. Cashion (1967) has assigned names to many of the individual tongues you will see exposed along the river.

During late Eocene time a flood of coarse, clastic sediments, the Uinta Formation, derived from the Uinta uplift and uplifts in central Colorado, filled and destroyed Lake Uinta. The Uinta Formation is exposed at Ouray, Utah, where you will begin your river journey.

The lacustrine Green River strata are thus underlain and bordered laterally by fluvial beds of the Wasatch Formation and they are

overlain and bordered laterally by fluvial beds of the Uinta Formation. As Cashion (1967, p. 8) wrote, "The Green River Formation can be visualized as a jagged-edged lens of lacustrine strata enveloped in a shell of fluvial strata."

Further details on the fascinating history of Lake Uinta are given by Bradley (1929, 1930, 1948, 1964, 1966), who also described present-day lakes in which sediments similar to those of the Green River Formation are collecting.

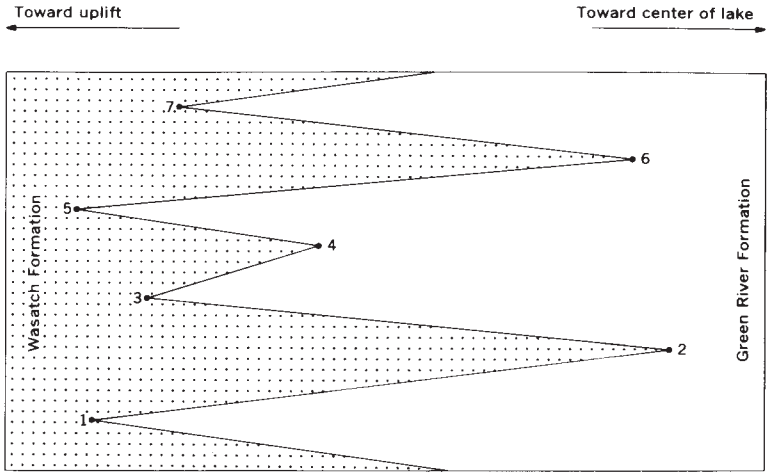


FIGURE 7 — *Diagrammatic cross section showing intertonguing of Green River and Wasatch Formations. 1-7 are positions of shoreline at selected times—1, earliest; 7 latest. 1, 3, 5, 7 maximum advances of lake toward uplift. 2, 4, 6 maximum advances of shoreline into lake. During times 1-2, 3-4, and 5-6 the lake was shrinking. During times 2-3, 4-5, and 6-7 the lake was expanding.*

There is no direct record of Oligocene, Miocene, or Pliocene events preserved in the part of the Uinta Basin through which you will be boating. Studies in surrounding areas indicate that there was extensive igneous activity to the west, east, and south, and that

uplifts continued to rise in the Colorado Plateau, the Rocky Mountains, and the Great Basin until the landscape had essentially reached its present form. The present drainage pattern of the Green and Colorado Rivers was not established until near the end of Miocene time (Hunt, 1956, 1969).

Probably about 500 feet of downcutting occurred in the canyons during Quaternary time (the last 3 million years). The record of these most recent events in the history of the Green River is preserved as terrace gravels, which as yet have not been studied in detail.

Many of the basic facts of this geologic history were originally recognized by Powell and his crews. Later geologists have filled in many details, but there is still much to be discovered in the rock books exposed on the walls of Gray and Desolation Canyons.

River Log

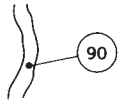
Mile 128.2[1] Launching site on right bank of Green River just downstream from Utah State Highway 88 bridge at mile 128.25 (see Fig. 8). The large cottonwood trees offer welcome shade, but the dense tamarisk and willow thickets at river's edge are infested by savage hordes of large, and very hungry, mosquitoes. George Y. Bradley of the 1869 Powell expedition gave a vivid description of these winged furies in his journal (Darrah, 1947, p. 44):

> "The mosquitoes are perfectly frightful. As I went through the rank grass and wild sunflower . . . they would fairly scream at me. I think I never saw them thicker even in Florida than at this place . . . One of the men says that . . . a mosquito asked him for his pipe, knife, and tobacco and told him to hunt his old clothes for a match while he loaded the pipe . . ."

The town of Ouray, a few hundred yards to the north, consists of a trading post-gas station, a few small houses, and stock loading pens set on a sun-baked alluvial terrace 20 feet above river level. The Uintah and Ouray Indian Reservation from which you are

[1]Mileages in this log are measured upstream from Green River, Utah, (mile 0.0) and are taken from the U.S. Geological Survey *Plan and Profile of Green River, Green River, Utah to Green River, Wyoming* (1924). Left and right banks as used in this log refer to the observer's left and right when looking downriver.

Explanation for figures 8, 10, 17, and 21



River mileage

Quadrangles outlined are U.S. Geological Survey topographic maps

Gilsonite vein

Oil or gas well

Fault

Dashed where approximately located

Anticline

Showing crestline and direction of plunge

Syncline

Showing troughline and direction of plunge

Explanation for maps (Figs. 8, 10, 17, and 21).

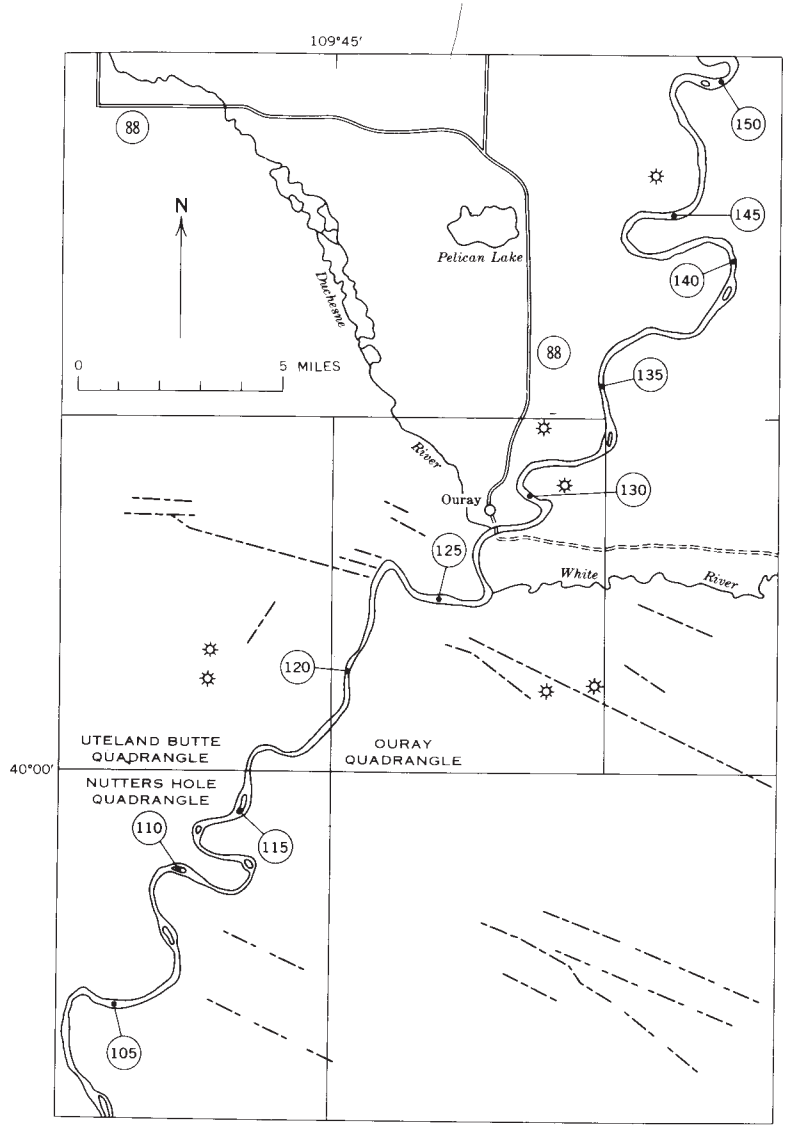


FIGURE 8 — *Sketch map of Green River from mile 151.0 to mile 100.6.*

embarking dates back to October 3, 1861, when President Lincoln designated the Uintah Valley as a reservation. Large carp and catfish lurk in the river, but non-Utes who would pursue them must obtain a tribal fishing license.

The parties of both of the Powell expeditions camped more than a week in this area, the 1869 party a short distance upstream on the west (right) bank, and the 1871 crew just opposite your launch site. In 1869 Powell and several men walked to the Ute Agency nearly 40 miles up the Duchesne River. At the Agency they sent out mail and copies of their field notes, and procured 300 pounds of flour. Frank Goodman, the Englishman who had lost his gear in the wreck of the *No Name* at Disaster Falls in Lodore Canyon, left the group at the Agency.

In 1871 Powell's brother-in-law, Almon H. Thompson, took temporary command for the voyage between Ouray and Gunnisons Crossing (just above Green River, Utah). The Major himself went overland to Salt Lake City and Manti, rejoining the river-runners at Gunnisons Crossing on August 29, and bringing flour, sugar, meat, and mail.

The 1869 party embarked from here on July 6, the 1871 expedition on August 5, and now—it's your turn. *Al rio!*

Mile 128.1 Mouth of Duchesne River on right. The sand bars and thickets on the left provide surroundings attractive to deer and many birds. As you float by you may glimpse, or hear, ducks, geese, herons, avocets, sand pipers, warblers, canyon wrens, doves, and blackbirds.

Mile 127.2 West Branch, a shallow slough, begins on the right. The low mesa ahead, downriver, is underlain by the reddish-brown siltstone and interbedded tan sandstone of the Uinta Formation. A massive sandstone caps the small buttes on the skyline.

The Uinta Formation represents stream, flood plain, lake, and playa deposition of clastic sediments which encroached upon and finally covered the site of Lake Uinta in which the underlying Green River Formation was deposited.

Mile 126.3 The White River enters the Green River on the left. The delta of the White River was an Indian winter camp in Powell's day. A Spanish trail crossed the Green River in this vicinity prior to 1830, and Kit Carson wintered here in 1832-33.

Mile 126.0 The bluff on the left exposes typical strata of the Uinta Formation. A massive sandstone forms the cliff which rises from

the river's edge and which is overlain successively by siltstone, another sandstone, and by more siltstone which is capped by terrace gravels 150 feet above the river.

Mile 125.0 Note gravel-capped terraces at 90 and 140 feet above river on left. Muskrats and deer may occasionally be seen at the edge of the pampas grass-covered flats bordering the river. On a summer morning or evening the thickets along this stretch of river resound with bird calls.

It was somewhere along here on July 6, 1869, that the Powell party . . .

> "Dropped down to a large island . . . where some white men had planted a garden; landed and the Professor [Powell], Dunn and Hall stole their arms full of young beets, turnips and potatoes. Rowed down a few miles past some splendid cottonwood islands and camped for dinner under the shade of one. Cooked our stolen forage, ate it, and pulled out again, but had not rowed a mile when all hands were as sick as landsmen on their first voyage. The Professor claimed that it was caused by some narcotic principle in the greens, but Hall decided the thing by swearing they were not half cooked, as the first thing he pulled out of his neck was a potato vine a foot long and as hard as when it was growing. We all learned one lesson—never to rob gardens."
>
> J. C. Sumner's journal (Darrah, 1947, p. 113)

Mile 124.5 House trailer and pumping station among cottonwoods on left bank. Water is pumped from the river to irrigate Tia Juana Bottom, a flat alluvial depositional terrace 5 to 10 feet above the river. Beaver cuttings may be seen in the stately cottonwood groves that grace the river's edge.

The first white men to explore the banks and tributaries of the Green River were the "mountain men" in search of beaver. William Ashley, leader of a company of trappers, traveled through the Uinta Mountains, and possibly as far downriver as Ouray, by bull boat (a pole frame covered with hides) and raft in 1825. By the time beaver hats went out of style, about 1840, most of the beaver in the easily accessible area between the Uinta Mountains and Desolation Canyon had been trapped out. Since then, however, the beaver have made a comeback, although on the river beaver are more often heard than seen.

The view downriver is of cliffs of Uinta Formation capped by alluvial terrace gravels. The terrace marks an earlier time when the river meandered laterally at a level 300 feet above its present channel.

Mile 124.0 The distant view on the horizon downriver is of the

peaks of the Uinta Mountains, 60 miles to the northwest, which are usually snowcapped until late June. The Uinta Mountains are a large east-west anticlinal uplift through which the Green River has cut the spectacular gorges of the Canyon of Lodore, Whirlpool Canyon, and Split Mountain Canyon.

Mile 123.45 West Branch, which left the river at mile 127.2, enters on right at the site of a ferry which formerly crossed the Green River here. A section of Uinta Formation is well exposed in the cliffs ahead. Note how several of the fluvial sandstones wedge out laterally, and that erosion surfaces occur locally at the bases of sandstone units. The sandstones represent stream channel, bar, and perhaps flood plain deposition during periods of high water. The channels at the base of the sandstones mark points where the late Eocene streams incised the underlying siltstones, and the wedge-outs of the sandstones mark the lateral limits of individual sand bodies.

The sizes of the talus fragments at the base of the cliff reflect differences in the rock types from which they were derived. Sandstone may break into blocks several feet in diameter, while the less well-cemented siltstone rarely yields fragments larger than a few inches in diameter. The two rock types also exhibit different fracture patterns. The sandstone beds tend to be divided into rectangular blocks by vertical joints essentially perpendicular to bedding planes, while the siltstone strata tend to be characterized by many discontinuous, closely spaced joints, many of which are not perpendicular to bedding.

Mile 123.1 Cable across river. An unimproved dirt road leads eastward from the left bank to Utah State Highway 88.

Mile 123.0 The small silo-like structure of corrugated sheet metal on the right bank is a river gaging station maintained by the U.S. Geological Survey. Instruments in the station record fluctuations in the river level. This information can be used to determine the discharge, or amount of water flowing past the station per unit time. Table 2 gives discharge data recorded at this station in the period January 1961 to September 1965. If you enjoy high-water boating, generally the best time for your river trip would be mid-May to early June.
The adit just behind the gaging station was driven along a 4-inch-wide west-northwest-trending gilsonite vein (see Fig. 8).

Many cliff swallow nests have been built beneath overhanging

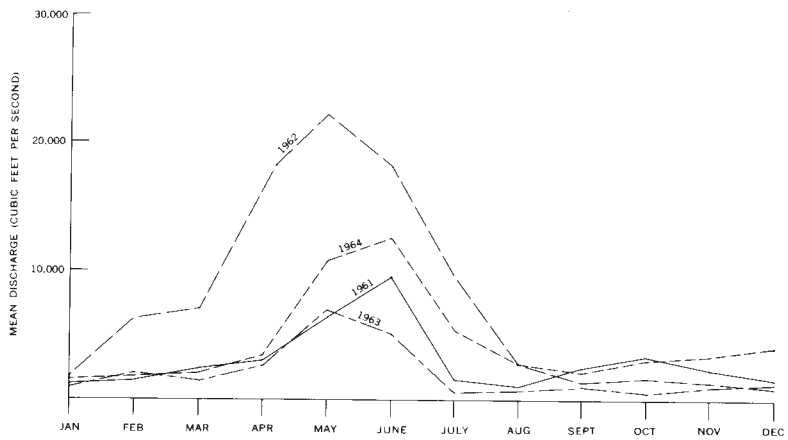


TABLE 2 — *Mean discharge 1961-1964 at gaging station near Ouray, Utah. Data from U.S. Geological Survey Water Supply Paper 1925, p. 376-378.*

sandstone beds on the cliffs, and during the summer months lizards, chipmunks, and canyon wrens can be seen frolicking in the talus piles.

