

**Guidebook to the Colorado River
Part 3:**

**Moab to Hite, Utah through
Canyonlands National Park**

by

J. KEITH RIGBY, W. KENNETH HAMBLIN, RAY
MATHENY AND STANLEY L. WELSH

Department of Geology, Brigham Young University

Brigham Young University Geology Studies

Volume 18 - Part 2 - 1971

Studies for Students No. 6

**Guidebook to the Colorado River, Part 3:
Moab to Hite, Utah
through Canyonlands National Park**

J. KEITH RIGBY, W. KENNETH HAMBLIN, RAY
MATHENY AND STANLEY L. WELSH

Brigham Young University

A publication of the
Department of Geology
Brigham Young University
Provo, Utah 84601

Editor: J. Keith Rigby

Studies for Students supplements the regular issues of *Brigham Young University Geology Studies* and is intended as a series of short papers of general interest which may serve as guides to the geology of Utah for beginning students and laymen.

Distributed July 30, 1971
Reprinted July, 1972

Guidebook to the Colorado River, Part 3: Moab to Hite, Utah through Canyonlands National Park

J. KEITH RIGBY¹, W. KENNETH HAMBLIN¹, RAY MATHENY²,
AND STANLEY L. WELSH³

Preface

A trip down the Colorado River from Moab to Hite in eastern Utah offers an opportunity to see a vast section of unspoiled scenery with a sense of adventure and exploration. Such a trip would not have been practical for students of geology or natural history a few years ago, but with the innovation of pontoon boats and the establishment of regular tours by experienced guides such trips are now not only feasible but also an experience most students should enjoy. This guide is the third of a series prepared for the Colorado River and is written to allow a self-conducted trip. All points are made in reference to miles downstream from Moab. A number of vertical aerial photographs and maps are included to give complete coverage of the entire trip so that locations can be established without difficulty.

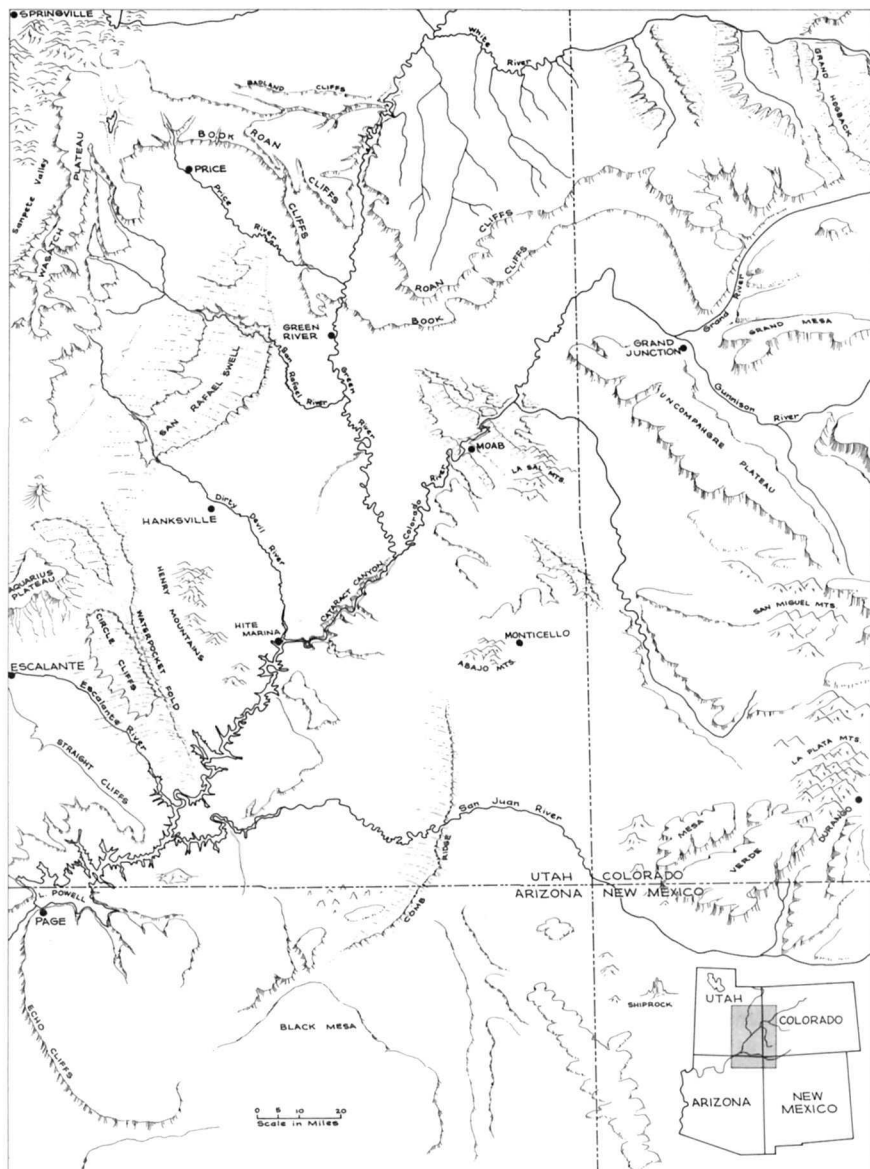
The Canyonlands region spans a vast area where various Upper Paleozoic and Mesozoic formations are well exposed and show lateral changes. The shape and development of the canyon of the Colorado River are complex responses to these formations and other geologic phenomena. We have included a brief description of the major rock units seen along the river in an introductory section, but brief descriptions of major features are also given, where significant, in the river log.

We appreciate the assistance of William L. Chesser, who drafted many of the illustrations. Initial trips through the Colorado River canyons were made as part of field investigations sponsored by the Canyonlands Natural History Association. We are indebted to the association and to various personnel of the Canyonlands National Park staff. Superintendent Bates Wilson, Chief Naturalist Bill Taylor, and other staff members greatly aided our field observations and their help is appreciated. Appreciation is also expressed to Drs. Joseph Murphy, William Lee Stokes, and others of the Research Advisory Committee of Canyonlands National Park for their assistance, discussions, and criticisms. Plant drawings are from the collection of Seville Flowers.

Introduction

The Canyonlands region of southeastern Utah is part of the scenic, intricately carved, lower part of the Colorado Plateau (Text-fig. 1) and is ringed by high plateaus and uplands around the north, west, and east. It is located near the east-central edge of the Colorado Plateau below the imposing Colorado Rocky Mountains on the east, and the Tavaputs, Wasatch, Fish Lake, and

¹Department of Geology, ²Department of Anthropology and Archaeology, ³Department of Botany; Brigham Young University.



TEXT-FIGURE 1.—Generalized map of the region around the Canyonlands section of the Colorado Plateau. High plateaus occur to the north and west, with the Colorado Rocky Mountains to the east, and the Grand Canyon section to the south.

Paunsagunt plateaus on the north and west. It is a region of nearly flat-lying sedimentary rocks, modified here and there by gentle, very broad folds and minor faults. Bordering highlands rise to an elevation of nine or ten thousand feet, with individual peaks reaching considerably higher. Depths of the inner canyon of the Colorado River range to over one thousand feet in the lower Cataract Canyon area and well over two thousand feet in the vicinity of Dead Horse Point where the high rim is preserved.

This is a region of strong contrasts, where sudden showers can saturate and broiling sun can dessicate within minutes of one another. It is an arid area, particularly in the lower parts of the innumerable canyons, yet snow hangs on peaks around the margin until far into the summer. It is a brightly colored region where broad plateaus are incised to show banded red, green, gray, and tan rocks in deep, narrow defiles.

The Canyonlands section of the Colorado Plateau extends northward from the Utah-Arizona line to the prominent escarpments that delimit the bordering highlands. It is characterized by broad plateaus, into which the Colorado River and its tributaries have carved intricate canyons. Jurassic, Triassic, Permian, and Pennsylvanian rocks are exposed throughout the section by erosion of the overlying Cretaceous and Tertiary rocks which have receded to the High Plateaus border.

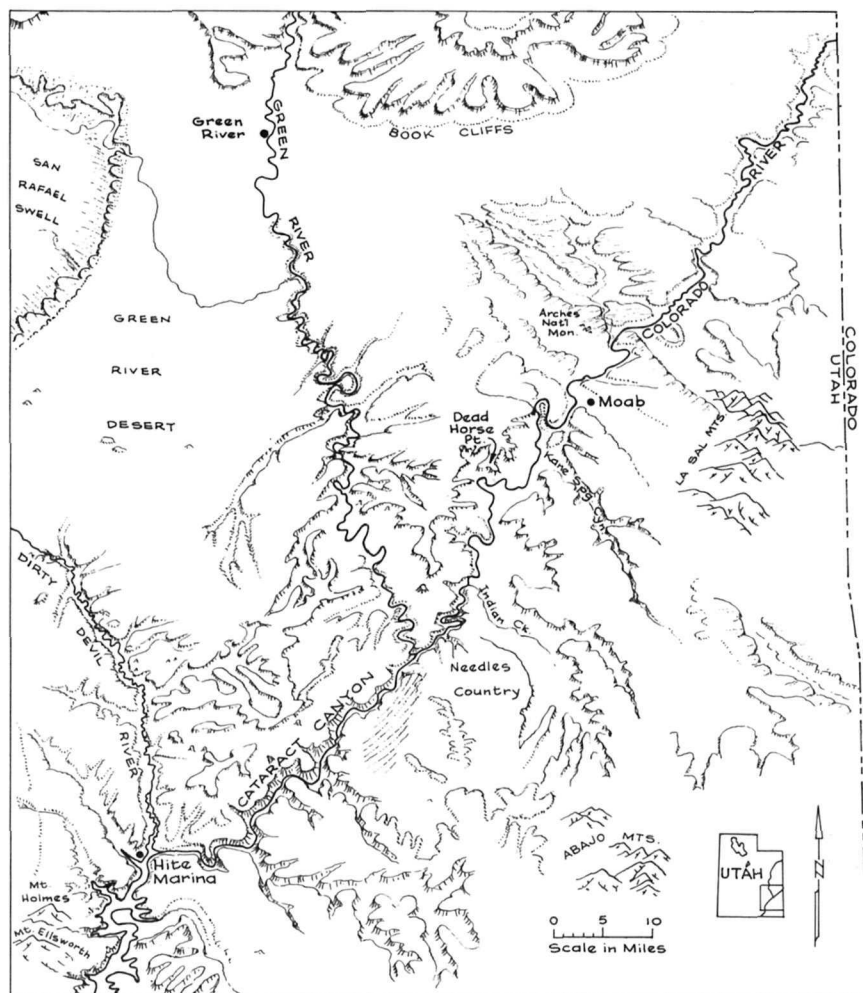
Throughout the course of the Colorado River through Cataract Canyon and Canyonlands, the canyon is deep and is crossed by bridges only at Moab, the beginning of the trip, and at Hite, the end of the trip (Text-fig. 2). No canyon is formed along the river where easily eroded rocks are exposed, and at these localities access routes to the river are developed. For several years Hite Ferry, at the now buried site some few miles downstream from the present high bridge, was the only automobile crossing of the Colorado River between Moab, Utah and Lees Ferry, Arizona. The Hite ferry was a cable operated raft that connected two legs of a primitive dirt road. The road was improved during the uranium madness that struck the area during the 1950s and was recently paved, once the majestic bridges were constructed over the narrow canyons of the Colorado River and Fremont River. The bridges were completed when the rise of Lake Powell forced abandonment of the old Hite Ferry.

Sequence of Rocks

DEWEY BRIDGE MUDSTONE (JURASSIC)

The youngest formation directly visible in the course of a river trip through the Canyonlands area is the dark-red to maroon, crinkly bedded Dewey Bridge Mudstone member of the Entrada Formation (Text-fig. 3). This unit separates the massive arch-forming Slick Rock Sandstone from the underlying massive, cross-bedded Navajo Sandstone.

The Dewey Bridge deposits are 25 to 75 feet thick, and are composed of dolomitic mudstone, siltstone, and shale, with traces of gypsum and chert. Bedding is lenticular and often crinkled and discontinuous, with clayey units separating more resistant knobby-weathering dolomitic units. The mudstone weathers easily and forms slopes between massive protecting sandstones.



TEXT-FIGURE 2.—Generalized map of the Canyonlands area. The river log describes the section between Moab and Hite, along the Colorado River.

Dewey Bridge rocks grade laterally into the Carmel Limestone toward the west and apparently represent marginal deltaic or mud flat deposits adjacent to the Carmel Sea where fossiliferous limestone, sandstone, and evaporites accumulated.

NAVAJO SANDSTONE (JURASSIC)

The light colored tan to buff Navajo Sandstone is one of the most distinctive rock units in the Canyonlands region. It is preserved along the course of

the Colorado River between Moab and Hite only in the trough of a large down-folded syncline along Kane Creek, between the broad anticlinal uplifts of Moab or Spanish Valley and Shafer dome, near Potash. The formation weathers into nearly vertical walls or "beehive" hills cut by widely spaced vertical joints. It forms the top of vertical walls in Kings Bottom and around Amasa Back and some exposures northwest and northeast of Moab Valley (Mile 4-14). Prominent fins of joint-fractured Navajo Sandstone are developed in many outcrops—for example, east of Kings Bottom where the formation dips to near river level. In this general region it is between 300 and 400 feet thick.

Large-scale cross-bedding characterizes the Navajo Sandstone over its total extent in Canyonlands. Many outcrops of the formation contain some of the most spectacular cross-beds to be found anywhere in the world.

Navajo Sandstone consists of quartz grains, most of which are well sorted, rounded, and etched or frosted. The grains are of translucent quartz and may be cemented with silica, limonite, or carbonate minerals to form the moderately resistant thick formation. Cross-bedding and the nature of individual grains suggest that the Navajo Sandstone accumulated in a desert which covered much of Utah, Arizona, and New Mexico in early Jurassic time.

KAYENTA FORMATION (TRIASSIC ?)