Mile 122.75 Don't take the righthand channel. It is a dead-end slough nearly a mile long!

Mile 122.5 Well-developed lenticular sandstones are exposed in the Uinta Formation outcrop on the butte on the right bank (see Fig. 9).

Mile 121.5 Uteland Butte Wash, which is visible on the right, terminates in an ephemeral lake before it reaches the river channel. The Uteland mine on the point just south of the wash exposes copper carbonate minerals associated with organic debris in Uinta sandstone.

Mile 121.0 Leaving Uintah and Ouray Indian Reservation. All you need now for a catfish dinner is a little luck!

Mile 120.3 Pariette Draw enters on right. There are several oil wells about 4 miles up the draw.

Mile 119.7 Willow Creek enters on the left. The 50-foot-high bluffs to the left expose Uinta Formation capped by terrace gravels.

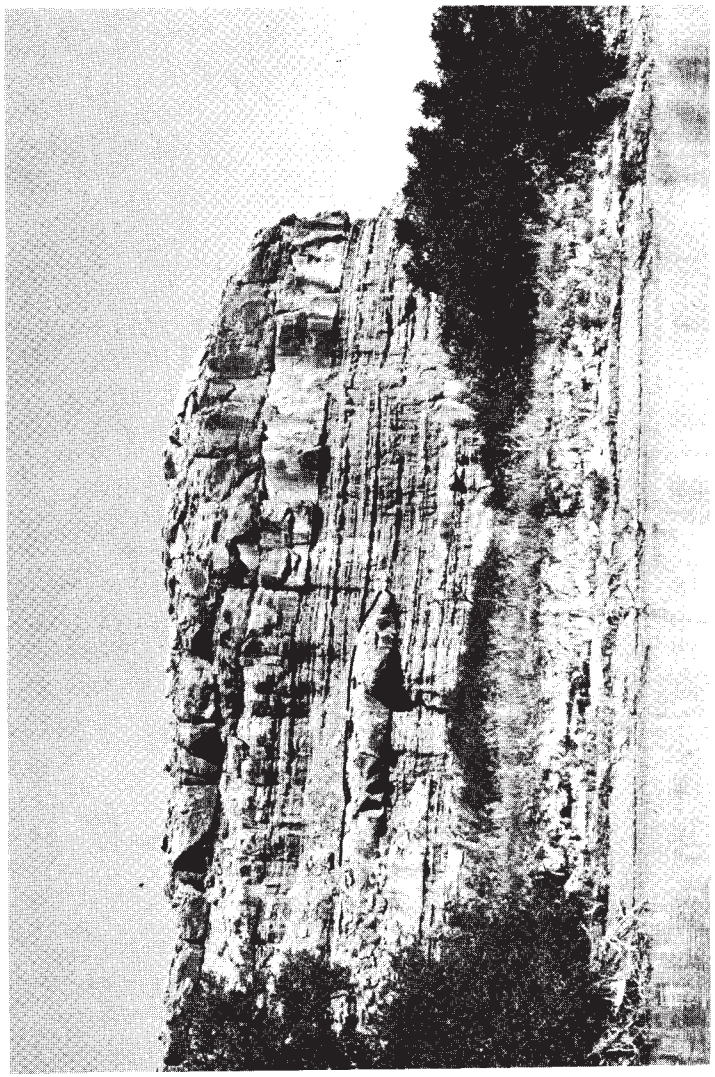


FIGURE 9 — *Lenticular sandstone (outlined) filling channel in Uinta Formation. Butte on right bank at mile 122.75. Photograph by Felix E. Mutschler.*

Mile 119.4 The light-gray-brown Uinta sandstone at river's edge on the left bank displays well-developed fluvial crossbedding. Study of the orientation of such inclined bedding allows the geologist to determine the direction of movement of the water that deposited these strata.

Mile 118.2 Wild Horse Bench ahead on left. The bluffs on the left expose Uinta Formation down to river's edge. The extensive alluvial flat on the right is bordered by cottonwoods and tamarisk. Tamarisk is a newcomer to the Colorado River basin and was not present at the time of Powell's river explorations. The plant was introduced from the Old World, and has spread throughout the Southwest.

Mile 117.8 Orange lichens brighten the Uinta sandstone outcrops at river's edge on the left bank. Scrub hawthorn(?) grows amidst the talus.

Mile 116.5 Note the gun-metal blue-black stains on some of the Uinta sandstone beds on the right. This "desert varnish" is formed by iron- and manganese-oxides precipitated when ground water, percolating out of the porous sandstone, evaporates. There are many cliff swallow nests beneath overhangs at the base of the highest sandstone exposed on the cliff.

Mile 115.9 Recent eolian (windblown) sand is plastered against wall of small alcove on right.

Mile 115.1 In the dissected talus cone on the left bank, pillars of poorly consolidated talus are capped by large blocks of sandstone. The blocks served to protect the material beneath them from erosion by rain and rill. The height of the pillars (called demoiselles, for their fancied resemblance to young ladies) gives a minimum measure of the amount of recent dissection of the talus.

Mile 115.0 Foot of midstream sand bar island. Sheep Wash enters on the right.

Mile 111.3 Keyhole-shaped amphitheater on left. Mormon Tea and rabbit brush grow profusely along the left bank near river's edge.

Mile 110.9 Note small alcove in Uinta sandstone about 60 feet above the river on the left. The white "alkali" stains and incrustations on the upstream side mark a point where ground water

Era	Period	Epoch	Stratigraphic unit	Approximate thickness (feet)	Character and remarks
Cenozoic	Quaternary	Holocene and Pleistocene	Alluvium, dune sand, talus, landslides, terrace gravels, desert varnish, and "alkali" deposits		Generally unconsolidated, alluvial, colluvial, and eolian deposits. Deposits from spring and surface waters.
			UNCONFORMITY		
	Tertiary	Eocene	Uinta Formation	1,750 (Top not exposed)	Brown and reddish-brown fluvial sandstone, siltstone, and shale.
			Green River Formation — Evacuation Creek Member	600	Tan, grayish-green, light-gray, thin-bedded lacustrine marlstone, siltstone, and sandstone. Numerous thin tuff beds. Top interfingers with Uinta Formation. 40- 50-foot-thick, ledge-forming Horse Bench Sandstone Bed at base.
			Green River Formation — Parachute Creek Member	450	Thin-bedded, lacustrine marlstone, sandstone, siltstone, oil shale, and tuff. Mahogany oil-shale bed at base.
			Green River Formation — Douglas Creek Member — Tongue A	600-750	Gray and green thin-bedded lacustrine siltstone, sandstone, and marlstone.
			Green River Formation — Douglas Creek Member — Renegade Tongue	780-900	Brown and gray irregularly bedded, lenticular sandstone with gray, green, and red shale interbeds. Mainly of fluvial origin.
			Green River Formation — Douglas Creek Member — Tongue E	200-250	Gray and green thin-bedded sandstone, shale, and limestone probably representing nearshore lacustrine and fluvial deposition.
			Green River Formation — Douglas Creek Member — Main body (Tongue Z of Cashion, 1967)	250	Buff to moderate-red irregularly bedded, lenticular sandstone with red shale interbeds. Mainly of fluvial origin. Includes several small tongues of Green River strata.
			Wasatch Formation — Tongue		stone probably representing nearshore lacustrine deposition.
			Wasatch Formation — Main body	About 2,000	Buff to moderate-red irregularly bedded, lenticular sandstone with red shale interbeds. Mainly of fluvial origin.
		Eocene(?)	Flagstaff Limestone	50	Gray fresh-water limestone interbedded with reddish-brown shale.
		Paleocene	North Horn Formation	200-250	Gray and buff sandstone and shale.
Mesozoic	Cretaceous	Late Cretaceous	Mesaverde Group — Tuscher Formation	220	Buff to light-gray, crossbedded sandstone, locally stained dark reddish brown, with a few thin conglomerate beds. Generally forms a steep cliff.
			Mesaverde Group — Farrer Formation	600	Buff sandstone and medium-gray to olive-green shale. Generally forms slopes.
			Mesaverde Group — Price River Formation — Bluecastle Sandstone Member	80-120	Buff, ledge-forming, massive sandstone with a few shale interbeds. Carbonaceous shale and coal at base.
			Mesaverde Group — Price River Formation — Unnamed member	350	Buff sandstone and light- to dark-gray shale, locally carbonaceous.
			Mesaverde Group — Castlegate Sandstone	80	Buff to light-gray, cliff-forming, massive, crossbedded sandstone.
			Mesaverde Group — Blackhawk Formation — Upper member	70-150	Medium-gray shale with interbedded buff to yellowish-gray sandstone. Several coal beds in lower part.
			Mesaverde Group — Blackhawk Formation — Middle sandstone member	100-200	Light-buff, cliff-forming, massive sandstone.
			Mesaverde Group — Blackhawk Formation — Middle shale member	100-150	Medium-gray shale with minor sandstone.
			Mesaverde Group — Blackhawk Formation — Lower sandstone member	150	Buff to light-gray sandstone with some interbedded medium-gray shale. Lower part generally forms slopes.
			Mancos Shale	3,500 (Base not exposed)	Medium- to dark-gray or blue-gray marine shale with local buff siltstone and sandstone beds and a few thin bentonite beds.

TABLE 3 — *Geologic units exposed along Green River between Ouray and Green River, Utah.*

seeped out through the rock. The "alkali" consists of sodium and calcium bicarbonates and sulfates.

Mile 110.7 The charred cottonwood trees on the right bank are a stark reminder to be careful with fire if you camp along the river. The Powell crew of 1869 had a dramatic lesson in fire safety when a capricious wind blew sparks from their fire into some nearby dry vegetation. The ensuing conflagration sent the men scrambling to their boats, where they were obliged to push off from shore and run a rapid willy-nilly!

Mile 109.6 Numerous large blocks of Uinta sandstone have slid toward the river from the cliff on the right. The blocks separated from the wall along joints parallel to the river.

Mile 109.4 Desert Spring Wash enters on the right. Moon Bottom, on the left, is an alluvial flat deposited by the river on the inside curve of a meander (see p. 41).

Mile 108.9 Turkey vultures often nest on the cliff to the right and are responsible for the prominent guano stains on the wall.

Mile 107.9 The transition zone between the fluvial Uinta Formation and the underlying lake sediments of the Green River Formation crosses the river in this area. Fluvial and lacustrine strata show considerable intertonguing through a vertical interval of 100 to 150 feet. W. B. Cashion, who is mapping the area for the U.S. Geological Survey, places the top of the Green River Formation at the top of the 10- to 15-foot-thick white- to light-gray-weathering dolomite and clay bed exposed on the cliff to the left.

The Green River strata exposed in this area are part of the upper, or Evacuation Creek, member of the Green River Formation (see Table 3). The tan, greenish-gray, and light-gray, thin-bedded marlstones, siltstones, and tuffs of the Evacuation Creek Member exposed in this area represent precipitation of lime from lake waters, fine-grained sediments carried by currents from shore areas, and fallout of volcanic ash into Lake Uinta (see p. 37). During deposition of the upper part of the Evacuation Creek Member, Lake Uinta was shrinking, and ultimately the area was covered by the coarser clastic sediments of the Uinta Formation, which represent deposition in streams and on flood plains.

Mile 107.3 Entering Kings Canyon Bottom on the left.

Mile 106.4 Kings Canyon enters on left.

Mile 106.1 Fourmile Wash enters on right.

Mile 105.4 Looking back upriver, you can see the transitional contact between the Uinta and Green River Formations which looks like a sharp line on the cliff walls.

Hydes Bottom on the left.

Mile 105.0 The small bottom on the right was formerly called "Indian Pasture" (Reeside, 1925, Fig. 2). The small ephemeral pond dammed off from the river by fluvial and eolian sands here is an outstanding mosquito nursery during the summer!

Mile 104.2 Note the large, partially dissected block talus piles on the right. The blocks fell from cliffs of the Uinta Formation above the Green River Formation which is exposed in ravines between talus piles.

Mile 104.0 The high plateaus on either side of the river were named the Tavaputs Plateaus by Powell. The river divides the West Tavaputs Plateau (right) from the East Tavaputs Plateau (left). Both are capped by Uinta Formation, which forms odd, blocky buttes on the right skyline.

Mile 103.4 Rays Bottom on right.

Mile 102.9 Excellent exposures of upper part of Evacuation Creek Member of Green River Formation capped by Uinta Formation on cliff above Long Bottom to left.

Mile 102.0 Remnants of split-log rail fence near the base of the hill to the right mark the boundary between T. 10 S. and T. 11 S.

Mile 101.0 In 1969 the main channel of the Green River had shifted to the left of this island from a position on the right of the island as shown on the Nutters Hole topographic map (1953).

Beaver-cut cottonwoods are numerous on the left bank, which is a favorite trysting ground for spring peepers in June.

Mile 100.1 The ledge about 60 feet above river level on the right bank is underlain by the Horse Bench Sandstone Bed at the base of the Evacuation Creek Member of the Green River Formation. The strata below the Horse Bench Sandstone Bed are part of the Parachute Creek Member of the Green River Formation.

The dark-grayish-brown-weathering Horse Bench Bed consists

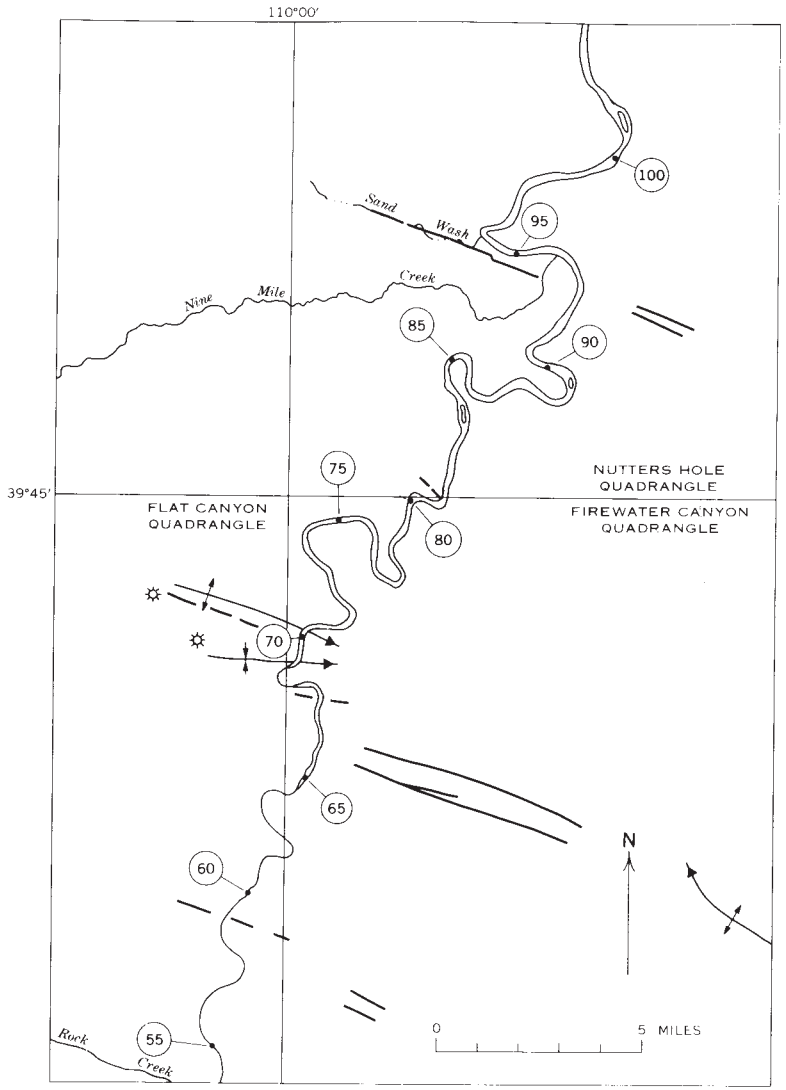


FIGURE *10 — Sketch map of Green River from mile 103.7 to mile 54.0.*

of 40 to 50 feet of thin- to medium-bedded tan siltstone and sandstone, broken into posts and blocks by joints.