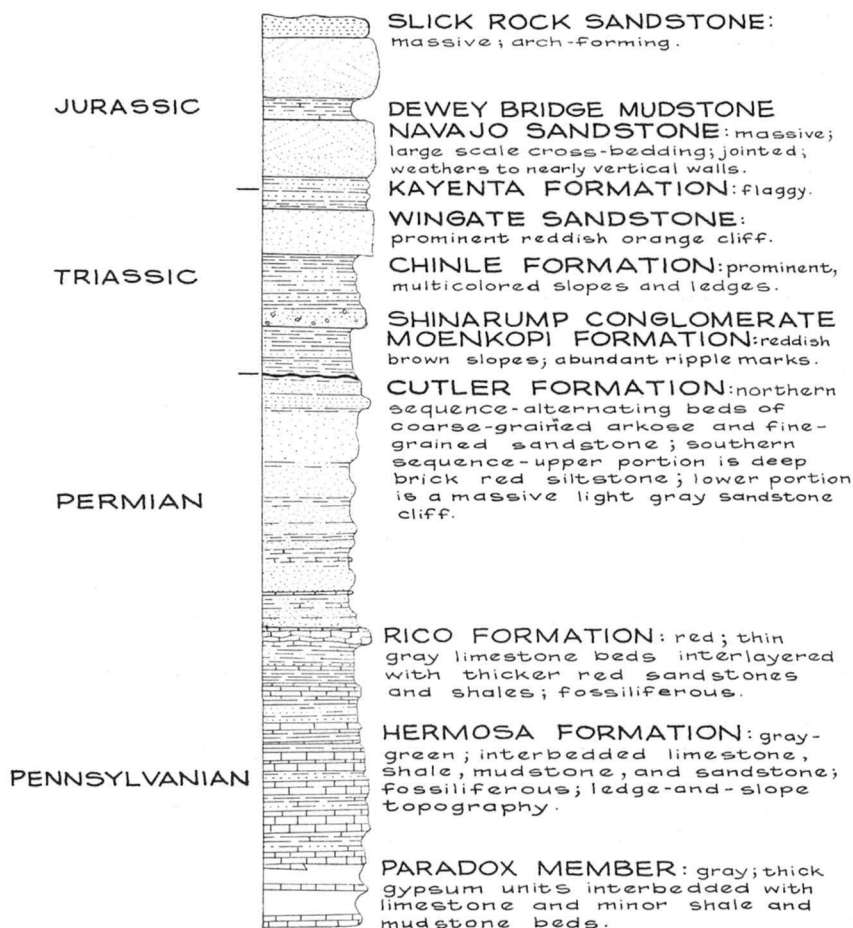
Kayenta Sandstone occurs as the flaggy-bedded semi-ledge outcrops below the Navajo Sandstone and above the angular-weathering cliffs of the Wingate Sandstone. Kayenta beds are well exposed in the flanks of the Kings Bottom syncline, particularly on the northeast side of Amasa Back and in the slopes near the mouth of Kane Creek (Mile 6). Because it is easily eroded compared to the overlying and underlying sandstone units, it commonly forms weak terraces in canyon walls and caps the resistant Wingate Cliff. It can be seen in the Deadhorse Point State Park and Island-in-the-Sky areas to the northwest of the Colorado River Canyon and in North Point and Hatch Point to the southeast.

The Kayenta Formation is approximately 200 feet thick in the area of Kings Bottom and is composed of interbedded, poorly sorted, coarse- to fine-grained sandstone and gritty clay-pebble conglomerate, shale, and siltstone. Silty beds and shaly beds are often maroon or pinkish gray in contrast to the lighter tan, buff, and pink sandstone units. Local lenses of coarse-grained to gritty sandstone and somewhat more limited limestone and dolomite occur in the upper part of the formation. Dinosaur tracks and reed impressions have been found in the formation locally but in general the formation is not fossiliferous.

Irregular, lenticular, and flaggy bedding, coupled with channels, and various sedimentary structures indicate stream deposition for the formation. Small lakes or ponds are probably represented as well.

WINGATE SANDSTONE (TRIASSIC)

Wingate Sandstone forms the lower part of the prominent tan orange, and brown cliffs along both sides of Moab Valley, and in the Amasa Back region (Mile 2-14). The angular vertical cliff on the high skyline of the Dead Horse Point and Island-in-the-Sky areas and the North Point-Hatch Point areas is formed by this formation.



TEXT-FIGURE 3.—Stratigraphic section of rocks exposed in the upper part of Canyonlands region, in the vicinity of Moab and Potash, Utah.

Wingate Sandstone is a very resistant, angular weathering, well-cemented unit approximately 300 feet thick. It is composed of fine-grained, rounded to subangular translucent quartz firmly cemented with silica, calcium carbonate or locally limonite. It weathers with sharp fins and rectangular blocks, commonly stained with desert varnish, and has a reddish orange to maroon-gray weathered face. In the nearly unbroken massive cliff formed by the formation, bedding is obscure, but in some weathered surfaces of low slope gently sweeping cross-bedding can be seen.

Although less spectacularly cross-bedded than the Navajo Sandstone, the Wingate is also considered a wind deposit of a desert environment.

CHINLE FORMATION (TRIASSIC)

Prominent, brightly colored slopes and ledges beneath the massive cliffs of the Wingate Sandstone are formed on the Chinle Formation. Excellent exposures of the formation can be seen along the walls of the Colorado Gorge near The Portal at the south side of Moab Valley and near the river between Long Canyon and Potash on both sides of the canyon (Mile 14-15). It forms the green, maroon, and gray slopes around the base of Dead Horse Point, North Point, Hatch Point, and Island-in-the-Sky.

The Chinle Formation, 200 to 250 feet thick, consists of an upper mudstone-siltstone sequence and a lower sandstone sequence in the Moab-Potash region. The upper mudstone section is maroon, gray-green, gray, and purplish gray, commonly mottled, and weathers to a peculiar surface like dirty "popcorn" because it contains considerable volcanic ash. Low ledges in the upper sequence are formed by cross-bedded lenses of coarse-grained sandstone or conglomerate that represent sections of old river channels.

The lower thick sandstone, the Moss Back Member, is composed of stream-deposited, cross-bedded sandstone and conglomerate sandstone. Interbedded laminae of fine-grained sandstone and siltstone emphasize the irregular cross-bedding.

Sandstone lenses within the Chinle Formation contain some of the economically important uranium deposits in the Canyonlands area, often associated with fossil plant debris in the old stream channels.

Fossils found in the formation include a variety of plants, mainly cycads and conifers. The formation is one of the most prolific fossil wood horizons in the Colorado Plateau.

The Chinle Formation was deposited over low plains by meandering streams, apparently draining lowlands to the south, east, and northeast.

MOENKOPI FORMATION (TRIASSIC)

The Moenkopi Formation occurs in the basal slope zone below the prominent cliffs of Wingate Sandstone. It is not well exposed in Moab Valley nor along the river in the Potash area, but is well exposed some distance above the river beneath Dead Horse Point and other promontories north and east of the Green River confluence, as well as to the west in the Orange Cliffs section north and south of Hite.

The formation is composed predominantly of red, light brown, and greenish brown siltstone and sandstone in thin to medium beds. The lower part of the formation weathers to rounded blocky masses and crude columns and pillars, while the upper part weathers to slabby, steplike ledges and slopes or to steep slopes.

Evidence of shallow-water deposition, including ripple marks, channels, raindrop impressions, mud cracks, together with the regional pattern of the formation suggest deposition in low, very broad tidal flats. Fossils, other than burrows and trails of various sorts, are uncommon in the formation.

PERMO-TRIASSIC UNCONFORMITY

Permian and Triassic rocks in the Canyonlands region and over much of the Colorado Plateau are separated by a marked erosional surface, with mud-

stone and siltstone of the Moenkopi Formation resting upon various Permian formations. It is not a surface of high relief, and rocks above and below generally appear nearly parallel, but on a regional scale rocks below the Moenkopi show some general weak dip that documents regional folding and erosion prior to Triassic deposition. In addition, approximately half of Permian time is not represented by recognizable deposits in the area. Apparently the Colorado Plateau area stood as eroding flat land for considerable time and did not accumulate sediments again until well into Early Triassic time.

UPPER PALEOZOIC ROCKS

The brightly colored Upper Paleozoic rocks of the Canyonlands region are divisible into four major formations or units: (1) a basal evaporite-carbonate sequence (Paradox Formation); (2) a gray-green interbedded limestone and minor shale sequence (Hermosa Formation); (3) an interbedded red sandstone-shale and minor limestone sequence (Rico Formation); and (4) an uppermost maroon to reddish orange conglomeratic sandstone and siltstone sequence (Cutler Formation). This group of rocks record gradual change from an evaporitic basin to open shallow marine to deltaic and finally to nonmarine fluvial environments and document the late history of the Paradox Basin.

The Paradox Basin developed in Late Paleozoic time as a sinking trough along the southwest side of the Uncompaghre Uplift. The basin received sediments from the gradual wearing away of the exposed Precambrian metamorphosed core of the uplift. Red and green colors of the rocks within the basin are related to iron pigments derived from weathering of iron-bearing minerals present in the Precambrian rocks. Textures of rocks within the basin give us clues concerning the history of uplift of the Uncompaghre landmass.

Recent detailed investigation of Pennsylvanian and Permian rocks in the Four-corners area has delimited a series of formations which differ somewhat from the older usage, followed in the guide. Much of the section here included in the Rico Formation is included in the Elephant Canyon Formation, a Permian unit named from The Needles Section of Canyonlands National Park (Baars, 1962), and most of what is here included in the Upper Limestone Member of the Hermosa Formation is included in the Honaker Trail Formation of the Hermosa Group (Wengerd and Matheny, 1958). The boundary between the Honaker Trail and Elephant Canyon formations is mainly a paleontologic break, suggesting missing Upper Pennsylvanian rocks, but it is difficult to identify from a distance. Because of this we have chosen to follow the older terminology which we feel is a meaningful field trip nomenclature.

CUTLER FORMATION (PERMIAN)

Two distinctive sequences of Cutler rocks are visible in the Canyonlands area; one in the north, well exposed near Potash, and the other in the southwest, well exposed in the walls of Narrow Canyon and nearby cliffs near Hite (Text-fig. 4). The northern sequence consists of alternating beds of coarse-grained arkose and fine-grained sandstone. The arkose units are thick, cross-bedded, coarse-grained, and maroon to purplish gray. The sandstone units are silty, reddish brown or orange-brown, well bedded, iron rich, and micaceous. Arkosic units form semislopes, and the more well-sorted sandstones form more angular

distinct cliffs and ledges. This alternation repeats many times throughout the 400- to 3000-foot thickness of the formation and produces a candy-stripped appearance.

The northern sequence represents floodplain and fluvial sediments of a non-marine environment, probably of large gentle alluvial fans and floodplain deposits around the southwest flank of the Uncompaghre Uplift. The formation represents the gradually expanding apron of debris derived from erosion of uplands to the east that ultimately filled the Paradox Basin to well above sea level.

Fossils are rare in the northern sequence but wood has been found locally.

The southern section is clearly divisible into two units on the basis of exposures seen along the river: (1) a lower massive light-gray sandstone, the Cedar Mesa Sandstone, and (2) an upper deep brick-red siltstone sequence, the Organ Rock Tongue (Text-fig. 4). These are so different that they will be treated as separate units in the log and discussion.

ORGAN ROCK TONGUE OF CUTLER FORMATION (PERMIAN)

The Organ Rock Tongue of the Cutler Formation is a brick-red to maroon-gray siltstone and sandstone that strips back from the massive resistant Cedar Mesa Sandstone. It is preserved in the river route only near the Hite Marina, in the cliffs and slopes west of the junction of the Dirty Devil (Fremont) River.

Organ Rock beds are almost entirely red siltstone with thin lenses of red sandstone. Their contact with the underlying Cedar Mesa beds is characterized by a transition zone which consists of interbedded reddish sandstone and siltstone with light tan or buff sandstone. This transition also marks the zone of horizontal shifting of facies between the clean, well-worked massive sandstone and the more silty, arkosic fluvial deposits of the red bed sequence to the north and east. Organ Rock beds also interfinger laterally with the purplish arkosic sandstones of the typical Cutler beds seen near Potash, and appear to be fluvial deposits away from the coarser piedmont sediments of the typical Cutler Formation.

CEDAR MESA SANDSTONE MEMBER OF CUTLER FORMATION (PERMIAN)

The Cedar Mesa Sandstone Member of the Cutler Formation forms the prominent, nearly vertical walls of the lighter cliffs in the lower part of the Cataract Canyon and Narrow Canyon regions. It is one of the most distinctive and dominating rock units within the Canyonlands part of the Colorado Plateau, holding up broad plateaus into which are carved deep recesses and canyons. It forms the rim of Cataract Canyon and Narrow Canyon from near the junction of the Green and Colorado rivers for 50 miles downstream to near Hite Marina.

The Cedar Mesa Sandstone is up to 1200 feet thick and is composed of calcite-cemented sandstone which contains small nodules and concretions of limonite. Quartzose sand grains range from coarse- to fine-grained and are angular to well rounded. Cedar Mesa Sandstone is massive to thick bedded with sweeping cross-beds that appear to be eolian. It is essentially unfossiliferous and grades laterally into the more arkosic red beds of the typical Cutler Formation seen near Potash in the early part of the river trip.

	CATARACT CANYON REGION		MOAB REGION
JURASSIC	ENTRADA SANDSTONE		SLICK ROCK SANDSTONE
	CARMEL LIMESTONE		DEWEY BRIDGE MUDSTONE
	NAVAJO SANDSTONE		NAVAJO SANDSTONE
	KAYENTA FORMATION		KAYENTA FORMATION
TRIASSIC	WINGATE SANDSTONE		WINGATE SANDSTONE
	CHINLE FORMATION		CHINLE FORMATION
	SHINARUMP CGL.		MOSS BACK SS.
	MOENKOPI FORMATION		MOENKOPI FORMATION
PERMIAN		ORGAN ROCK TONGUE	CUTLER FORMATION
	CEDAR MESA SANDSTONE		RICO FORMATION
	RICO FORMATION		HERMOSA FORMATION
	HERMOSA FORMATION		
PENN.	PARADOX BEDS		PARADOX BEDS

TEXT-FIGURE 4.—Stratigraphic section exposed in the Canyonlands region, comparing the rock sequence exposed near Moab with that in the Cataract Canyon or Narrow Canyon area.

RICO FORMATION (PENNSYLVANIAN-PERMIAN)

Rico Formation gradationally overlies the upper beds of the Hermosa Formation and is exposed along the canyon walls virtually the entire length of the trip from near Potash, downstream to a short distance above Hite, in Narrow Canyon. It is a dominantly red-colored unit, in contrast to the gray-green of the underlying Hermosa Formation, and also contrasts sharply with the overlying light gray Cedar Mesa Sandstone. In areas near Potash and Deadhorse Point, however, the reddish Rico is overlain by purplish Cutler beds.

The Rico Formation is from 300 to 450 feet thick and separates the dominantly marine rocks of the Paradox Basin from the dominantly nonmarine rocks surrounding the Uncompaghe Uplift.

Individual thin resistant beds of limestone form gray ledges that are similar to those of the Hermosa below. They are locally fossiliferous but often lack recognizable organic remains. Thin limestone beds are separated by thicker shale and sandstone that give the formation its distinctive color. These sandstones are usually medium- to fine-grained quartz with minor feldspar, indicating well-washed sediments in contrast to the overlying Cutler Formation. Sandstone units are thin to thick bedded and form prominent reddish ledges and cliffs. Their depositional environment varies from probably wind blown shore dunes, coastal floodplain, to marine sediments. Individual units are lens-shaped and suggest deposition in small complex deltaic masses.

Brachiopods, bryozoans, crinoidal debris, various gastropods and pelecypods occur in the formation and indicate a Late Pennsylvanian to Early Permian age for the formation.

HERMOSA FORMATION (PENNSYLVANIAN)

UPPER LIMESTONE MEMBER

Hermosa Limestone is extensively exposed along the walls of much of the canyon from the Loop through Cataract Canyon. It is also exposed in cores of smaller folds in the upper part of the Canyonlands region near Potash in Kane Creek and Shafer anticlines.

The Upper Limestone Member consists of interbedded limestone, shale, mudstone, and sandstone. It is approximately 800 feet thick where completely exposed in Cataract Canyon, but usually only the upper beds are exposed along most of the river course.

Limestone of the formation is gray to gray-green and ranges from thin-bedded to massive. It weathers in alternating ledges and slopes, some of which are blanketed with abundant fossil debris. Most limestone contains some gray, pink, or black chert, often as burrow fillings or fossil replacement.

Interbedded shale grades into the limestone and is generally light gray-green, often calcareous, fossiliferous, and sometimes muddy or silty. It weathers into recesses and helps produce the gray-green ledge-and-slope topography typical of the formation.

Upper beds of the Hermosa Formation represent the greatest thickness of dominantly marine rocks to be seen between Moab and Hite. They contain abundant brachiopods, bryozoans, corals, foraminifera, pelecypods, gastropods, and algae. These beds represent the maximum invasion of the sea into the Paradox Basin.

PARADOX MEMBER (PENNSYLVANIAN)

HERMOSA FORMATION

The Paradox Member is the oldest rock unit seen in the Canyonlands area and is most extensively exposed in the lower part of Gypsum Canyon where 300 feet of the upper beds can be seen. It also crops out along the middle Cataract Canyon section between Spanish Bottom, at Mile 67, and Gypsum Canyon, at Mile 85 where less of the formation is visible in canyon walls. It forms the lower ragged gray exposures in the semi-ledges of the lower slopes of the canyon and tan to light gray domes and rounded hills.

Paradox beds are characterized by thick gypsum with interbedded limestone and minor beds of shale and mudstone. The gypsum is locally massive, white, and has a sugary texture, but elsewhere occurs as banded light and dark gray beds or as grapelike clusters of concretions. Most beds weather to a punky or spongy surface. Limestone of the unit is commonly granular, dark to medium gray, and often smells of petroleum when broken.

Plastic flowage of gypsum has undoubtedly helped produce the broken, easily slumped walls through most of Cataract Canyon. Piercing gypsum domes, like that at Spanish Bottom, or like the discontinuous lenses near Moab, apparently result from upward migration of Paradox beds when the loading of overlying beds is locally disrupted. The more plastic beds flowed or were squeezed upward, locally doming the beds like those seen around the Paradox exposures at the mouth of Lower Red Lake Canyon at Spanish Bottom.

Fossils, *Mesolobus* and *Chonetina*, have been reported from the Paradox beds in the Gypsum Canyon region and indicate a Middle Pennsylvanian age for the rocks there.

The River

From Moab to the Hite Marina on Lake Powell, the Colorado River flows for a distance of nearly 112 miles through some of the most scenic canyons in the West. The river falls from an elevation of approximately 3920 feet above sea level at Moab to approximately 3570 feet at Lake Powell. The upper 67 miles of the canyon provide quite water which breaks into nearly continuous rapids in Cataract Canyon, below Spanish Bottom. The difference is well expressed in gradients of the river in the two sections. The river falls only 0.85 feet per mile in the upper part and 17.6 feet per mile in the lower section. The last part of the trip is on quiet headwaters of Lake Powell which are reached at present water level near Gypsum Canyon.

For the first 14 miles, from Moab to near Potash, the river cuts through a narrow canyon, walled with shear sandstone cliffs; but near Potash the canyon widens into a broad, red amphitheatre at Shafer Basin. A short distance below Potash the river begins to cut deeper into older rocks and the canyon develops a V-shaped profile with vertical inaccessible walls at the canyon rim. From Dark Canyon and Sheep Canyon to near Hite Marina the headwaters of Lake Powell are in Narrow Canyon, between vertical walls of light-colored sandstone that rise above the lake, with very few spots where even small boats can be beached.

RAPIDS

With the exception of some minor ripples in the upper section, major rapids are limited to the unflooded part of Cataract Canyon between Spanish Bottom and Gypsum Canyon. Several severe rapids which gave Powell and his men, as well as other early river expeditions, so much trouble have now been flooded by rising waters of Lake Powell. The originally nearly continuous rapids of Cataract Canyon stretched from approximately Mile 68 to Mile 104 at Sheep Canyon, but now only the uppermost 17 miles of rapids are unflooded and available for "white water" experiences.

Rapids and falls in most rivers are produced by resistant rocks which project above the general gradient of the stream. A fall is produced, for example, as water cascades over the resistant dolomite lip of Niagara Gorge. As in the Grand Canyon area, where rocks of strongly varying resistance to erosion are encountered by the Colorado River, one would expect rapids or waterfalls to develop over the alternating resistant and nonresistant units. Such is not the case, for there appears no single rapid in Grand Canyon or Cataract Canyon which results from a resistant ledge sticking above the normal projected gradient of the stream bed.

Rapids in Cataract Canyon are produced by lateral constriction of the channel either by debris fans from steep tributary canyons or by slumps from the canyon walls (Text-figs. 5 and 6). Most of the minor ripples in the upper part of the river trip are related to fans produced by tributaries, but most of the continuous rapids of the head of Cataract Canyon are produced by slumps. Both processes produce partial dams across the river, with rapids developed at the overflow point in the main channel.

Abnormally steep tributaries are able to transport great quantities of erosional debris from Canyonlands down into the gorge of the Colorado River at a rate far greater than the main stream is able to move the debris on down stream. One can see on aerial photographs (Mile 68-84), as well as on the ground, the broad fans of this coarse debris at the mouth of nearly every tributary. Even in the upper part of the canyon these fans are present at the mouths of all but the smallest side canyons. Rapids at the mouths of Y Canyon, Cross Canyon, Paige Canyon, Range Canyon, Calf Canyon, Imperial Canyon, and other minor canyons are related to debris fans (Text-fig. 5).

Generally speaking, debris fans dam the river and produce stretches of quiet water for some distance above the dam. The overflow point is forced against the opposite canyon wall and causes the river to wear away the opposite wall and to produce rapids which swing into the cut bank. Size of debris dumped into the main channel by the tributary reflects in the severity of the rapid. Low-gradient streams that carry only sand and fine gravel may produce only a ripple or no rapid at all, but steep tributaries where summer thunderstorms are frequent may dump coarse blocks up to several feet in diameter into the Colorado Gorge. Where these occur, the fan-produced rapids are usually most severe.

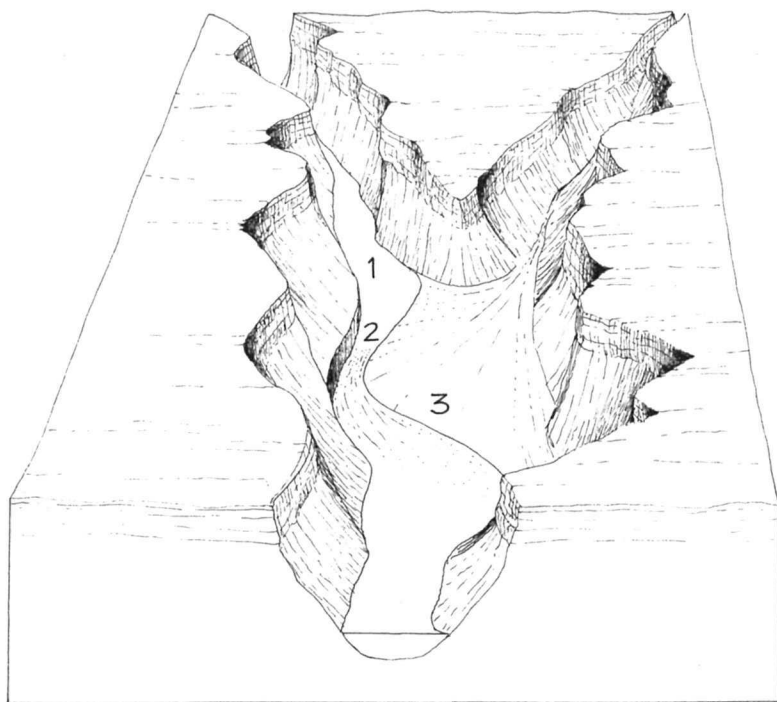
Slump-produced rapids are the main "white water" areas in Cataract Canyon. Brown Betty, Dubendorf, Mile Long, Big Drop (Kolb), and Gypsum Canyon rapids are all related to slump blocks sliding or falling into the canyon bottom (Text-fig. 6). Slump masses may vary from the large, single block that restricts the river just above Gypsum Canyon to smaller masses like those in the

area between Spanish Bottom and Cross Canyon, or in Mile Long Rapid a few miles on downstream.

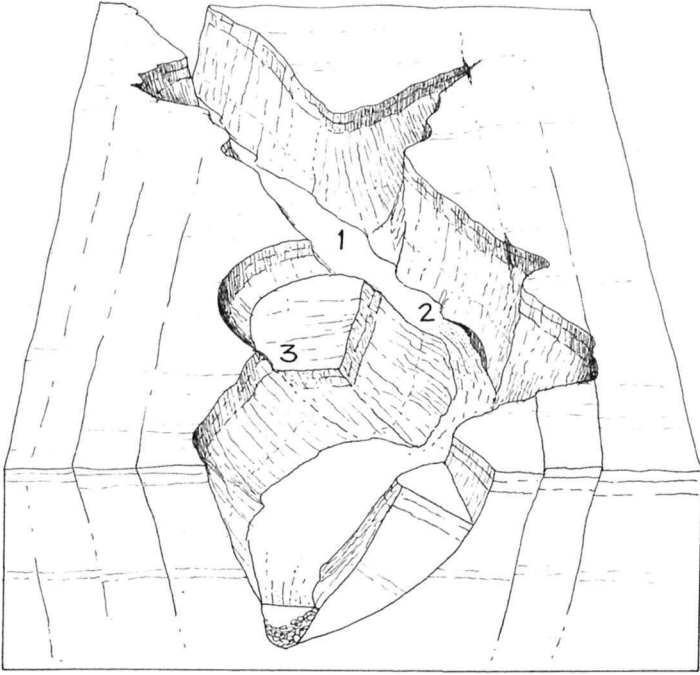
The Gypsum Canyon block at Mile 84.4 has slumped down several hundred feet from the rim of the west margin of the canyon. It is approximately three quarters of a mile long and five or six hundred feet high and stands as the hill directly opposite the mouth of the tributary canyon. Rocks in the slump have slip 1500 feet below their original position on the high western canyon rim, with a moving toe which continuously restricts the Colorado River against the debris fan from Gypsum Canyon.

Kolb Rapid and Mile Long Rapid are produced by smaller slump masses in which the entire canyon wall is sliding slowly down into the river, maintaining a continuously restricted and rock-strewn channel.

Instability of the canyon wall is related to complex joints and small faults that break the normally resistant cliffs of the canyon wall into discrete blocks and slices which move downslope under the pull of gravity. Jointing and faulting are probably related to movement of gypsum and salt in the exposed or very shallowly buried Paradox beds from near Spanish Bottom down river to at least Palmer and Bowdie canyons.



TEXT-FIGURE 5.—Rapids in Cataract Canyon may form from narrowing of the channel by debris fans produced at the mouths of steep tributaries. Calm water (1) is commonly developed above the rapids (2) which are caused by a restriction of the channel as result of expansion of the debris fan (3). The river is often forced against the opposite wall and produces a relatively steep, undercut slope.



TEXT-FIGURE 6.—Many rapids are also produced in Cataract Canyon by slumping of the canyon walls in large landslide blocks such as that shown in cross-section in the front of the block and the block at 3. The rapid (2) is a result of constriction of the channel by the landslide mass. Quiet water (1) is produced upstream where the river is temporarily ponded.

Debris brought into the canyon by either tributary canyons or by slumps is moved down slope so that without continuous renewal rapids would gradually disappear. Because of intermittent intense thunderstorms in Canyonlands, single rapids produced by debris fans can change from year to year. Intermittent movement of slump blocks or debris can have similar effects. Because of the relative rates of removal by the main stream and construction of obstacles by tributaries and slumps the gradient shows little signs of smoothing in Cataract Canyon above Lake Powell. With control of water flow down the Green River so that major "cleaning" floods will be increasingly less frequent, it is possible that the rapids could become more rigorous with time.

Vegetation

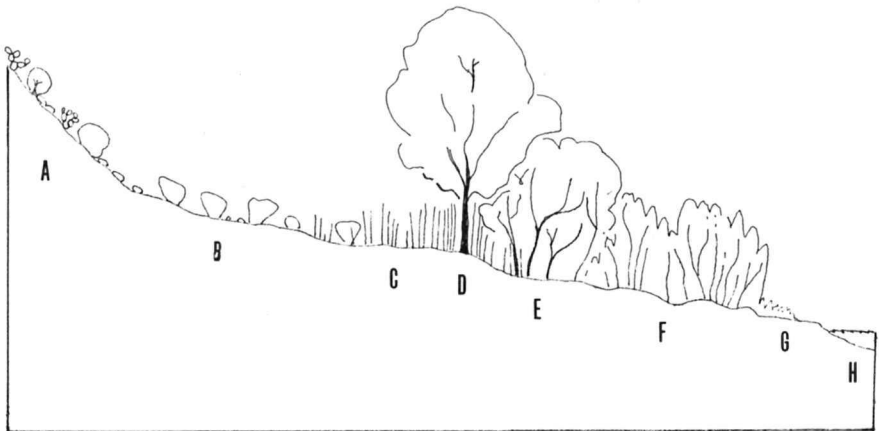
The canyon of the Colorado River below Moab southward to Hite is located in a region of scanty rainfall, warm summer temperatures, and high

evaporation. Except where an additional ration of water is available from seeps, springs, streams, or rivers, the vegetative cover is not conspicuous. It is not a sparse vegetation, however, for the plants are numerous and the species many. Most of the plants are those which can endure the drought and heat of summer or which can take advantage of infrequent rains and can complete their life cycle in a brief period of relatively abundant moisture.