A quarter-circle wall of dry-laid siltstone blocks on the ledge here is probably a prehistoric Indian ruin.

Mile 99.2 The view downriver to the right bank shows thin-bedded grayish marlstone, siltstone, and oil shale strata of the Parachute Creek Member rising from river level to the prominent bench held up by the chocolate-brown Horse Bench Sandstone Bed.

This is succeeded upward by slopes underlain by the Evacuation Creek Member, which is capped at the skyline by Uinta Formation cliff.

Mile 97.5 Boat Bottom on left.

The "cave" in the Parachute Creek strata just below the Horse Bench Sandstone Bed, which forms the upper cliff to the right, was probably produced by spring sapping along closely spaced vertical joints. Ground water moving along the joints dissolves away calcium carbonate in the rock and washes away the remaining fragments. Farther down the cliff, along vertical joints that strike across the river, pinnacles which were formed by selective rain and rill erosion occur locally in Parachute Creek strata.

Mile 97.3 The thin (about 6 inches thick) yellowish-orange beds in the Parachute Creek cliff rising from the river's edge on the right bank are tuffs which represent aerial fallout of volcanic ash into Lake Uinta. Tuff beds are excellent time markers for stratigraphic correlation because many of them extend over hundreds of square miles and their deposition represents essentially instantaneous, or very short-term events. The location of the volcanoes from which the volcanic ash was erupted during middle Eocene time is uncertain. They may have been in the Great Basin of Utah and Nevada to the west of Lake Uinta, in the Yellowstone area to the north, or in Colorado to the southeast.

Mile 96.4 On the right, the small gentle folds and locally broken and contorted beds in the Parachute Creek strata exposed in the cliff at river's edge may reflect differential flowage in underlying tuff beds, or they may reflect slumping of water-saturated unconsolidated sediments on the floor of Lake Uinta.

The contact of the Parachute Creek and Douglas Creek Members of the Green River Formation crosses the river here.

Mile 95.9 Sign on the right bank reads:

HISTORIC MARKER 1000 FEET AHEAD RIGHT BANK

FIGURE 11 — *Cliffs exposing Green River Formation. Tongue A of the Douglas Creek Member (Tgda), Mahogany oil-shale bed (Tgmo), Parachute Creek Member (Tgp), and Horse Bench Sandstone Bed (Tghb). View east near mile 85.5 Photograph by Felix E. Mutschler.*

Mile 95.8 Sand Wash enters on the right, near the site of a wagon ferry which formerly crossed the river here. This is the beginning of Desolation Canyon. Just upstream from the mouth of the wash is a stone and cement monument erected in 1969 by the Bureau of Land Management, U.S. Department of the Interior. Plaques on the monument designate Desolation Canyon as a Registered National Historic Landmark, and describe Powell's canyon voyages. Since the monument is only a few feet above summer river level, and stranded driftwood can be observed at higher levels than the base of the monument, it seems unlikely to remain a permanent tourist attraction!

Up Sand Wash, 150 feet from the monument, two abandoned log cabins and a corral squat beneath venerable cottonwoods. A few hundred yards farther up the draw is a small adit driven into the 2- to 3-foot-thick, blue-gray-weathering unit of rich oil shale, the Mahogany bed, at the base of the Parachute Creek Member. Oil shale is marlstone with a high content of organic matter in the form of kerogen, from which oil may be driven off by heating. Oil shale beds are numerous in the Green River Formation, and Bradley (1966) believed that they may represent accumulations of organic ooze consisting largely of fecal pellets, or material which passed through the digestive tracts of tiny aquatic animals such as ostracods, who dined on microscopic algae.

The Mahogany bed is the richest, and most persistent, oil shale in the Uinta Basin. On a freshly broken surface it is dark reddish-brown, and the layered effect produced by closely spaced bedding planes resembles wood—hence its name.

Much of the Mahogany bed, when heated, will yield at least 30 gallons of oil per ton. The story is told of a local rancher who built a fireplace of this attractive stone, and whose housewarming ended in a blazing chimney!

A dirt road leads from the mouth of Sand Wash westward to Utah State Highway 53, a distance of 28 miles. Although this approach is rather rough, many river runners have used Sand Wash as a starting point for the float to Green River.

Mile 95.0 Many swallow nests festoon the sheer cliff rising from the river on the right. When the young swallows make their first flight from nests here—it's fly or swim! Perhaps a word of appreciation is in order here—these delightful birds consume large numbers of mosquitoes!

Mile 94.8 On the right, the Mahogany oil shale bed is the 3- to 4-foot-thick, gray-weathering, relatively resistant bed that crops out in the gentle slope 10 to 15 feet above the 40-foot cliff at river's edge. The Mahogany bed marks the base of the Parachute Creek Member in this area, and the strata exposed below it are the upper part of the Douglas Creek Member of the Green River Formation.

The Douglas Creek Member consists principally of lacustrine sandstones, siltstones, shales, and limestones; a few oil shale beds are found in its upper part. The lake deposits of the Douglas Creek Member intertongue with the coarser clastic flood plain, delta, and stream-channel deposits of the Wasatch Formation formed at the shifting edge of Lake Uinta (see Fig. 7). Cashion (1967) has assigned the strata exposed at river level here to tongue A, the highest (youngest) tongue of the Douglas Creek in the intertonguing sequence.

The view over the left bank ahead shows brown strata of the Uinta Formation on the high skyline point, beneath which complete sections of the Evacuation Creek and Parachute Creek Members and the upper part of tongue A of the Douglas Creek Member of the Green River Formation are exposed on barren slopes and cliffs.

Mile 94.1 Looking into the alcove on the left you can see several caves about 200 feet above the river.

Mile 93.75 Nine Mile (or Minnie Maud) Creek, a perennial stream, enters on the right. Ruins and petroglyphs in the upper part of the Minnie Maud valley indicate that the area was inhabited by Indians of the Fremont culture, which flourished in the Uinta Basin between about 900 and 1275 A.D.

Mile 93.3 Nutters Hole, an open amphitheater about 2 miles across and 180 feet above river level, can be reached via the small side canyon on the left.

Mile 92.8 You are crossing the projection of a west-northwest-trending fault zone which has been mapped on either side of the river (see Fig. 10) but which is not apparent on the riverside cliffs here.

Mile 92.4 On the upper part of the cliff rising from the river on the left bank is an area several hundred feet long in which the Douglas Creek strata are disturbed. Bedding is contorted and displaced as much as 20 feet along concave surfaces that appear as a series of scallops on the cliff face. These contorted beds may represent slumping of partially lithified sediments into channels scoured by currents on the floor of Lake Uinta.

Mile 92.2 An entrance to Nutters Hole on the left. The Wrinkles, jagged cliffs rimming the Hole, provide a spectacular view to the northeast. The contact between the Parachute Creek and Evacuation Creek Members of the Green River Formation extends across the face of the Wrinkles as does a scary jeep trail to the site of the abandoned Sand Wash ferry.

The greensward on the right-bank bar is a splendid place for camping and touch football.

Mile 91.3 The Carbon County-Uintah County boundary line comes in from the west and turns southward along the river at this point. From here down to mile 46.85, if you float to the right of the river's center line you are in Carbon County, while if you float to the left you are in Uintah County.

Mile 91.0 Entering Duches Hole on the left.

The "Gothic Cathedral" wall on the cliff to the right consists of vertical walled alcoves separated by buttresses. Differential erosion along vertical joints has sculptured the wall. Talus fills the lower parts of the alcoves.

Mile 89.5 Another buttressed wall on the left extends to mile 88.5. Two generations of talus can be observed between some of the buttresses. The older talus is stabilized by vegetation including some unusually thick, for this area, grass growth. The more recent, unstable talus occurs in gullies or overlying stable talus, and is barren of vegetation.

Note the differences in the profile of the canyon walls on opposite sides of the river as seen here, or looking back toward Duches Hole. In both cases the wall on the inside of the meander bend slopes gently toward the river, while the wall on the outside of the bend forms an abrupt cliff rising almost vertically from the river. The steep cliffs represent lateral undercutting by the fast current on the outside of a meander in the river. On the inside of the bend the slower current is usually depositing material. As the river cuts downward, its channel shifts toward the undercut bank and slips off the inner bend. Successive stages in the evolution of the canyon profile at mile 90.8 are shown in Figure 12.

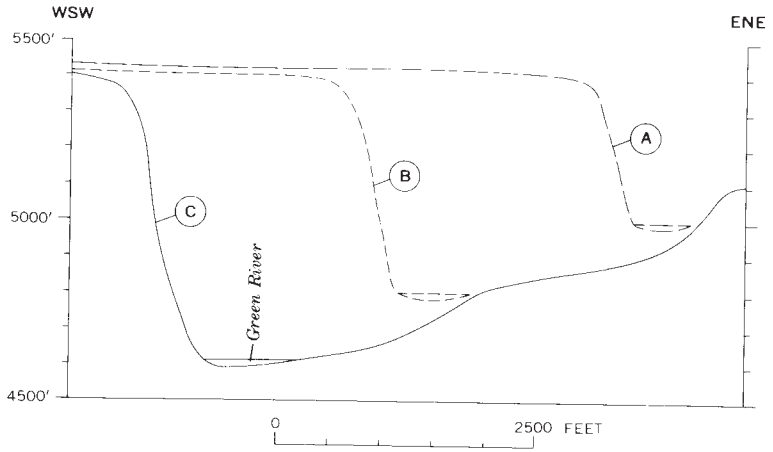


FIGURE *12 — Successive stages in the evolution of the canyon profile at mile 90.8. A) profile when Green River channel was 400 feet above its present level; B) profile when Green River channel was 200 feet above its present level; C) present profile.*

Mile 89.0 Bar on right is Gold Hole, according to the 1953 edition of the Nutters Hole topographic map. See mile 81.35 for another Gold Hole.

Mile 88.25 Entering Uncompahgre Addition of the Uintah and Ouray Indian Reservation on left bank. The river is the western border of the reservation from here downstream to Coal Creek at mile 26.1.

Mile 87.8 On the vertical cliff to the right, fluvial crossbedding can be observed in the thick Douglas Creek sandstone beds.

Mile 86.65 Tabyago Canyon enters on the left. During high-water there may be a riffle caused by the gravel bar at this point. The 1871 Powell party recorded this as the first rapid in Desolation Canyon.

Tabyago Canyon drains the east side of a large "rincon," or abandoned meander, cut by the Green River when it was flowing about 400 feet above its present level (see Fig. 13).

Mile 86.2 The large talus cones on the left are being undercut and carried away by the river on the outside of this bend. Little

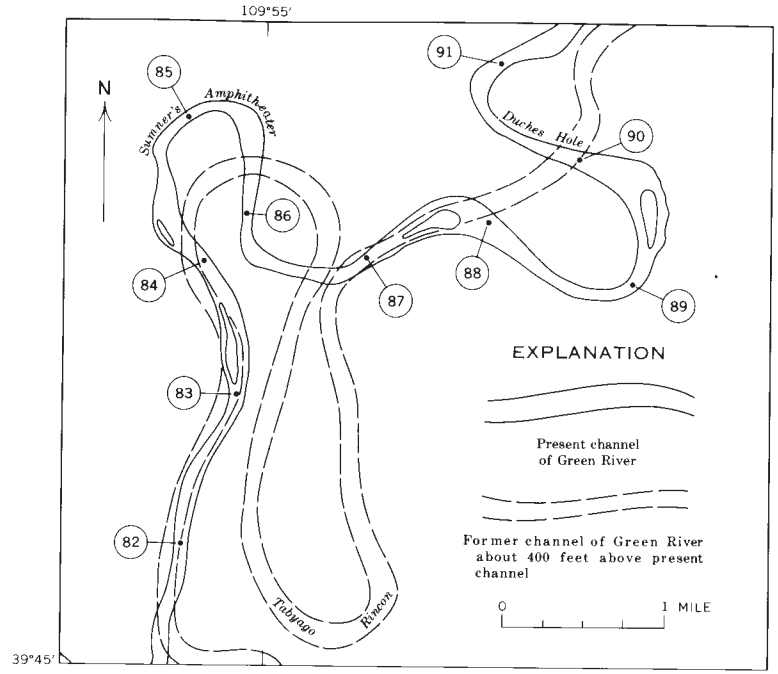


FIGURE *13 — Sketch map showing changes in channel of Green River between mile 91.5 and mile 81.3.*

Horse Bottom to the right has been formed by deposition of sand on the inside of the same bend.

Mile 85.0 Powell named the great curved cliff on the right "Sumner's Amphitheater," for Jack Sumner of the 1869 expedition. The 1871 party camped on the left bank here on August 8 and 9, and E. O. Beaman took photographs of Sumner's Amphitheater from the top of the ridge that runs south-southeast from the campsite (Fig. 14).

Mile 84.6 Three small canyons beckon from the right. On August 9, 1871, several members of the Powell expedition attempted to reach the canyon rim through one of them. A. H. Thompson (Gregory, 1939, p. 33) described the setting:

"On either side rose castellated towers as gate posts to the height of 800 feet, fluted and pinnacled like some gigantic columning fit for the Temple of Nature. The way between these "sentinels" is perhaps 200

FIGURE *14 — Sumner's Amphitheater. View from southeast across Green River. The engraving, which is reproduced from Powell (1895), was made from a photograph taken by E. O. Beaman on August 9, 1871.*

feet wide. You enter. Rock loose in your path. Crags hundreds of feet high around. Above a narrow way or path leads on for perhaps a hundred feet, then loses itself behind a bastion from the mighty wall. You follow up. The lines of a spring torrent afford foothold. Soon you reach the spot where a leap has been taken. It may be ten or it may be fifty feet. No matter. If the sides do not afford a place for footing we make detour, climb over loose gravel, dig foothold in the shale until we get above. Sometimes the walls narrow to perhaps two feet. In one the cleft is not more than two feet and yet turns at right angles. We went up with varying ease until within 200 feet of the top when the 'crack' we were following widened out into an amphitheatre with overhanging walls. No ascent possible, so down we go."

Mile 84.0 Maverick Canyon enters on the right.

About 60 feet above the river on the left bank is a 30-foot-thick, yellowish- to grayish-brown, fluvial sandstone bed interbedded with typical Douglas Creek strata. Differential weathering of the sandstone has produced a honeycomb texture on parts of the desert-varnished outcrop. A higher fluvial sandstone locally called the "Coffee Bench" caps the cliff on the left.