In general aspect, the desert gray colors predominate, but the vivid greens of conifer and broadleaf species are not wholly lacking; and where extra water is available, there develops a bright green color made more vivid by its contrast with the brilliant hues of rocks and soil. Generally, the vegetation is considered as belonging to the warm-to-cool desert shrub vegetative types. The plants are mostly widely spaced, except where additional water is available along the riverbanks and in seeps.

In the deep canyons of the inner gorge of the Green and Colorado rivers, there is developed a green border of vegetation along both sides of the rivers. Here, the plants find some measure of release from the penurious climate and respond with a luxuriance lacking elsewhere in the region. The green sward along each side of the river is made up of poplar, willow, tamarix, and forestiera. A definite pattern is displayed in the vegetation. Along the sandy bank adjacent to the river the weedy Old World shrub, tamarix, forms an almost impenetrable thicket. In some places the sandbar willow still holds out against the aggressive Old World introduction, but the green of the river's edge is mostly tamarix. Here and there the peachleaf willow holds precariously to the bank, and occasionally, a solitary tree or small grove of Fremont poplar displays its bold green color.

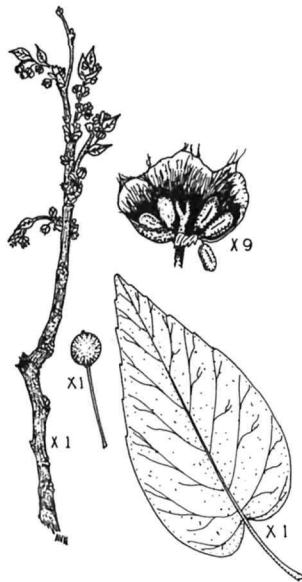
Back from the river's edge is a series of terraces and swales which, as the distance from the river increases, are progressively drier. Commonly, the first terrace behind the tamarix is overgrown by a thicket of forestiera, with its bright green leaves and pale, grayish-green stems. This plant is a member of the



TEXT-FIGURE 7.—Typical plant zonation along the stream margin in a mature section. A, canyon slope with saltbrush and *Ephedra* with pricklypears; B, gentle slope with rabbitbrush and blackbrush; C, reedgrass in alluvial plain; D, Fremont poplar; E, peachleaf willow; F, tamarix; G, new tamarix and three-square rush; H, river.



TEXT-FIGURE 8.—A, *Achillea millefolium*, common name yarrow, approximately one fifth natural size. B, *Allium acuminatum*, common name Hooker onion, approximately one fifth natural size.



TEXT-FIGURE 9.—*Celtis reticulata*, common name hackberry, leaf, stem, and fruit approximately one half natural size, flower four times natural size.



TEXT-FIGURE 10.—A, *Chaenactis douglasii*, common name Douglas false-yarrow, approximately one fifth natural size. B, *Delphinium nelsonii*, common name larkspur, approximately one fifth natural size.



TEXT-FIGURE 11.—*Hedysarum boreale*, common name northern sweetvetch, approximately one fifth natural size.



TEXT-FIGURE 12.—A, *Lygodesmia grandiflora*, common name rush-pink, approximately one fifth natural size. B, *Oenothera pallida*, common name pale evening primrose, approximately one fifth natural size.



TEXT-FIGURE 13.—*Phlox longifolia*, common name long-leaved phlox, approximately one fifth natural size.



TEXT-FIGURE 14.— A, *Quercus gambelii*, common name gambel oak, approximately one fifth natural size. B, *Ranunculus cymbalaria*, common name buttercup, approximately one fifth natural size.



TEXT-FIGURE 15.—*Rumex crispus*, common name dock, approximately one tenth natural size.



TEXT-FIGURE 16.—*Salix amygdaloides*, common name peachleaf willow, approximately one half natural size.



TEXT-FIGURE 17.—*Sarcobatus vermiculatus*, common name greasewood, approximately one fifth natural size.



TEXT-FIGURE 18.—*Scirpus americanus* (left) and *S. paludosus* (right), common names three-square rush and marsh rush respectively, approximately one fifth natural size.



TEXT-FIGURE 19.—*Sphaeralcea coccinea*, common name globe mallow, approximately one fifth natural size.



TEXT-FIGURE 20.—*Tragopogon dubius*, common name yellow salsify, approximately one fifth natural size.

olive family, and in autumn it produces clusters of purplish fruits which resemble tiny olives. These are eaten by foxes and coyotes, staining their fecal droppings a dark purple color. In some areas *forestiera* is intermixed or replaced by common reed-grass, and in more saline areas by seepweed. Where still another terrace is present back from the first, it is commonly overgrown by Fremont poplar, rabbitbrush and sand dropseed. A short distance back from the river, the abrupt canyon slopes remove the possibility of plants sending their roots to the water table, and the green of the river bottom gives way to the sparse desert shrubland of the slopes of the inner gorge.

The environment of the slopes of the inner gorge is harsh, and at first glance the landscape appears to be barren. However, a closer look demonstrates a vegetative cover of black brush, shadscale, and numerous other plants. Here in midspring plants flower in profusion. The long, yellow stalks of prince's plume and numerous clumps of cryptantha and enceliopsis go far to make yellow the prevailing flower color of the area; but, in some places the Mohave aster and twistleaf aster, which both rival and resemble the cultivated Shasta daisy, add white and many shades of pink and lavender. The presence of these asters, prince's plume, and some pink-flowered milk vetches indicates the presence of the element selenium, a poisonous mineral in the soils. Here and there fishhook cactus and prickly pear display their rugged, armed stems, softened by the beauty of their blossoms.

Thus, the flora of the inner gorge is rich, varied, and remarkably beautiful. In some places, where sandstone caps mudstone, siltstone, or shale there develops along the lower surface of the sandstone outcrop, a wet spot. In these wet spots develop "hanging gardens," a mass of dense, bright green vegetation clinging precariously to the face of the cliff. "Hanging gardens" are present in cliff faces and alcoves throughout the southeastern portion of Utah. They begin with the growth of plants on the moistened cliff face. As time passes, soil accumulates around the plants and the soft sandstone is weakened further by the growing roots. Finally, the weight of the plant and soil mass causes slippage and the plants fall to the base of the cliff where eventually there is built a pile of moist sand, rich and humus, on which numerous other plants grow. The cliff face is again reoccupied by plants, and the cycle begins again. Whereas, the plant composition varies from garden to garden, some plants are common to most of them. Among these are the heleborine orchid, elegant death-camas, cave primrose, and scarlet monkey-flower.

River Log

Mile 0.—Highway Bridge over Colorado River near docking area northwest of Moab (Text-fig. 21).

Mile 0.6.—Exposures of laminated white and red beds in the upper part of the Cutler sequence on the southwest side of Moab Valley near Utah Highway 279. Tailings pits of Atlas Uranium ore reduction plant continue to the right. Faulted Chinle and Wingate beds are exposed directly ahead in the vicinity of the railroad.



TEXT-FIGURE 21.—Vertical aerial photograph of the Colorado River covering the area from approximately Mile 0 to Mile 5, in Moab Valley near The Portal region at the beginning of the trip, taken prior to construction of uranium processing plant and roads along the river. The prominent joint-controlled ribs are in massive Triassic and Jurassic sandstone near Mile 4 and 5 in King's Bottom syncline.

Mile 0.8.—Southern end of the tailings pit from the uranium leaching plant. Tamarix and willow flats line the natural levee system along the Colorado River south of the tailings pits. Chinle beds are exposed beneath the Wingate cliffs to the south. The West Spanish (Moab) Valley Fault is close against the mountain front in here, but it is difficult to precisely locate from the exposures which are available and visible from the river.

Mile 1.0.—Colorado River swings in close against the road. Point bar development is obvious on the eastern inside of the meander bend. Directly downstream The Portal or the exit of the Colorado River from Moab Valley is capped by angular-weathering Wingate Sandstone, with Chinle beds forming the underlying slope. Navajo Sandstone is exposed on the skyline downstream a short distance (Text-fig. 22).

Mile 2.0.—The light-colored beds immediately east of the river by the telephone poles are in the Paradox Formation. These rocks have pierced upward along the Moab Valley or Spanish Valley fault system and are exposed here several thousand feet above their normal stratigraphic position. No such piercement features are visible on the western side of the river.



TEXT-FIGURE 22.—View to the southwest to the west side of The Portal, where the Colorado River exits from Moab Valley. Dead Horse Point State Park is along the skyline to the right and Hatch Point along the skyline to the left. Streamside vegetation is principally tamarix, sandbar willow, and Fremont poplar.

Mile 2.4.—THE PORTAL OF THE COLORADO RIVER. Sandstones and shales of the Chinle Formation are exposed at road level alongside the river. The road along the east side leads southward into the Kane Springs Canyon area. The silver-colored line on the east bank is a petroleum natural gas line.

Mile 2.7.—Base of the massive Wingate Sandstone on variegated Chinle Shale. The Wingate Sandstone is more prominently bedded here than it is in many areas (Text-fig. 23).

Mile 3.0.—Excellent sheeting is developed in the Wingate Sandstone.

Mile 3.1.—Indian ruins (probably grainary structures) high on the east side of the canyon are beneath the overhanging ledge of the Kayenta Sandstone above the Wingate cliffs. Wingate Sandstone forms a massive cliff along both sides of the river and is here blanketed by desert varnish. Ahead, hummocky round hills of Navajo Sandstone occur on top of the flaggy-bedded Kayenta Formation.

Mile 3.2.—Top of the Wingate Sandstone and base of the flaggy-bedded Kayenta Formation at road level. Kayenta Formation forms the rubbly semi-slopes. It is composed of channel sandstones with interbedded red clays.

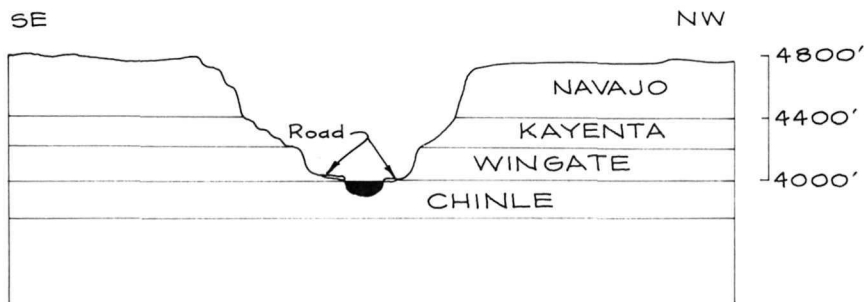
Mile 3.4.—High-level terrace gravels on the east bank are composed in large part of metamorphic rocks brought down from the Rocky Mountains upstream.

Mile 3.5.—Alcoves and hanging gardens can be seen in the Navajo Sandstone, the formation that forms the rounded vertical cliffs on both sides of the canyon. Terrace gravels continue downstream on both sides at varying elevations up to 50 feet above the river.

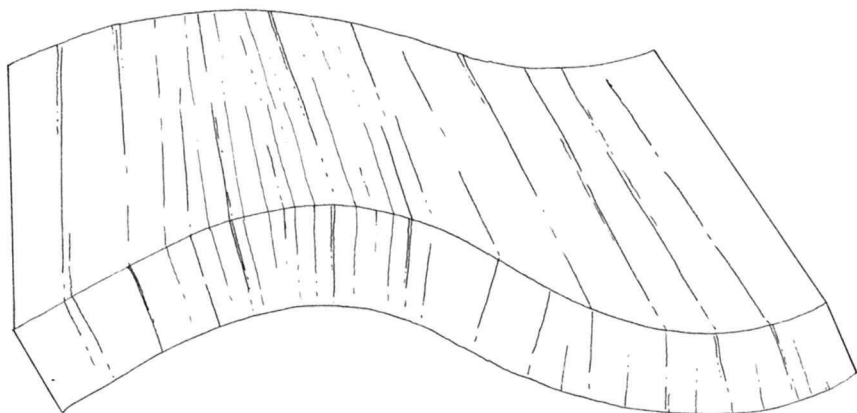
Mile 3.9.—Base of the Navajo Sandstone on top of the Kayenta Sandstone. Terrace gravels are particularly evident along the east side of the Valley. Rocks continue with downriver dip.

Mile 4.1.—Cross-bedded Navajo Sandstone is well expressed in the cliff on the east (left) side and is coated with shiny desert varnish.

Mile 4.3.—Massive Navajo Sandstone. Some erosional arch features show well in the sandstone. Fins are developed in the Navajo Sandstone on the



TEXT-FIGURE 23.—Cross-canyon topographic profile shows geologic control at Mile 4. Massive Wingate and Navajo Sandstone form the vertical cliff with Kayenta beds forming the slabby intermediate slope zone.



TEXT-FIGURE 24.—Joints or small fractures are produced when brittle sandstones are folded like that shown in the diagram. Prominent fins in the massive sandstone developed in the King's Bottom syncline between Mile 4 and Mile 5 are controlled by joints.

east wall of the gorge along the strong joint system which is parallel to the Spanish Valley Fault to the north. Navajo Sandstone usually shows jointing more spectacularly than other units in the Mesozoic sequence (Text-fig. 24).

Mile 4.8.—Indian petroglyphs chipped in desert varnish in the Navajo Sandstone 10 to 15 feet above the road on the right. These petroglyphs are typical Fremont carvings.

Mile 4.9.—Additional petroglyphs in the Navajo Sandstone. Fins of the Navajo Sandstone are well developed along the east side of the gorge beyond Kings Bottom. The rocks are nearly flat-lying here in the trough of the Kings Bottom syncline.

Mile 5.4.—Base of the Navajo Sandstone on top of the Kayenta exposed at road level at the red shaly break beneath the massive sandstone ledge. The beds are now dipping gently upstream to the north on the south flank of the Kings Bottom syncline.

Mile 5.5.—KANE SPRINGS CREEK enters the Colorado River from the east. Dinosaur tracks in slumped blocks and Indian petroglyphs in top of the Kayenta Cliffs are visible to the north. Alcoves and arches developed in the Navajo Sandstone can be seen high on the canyon wall to the east. The Kayenta Formation is expressed here in the typically ledgy slope zone, which is capped with much high-level terrace gravel marking former positions of the Colorado River.

Mile 6.1.—Top of the Wingate Sandstone exposed in cuts on the north side.

Mile 6.3.—Massive upper part of the Wingate Sandstone exposed in cuts on the north and in river-cut banks on the south. Thickets of tamarix have formed on levees, almost crowding out the willows everywhere but right along the banks of the river. Weak cross-bedding and considerable desert varnish characterize the red angular-weathering Wingate Sandstone.

Mile 6.6.—The canyon rim to the south is formed in the slabby Kayenta Sandstone (Text-fig. 2).

Mile 7.2.—Alcoves are developed in the Wingate Sandstone to the south. Slabbing and arch development are evident in the Wingate Sandstone on the north in the immediate vicinity of the road.

Mile 7.3.—Navajo Sandstone beehive-like erosional forms are visible ahead on the south side of the river.

Mile 7.6.—Top of the Wingate Sandstone and base of the slabby Kayenta Formation exposed at road level on the north side.

Mile 8.2.—Kayenta Sandstone is well expressed at river level on the north bank. Several high gravel terraces can be seen to the south. One prominent terrace approximately 80 feet above river level is blanketed by thick, rounded gravel.

Mile 8.5.—Sandstone beds with interbedded red shale and siltstone in the uppermost part of the Kayenta Formation are exposed in cuts on the north side.

Mile 8.8.—Base of the Navajo Sandstone is exposed at road level. For the next half mile Navajo Sandstone forms the outcrops in cuts on the north side. Some Kayenta beds are still exposed above river level on the southwest bank, with massive "beehives" of Navajo Sandstone high on the skyline ahead and to the south.

Mile 9.5.—Tumbled blocks of Navajo Sandstone in cuts on the north side. The lower part of the unit is relatively well bedded.

Mile 9.6.—Kayenta Sandstone appears at road level.

Mile 9.7.—Well-developed Kayenta Sandstone at road level.

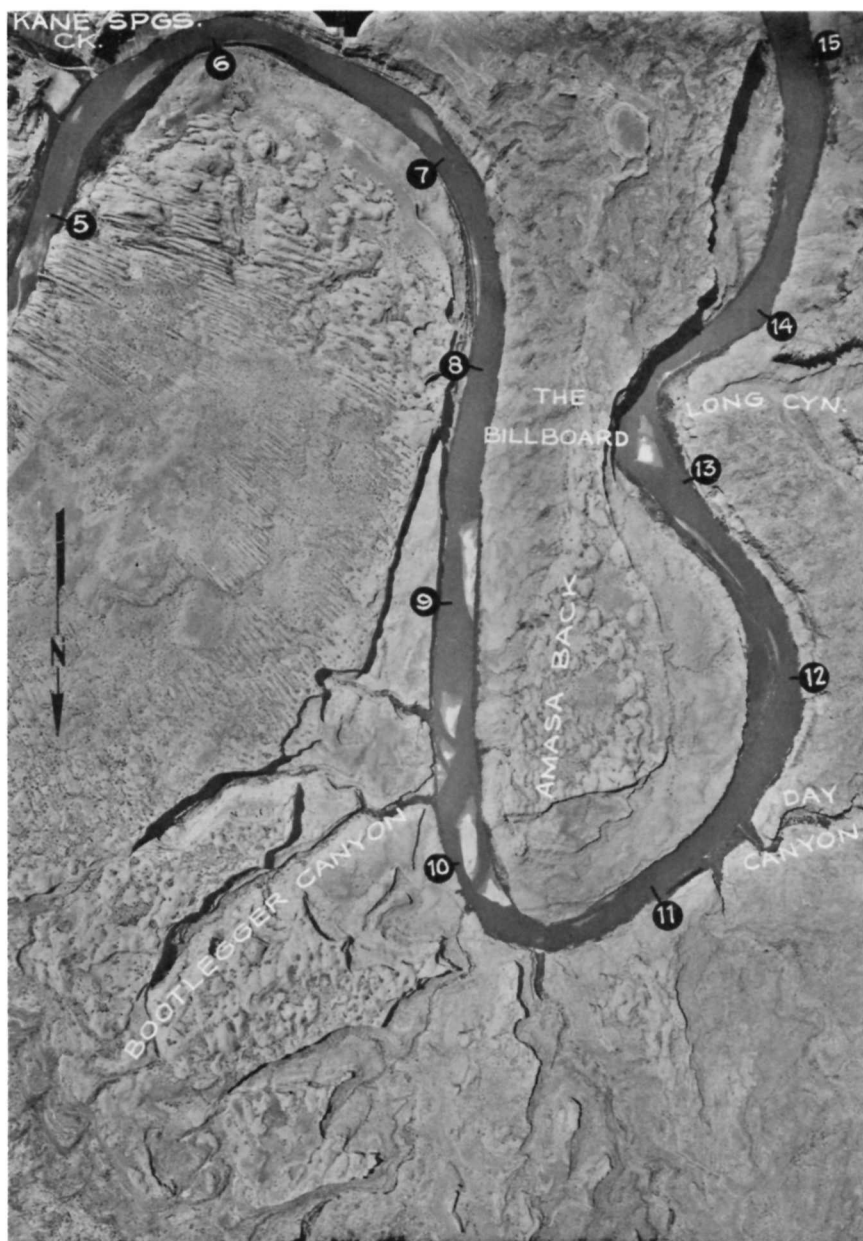
Mile 9.8.—BOOTLEGGER CANYON enters from the north. A road leads up the canyon to near Little Rainbow Bridge.

Mile 9.9.—Gold Bar Arch is a small arch in Navajo Sandstone visible on the north. Gravel terraces capping Kayenta beds on both the north and south sides of the river.

Mile 10.1.—The river now swings approximately parallel to the branch line of the D&RG railroad leading from Crescent Junction south to Potash. The railroad tunnels through a long meander spur. It is approximately one mile long and opens into the headwaters of Bootlegger Canyon. Kayenta rocks are exposed both east and west of the river with gravel terraces well developed on the point of Amasa Back, the meander core (Text-fig. 25).

Mile 10.7.—Gravel terraces are well expressed on the east bank but are difficult to identify on the west side in railroad cuts because of recent excavation for the railroad.

Mile 10.9.—Bedded Wingate Sandstone forms the prominent cliffs both in the railroad cut and on the east side of the canyon directly ahead. Kayenta beds cap both the east and west bank on the skyline.



TEXT-FIGURE 25.—Vertical aerial photograph of the Colorado River from approximately Mile 5 to Mile 15 around Amasa Back. The large meander was probably inherited from a gentle topography developed above the massive sandstones which are now exposed along the canyon wall. The photograph was taken prior to construction of the roads along the river.

Mile 11.1.—Little Canyon enters from the northwest (right).

Mile 11.4.—*VERY NARROW DAY CANYON LEADS OFF TO THE WEST* (right). Parallel jointing is well expressed in vertical walls of Wingate Sandstone.

Mile 11.9.—Exposures of uppermost Chinle beds in railroad cuts on the west (right). Chinle beds are not exposed here on the east side of the river in the meander bend around Amasa Back because of the dip.

Mile 12.6.—Exposures of uppermost Chinle Formation in road cuts. The natural levee of Lake Bottom and the adjacent point bar on the east side were worked by a small gold dredge a few years ago with limited success.

Mile 12.7.—Cross-bedding of channel fill well developed in uppermost beds of the Chinle exposed in road and railroad cuts.

Mile 12.8.—Channel sandstone filling in uppermost beds of the Chinle beneath the massive shear wall of Wingate Sandstone exposed in railroad cuts to the southwest (right). To the left the massive wall of Wingate Sandstone is interrupted by a semi-ledge zone of well-bedded Kayenta rocks which are overlain by massive Navajo Sandstone near the top. The wall is called *THE BILLBOARD* (Text-fig. 25)

Mile 13.1.—Base of the northward dipping Wingate Sandstone at railroad level.

Mile 13.0.—*JUG HANDLE ARCH* visible high and to the right in the Wingate Sandstone.

Mile 13.4.—*MAJOR TRIBUTARY OF LONG CANYON ENTERS FROM THE WEST.* Chinle beds are exposed at the Long Canyon Junction and are also exposed on the east side of the canyon. Beds dip sharply northward off the Kane Creek anticline into the Kings Bottom syncline (Text-figs. 26, 27).

Mile 13.8.—Development at Potash can be seen ahead downstream.

Mile 13.9.—Massive channel sandstones of the Chinle Formation are exposed in cuts along the railroad to the right.

Mile 14.0.—Slumped Chinle beds. Much of the lower canyon wall is covered with slope-wash material. Some areas have slipped over the shaly beds of the Chinle Formation.

Mile 14.2.—Gray high-level terrace gravels are visible across the river to the east.

Mile 14.3.—*STORAGE BINS AND PROCESSING PLANT OF POTASH DEVELOPMENT ARE DIRECTLY AHEAD* (Text-fig. 28). Moenkopi rocks should appear near here but are not exposed through the thick cover.

Mile 14.5.—Top of the Cutler beds is exposed at road level at the north end of the Potash railroad yards. The overlying Moenkopi Formation is thin here and forms the brownish shaly slope above the brick red units of the upper part of the Cutler sequence.

Mile 14.6.—Red and pink, flaggy-bedded arkosic sandstone of the Cutler Formation can be seen in outcrops away from the river. The northeast dip off



TEXT-FIGURE 26.—The south flank of the King's Bottom syncline is expressed by cliffs in front of the mining activity at Potash, as seen downstream from near Mile 15. The prominent sharp cliffs in the middle distance are held up by Wingate Sandstone, the same unit which holds up Hatch Point, along the skyline in the distance.

The meander in the center of the picture is margined by a tamarix-dominated bar. Uplands have a sparse cover of blackbrush, the small shrub, and of pinyon and juniper, the larger shrubs.

the Kane Springs anticline is evident in Cutler rocks. Purplish and pink Rico beds are exposed south of the canyon.

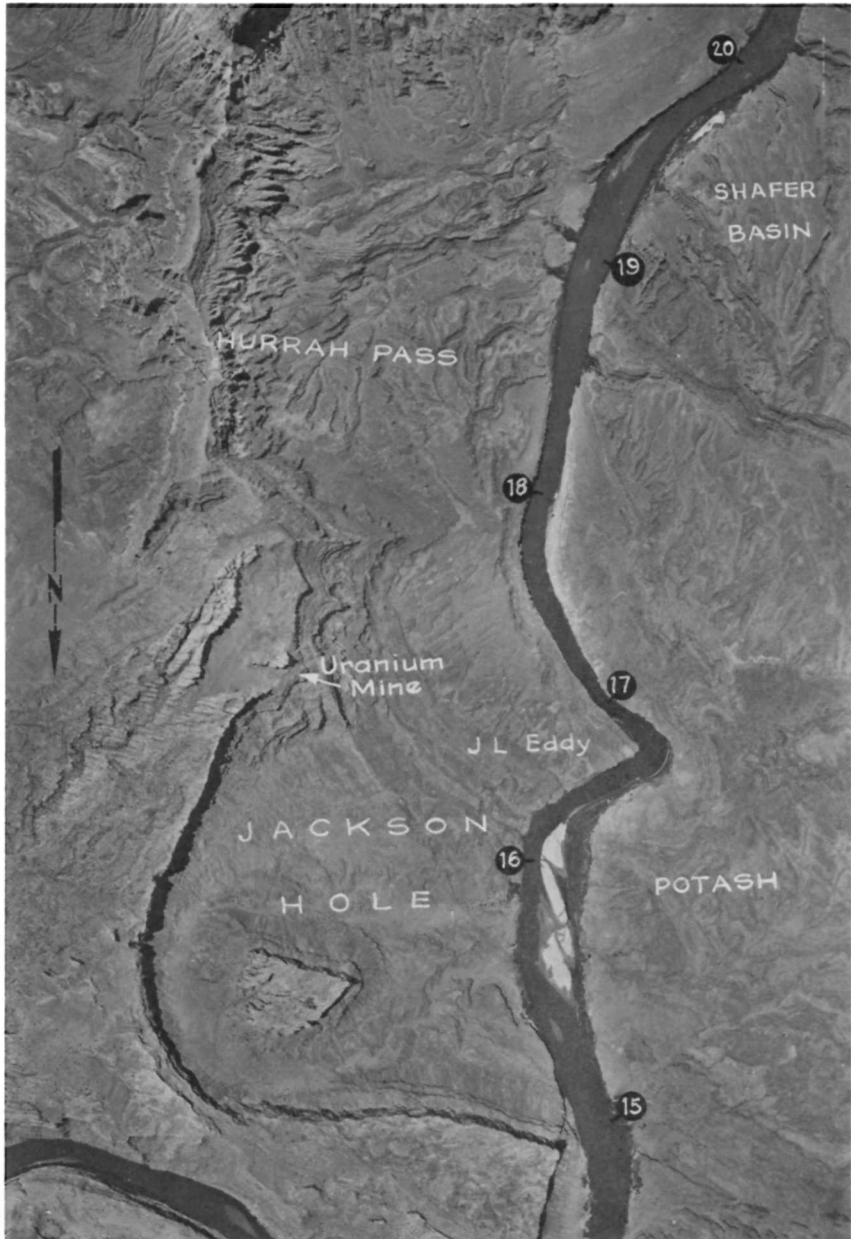
Mile 14.8.—Massive red sandstones in the Rico Formation are exposed in low exposures away from the river. The high rim on the skyline to the west is in Wingate Sandstone and forms the margin of Big Flat.

Mile 15.1.—Excellent rounded exposures of the reddish upper beds of the Rico and Cutler sequence occur in river bluffs on the east side.