Mile 83.5 During low water this section of the river is often choked with sandbars, necessitating a good bit of wading and pushing or pulling of boats. John Steward of the 1871 expedition clearly understood the dynamics of bar development when he wrote,

"Having encountered sand-bars, we have had an opportunity to study their origin and their various features. They always increase in height very gradually, . . . rising evenly and regularly until, approaching within a short distance of the surface of the water, they drop off very suddenly at the downstream termination. The height they reach is regulated in the following manner: The sand being carried up the long slope, the bank is elevated until it comes so near the surface that it renders the channel so shallow as to increase the rapidity of the current; this permits it to rise no further; then the particles of sand are rolled along until they fall over the lower margin of the ridge. Each grain is taken at a point upstream and moved along until it falls into deep water. It is thus that the bars keep moving down-stream. They are usually nearly all the way across the river."

(Darrah, 1948-49, p. 215)

Mile 82.3 On the right bank, the massive sandstone bed rising from river level at the base of the cliff is the top of the Renegade Tongue of the Wasatch Formation which intertongues with the Douglas Creek Member of the Green River Formation (see Fig. 7 and p. 20). The Rengade Tongue sandstone shows well-developed cross-bedding and many channel and scour features.

Mile 81.35 On the left bank a small alluvial bar covered with grass and shaded by box elder trees offers an inviting stopping place beneath a massive, tan, locally desert-varnished cliff of Renegade Tongue sandstone. A corral fenced by a log palisade and an old iron-prowed flat-bottom boat lying beneath an overhang at the foot of the cliff were used by stockmen.

Beware the lush poison ivy along the base of the cliff. You already have enough scratching to do with all those mosquito bites!

A short walk down the river takes you into Gold Hole, a large rincon. Gold Hole is named on the River Survey Map, but is not named on the Firewater Canyon topographic map.

Mile 81.3 A small northwest-trending fault zone is exposed in the gully on the right. Several other small faults are exposed on the point at mile 81.2. To the left the Mahogany bed may be observed near the top of the cliff on the south side of Gold Hole.

Mile 80.9 Excellent view upriver into Gold Hole rincon on the left bank.

Mile 80.4 A few small juniper trees and an occasional stunted pinyon pine hug the slope to the left.

Mile 80.0 Rock House Creek enters on right in Rock House Bottom.

RAPIDS AHEAD. Life jackets should be worn from here to mile 7. In the stretch between here and mile 7 the river falls 515 feet in 83 miles. This is an average rate of fall of 6.2 feet per mile, while the average rate of fall between Ouray and Rock House Creek is only 1 foot per mile. Most of the drop in Desolation and Gray Canyons occurs in relatively short rapids, 68 of which occur between here and mile 7.

In this log rapids are numbered consecutively downstream. The number of each rapid is followed by another number in parentheses that rates the severity of the rapid and the relative difficulty of running it. The higher the rating, the more hazardous the rapid. White-water enthusiasts of the Green and Colorado Rivers commonly classify the rapids according to a system of numbers from 1 to 10, and the rapids in Desolation and Gray Canyons range in difficulty from (1) to (6). All rapids should be approached with caution, and those rated (4) or higher should definitely be studied from the bank before running. The character of individual rapids changes with river stage and with changes in the river channel. The rapids were rated when the river was flowing about 12,000

cubic feet per second. In lower water stages, some rapids (often those with low ratings) become more difficult, others become less difficult.

Rapid 1 (1)—Caused by boulder fan from Rock House Creek constricting the Green River channel. John Steward of the 1871 expedition observed the rapids and accurately described the way they were formed. On August 12 he wrote in his journal:

> "All of the rapids in this canyon so far are opposite the entrances of lateral canyons, which bring down rocks and deposit vast moraines that have forced the current toward the opposite wall."
>
> (Darrah, 1948-49, p. 216-217)

Mile 79.0 Rapid 2 (1)—Little Rock House Canyon enters on left. Note talus cones truncated by the river on the right.

Stampede Flat (not named on the Firewater Canyon topographic map) is the bar ahead on the left.

Mile 78.0 The view ahead into the side canyon on the left at mile 77.8 shows an old talus cone which is being incised by ephemeral streams. The 35-foot-tall boulder-capped demoiselles give a minimum measure of the amount of incision. On the south side of the side canyon a scallop-shaped scar on the cliff wall marks the place where a small landslide occurred.

Cliffs on the left skyline are capped by the Evacuation Creek Member of the Green River Formation, and are studded with juniper trees.

Mile 77.5 Depending on water conditions a riffle is sometimes present here, forming over the gravel bar at the mouth of the alcove on the left. Demoiselles stand above another dissected talus cone in the alcove.

Mile 77.2 "Wishbone Wall" on the left. The wishbones are buttresses divided at their bases by small alcoves. On a summer day, with the song of the cicada rising lazily in the warm air, 'tis hard to find anything to wish for as you drift slowly beneath these majestic cliffs. There is ample time to enjoy the vistas of joint-controlled alcoves, spires, buttresses, overhangs, and occasional exfoliation slabs which form a frieze on the canyon walls.

The Renegade Tongue of the Wasatch is exposed here, capped by strata of the Douglas Creek Member of the Green River Formation.

Mile 74.0 It may well be that on the cliffs bordering this stretch

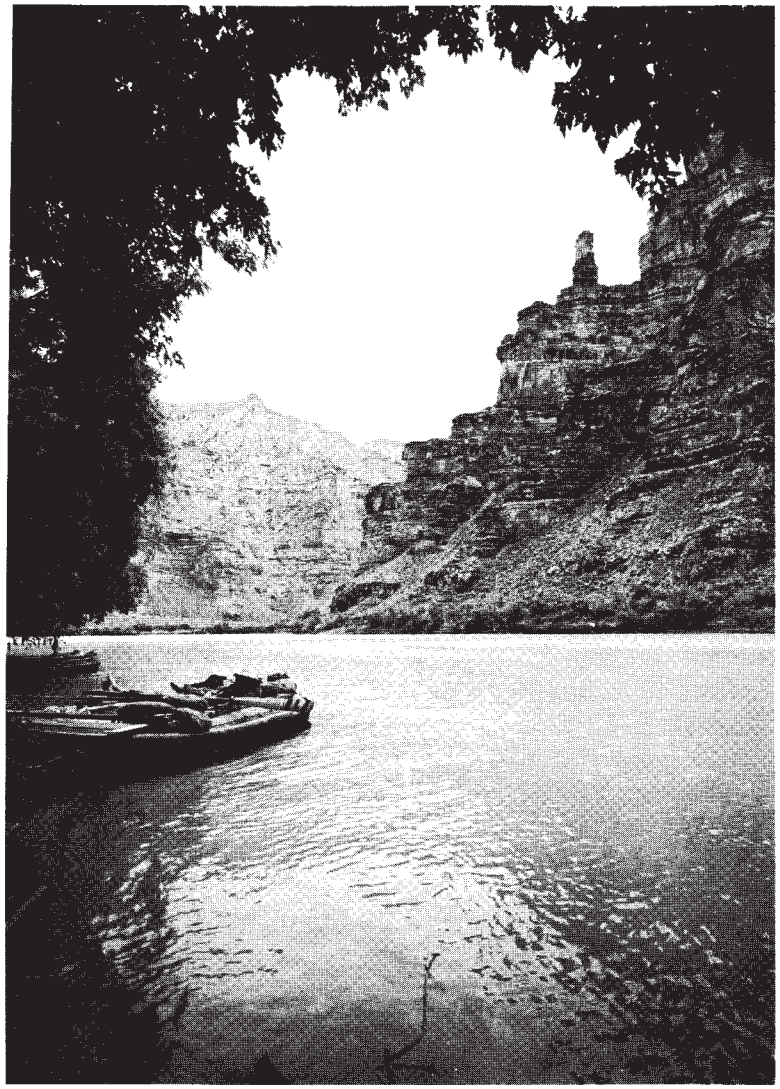


FIGURE 15 — *Lighthouse Rock, a pinnacle of Wasatch sandstone, at mile 71.9 named by the 1871 Powell expedition. Photograph by Hal G. Stephens.*

of the river George Y. Bradley saved Powell's life on July 8, 1869. The one-armed Major reached a point where he could move neither up nor down the wall, but Bradley climbed above him and lowered his long underwear down to Powell who grasped the improvised rope and swung to safety. Powell (1895, p. 168-169) described the incident as occurring in Echo Park, but Bradley's journal fixes it in Desolation Canyon.

Mile 72.7 The spire on the point on the right bank ahead was named Lighthouse Rock by the members of the 1871 Powell expedition. They made camp on the left bank at mile 71.7 while Beaman photographed the scene (see Fig. 15).

The view of the skyline cliff straight ahead on the left bank shows the Parachute Creek and Douglas Creek Members of the Green River Formation capping Wasatch strata.

Mile 70.6 Several large spring-sapped caves in the Wasatch beds are exposed in the alcove to the right.

Mile 70.0 Rapid 3 (2-3)—Caused by boulder fan from Jack Canyon which enters on right. The boulders piled around living cottonwoods on the downriver side of the mouth of Jack Canyon attest to a recent flash flood in the side canyon. Frogs and toads often sport in small pools of clear water beneath the cottonwoods at the mouth of the side canyon.

Note the dissected talus and colluvial cone on the left bank of the river.

In this area several very gentle folds cross the river (see Fig. 10).

Mile 68.6 Tall pine trees on the higher slopes ahead on the right are probably at the lower limit of their environment. Farther downhill the higher temperature and decreased moisture prevent their growth. They are restricted to north-facing slopes.

Large spring-sapped caves in sandstone are visible on the cliff. Ground water flowing along the base of the sandstone has dissolved the calcium carbonate cement of the sandstone and washed away the loosened quartz sand grains.

Natural gas is produced from lenticular sandstones in the upper part of the main body of the Wasatch Formation at the Peters Point Field 3 to 6 miles west of the river.

Mile 67.5 Note the large rock column on the left that has slipped down about 3 feet to river level along a joint dipping toward the river.

Mile 67.3 Closely spaced east-trending joints and a small sag in the upper strata exposed on the point to the left are parts of a fracture zone that extends for several miles on either side of the river.

Mile 67.0 Rapid 4 (3)—Caused by constriction of the channel by boulder fan from side canyon entering on left.

Powell (1895, p. 191) described this area where the canyon walls tower more than 2,000 feet above the river:

> "The canyon is very tortuous, the river very rapid, and many lateral canyons enter on either side. These usually have their branches, so that the region is cut into a wilderness of gray and brown cliffs. In several places these lateral canyons are separated from one another only by narrow walls, often hundreds of feet high—so narrow in places that where softer rocks are found below they have crumbled away and left holes in the wall, forming passages from one canyon into another. These we often called natural bridges; but they were never intended to span streams. They would better, perhaps, be called side doors between canyon chambers. Piles of broken rock lie against these walls; crags and tower-shaped peaks are seen everywhere, and away above them, long lines of broken cliffs; and above and beyond the cliffs are pine forests, of which we obtain occasional glimpses as we look up through a vista of rocks. The walls are almost without vegetation; a few dwarf bushes are seen here and there clinging to the rocks, and cedars grow from the crevices—not like the cedars of a land refreshed with rains, great cones bedecked with spray, but ugly clumps, like war clubs beset with spines. We are minded to call this the Canyon of Desolation."

Mile 66.7 Up the side canyon to the left is a view of pinnacles and a keyhole arch.

Firewater Point to the southeast is the home of several bands of wild horses.

Mile 66.2 Note small vertical fault on left-hand cliff. Strata on the south side of the fault have been dropped down a few feet.

The thin-bedded strata on the left with a few intercalated massive sandstone beds comprise Cashion's (1967) tongue E of the Douglas Creek Member of the Green River Formation. The siltstones of the Wasatch Formation which enclose tongue E have a more maroon color than similar strata exposed upstream.

Mile 66.07 A side canyon enters on the left, and there may be a small riffle at this point during low water.

Mile 65.8 Rapid 5 (3)—Where Firewater Canyon enters on the left.

Mile 65.5 On the cliffs in Firewater Canyon and just downriver are several high-angle faults.

Mile 65.4 Rapid 6 (1)—Where Cedar Ridge Canyon enters from the right. On the left bank is a spectacular example of a colluvial cone plastered against the rock wall. The cone is being actively dissected by the river and by rainfall runoff.

The bar at the mouth of Cedar Ridge Canyon is an excellent place to study the ecology of a side canyon fan. The lower part of the bar, built of boulders from the side canyon and sand and silt deposited by the river, supports cottonwoods, box elders, and a lone juniper tree, together with tamarisk, milkweed, and horsetail rushes. Most of these plants draw their moisture from ground water supplied by the river. The higher part of the bar, built largely of boulders from the side canyon and mantled by some windblown sand, supports only greasewood, shad scale, sage, Russian thistle, cheat grass, and prickly pear. Vegetation on the upper part of the bar is dependent for moisture on the sparse rainfall and on seepage from the rare flash floods in Cedar Ridge Canyon.

Mile 64.95 On the cliff rising from the river to the right are several gray-weathering thin beds of dark shale and thick beds of sandstone. These strata constitute a thin tongue of Green River Formation within the Wasatch Formation.

Mile 64.0 There is a large overhung cliff in massive Wasatch sandstones two-thirds of the way up the right wall ahead. Alkali stains are evident in spring-sapped caves in the lower sandstones on the cliff.

Mile 63.9 Looking downstream you can observe a well-developed alluvial fan at the mouth of the small side canyon on the right at mile 63.7. Boulder levees on top of the grass-covered fan mark the course of the most recent flash floods. As you draw opposite the side canyon note several demoiselles which mark a dissected colluvium older than the fan deposits at the mouth of the side canyon.

Mile 62.9 Rapid 7 (3)—Caused by boulder fan from Flat Canyon entering on the right. Beware of the rocks on the left when running the rapid.

Colorful gardens of yellow marsh marigolds, blue forget-me-nots, red paint brush, scarlet gilia (fairy trumpet), and water cress

surround small pools of clear water in Flat Canyon during relatively moist summers.

Mile 62.3 The alcove at the mouth of the side canyon on the left contains dissected remnants of high level alluvial fans which were graded to the Green River when it was flowing about 60 feet above its present channel.

There is a fine growth of pines on the upper cliff on the south wall of the side canyon.

Mile 62.0 Rapid 8 (1)—On either side of a small gravel island.

Mile 61.4 Note exfoliation slabbing in massive Wasatch sandstone on the cliff to the right.

Mile 60.7 Tongue F of the Douglas Creek Member of the Green River Formation (Cashion, 1967) is visible about halfway up the cliff on the right. Although the Green River beds and the enclosing Wasatch strata are the same color, the Green River beds may be recognized by their thinner and more regular bedding in contrast to that of the Wasatch. The lenticular character of the sandstones and interbedded maroon shales in the Wasatch Formation is especially well displayed beneath tongue F.

The Wasatch strata beneath tongue F, which are exposed from here downstream to mile 37.6, are within the "main body of the Wasatch Formation" as used by Cashion (1967).

Mile 60.0 Rapid 9 (1)—Note how the wind has reworked the alluvial sand on the end of the bar to the left.

The basin to the left may be a rincon. Fan deposits in the basin appear to be graded to several levels, suggesting that they formed at different times while the river flowed in channels above the present one.

Mile 59.5 Rapid 10 (4)—A recent (post-1962) flash flood from the side canyon on the right has built up a fan of boulders as much as 6 feet in diameter at the canyon mouth. A large "hole" on the left side of the rapid makes for tricky boating.

The 1871 Powell party named this rapid Fretwater Falls. After running the rapid on August 14 the group stopped on the bar.