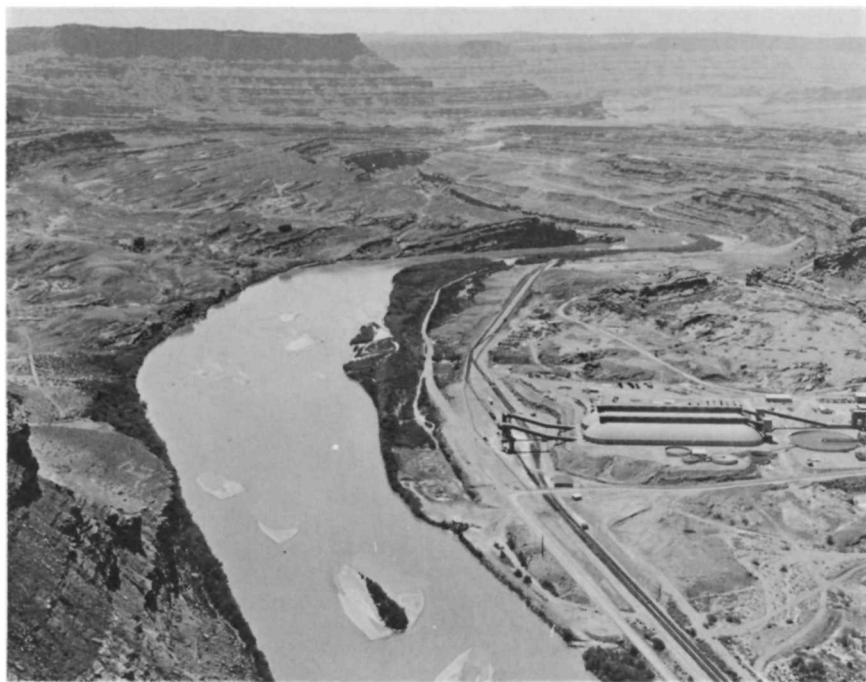
Mile 15.3.—POTASH PLANT TO THE RIGHT.

Mile 15.8.—Typical terrace gravels of the Colorado River can be seen to the west (right).

Mile 16.0.—Jackson Bottom to the right (west) is on the floodplain of the Colorado River. Tamarix and willow groves are growing on the pointbar. Northward dipping Rico and Hermosa beds can be seen ahead on the north flank of the Kane Creek anticline. Jackson Hole to the east is an abandoned meander of the Colorado River.



TEXT-FIGURE 27.—Vertical aerial photograph of the Colorado River from approximately Mile 15 to Mile 20. Jackson Hole is an abandoned meander of the Colorado River on top of resistant Rico and Hermosa beds. The Kane Creek anticline diagonals across the river at approximately Mile 18. The north tip of Hatch Point is visible at the upper left. Photographs were taken prior to mining development at Potash.



TEXT-FIGURE 28.—View of the development at Potash at approximately Mile 15.5. The gentle Kane Creek anticline in Hermosa and Rico beds shows in the middle distance.

Mile 16.3.—Tamarix forms a dense growth along the river bank. Large frogs and evidence of river beaver are locally common along the west bank.

Mile 16.6.—Excellent exposures of Rico red beds ahead and to the north, with terrace gravels draped against flanks of the exposures.

Mile 16.7.—J. L. EDDY, POTASH COMPANY BOAT RAMP (Text-fig. 27). Rocks east and west of the river are alternating limestone, red siltstone, and coarse arkosic sandstone. Lower limestones are in the Hermosa and upper reddish units are in the Rico. Hermosa Limestone immediately downstream from the boat landing shows the northward dip. Cross-bedding shows very well in the Rico Sandstone, particularly along the west side of the canyon. Light-colored rocks in overhanging ledges are red stained from higher units. On fresh surfaces these are clean, light-colored sandstone and sandy limestone.

Mile 17.—Cross-bedding in sandstone shows very well below the bedded limestone which holds up the prominent cliffy zone. Dense thickets of willows and tamarix grow along the east side.

Mile 17.4.—Relatively thin-bedded marine units of the upper part of the Hermosa Formation. Outcrops near the river are capped by fossiliferous gray limestones. These beds form the gray slope immediately southeast of Dead Horse Point and that on Shafer Basin. Most of the red color near river level

is staining of light gray sandstone and limestone by iron oxide washed down from overlying beds.

Mile 17.5.—Cross-bedded sandstone, fossiliferous marine limestone, and gray shale of Hermosa Formation exposed on both sides of the canyon. Gray shale units form the slope zones between the cliffs.

Mile 17.6.—Old dugway and loading dock area on the west, a ghost of petroleum exploration here in the 1920s. Road leads down from the gray, limestone-capped rim on the north slope of Shafer Basin. Several dry holes were drilled in this general area on the anticline, which is expressed in the arched limestone cap to the west. From this point the south dip off Kane Creek anticline can be seen downstream.

Mile 17.9.—Dwellings ahead on the west (right), are part of an abandoned oil development attempt along the Colorado River on the crest of Kane Creek anticline. Northeast dip can be seen in exposures of the Hermosa Formation in the banks behind the older buildings. Fossiliferous marine limestone and sandstone are well exposed. Abandoned old barges along the shoreline are from the development (Text-fig. 29).

Mile 18.0.—SEEPAGE FROM AN ABANDONED OIL WELL, Frank Shafer #1, on the west (right) side of the river (Text-fig. 30). The well produces hydrogen sulfide along with rather limited quantities of warm, salty water. DO NOT TASTE: IT CAN BE A VIOLENT EXPERIENCE.

The Frank Shafer #1 well was begun in 1924 and was drilled to a depth



TEXT-FIGURE 29.—Abandoned barges are part of the oil development along the crest of the Kane Creek anticline. They are partially buried in silt in the west bank at approximately Mile 17.9, in a mixed thicket of tamarix and willow.



TEXT-FIGURE 30.—Seepage from an abandoned oil well, the Frank Shafer #1, at Mile 18.0.

of 5,000 feet through the Hermosa and into the Paradox evaporite sequence. Showings of oil and gas were encountered, but at a depth of 2,028 feet gas and oil gushed to the surface and caught fire, burning the rig. It was successfully controlled and the horizon cased off so that the well could be deepened. After it had reached the projected total depth attempts were made to produce the previously discovered horizons but they failed and the well was abandoned.

Mile 18.2.—Prominent downstream dip of marine Hermosa Limestone on the south flank of Kane Creek anticline (Text-fig. 31). Imposing feature along the skyline directly across the canyon southeast from Dead Horse Point is Hatch Point, and is held up by Wingate and Kayenta beds.

Mile 18.5.—Top of the gray Hermosa Limestone dips below the river on the south side (Text-fig. 32). Shafer Basin occurs to the west, beyond the brick red alternating ledges and slopes of the Rico sequence.

Mile 19.0.—Broad open area in the Rico Formation. Fossiliferous limestones can be seen on the east side, beyond the tamarix-covered siltstone banks. High gravel-capped terraces on the east are in front of reddish sandstone of the Rico-Cutler rocks.



TEXT-FIGURE 31.—View toward the north across the Kane Creek anticline, with prominent ledge-forming Hermosa beds exposed in the anticlinal core along the river. Arching over the anticline is well expressed by the rocks on the skyline.

Mile 19.2.—Terrace gravels on either side of the river, with tamarix and willows along the silt-laden banks. Rico arkose exposed on both east and west with a typical cyclic pattern of ledge-forming pink and maroon, coarse arkose, capped with more evenly bedded, reddish siltstone. An old miner's shack can be seen along the east bank on the alluvial flat. Some old car parts strewn about the site suggest high hopes for mineral production since some were modified for smelting (?).

Mile 19.5.—Downstream can be seen a terrace on one of the prominent resistant thin limestones in the Rico Formation. Moenkopi and Cutler rocks form the high pyramid directly ahead.

Mile 20.—Prominent terrace gravel occurs 20 to 30 feet above river level on Rico-Cutler rocks. On the skyline to the west can be seen the east rim of Dead Horse Point in the Wingate and Kayenta formations.

Mile 20.2.—Small, prominent canyon coming in from the west, cut in Rico

siltstone and shale. Cross-sections of ancient channels are filled by massive cross-bedded sandstone. The prominent point on the skyline to the east is in Wingate and Kayenta sandstones above the gray of the Moenkopi and Chinle beds.

Mile 20.4.—A typical sequence of Rico beds is exposed in a tributary canyon to the west.

Mile 21.5.—River continues through relatively flat-lying Rico beds (Text-fig. 33). Cutler, Moenkopi, Chinle, Wingate, and Kayenta formations are visible ahead and to the east in the Hatch Point area. The small canyon to the east leads up to Dripping Spring, approximately three miles up the canyon. Terrace gravels are prominently developed on top of some of the resistant limestone ledges.

Mile 21.6.—Sandbar on the east side. A jeep road to old uranium prospects around the base of Hatch Point is located on top of the low, gravel-covered terrace on the east bank. To the southeast, windblown sand forms pinkish dunes over the gray gravel terrace.

Mile 22.—The river makes a relatively abrupt bend toward the west around a prominent, low, willow-blanketed pointbar (Text-fig. 34). The rocks are dipping very gently upstream into a broad syncline which separates Kane Creek anticline from Shafer dome to the southeast below Dead Horse Point. Rico-Cutler beds are exposed on both the north and the south side as the alternating maroon and red-orange ledges and slopes (Text-fig. 35). The marginal marine part of the section is probably the thin-bedded material which separates the thick-bedded red-orange units.

Mile 23.5.—Small, prominent canyon cutting in from the north (right). The



TEXT-FIGURE 32.—Upstream on the south flank of the Kane Creek anticline in Hermosa Limestone. Many of the low ledges in the upper part are fossiliferous.



TEXT-FIGURE 33.—Vertical aerial photograph of the Colorado River from approximately Mile 21 to Mile 26. Wingate Sandstone is exposed in the upper left corner at the north end of Hatch Point. The inner gorge is in Hermosa and Rico beds with Cutler beds preserved in Pyramid Butte.



TEXT-FIGURE 34.—View downstream from approximately Mile 22. Dead Horse Point is along the skyline at the upper right and is held up by Wingate Sandstone. Abundantly fossiliferous marine limestones are exposed in gray ledges in the foreground, many of which are now capped by terrace gravels.

The sand flat in the lower right corner shows the typical development of bars occupied by tamarix. Tamarix occurs in dense growths near the river margin, in front of *Forestiera*, which has the common name adelia. Behind that there is a grassy belt, dominated by the tall grass *Phragmites communis*, which grades into a belt of salt tolerant vegetation and finally into the talus slope, with its specialized flora.

cyclic pattern of Rico sedimentation shows well here as interbedded, maroon sandstone, siltstone, and gray limestone below the light orange-red, cliff-forming Cutler beds.

Mile 24.2.—Prominent willow-covered pointbar on the north side. Excellent exposures of lower Rico beds on the west (left) side. Deformed bedding due to slumping occurs in thin-bedded units.

Mile 24.3.—Hermosa Limestone appears at river level on the south flank of Shafer dome on the west bank.

Mile 25.0.—Near prominent bend, DEAD HORSE POINT VISITOR'S CENTER CAN BE SEEN HIGH ON THE SKYLINE TO THE NORTHWEST, downstream and to the left. Hermosa beds are exposed at river level on both east and west banks.



TEXT-FIGURE 35.—Exposures of uppermost Rico and lower Cutler beds at approximately Mile 23.1.

Mile 25.1.—Thin gray Hermosa limestone ledges exposed north and south of the prominent point bar are abundantly fossiliferous, containing several kinds of brachiopods, fusulinids, pelecypods, crinoid stems, and lacy bryozoans.

Mile 25.5.—The gray ledge zone, 20 to 30 feet above the bank, on the south (left) side is a fossiliferous marine limestone in the Hermosa Formation exposed here in the core of Shafer dome (Text-fig. 36, 37).

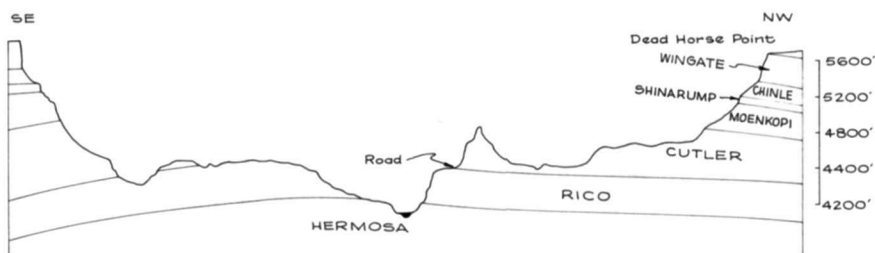
Mile 26.0.—ABANDONED OIL WELL SITE of J. H. Shafer #1 is well against the north bank on the terrace. Old rock foundations mark building sites near which can be seen two churn drill bits, a "reamer bit," and an old "bullwheel" and some well casing (1971) (Text-fig. 38). The gray rocks on the slope and in the building foundations are fossiliferous marine Hermosa Limestone coming from 30 or 40 feet above the terrace on the slope. This oil prospect was located on the low crest of Shafer dome, expressed here by beds dipping gently both upstream and downstream (Text-fig. 39).

The J. H. Shafer #1 well was drilled to a depth of 5,863 feet before it was abandoned because of poor showings of gas and oil.

Mile 26.4.—Southwestward dip on the flank of Shafer dome can be seen down-river, with thin-bedded Hermosa Limestone forming a prominent gravel-covered terrace on the side of the river. Angular jointing in massive sandstones



TEXT-FIGURE 36.—View toward the north around the crest of the Goose Neck meander, across Shafer dome. The road in the middle distance, on the left, leads from Potash around the base of Dead Horse Point and connects with the Shafer Trail and Island-in-the-Sky section of Canyonlands National Park. The LaSal Mountains form the skyline.



TEXT-FIGURE 37.—Cross-canyon profile from Dead Horse Point, through Pyramid Butte to Hatch Point. The prominent cliffs are in the upper part of the Triassic sequence and broad terraces are formed in the Cutler and Rico sections.



TEXT-FIGURE 38.—Drill bits preserved at the abandoned oil well site J. H. Shafer #1 at Mile 26. Fossiliferous marine limestone is exposed ledges in the background.

of Rico Formation shows well on the right bank where some of the blocks appear to be unstable. The road around the base of Dead Horse Point is on the gray terrace 400 feet above the river to the north (Text-fig. 36). The prominent point on the northwest is the point from which a local guide fell to his death in 1967.

Mile 27.—The low gravel-covered terrace, 10 to 15 feet above water level, is on a persistent fossiliferous limestone. It is the same unit exposed above the oil well site near Mile 26 and marks the top of the Hermosa Limestone. The intricate erosional features downstream to the southwest are in the core of the Goose Neck (Text-fig. 40). The limestone unit high to the northwest is the same limestone that forms the broad, gray slope near the White Rim and that caps the high west rim of Shafer Flats area on the Kane Creek anticline.

Mile 27.5—Gravel terraces on the pointbar on the north side. Narrows of the

Goose Neck are directly downstream. Top of the Hermosa Limestone plunges below river level on the southwest flank of Shafer dome.

Mile 28.—DEAD HORSE POINT AND THE VISITOR'S CENTER CAN BE SEEN ON THE SKYLINE TO THE NORTH (Text-fig. 40). Kayenta Sandstone caps the prominent Wingate Sandstone cliff. The gray, gray-green, and reddish slope below the cliff is in the Chinle Formation above the reddish brown Moenkopi Formation. The castellate surface in the intermediate zone is eroded in the Cutler sequence. The thin White Rim Sandstone can be seen separating the upper and lower part of the Cutler Formation. Downstream to the north the rocks start to dip up onto the same small anticlinal structure that was seen near the abandoned oil well site at Mile 26. The deep maroon rocks close to the river at the top of the meander around Goose Neck (Text-figs. 40, 41) are Hermosa Formation. The Rico sequence here is reddish brown and a more evenly bedded sequence than to the north near Potash.

Mile 28.5.—SHAFLER CANYON comes in from the northwest. Rico rocks at river level show the pronounced joint system typical of the uplift zone. The White Rim Sandstone is well exposed up Shafer Canyon as the light-colored top of the lower shelf. Dead Horse Point visible upstream (Text-fig. 42).

Mile 29.1.—The river continues in Rico rocks with Cutler beds above. A shelf of fossiliferous Rico Limestone is well expressed midway up the inner gorge with White Rim Sandstone forming the upper unit of the inner gorge (Text-fig. 43). The Rico Limestone is well exposed on the east side of the canyon in the core of the Goose Neck. The high point directly downstream to the southeast is Hatch Point, held up by Kayenta and Wingate sandstones.

Mile 29.5.—South of Shafer Canyon thin lenses of white sandstone can be



TEXT-FIGURE 39.—View downstream, northwestward, from approximately Mile 28 towards Dead Horse Point State Park. The covered overlook is on the skyline in the center (arrow).



TEXT-FIGURE 40.—Vertical aerial photograph of the Colorado River from approximately Mile 26 to Mile 32, around the Goose Neck. Dead Horse Point State Park includes the high country at the lower left.



TEXT-FIGURE 41.—View toward the south from near Dead Horse Point looking across the river to the Goose Neck carved in Hermosa, Rico, and Cutler beds. The prominent White Rim Sandstone shows a light-colored scarp in the right middle distance.

seen beneath the gray limestone on the east side of the canyon. Rico and Cutler beds are exposed beneath Triassic beds in Hatch Point on the skyline.

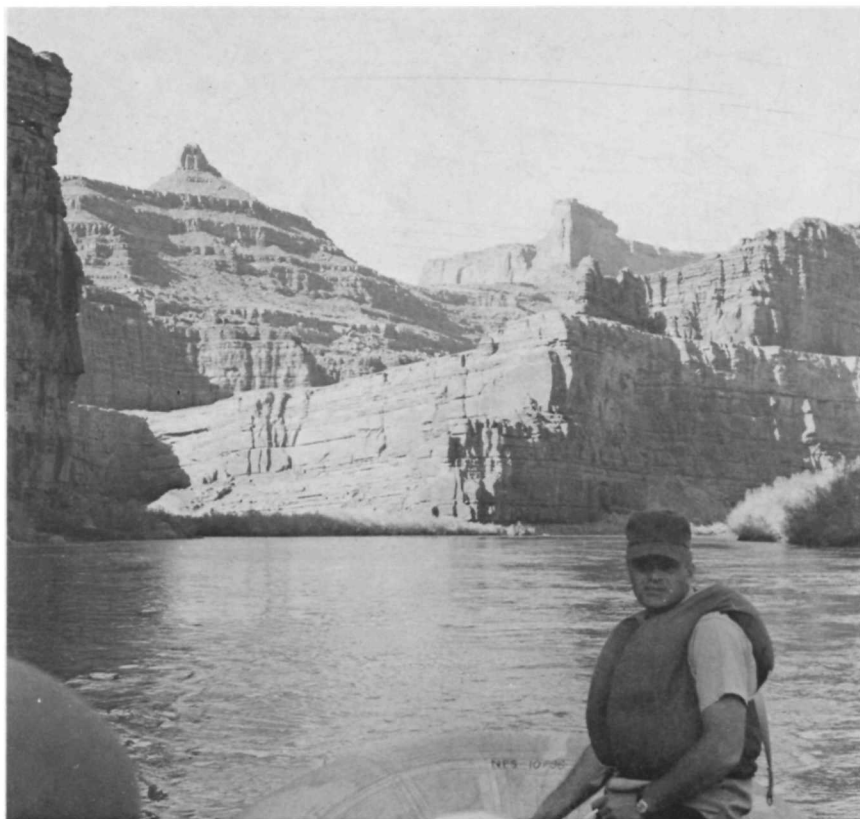
Mile 31.3.—Small, narrow, meandering Little Bridge Canyon from the west forms broad alluvial fans and somewhat constricts the river.

Mile 32.—High silt band of pointbar with thick tamarix growth along river margin. The river continues through southward dipping Rico beds. The prominent limestone that forms the gray ledge upstream is not as well developed here on the east side, but on the west side it still forms a prominent break, capped by a gravel terrace.

Mile 32.3.—CROSS THE BOUNDARY INTO CANYONLANDS NATIONAL PARK (1971). Collecting by special permit only.

Mile 33.—The fossiliferous Rico Limestone forms a terrace near river level on the west side but is well above river level on the east, showing a significant dip toward the west.

Mile 33.5.—Small canyon entering from the west. In this general area gray



TEXT-FIGURE 42.—View upstream from Mile 29 towards Dead Horse Point on the skyline. Rico rocks are exposed at river level.

Rico Limestone now contains considerable nodular white and pink chert. A limestone occurs as an almost continuous ledge along the west side of the river at water level (Text-fig. 44).

Mile 34.—Fossiliferous Rico Limestone is exposed on both the east and the west sides of the river and holds up a typical terrace covered with gravel. The red Cutler beds are well exposed above, forming the inner narrow gorge.

Mile 24.6.—Canyon enters from the west. White Rim Sandstone forms the tumbled, angular, white blocks on the skyline, beneath the castellate Cutler beds.

Mile 35.5.—Rico beds are exposed low on both sides of the canyon, with a resistant shelf of limestone capped by gravel terrace. Directly ahead on the skyline to the south is the west end of South Hatch Point.

Mile 37.—Lockhart Canyon enters from the east from Lockhart Basin.

Mile 37.3.—HORSETHIEF CANYON enters from the southeast.



TEXT-FIGURE 43.—Vertical aerial photograph of the Colorado River covering the area from Mile 32 to Mile 41.

Mile 38.—The westward dip of the Cutler beds shows as the fossiliferous limestone sequence dips downstream.

Mile 38.5.—The limestone, 14 to 30 feet above river level on the north side, is at the top of the Rico Formation and is the same limestone bed that is exposed at Mile 33.5. This is one of the most prominent limestones of the area.

Mile 40.—The fossiliferous uppermost Rico limestone beds are exposed at river level both north and south on the bend. They dip beneath the river to the west. On the skyline, directly downstream from the bend, is Grand River Point or Island-in-the-Sky, the major viewpoint of Canyonlands National Park. Hills on the skyline of Grand View Point are in the Navajo Sandstone, with the gentle upper surface in Kayenta beds and the underlying angular vertical cliff in Wingate Sandstone.

Mile 40.9.—LATHRUP CANYON (Text-fig. 45). This is one of the large meandering tributary canyons that drain into the Colorado River from the west. A jeep road has been constructed down the canyon to the river from the west-



TEXT-FIGURE 44.—View downstream from approximately Mile 32 showing the vertical-walled inner gorge in Rico beds with the Hermosa Limestone forming a gray lower terrace which rises to the south.



TEXT-FIGURE 45.—Lathrup Canyon at Mile 40.9, with an abandoned meander near the mouth. A jeep road down Lathrup Canyon provides the only vehicle access route to the river between Potash and Hite. Light-colored beds are interfingering units of Cedar Mesa Sandstone from the south intertonguing with the maroon Cutler beds from the north. White Rim Sandstone forms the prominent escarpment near the top of the photograph.

ern rim road. Cutler beds are at river level; the White Rim Sandstone caps the cliffs ahead.

Mile 41.9.—Small Buck Canyon coming in from the west (Text-fig. 46). The rocks in the walls of the inner gorge are typical red Cutler Sandstone. As the rocks now dip gently to the north, Rico Limestone appears above river level above the small canyon. Prominent silty pointbar on the west is deposited against the fossiliferous limestone ledges.

Mile 43.—The marine upper Rico Limestone forms gray terraces on the margin of the canyon wall below the red Cutler beds. Upstream, to the north, Triassic Wingate Sandstones can be seen forming the high promontory in the Island-in-the-Sky section of Canyonlands National Park.



TEXT-FIGURE 46.—Vertical aerial photograph of the Colorado River covering between Mile 38 and Mile 47. Intricate badland topography is carved in Rico and Cutler beds. Prominent light sandstone units of the intertonguing Cedar Mesa Sandstone are shown interbedded with the darker reddish Cutler beds.

Mile 43.5.—Small tower of Rico beds capped by gray marine limestone can be seen on the east shore. A small Anasazi Indian granary can be seen from the river in the area above the sandstones and below the light-colored marine beds on the column.

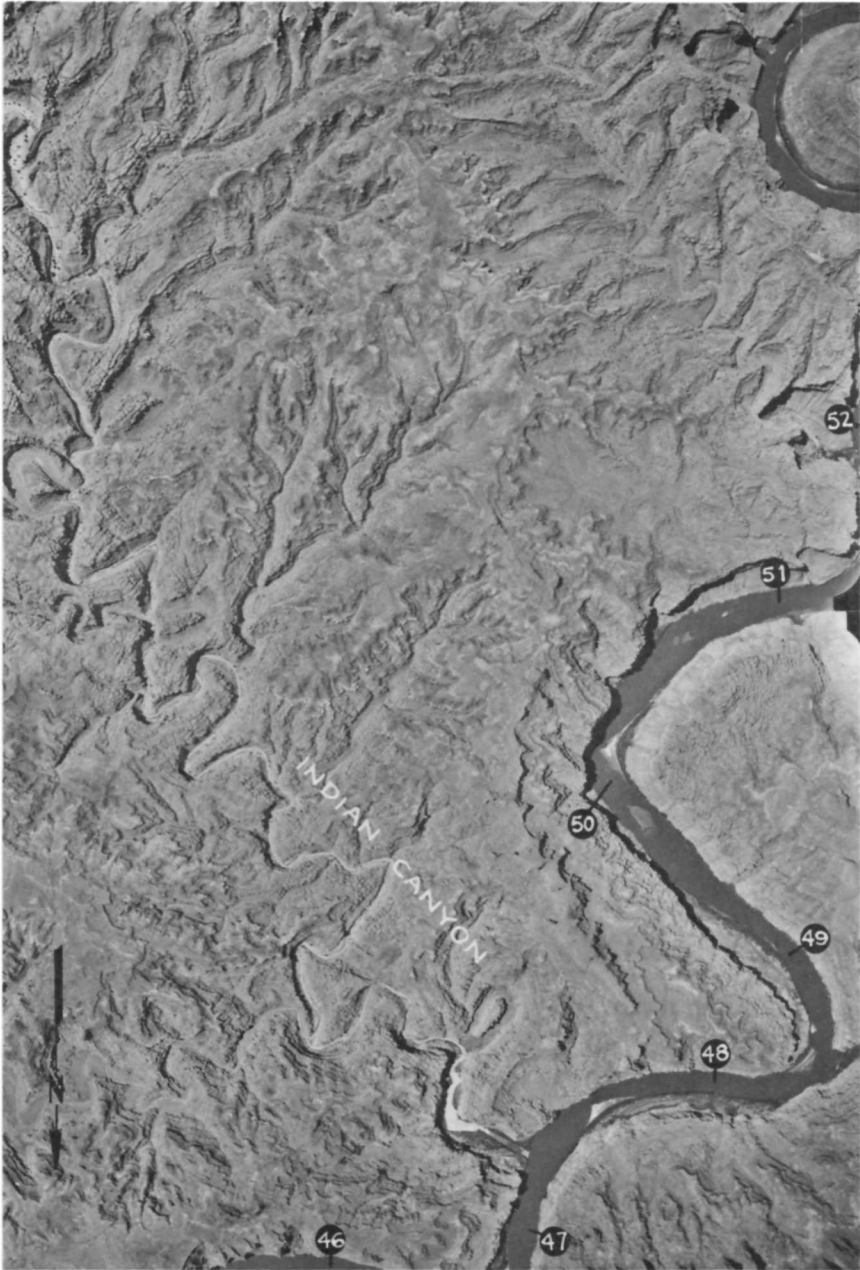
Mile 45.5.—Prominent, thin, white unit in the middle part of the Rico beds in the river band cliff is sodium carbonate and gypsum deposited by groundwater on the surface of one of the porous sandstones (Text-fig 47). Sheep Bottom is the pointbar in the center of the bend on the northwest side of the canyon.

Mile 46.7.—White Rim Sandstone forms the high promontory of the White Rim on the west side, visible above the sharp bend in the river.

Mile 47.3.—INDIAN CREEK joins the Colorado River from the east (Text-fig. 48). Several small granaries (Text-fig. 49) can be visited along the north wall of Indian Canyon by a short hike of approximately one-fourth mile into Indian Creek Canyon. Today (April 20, 1969) Indian Creek is flowing and is bright red where it joins the Colorado River. The upper surface of natural levees of Indian Creek by the Colorado are here blanketed by adobe of thin mud flows (Text-fig. 50). The crest of natural levees of Indian Creek are now 12 to 15 feet above water level and would make an excellent place to camp, for there are extensive clumps of dry willows and plenty of places for sleeping bags. Upstream to the north, from the mouth of Indian Canyon, the White Rim Sandstone shows boldly on the skyline, particularly on the west side of the canyon. Rico beds are at river level below the red Cutler rocks. The five small granaries are made of mixed dry wall and mortared construction and



TEXT-FIGURE 47.—View of the canyon wall upstream at approximately Mile 45.5. The prominent white unit is in middle Rico beds and is a sodium carbonate and gypsum unit, minerals deposited at the surface by groundwater percolating through one of the porous sandstones.