"What a picture sitting here under a huge cottonwood; Clem sitting on a massive root is pounding the pile of driftwood and singing "Put Me In My Little Bed"; Steward just below him with his hat and shirt on writing up his diary. Mr. Beaman a little to his left is sitting in undress uniform. Fred is sitting on a pine log just above me drying his

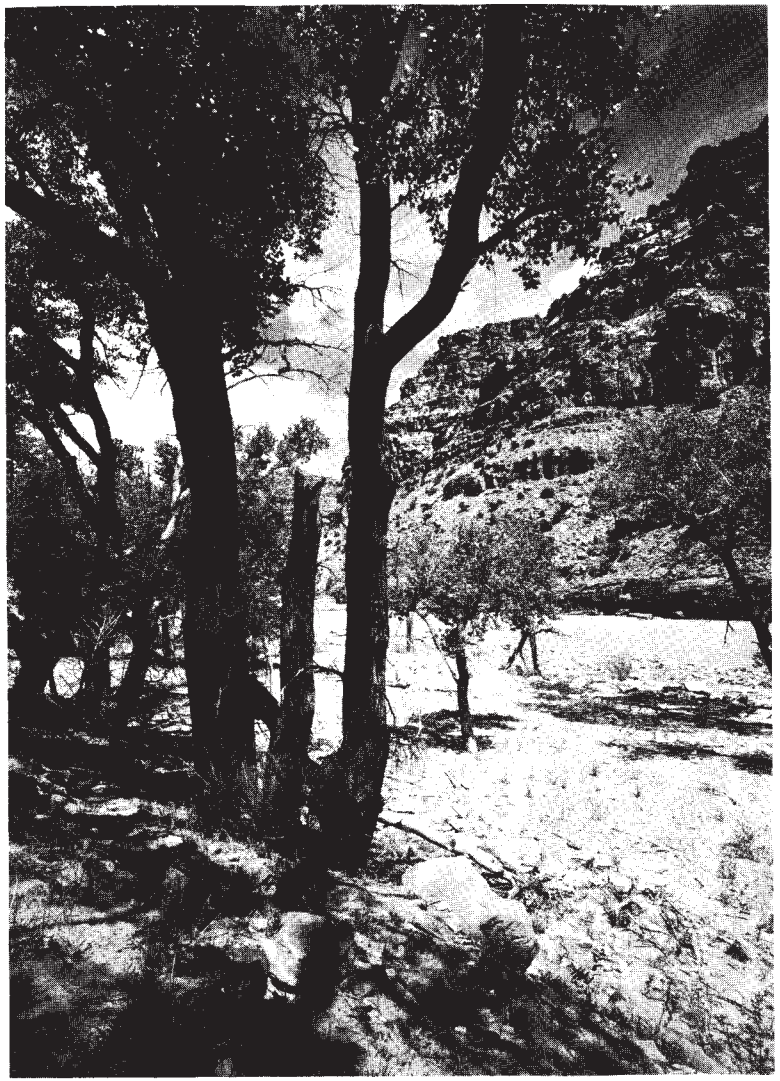


FIGURE *16 — Fretwater Falls at mile 59.5. The bar in the foreground is where the 1871 Powell party stopped (see p. 52). Photograph by Hal G. Stephens.*

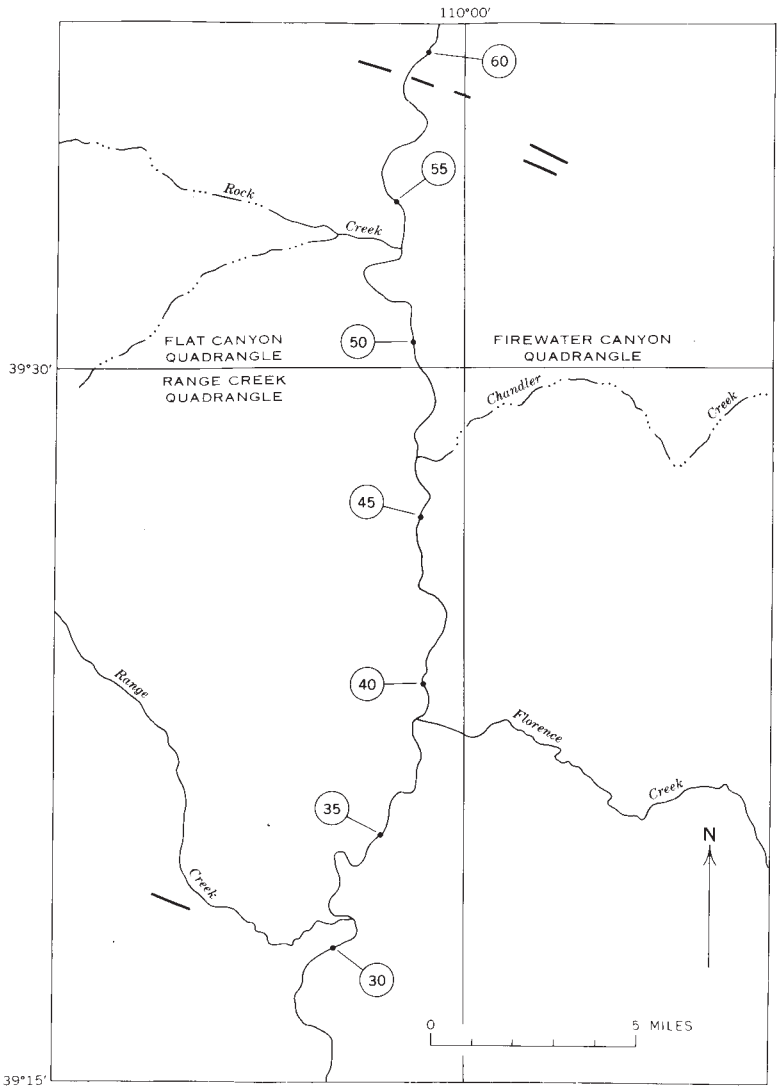


FIGURE *17 — Sketch map of Green River from mile 60.8 to mile 25.9.*

pants on a tree; Jack in the same occupation, only turning before the fire like a spitted chicken. Andy is cooking dinner and I am reclining on the sand and driftwood writing, while the more substantial part of my dress is hanging on a dead tree keeping the company of two or three others of the same sort. Clem seems to think it capital fun to knock sand into my face while I am writing. It may be to him, but I fail to see the point of his gaudy amusement. Dinner is called and there is a general rush and rally on the biscuits and coffee. Beaman has gone up to take a picture of "Fretwater Falls," the name we gave to the last rapid."

F. M. Bishop's journal (Kelly, 1947, p. 188)

On the bar, boulders from the flash flood are mounded around cottonwood trees. A large cast-iron cogwheel and rotting timbers lying on the fan behind the upstream end of the cottonwood grove provide a puzzle. What were they for? How did they get here?

Mile 59.05 Rapid 11 (1)—On either side of a small midchannel bar island.

The sand dunes on the right bank were formed by winds blowing up canyon. Sometimes these winds are so strong at midday that it is necessary to row to avoid being blown upstream.

Mile 58.4 Rapid 12 (2)—Formed by boulder fan from Wild Horse Canyon (left bank), and block talus pile (right bank) constricting channel.

Mile 57.7 Rapid 13 (3)—Side canyon enters on left.

Mile 57.3 Rapid 14 (2)—On either side of island.

Mile 56.6 Rapid 15 (5)—Studded by huge boulders derived from the fans of the small side canyon on the right and Steer Ridge Canyon entering on the right at mile 56.4.

This is probably the rapid in which Powell's *Emma Dean* capsized on July 11, 1869:

"We shoot by a big rock; a reflex wave rolls over our little boat and fills her. I see that the place is dangerous and quickly signal to the other boats to land where they can. This is scarcely completed when another wave rolls our boat over and I am thrown some distance into the water. I soon find that swimming is very easy and I cannot sink. It is only necessary to ply strokes sufficient to keep my head out of the water, though now and then, when a breaker rolls over me, I close my mouth and am carried through it. The boat is drifting ahead of me 20 or 30 feet, and when the great waves have passed I overtake her and find Sumner and Dunn clinging to her. As soon as we reach quiet water we all swim to one side and turn her over. In doing this, Dunn loses his hold and goes under; when he comes up he is caught by Sumner and pulled to

the boat. In the meantime we have drifted down stream some distance and see another rapid below. How bad it may be we cannot tell; so we swim toward shore, pulling our boat with us, with all the vigor possible, but are carried down much faster than distance toward shore is diminished. At last we reach a huge pile of driftwood. Our rolls of blankets, two guns, and a barometer were in the open compartment of the boat and, when it went over, these were thrown out. The guns and barometer are lost, but I succeeded in catching one of the rolls of blankets as it drifted down, when we were swimming to shore; the other two are lost, and sometimes hereafter we may sleep cold.

A huge fire is built on the bank and our clothing spread to dry, and then from the drift logs we select one from which we think oars can be made, and the remainder of the day is spent in sawing them out."

Powell (1895, p. 195)

Mile 55.9 Rapid 16 (4)—A boulder fan from the short side canyon on the right has pushed the river against the bedrock spur on the left bank. There is a nasty "hole" near the bottom of the rapid.

Mile 55.5 Rapid 17 (1-4).

Mile 54.6 Rapid 18 (3)—Note sand dunes on left bank.

Mile 54.2 Rapid 19 (2)—From river level to the top of the prominent bench, on the left about 450 feet above the river, the Wasatch strata are reddish brown, whereas the beds on the higher slopes are mainly grayish tan. The reddish color is due to the oxidation of iron-bearing minerals in the sediments after deposition, but probably before complete lithification.

Mile 53.95 Rapid 20 (2)—Rock Creek, a perennial stream, enters on the right, just below a grove of majestic cottonwoods, beneath whose canopy many voyageurs have rested. The Kolb brothers, who made an extensive photographic record of the canyon country, were here on October 13, 1911 (Kolb, 1927). The second Powell party camped about one-quarter of a mile downstream on August 17, 1871.

The cottonwood-bordered creek flows through an open valley between Wasatch cliffs. It offers opportunities for bathing in clear cold water and a welcome change from canned rations if you can lure the 10- to 16-inch rainbow trout to a hook.

The 2,750-foot-high cliffs on the left bank of the river were named Log Cabin Cliff by the Powell party in 1871.

Mile 53.5 Rapid 21 (1-3).

Mile 53.2 Rock Creek Ranch on the right. Ruins of a stone ranch

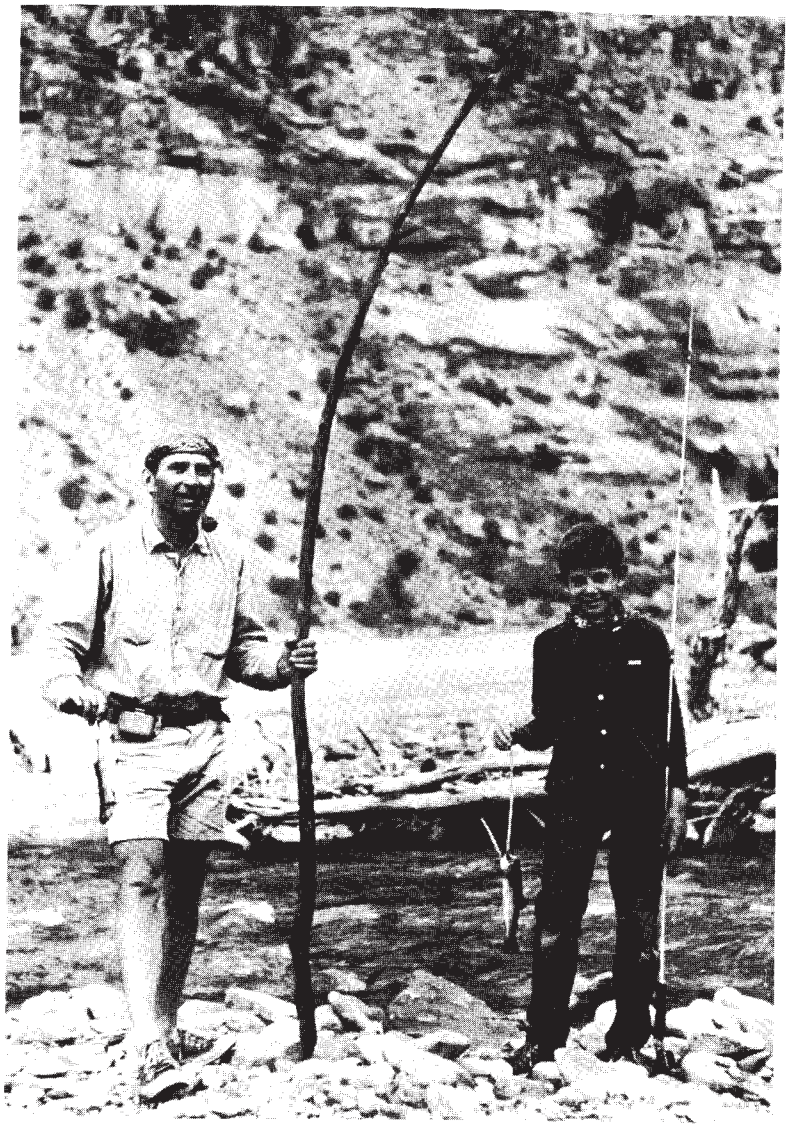


FIGURE 18 — *Fisherman's luck at Rock Creek (mile 53.9). Photograph by Felix E. Mutschler.*

house, and several log cabins, sheds, and corrals are set about with mulberry trees. These, plus an apricot, cherry, and apple orchard, provide fresh fruit if you arrive in season. The abandoned farm implements, forge, and contents of the tack shed speak of a simple and self-sufficient life before the farm was abandoned sometime after 1945. Independence was essential since the nearest town, Sunnyside, Utah, was 50 miles away by rough trails.

The fields south of Rock Creek, which once were irrigated by ditch from the creek, have been taken over by Russian thistle, cheat grass, and sunflowers.

Mile 52.7 Rapid 22 (1).

Mile 52.4 Rapid 23 (2)—Calf Canyon enters on the right.

Mile 52.0 Rapid 24 (1)—May be a (4) in low water.

Mile 51.3 Rapid 25 (2)—At mouth of Snap Canyon entering from the right.

Mile 51.0 Rapid 26 (3)—May be a (5) in low water.

Mile 50.7 Rapid 27 (2).

Mile 50.0 Rapid 28 (1)—May be a (4) in low water.

The open basin on the right is a rincon, or oxbow meander, abandoned when the river was about 350 feet above its present level.

Mile 49.9 Recent eolian white sand overlies talus slopes on the left bank.

Mile 49.7 Rapid 29 (1)—Three Canyon enters on right. View of a large balanced rock on right skyline.

Mile 49.1 Rapid 30 (4)—The large sand dunes on the left near the foot of the rapid are being anchored, or stabilized, by vegetation.

Very thick Wasatch sandstone beds separated by thin shale interbeds are exposed on the cliff to the left.

This may be the rapid referred to as "Melvin Falls" by F. M. Bishop, of the second Powell expedition, in his journal on August 18, 1871 (Kelly, 1947, p. 189).

Mile 48.6 Rapid 31 (1).

Mile 48.4 There may be a riffle here during low water.

Mile 48.15 Rapid 32 (1)—Lion Hollow enters on the right. Junipers reach the river bank.

Mile 47.2 Rapid 33 (4)—The upper part is easy but the lower part,

below Chandler Creek, is heavy water. Chandler Creek and Chandler Falls were named by the 1871 expedition when it camped here on August 19. Chandler was the maiden name of the wife of John F. Steward, the expedition's geologist.

Mile 47.0 Chandler Creek, a perennial stream, enters on the left from an alluvium-floored valley walled by cliffs of the Wasatch Formation. Cottonwoods border the creek, sagebrush covers the alluvial flat, and junipers grow at the base of the cliffs. Spruce and pine are visible on the higher slopes.

Near the mouth of Chandler Creek are well-developed boulder levees and a good view across the rapid (Chandler Falls) to a 30-foot cutbank of coarse alluvium deposited from the small side canyon on the opposite side of the river.

Several members of the 1871 Powell expedition commented in their journals that a large natural bridge was visible either directly opposite, or to the southwest of, Chandler Creek. Can you see it?

Broken projectile points and other Indian artifacts have been found in this area.

A Bureau of Indian Affairs jeep trail reaches the river here from the east, but is now impassable. A mud and stone chimney next to a large talus block on the north side of Chandler Creek must once have been part of a house.

The scar of a recent rockfall can be seen on the cliff facing the Green River just south of the mouth of Chandler Creek.

Mile 46.8 Looking straight down the river you can see a large arch on the far skyline of the right bank.

Mile 46.4 Rapid 34 (1)—Around a midchannel gravel bar island.

From about the middle of the island downstream to the town of Green River, Utah, the river marks the boundary between Emery County (right bank) and Grand County (left bank).

Mile 45.9 Rapid 35 (1)—Caused by boulder fan from Trail Canyon on the right.

Mile 45.7 Rapid 36 (3)—Caused by fan from Bluebell Creek which enters from the left at mile 45.5.

On the skyline point just north of Bluebell Creek are two large balanced rocks of Wasatch sandstone. "Clem" Powell mentioned these rocks in his journal (Kelly, 1948-49, p. 305) as "Columbus' Eggs."

Mile 44.95 Rapid 37 (1)—May be a (4) in low water.

Mile 44.7 The skyline ahead is marked by pinnacles, spires, and turrets blocked out by joints in massive Wasatch sandstones.

Mile 44.2 Rapid 38 (3)—Bull Canyon enters on the right.

Mile 44.0 View up Bull Canyon of a mushroom rock on the right skyline.

Mile 43.6 Rapid 39 (1).

Mile 43.35 Springs are depositing alkali about 150 feet above river level on both banks. The springs issue from the base of a red sandstone at the top of a slope underlain by shale.

Mile 43.0 Rapid 40 (4).

Mile 42.6 Rapid 41 (4) has some nasty holes. Big Canyon enters on the right.

Red Point ahead on the right takes its name from the reddish-brown to maroon Wasatch strata exposed from river level to the summit.

Mile 42.2 Rapid 42 (1)—The panoramic view ahead shows the canyon floor broadening and, in the distance, high cliffs and an arch. On the left are green-clad alluvial terraces deposited by the tributary streams of Joe Hutch Creek and the side canyon to the north.

Mile 41.6 Rapid 43 (6)—The entrance to this rapid is guarded by huge boulders below which is a tricky run through a series of holes and sleepers (boulders just beneath the surface). Maroon shales with interbedded sandstones in the Wasatch crop out on the right, but once you are in the rapid there will not be time to examine the geology.

Joe Hutch Creek entering on the left occasionally has fresh water.

Mile 40.7 Rapid 44 (5)—Starts just below a gravel bar island and usually has heavy water.

Mile 40.5 Joe Hatch Canyon enters on the right.

Mile 40.3 Note the large arch on the skyline behind the valley of Florence Creek on the left ahead.

Mile 39.3 Rapid 45 (1).

Mile 38.75 Rapid 46 (2)—Rain Canyon enters on the right, Florence Creek (a perennial stream) beckons from the left.

This is a majestic stretch of canyon. The valley floor is relatively open, the cliffs are incised into great ribs by tributary canyons, and a castellated skyline with three arches visible rises to the southeast.

On the right side of the river an almost complete section of the lower red unit of the Wasatch Formation is exposed between the river and an elevation of 5,200 feet where it is capped to the skyline by massive tan sandstones with red shale interbeds of the upper part of the Wasatch Formation.

After a pause to enjoy the shade of the cottonwoods and the refreshing waters of Florence Creek, it is a pleasant walk upriver to the McPherson Ranch at mile 39.4. The ranch has been abandoned to the deer, rabbits, foxes, and coyotes since it was purchased by the Federal government in 1942 for inclusion in the Uncompahgre Addition of the Uintah and Ouray Indian Reservation, but it saw some lively times about the turn of the century. It was a way station on the "Owlhoot Trail" used by Butch Cassidy and the Wild Bunch. The "Trail" ran from the San Rafael Swell to the Price River—down the Price—up the Green River to Florence Creek—then northeast to Brown's Hole and ultimately into Wyoming.

McPherson accepted the outlaws as transient neighbors. Pearl Baker (1965) tells the story of McPherson leaving Joe Walker, a member of the Wild Bunch, in charge of his ranch while he went to town for supplies. In town McPherson heard about a saloon holdup at Thompson Springs that sounded like Joe Walker's work. When he got back to Florence Creek, McPherson took Walker to task for abusing his hospitality. Walker's answer was classic: "You made me promise to tend the stock, and I did. They've n fed and watered twice a day, even if it was early and pretty damn late one day. But you didn't tell me what to do with my spare time." (Baker, 1965, p. 81)

The ranch buildings include a stone house, now sans roof, that once boasted the only piano between Green River and Jensen, several log cabins, a smithy, a chicken coop, corrals, a one-holer, and an outdoor shower. Numerous box elder trees offer their shade, and a sprawling orchard still produces mulberries, pears, and apples each year. A bountiful harvest indeed for those who prefer their fruit free of pesticides!

Water for the ranch came from a seep just south of the orchard, and this cool, moist area is frequented by little frogs. The seep

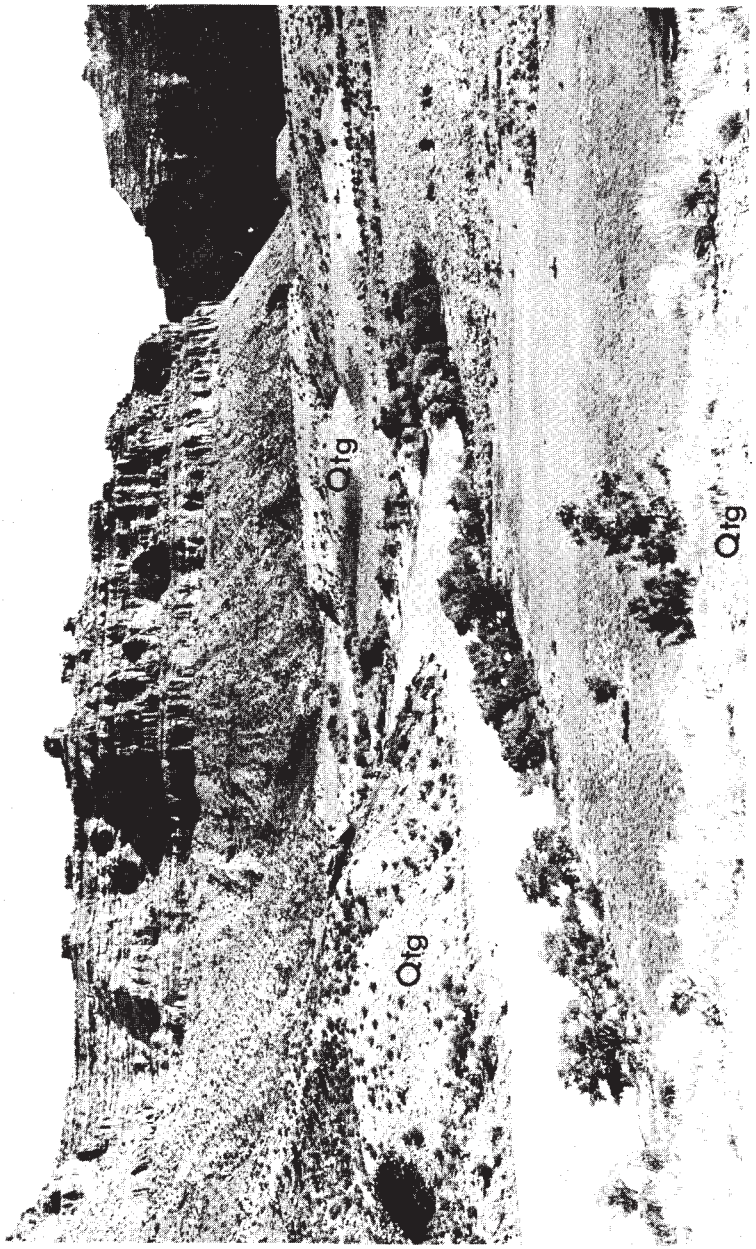


FIGURE 19 — *View up Green River from McPherson's Ranch (mile 39.4). Cliffs in background expose the lower 1,200 feet of the main body of the Wasatch Formation. Terrace deposits (Qtg) graded from side canyons to levels as high as 240 feet above present river level are being incised by the Green River. Photograph by John R. Dyni.*

is in a spring-sapped cave beneath the low bench underlain by conglomeratic Wasatch sandstone. The lower terraces along the Green River and Florence Creek were irrigated by ditches.

Looking up the river from the low ridge south of the ranch, one can discern alluvial terraces of several ages (see Fig. 19). They appear to have been graded from the side canyons to levels up to about 240 feet above the present Green River. Florence Creek is actively incising some of these Quaternary terrace deposits.

On the north side of Florence Creek, at the foot of a cliff exposing crossbedded Wasatch sandstone, are petroglyphs of mountain sheep, snakes, geometric designs, and stylized human figures. Several small rock shelters partially enclosed by dry-laid rock slabs are also present at the foot of the cliff between the first and second fences encountered as you walk up the valley of Florence Creek. The shelters and petroglyphs probably were made by Indians of the Fremont culture (A.D. 900 to 1275).

Before re-entering the river, look over the rapid and plan your route through it. You will probably have to stroke out into the stream quickly so as to get into position before entering the rapid.

Mile 37.6 On the right bank, at river level, is a 2- to 3-foot-thick gray limestone. Several similar thin, tan-weathering limestones interbedded with reddish-brown shale in an interval about 50 feet thick in this area constitute the Flagstaff Limestone of late Paleocene and early Eocene(?) age which underlies the Wasatch Formation. The main body of the Flagstaff Limestone was deposited in a lake to the west of here. The thin limestones here represent chemical or organic precipitates near the edge of the lake, whereas the interbedded shales represent clastic sediments brought into the lake by streams.

On the right skyline is a spectacular view of towers and fins cut from the Wasatch Formation.

Mile 37.0 Rapid 47 (4-5).—Wire Fence Canyon enters on the right. Gray beds of Flagstaff Limestone are exposed on the left bank.

Mile 36.6 Rapid 48 (6)—Three Fords Canyon entering on the left has created a boulder-studded maelstrom. The current tends to suck the unwary boatman into the boiling holes along the right wall. The nearly vertical cliff on the upper part of the point (eleva-

tion 6,295 ft.) on the left forms an imposing backdrop for the rapid.

This area is often chosen as the dividing line between Desolation Canyon and Gray Canyon, which extends downstream to the Book Cliffs (mile 12). When Powell passed through the lower canyon in 1869 he named it Coal Canyon for the coal beds exposed along the walls, but by the time he published his "Canyons of the Colorado" in 1895, he had changed the name to Gray Canyon.

On the right bank the Flagstaff Limestone caps a massive sandstone rising from river level. This sandstone is the top of the North Horn Formation, a succession of mainly fluvial gray and tan shales and sandstones derived from rising uplifts during the late Paleocene.

Mile 35.9 Head of three islands. Picturesque joint-controlled spires and a keyhole arch dominate the left skyline.

Mile 35.5 The massive 25-foot-thick sandstone rising from river level is probably the top of the Tuscher(?) Formation as used by Spieker (1946, p. 140-142). The same sandstone holds up the bench at the mouth of Three Fords Canyon (this one is on the right) at mile 35.3.

Mile 35.4 Rapid 49 (1)—At foot of three islands.

Mile 34.9 Tuscher Formation on right. The upper sandstone makes the cliff at the rim of the inner canyon, and a buff to light-gray crossbedded sandstone is exposed at river level. This sandstone shows honeycomb weathering surfaces, and includes a few buff-weathering shale interbeds.

Mile 34.5 Approximate contact between light-colored sandstones of the Tuscher Formation and the underlying, browner, more massive sandstones of the Upper Cretaceous Farrer Formation, of the Mesaverde Group. Because of the complex intertonguing between units, the lenticular nature of many strata, the lack of detailed geologic mapping along the canyon, and the fact that the Green River has been used as a dividing line between stratigraphic nomenclature developed in the western and central Book Cliffs, a trip through Gray Canyon can be a traumatic experience for a stratigrapher. The nomenclature for the Mesaverde Group used in this log is modified from Fisher and others (1960, p. 11) and is summarized on Table 3. For further details see Fisher (1936), Fisher and others (1960), Spieker (1946), and Young (1955).

Broadly viewed, the Mesaverde Group represents deposition of marine, beach, lagunal, and fluvial sediments at the edge of the Late Cretaceous sea as the marine waters retreated toward the east. The coal beds probably were formed in lagoons and swamps.

Mile 33.8 Luxuriant growth of poison ivy along the left bank.

Terrace gravels mantle sandstone hills about 60 feet above river level on the right.

The topographic contrast between the views upstream and downstream is striking. Upstream the Wasatch Formation holds up high, rugged, nearly vertical cliffs; downstream the lower, more subdued hills are underlain by rocks of the Tuscher Formation and older rocks of the Mesaverde Group.

Mile 32.5 Rapid 50 (1)—Spring Wash Canyon enters on the left and Last Chance Canyon on the right.

Mile 31.5 Rapid 51 (4)—Range Creek, a perennial stream, enters on the right. The view up Range Creek shows spectacular Wasatch cliffs capped by a forested plateau, where deer, elk, and bear still roam.

Mile 31.0 Note the small northwest-trending fault, downthrown to the north, on the north side of the small gulch to the left.

Mile 30.2 On the right ahead, the massive tan sandstone with local gray shale interbeds which forms the prominent cliff is the Bluecastle Sandstone Member of the Price River Formation.

Mile 29.7 Several coal beds are exposed at the base of the Bluecastle Sandstone Member on the buttress between two alcoves to the right ahead.

Mile 29.0 Rapid 52 (5)—At the boulder fan from Rabbit Valley entering on the right.

Mile 28.5 Note recent sand dunes on the right.

Mile 28.4 A small arch is visible on the right skyline.

At river level on the right bank the massive crossbedded sandstone showing well-developed cut-and-fill channel structures is the Castlegate Sandstone. Downstream it forms vertical cliffs on both sides of the river.

Mile 28.1 Rapid 53 (1)—Curry Canyon, named for "Flat Nose" George Curry (see mile 22.2), enters on the right.

FIGURE 20 — *View up Green River from mouth of Poverty Canyon (mile 25.4). Castlegate Sandstone (Kc) rising from river level is overlain by Price River Formation (Kp), and Farrer Formation (Kf). Photograph by John R. Dyni.*

The Bluecastle Sandstone Member on the left skyline is underlain by a coal zone (the Chesterfield coal zone, Fisher, 1936).

Excellent exposures of channel structures occur in Castlegate Sandstone on the left bank.

Mile 27.7 Rapid 54 (1).

Mile 26.9 Rapid 55 (1)—Saleratus Canyon enters on the left.

Mile 26.0 Rapid 56 (6)—Caused by large boulder fan from Coal Creek entering on the left. Coal Creek marks the southern boundary of the Uncompahgre Addition of the Uintah and Ouray Indian Reservation.

Mile 25.85 Ruin of stone house on alluvial terrace on left bank.

Mile 25.5 Just above river level on the left bank numerous alkali seeps, marked by lush green hanging gardens, flow from the Castlegate Sandstone. A distinct odor of hydrogen sulfide is apparent in the vicinity of the seeps.

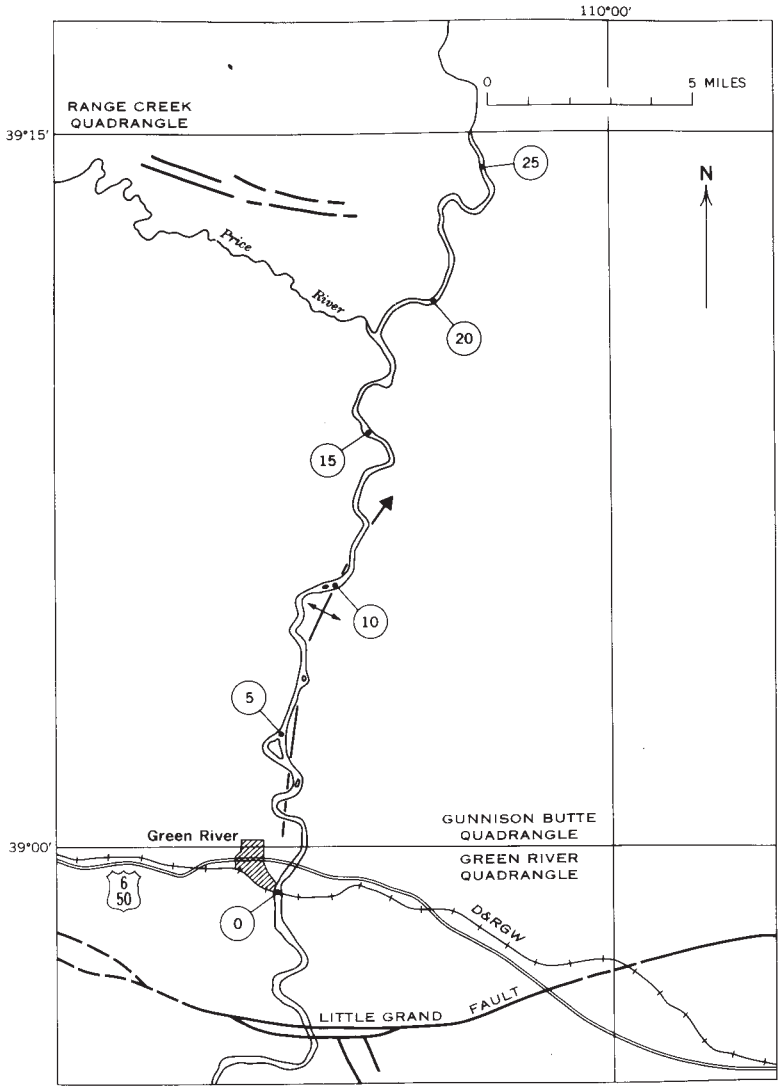


FIGURE 21 — *Sketch map of Green River from mile 29.2 to mile 0.*

Mile 25.3 Rapid 57 (3)—Caused by boulder fan and bar from Poverty Canyon entering on the left.

The alkaline water flowing from Poverty Canyon comes from a series of spring seeps a few hundred yards up the canyon.

Mile 25.0 Rapid 58 (1).

Large, luxuriant hanging gardens of pampas grass, moss, poison ivy, box elder, willow, tamarisk, and grasses on the left bank continue downriver to about mile 23.5, where the spring line is covered by talus.

Mile 24.5 View back up river shows two lyre-shaped pinnacles in the Bluecastle Sandstone Member on the left bank skyline.

Mile 23.6 The Tuscher Formation can be seen downriver on the far skyline.

Mile 22.9 On the left medium- to thick-bedded, tan to yellowish-gray sandstones with shale interbeds extending from river level to the cliff formed by the Castlegate Sandstone are the upper part of the upper member of the Blackhawk Formation. These strata form more rounded outcrops than the Castlegate, and are usually mantled by talus.

Mile 22.4 On the right is a large spring-sapped alcove on the Castlegate-Blackhawk contact. The roof is Castlegate Sandstone and the walls expose strata of the upper member of the Blackhawk.

Downriver is a view of large joint-controlled fins in the Castlegate Sandstone.

Mile 22.2 Rapid 59 (4)—Rattlesnake Canyon enters on the left. Flat Nose George Curry (he claimed to have been kicked in the face by a horse), a member of the Wild Bunch, was shot by a posse here during the winter of 1899-1900. George lived in a cave up Rattlesnake Canyon, and was building a raft on the Green when the posse appeared on the opposite bank (Baker, 1965).

The free-standing fin on the right is capped by Castlegate Sandstone, beneath which is an essentially complete section of the upper member of the Blackhawk Formation. A 12- to 15-inch-thick coal bed occurs just above a massive, honeycomb-weathered sandstone unit rising 20 feet above the river. This sandstone unit marks the base of the upper member of the Blackhawk.

The massive sandstone on the far skyline upstream (right bank) is the Tuscher Formation.

Mile 20.2 Rapid 60 (3)—A fun ride in the large waves formed over a fan where a side canyon enters on the left.

Mile 20.0 The pinnacle on the right bank has a striking resemblance to the famous bust of Nefertiti.

Mile 19.9 The view downriver shows the stratigraphic section from the middle shale member of the Blackhawk Formation upward through the Bluecastle Sandstone Member (see Fig. 22). The two units which were not pointed out upriver are the middle shale member of the Blackhawk Formation, which consists of the 60 feet of gray shale rising above the river, and the middle sandstone member of the Blackhawk Formation, forming the 80-foot-high cliff above the shale slope.

Mile 18.2 The Price River enters on the right through alluvial bars covered with tamarisk. The second Powell expedition camped here on August 25, 1871. There was no water at the mouth of the Price then, but members of the party who walked up the Price reported water and signs of deer and mountain sheep within a few miles of the Green. That evening,

> ". . . Steward gave us a mouth-organ recital and Jack [Hillers] sang a lot of his songs in fine style." (Dellenbaugh, 1908, p. 92)

The cliffs on the right below the Price River expose the same section described at mile 19.9 and illustrated on Figure 22.

Mile 17.2 Rapid 61 (1).

Mile 16.0 Rapid 62 (4)—Butler Canyon enters from the left and an unnamed small side canyon enters from the right.

Mile 15.8 Eolian sand dunes shaped by upcanyon winds overlie terrace gravels on the right. Terrace gravels occur as high as 120 feet above present river level.

Mile 15.5 Rapid 63 (4)—Sand Knolls Canyon enters on the right. Sand dunes are visible from the small flat at the side canyon mouth. In view upriver on the right bank are dissected talus cones and several alluvial terrace levels graded by tributary streams.

Mile 14.4 Rapid 64 (4)—The side canyon entering on the left is identified as Coal Canyon on the River Survey Map, but is not named on the Gunnison Butte topographic map.

An abandoned stone house and corral stand in the cottonwood grove on the left. Eolian sand dunes mantle terrace deposits.

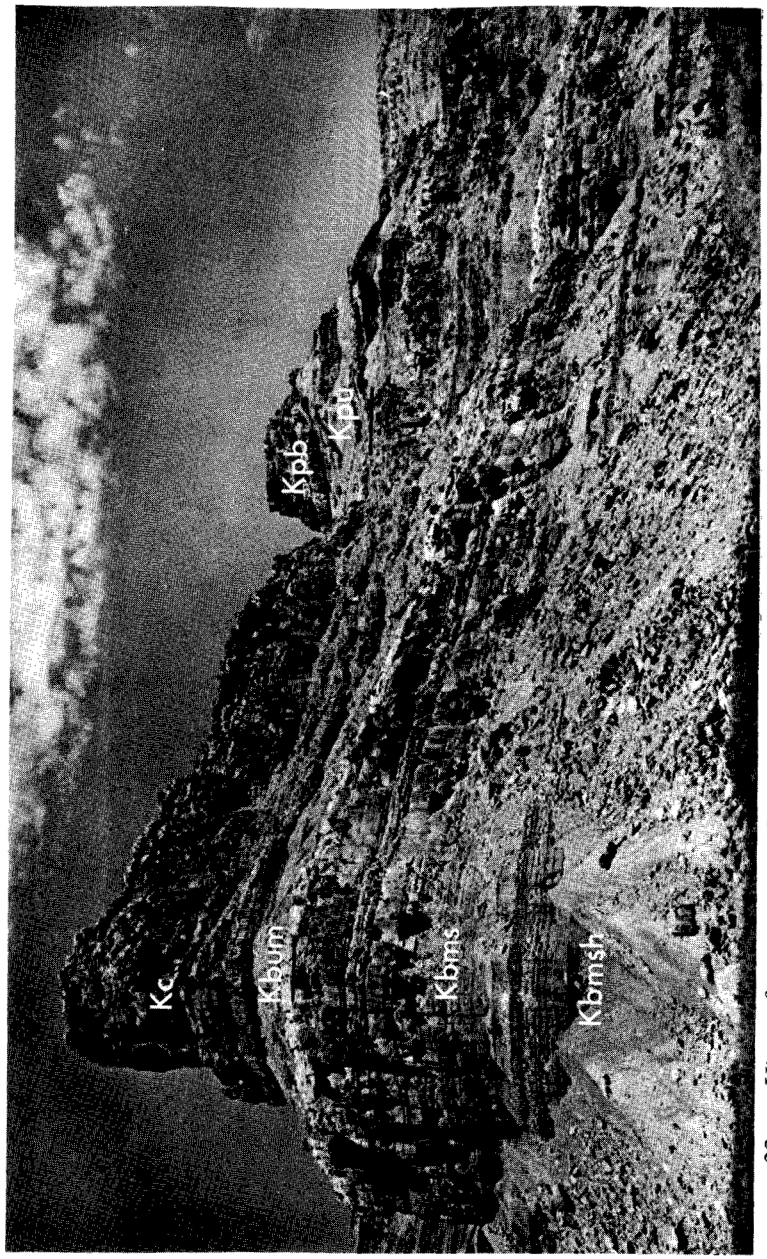


FIGURE 22 — *View of strata exposed on right bank of Green River at mile 19.9. From river level upward: Blackhawk Formation including middle shale member (Kbmsh), middle sandstone member (Kbms), and upper member (Kbum); Castlegate Sandstone (Kc); Price River Formation including unnamed member (Kpu), and Bluecastle Sandstone Member (Kpb). Photograph by John R. Dyni.*

Mile 13.8 On the left bank ahead note the remnant of an old colluvial and talus cone which has been completely isolated from the cliff wall by recent erosion.

The trail on the left bank is used by local stockmen, but the jeep trail on the right is impassable.

Mile 13.1 Rapid 65 (4)—Short Canyon enters on the right.

Mile 13.0 Gunnison Butte and Brighams Thumb (the pinnacle on the west end of the butte) dominate the right skyline downriver.

Several terraces graded to the small side canyon on the right are apparent.

The lower sandstone member of the Blackhawk Formation is above river level here, but is largely covered by Quaternary deposits.

Mile 12.2 Rapid 66 (5)—Long Canyon enters on the right. Ruins of Swazey's Ranch on the right.

Mile 12.0 The cottonwood grove on the left sheltered the 1871 Powell expeditioners after they emerged from Gray Canyon on August 26, 1871. Steward's journal entry for August 27 describes the scene:

"The morning sun is beginning to gild the crags and cathedral-like buttes that stand as silent sentinels watching over us. The fretting of the last fall that we passed fills our ears with its continuous roar. The boats are on the shore for repairs, keels upwards, drying out. Our worldly goods are in little piles beside them. The boys are yet lying as prisoners in the arms of Morpheus, with blankets spread on a few willow bushes laid on the sand. They are dreaming, maybe, of home, mothers, and Bishop, perhaps, of his sweetheart, Lena. Each one has his Winchester rifle by his side willing to trust to it for ready execution. Soon after breakfast Professor [A. H. Thompson] and I went down the river to reconnoitre, for a distance of 5 miles. The valley is literally covered with remains of Indian wigwams. The river, at the bend, is crossed by what is called the old Spanish trail. It was the crossing point also of Lieutenant [Captain] Gunnison several years ago, previous to his meeting death at the hands of the Utes. It is more patronized by bands of Indians who cross in the fall and spring than by any living near. The valley is low for several miles from the river, and the river bank on either side is easily approached. Evidences of the presence of Indians, last spring, are to be seen in the shape of moccasin tracks, horse tracks, etc."
(Darrah, 1948-49, p. 225-226)

This is the spot where Powell rejoined the group on August 29, after journeying to Salt Lake City and Manti for supplies.

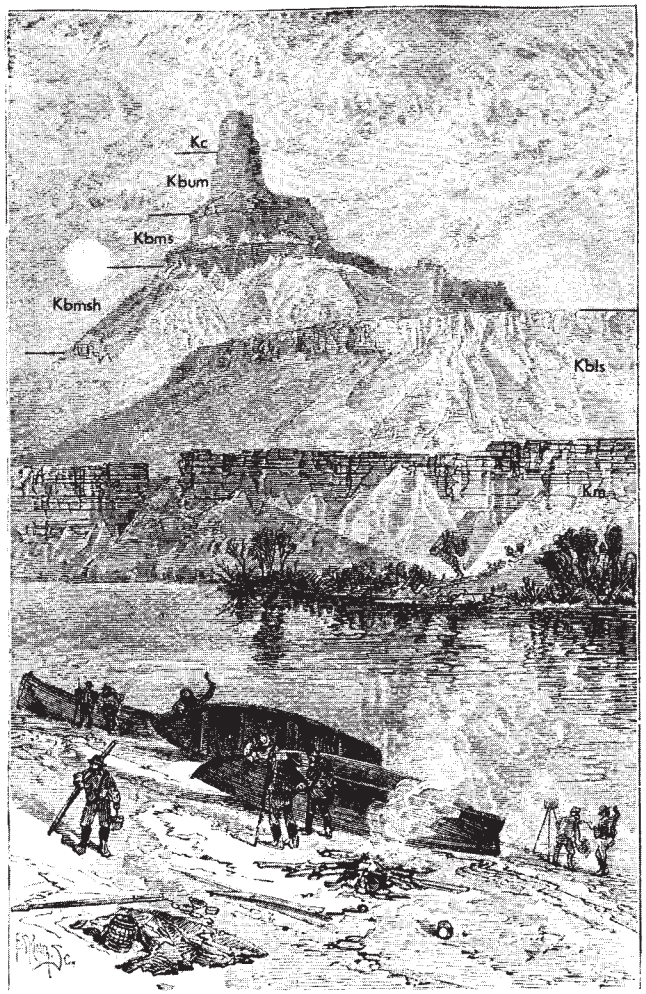


FIGURE 23 — *Gunnison Butte. The engraving is reproduced from Powell (1895), and was made from a Beaman photograph taken August 27, 1871. From river level upward the exposed formations are: Mancos Shale (Km); the Blackhawk Formation including the lower sandstone member (Kbls), middle shale member (Kbmsh), middle sandstone member (Kbms), and upper member (Kbum); and the Castlegate Sandstone (Kc).*

The etching reproduced from Powell (1895) as Figure 23 was copied from a Beaman photograph taken from this point.

Mile 11.5 The bluff on the right exposes gray shales with tan siltstone interbeds of Mancos Shale capped by terrace gravels.

A log cabin and an irrigation pump are on the left bank. Water pumped from the river is used to irrigate the extensive terrace 10 feet above river level.

Mile 10.3 Mancos Shale is exposed in the 45-foot-high, terrace gravel-capped bluffs on the left. The Mancos represents relatively shallow water marine deposition during the Late Cretaceous, and locally contains fossil pelecypods, ammonites, and fish scales.

Upstream the wall of the Book Cliffs, broken by the Green River canyon, stretches away to the east and west and exposes magnificent sections of the Mesaverde Group.

An irrigation pump and very large tamarisks with some willows and cottonwoods can be seen along the right bank. These plants are all phreatophytes—that is, their roots extend below the water table—and they suck up large quantities of water which is ultimately transpired into the atmosphere. In arid environments such as this, phreatophytes may remove an appreciable percentage of the water from a river system.

Mile 8.5 "Rapid" 67—The remnant of a concrete dam crosses the river. Running the dam and the boulder- and concrete-studded channel below it can be classed as a (4) rapid. Tusher Wash enters on the left just below the dam.

The water wheel on the left was used to lift water to a system of irrigation ditches. During the summer, flowers still bloom in the gardens of the old buildings nearby.

This point can be used as a takeout spot for river trips inasmuch as graded roads from the town of Green River extend up both sides of the river to the dam.

Mile 8.0 Concrete pump house on the right bank.

Mile 7.6 Rapid 68 (1)—On either side of boulder bar island.

This area is the approximate site of Gunnisons Crossing, a historic fording point used successively by Indians, Spanish Padres, mountain men, and westward-bound American explorers and settlers. The Spanish used the crossing during the late 1700's en route from Santa Fe, New Mexico, to their settlements and missions on the California Coast. In 1830 William Wolfskill and a party of 21

trappers from Taos, New Mexico, reopened the "Old Spanish Trail." Captain John W. Gunnison of the U.S. Army crossed the river here on October 1, 1853, and determined the longitude and latitude of the crossing. When Powell and his party passed here on July 13, 1869, they noticed a number of crude rafts moored at the bank, and other evidence that a party of Indians had recently crossed the river.

The river is flowing along the crest of a very gentle north-trending anticline in this area (see Fig. 21). The anticline may reflect subsurface flowage in evaporite strata of the Pennsylvanian Hermosa Formation. A short distance south of Green River, several structures, including the Little Grand fault and the Salt Wash graben, are known to be related to subsurface evaporite flowage (Mutschler, 1969).

Mile 6.5 Low bluffs on the left expose Mancos Shale.

Mile 6.0 Buildings on left bank. This stretch of river is bordered on both sides by thick growths of cottonwood, willow, tamarisk, and pampas grass, which in summer provide a refuge for many birds including herons and sandhill cranes. Early or late in the day, beavers sport along the edge of the river.

Mile 5.7 Corrals on right bank.

Mile 5.0 Head of large sand bar island. Take the right-hand channel.

Mile 4.3 Buildings on the right.

Mile 3.5 Mancos Shale exposed on the left. Note the planed surface between the shale and the overlying terrace gravels about 35 feet above the river. Terraces as much as about 200 feet above river level can be recognized a mile east of here. In contrast to most of the terraces in Gray Canyon, which are graded to side canyons and covered largely by locally derived rock fragments, the terraces in this open valley were clearly cut by the main Green River. They are mantled by gravels containing quartzites, cherts, and dinosaur bone, derived from the Uinta Mountains about 200 river-miles away.

Mile 3.2 A low-level terrace gravel, about 15 feet above river level, caps Mancos Shale on the left bank.

Mile 3.0 The ridges, buttes, and towers on the skyline downriver (to the southwest) are Triassic(?) and Jurassic rocks exposed on

the flank of the San Rafael Swell. The Swell is an 80-mile-long and 35-mile-wide, north-northeast-trending, asymmetrical, flat-topped uplift in which sedimentary rocks of Permian to Cretaceous age are exposed.

On the outside of the meander the bank has been rip-rapped with blocks of Mesaverde sandstone to prevent erosion. The river channel in this area has shifted position relatively recently. These shifts are apparent when comparing the River Survey Maps of 1924 and the 1963 Gunnison Butte topographic map.

Mile 2.0 Bluff on the left exposes Mancos Shale overlain by terrace gravels whose base is about 18 feet above river level.

Mile 0.8 U.S. Highways 6 and 50 cross the Green River on a concrete bridge.

Mile 0.2 Green River State Park boat ramp on right bank. Town of Elgin on the left. The park is on a sand bar, lined by willow and tamarisk at river's edge. The campground is to the west in a grove of cottonwood trees. Downstream on the right bank is a U.S. Geological Survey river gaging station at mile 0.1.

The town of Green River was founded in 1878 as a mail relay station. The Denver and Rio Grande Western Railway bridged the river in 1883. Mile 0.0 for the river log is the railroad bridge.

The view down river is toward the enchantments of Labyrinth and Stillwater Canyons and the joyous, thundering adventure of Cataract Canyon.

"And if the rocks, they don't stop us,
We will cross to Killiloo, whacky-whay!"
Refrain of a song sung by Jack Hillers of the 1871 expedition.

Glossary of Geologic Terms

Geologists use technical terms to describe earth materials, structures, and processes. This terminology serves as a sort of scientific shorthand, but may be unfamiliar to the nongeologist. An attempt has been made to use as few technical terms as possible in the river log, and brief definitions are given below of those terms that are not self-explanatory. Most of the terms are modified from a glossary by Stokes and Varnes (1955).

Adit. A nearly horizontal mine opening.

Alluvial. Pertaining to material carried or laid down by running water. Alluvium is the material deposited by streams. It includes gravel, sand, silt, and clay.

Ammonites. A group of extinct invertebrate marine animals related to, and resembling, the chambered nautilus.

Anticline. A convex-upward fold in rocks; that is, one in which the limbs or sides slope away from the crest, like an inverted trough.

Bar. Accumulation of sand or gravel in a river channel or along the banks.

Basin. A depressed area in the earth's crust in which the strata dip toward the center.

Bedding. The arrangement of rocks, especially sedimentary rocks, in layers or strata. Bedding planes are the surfaces that separate successive layers.

Bedrock. Solid rock exposed at the surface of the earth or overlain by unconsolidated material.

Bentonite. Clay derived from the alteration of volcanic ash.

Boulder fan. A sloping, fan-shaped mass of boulders deposited by a tributary stream where it emerges into the main canyon.

Calcium carbonate. A chemical compound of calcium, carbon, and oxygen ($CaCO_3$). The mineral calcite is the common natural form of calcium carbonate.

Cambrian. The earliest period of the Paleozoic Era including the time between 570 and 500 million years ago.

Cenozoic Era. The time between 65 million years ago and present.

Chert. A very dense rock, composed of microscopic grains of quartz.

Clastic. Composed of broken fragments of rocks or minerals.

Colluvial. A term applied to rock masses and soil that have been moved chiefly by gravity.

Contact. The surface separating two rock units of different kind, age, or origin.

Cretaceous. The third and latest period of the Mesozoic Era including the time between 135 and 65 million years ago. See Table 3 for rocks formed during the Cretaceous.

Crossbedding. A diagonal arrangement of layering in sedimentary rock in which layers are inclined at various angles to more general bedding planes. Commonly formed in stream deposits, deltas, sand dunes, and beaches.

Dolomite. A rock consisting mostly of the mineral dolomite (calcium-magnesium carbonate).

Eocene. The second epoch of the Tertiary Period including the time between 54 and 38 million years ago. See Table 3 for rocks formed during the Eocene.

Eolian. Pertaining to the wind.

Erosion. The wearing away and removal of materials of the earth's crust by natural means.

Exfoliation. The breaking or spalling off of thin concentric sheets from rock surfaces.

Fault. A fracture in the earth's crust along which there has been movement parallel to the fracture plane.

Flood plain. The plain bordering a river upon which the river deposits a layer of sediment during each flood.

Fluvial. Pertaining to rivers.

Fold. A bend or flexure in layered rock. See also *anticline* and *syncline.*

Formation. A mappable rock unit, distinctive from the rocks lying below and above. The names of formations include two parts: the first geographic, the second describing the rock type—for example, Castlegate Sandstone. Where several rock types are included in a formation, the word "Formation" is used instead of rock type—for example, Uinta Formation. A member is the principal subdivision of a formation. A tongue is a part of a rock unit that wedges out laterally. A group consists of several formations—for example, Mesaverde Group. See Table 3.

Fossil. Evidence of animals or plants preserved in rock.

Gilsonite. A lustrous, solid variety of asphalt formed by the evaporation of petroleum.

Gneiss. A metamorphic rock characterized by bands or layers of visibly unlike composition.

Granite. A light-colored, coarse-grained igneous rock composed of potassium and sodium feldspars and quartz.

Group. (see *Formation*)

Joint. A fracture in rock along which there has been little movement.

Jurassic. The second period of the Mesozoic Era including the time between 195 and 136 million years ago.

Kerogen. The bituminous matter in oil shales.

Lacustrine. Pertaining to lakes.

Lagunal. Pertaining to lagoons.

Lenticular. Applied to a body of rock that thins out in all directions from the center. A lentil-shaped body.

Limestone. A sedimentary rock composed chiefly of calcium carbonate.

Lithified. Consolidated into rock. Loose sediments such as sand may become rock (sandstone) as a result of lithification.

Littoral. Pertaining to the shore of the ocean, and the area of the sea floor lying between high and low tide levels.

Marlstone. A sedimentary rock composed of clay and calcium carbonate.

Meander. A looplike bend in the course of a river.

Member. (see *Formation*)

Mesozoic Era. The time between 225 and 65 million years ago. See Table 3 for rocks formed during the Mesozoic.

Mineral. A naturally occurring, inorganic substance of definite chemical composition and distinctive physical properties.

Miocene. The fourth epoch of the Tertiary Period including the time between 26 and 12 million years ago.

Oligocene. The third epoch of the Tertiary Period including the time between 38 and 26 million years ago.

Ostracods. Minute shrimplike animals whose bodies are completely enclosed in bean-shaped shells.

Paleozoic Era. The time between 570 and 225 million years ago.

Paleocene. The earliest epoch of the Tertiary Period including the time between 65 and 54 million years ago. See Table 3 for rocks formed during the Paleocene.

Permian. The latest period of the Paleozoic Era including the time between 280 and 225 million years ago.

Playa. An ephemeral desert lake.

Pliocene. The fifth (latest) epoch of the Tertiary Period including the time between 12 and 3 million years ago.

Precambrian. The time before the beginning of the Paleozoic Era 570 million years ago.

Quartz. Silicon dioxide, a common mineral occurring in sedimentary, igneous, and metamorphic rocks. Most of the glassy grains in river sands are quartz.

Quartzite. A metamorphic rock composed dominantly of quartz.

Quaternary. The second and latest period of the Cenozoic Era, including the time between 3 million years ago and the present. See Table 3 for deposits formed during the Quaternary.

Rincon. An abandoned meander of a river formed when the river flowed at an elevation above its present channel.

Ripple marks. Undulatory washboardlike markings produced on sediments by waves, currents, or winds, and commonly preserved in sedimentary rocks.

Rock. Any naturally formed aggregate of minerals constituting a sizable part of the earth's crust.

Sandstone. A sedimentary rock composed of cemented sand grains.

Schist. A layered metamorphic rock containing a large proportion of platy minerals such as mica.

Sedimentary rocks. Rocks composed of sediment such as mud, sand, gravel, or organic fragments, and organic or chemically precipitated minerals. They are formed through the agency of water, wind, ice, or organisms, and are originally deposited at the surface of the earth.

Shale. A fine-grained sedimentary rock formed from consolidated clays or muds.

Siltstone. A sedimentary rock composed of consolidated silt. Silt is material finer than sand and coarser than clay.

Strata. Layers of sedimentary rock.

Syncline. A concave-upward, or troughlike fold in rocks.

Talus. An accumulation of coarse, angular rock fragments derived from and resting at the base of a cliff.

Terrace. A long, relatively narrow flat bench along a river. Terraces were cut by lateral erosion when the river flowed at a higher level, and are commonly covered by sand and gravel left by the river.

Tertiary. The first period of the Cenozoic Era including the time between 65 and 3 million years ago. See Table 3 for rocks formed during the Tertiary.

Tongue. (see *Formation*)

Triassic. The first period of the Mesozoic Era including the time between 225 and 180 million years ago.

Tuff. A rock formed of volcanic ash, rock, and glass fragments thrown out by a volcanic explosion.

Uplift. An area of the earth's crust that has been raised above the surrounding area.

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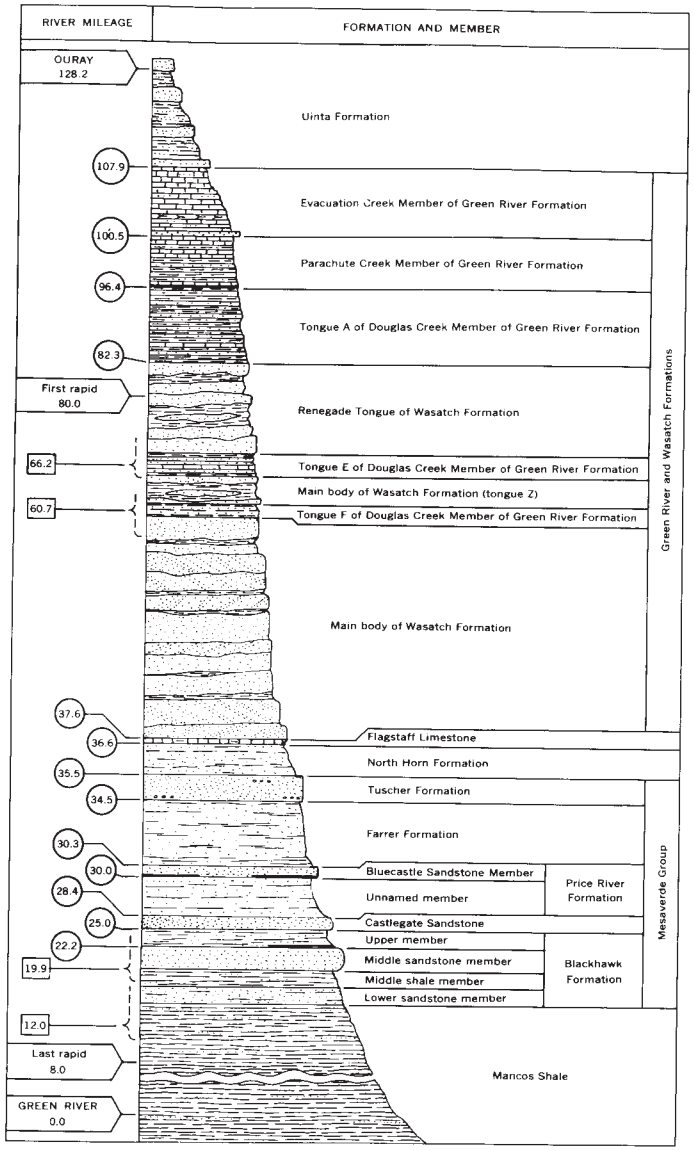

Generalized section of rock units exposed along Green River between Ouray, and Green River, Utah. Circles, approximate mileages where contacts cross Green River. Rectangles, mileages from which views of contacts may be seen.