TEXT-FIGURE 48.—Vertical aerial photograph of the Colorado River covering the area between Mile 47 and Mile 51. There are several small abandoned meanders along Indian Creek. Much of the flat floor of Indian Creek apparently was cultivated by early Indian inhabitants.

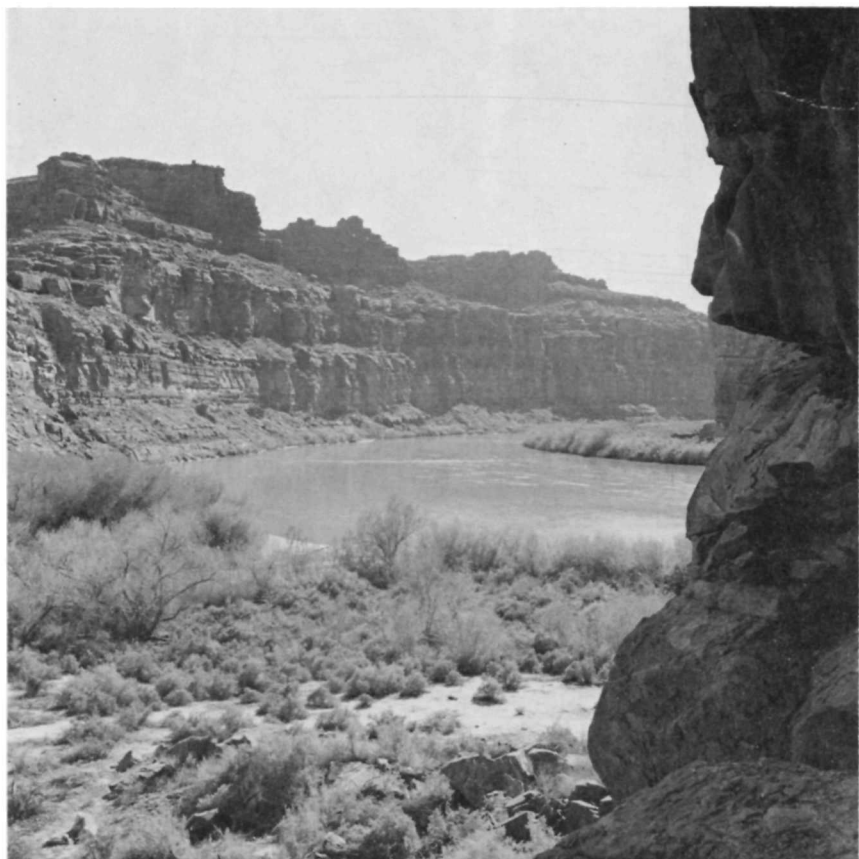


TEXT-FIGURE 49.—Dry-wall construction of Indian ruins along the north wall of Indian Creek at approximately Mile 47.3.

appear to be Anasazi Pueblo II, with a possible date of from A.D. 900 to 1000. Many of the broader alluvial flats must have been occupied by Indians during this particular period although in general there are few ruins in the canyon compared to areas to the southeast.

Mile 48.5.—Cutler rocks are exposed on both sides of the canyon. The tributary canyon straight ahead, which comes in from the west on the undercut side of the bend, drains Standing Rock Basin. Three small granaries and a very unstable arch can be seen on ledges on the south abutment of the mouth of the canyon to Standing Rock Basin. Gravel terraces occur well above river level on the point-bar on the east side of the river.

Mile 51.—Excellent exposures of fossiliferous Hermosa Limestone on both the north and the south side of the canyon occur in low gray-green ledges close to the river below the reddish Rico and Cutler beds in Meander anticline. In this general area the sandy rocks in the higher part of the Cutler Formation are grading into lighter gray units. These zones are "fingers"



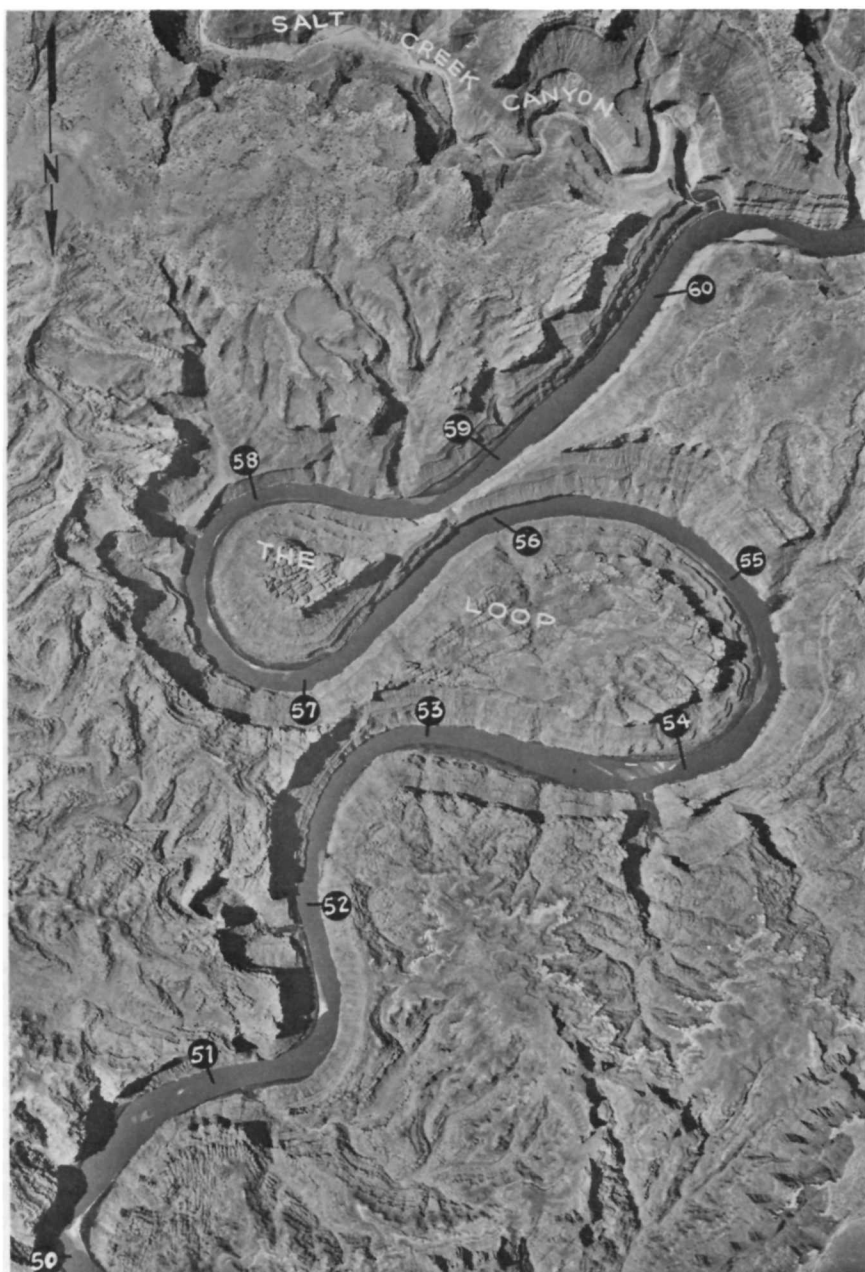
TEXT-FIGURE 50.—View downstream across the adobe flats of Indian Creek toward the Colorado River showing the pronounced plant zonation along the margin of the river and tributary.

The large shrub in the left foreground is peachleaf willow. Tamarix occurs along the river margin with greasewood somewhat removed from the bank.

of the light Cedar Mesa Sandstone of the southern part of Canyonlands National Park, interfingering with the Cutler red beds to the north (Text-fig. 51).

Mile 52.—Hermosa Limestone crops out along the river below Rico and Cutler beds. Upstream on the high canyon walls the White Rim Sandstone forms the highest escarpment of the inner gorge that is visible from here. Rocks on both banks dip relatively steeply away from the river and define Meander anticline whose axis follows the course of the river.

Mile 52.8.—THE RIVER HERE SWINGS WESTWARD AROUND THE FIRST MEANDER OF THE LOOP (Text-figs. 51, 52) away from the northeast-southwest trending axis of the anticline. The fold shows very well in the southeast wall of the canyon in the tilted Hermosa Limestone. The



TEXT-FIGURE 51.—Vertical aerial photograph of the Colorado River covering from approximately Mile 50 to Mile 61 near The Loop. White tongues of Cedar Mesa Sandstone show as the very sinuous light-colored bands in the lower part of the photograph. Meander anticline diagonals, across the narrow necks of the two meanders.



TEXT-FIGURE 52.—View downstream from near Mile 52 showing the intricate pattern of The Loop meanders. The river in the background is at Mile 59. Light massive sandstones at the top are Cedar Mesa beds above darker ledges of Rico rocks in the intermediate walls of the canyon. Massive Hermosa Limestone shows in the core of the anticline at the bends of the river. The axis of the Meander anticline diagonals across the three visible sections of the river.

narrow neck of the meander marks the axis of the anticline. The neck across the first loop is less than half a mile across although the river flows approximately 4 miles around the meander. One can climb over the crest of the neck from the north and down to near Mile 57. The axis of Meander anticline is parallel to the main graben in the Needle Section of the Canyonlands National Park, 10 miles to the southeast.

Mile 53.8.—Narrow tributary canyon coming in from the north. Slopes both on the north and south are accessible for examining fossiliferous Hermosa beds exposed 80 to 90 feet above the river.

Mile 54.8.—Small reentrant on the west at the crest of the bow around the first meander of The Loop. Fossiliferous Hermosa Limestone is exposed in the accessible bluff. The canyon crest is in the cliff-forming Cutler beds on both sides of the river. Downstream, the northwestward dipping limb of Meander anticline can be seen in the upper part of The Loop. The dip is expressed as the Hermosa Limestone rises above the river downstream.

Mile 55.2.—Hermosa beds on the northwest flank of the anticline form nearly vertical walls and a narrow gorge with upper shaly zones in the upper part of the formation, below the more reddish Rico beds, which form the lower

cliffs. The canyon rim is in interfingering Cutler red beds and light gray Cedar Mesa Sandstone.

Mile 56.—To the south is the narrow neck across the second meander of The Loop. Shaly beds of the Hermosa Formation form a broad saddle. Here the meander neck is less than one-fourth mile across.

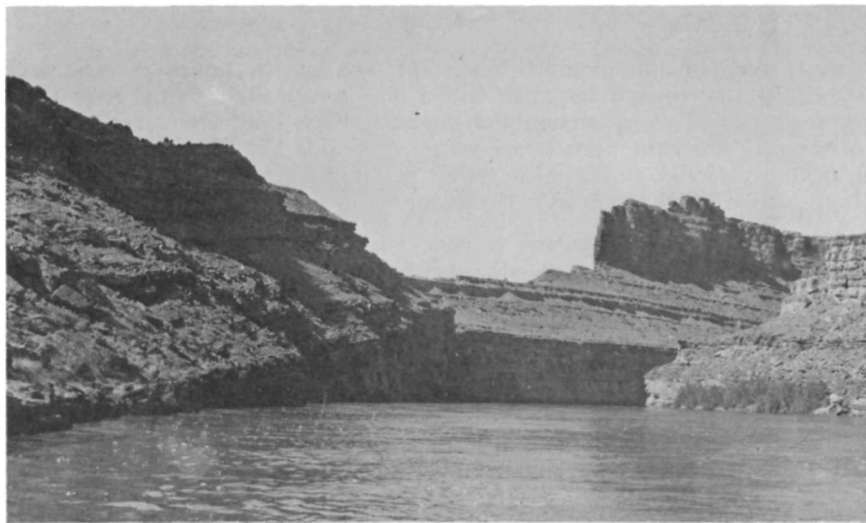
Mile 55.8.—Cross the axis of the Meander anticline (Text-fig. 53).

Mile 56.2.—A broad slope zone along the narrow neck of the second part of The Loop to the south is related to minor flexing and minor faulting along the flank of the Meander anticline. Between Mile 56 and 57 the anticlinal axis diagonals across the river, with the Rico and Hermosa rocks dipping outward both to the northwest and southeast away from the axis. The axis trends across the narrow necks of the meander bends and along the reaches north and south of the Loop.

Mile 56.9.—Minor crumpling resulting from slumping contemporaneous with deposition can be seen in Hermosa beds near river level on the outside of the bend on the north wall.

Mile 57.4.—Minor slumping and "flame" structures in cross-bedded sandstone on the eastern outside bend of the loop just above river level. Most of the angular, thin, gray ledges above are fossiliferous limestone. Alternating interbedded light gray and red cross-bedded sandstone shows well in canyon walls for the next several miles resulting from interfingering of the reddish Cutler and the light gray Cedar Mesa rocks.

Mile 58.—Hanging gardens can be seen around the outside bend of the loop to the southeast, up some of the tributary valleys. These small spots of greenery



TEXT-FIGURE 53.—Massive Hermosa Limestone is exposed in the core of the Meander anticline in The Loop at approximately Mile 56.

contain cave primrose, ferns, columbine, and heleborine orchid. A thick, prominent terrace directly ahead is held up by one of the typical marine limestones.

Mile 58.3.—One may stop on the south bank and hike back into one of the large alcoves to visit an accessible hanging garden. The alcove is carved in a sequence of "flame"-bedded to thick-bedded Rico Sandstone. Fossiliferous Hermosa Limestone is exposed near river level in the lower part of the sandy section. This is a good place to camp with sandbars and rocky shelves readily accessible. Fossil ripple-marked, thin, marine beds and fossiliferous limestone are well exposed at river level.

Mile 58.8.—The sharp fin on the right separates the upper and lower part of the second loop. In this general vicinity, the Hermosa rocks near river level are broken by fractures in the core of the Meander anticline.

Mile 59.5.—Hermosa and Rico beds in the Meander anticline show lateral dips away from the axis of the fold which is generally along the river. Hermosa beds form the lower three cliffs below the slope zone of red Rico beds above.

Mile 60.5.—SALT CREEK CANYON COMES IN FROM THE SOUTH-EAST and is one of the major drainages of the Squaw Flat area of Canyonlands National Park. Each of the resistant units in the lower part of the canyon wall is a fossiliferous limestone. These contains a variety of productid and spiriferoid brachiopods with *Composita*, *Hustedia*, *Linoproductus*, *Spirifer*, *Neospirifer*, and *Dictyoclostus* and lacy and twiggy bryozoans. Some fusulinids and abundant crinoid stems are also present (Text-figs. 54, 55).

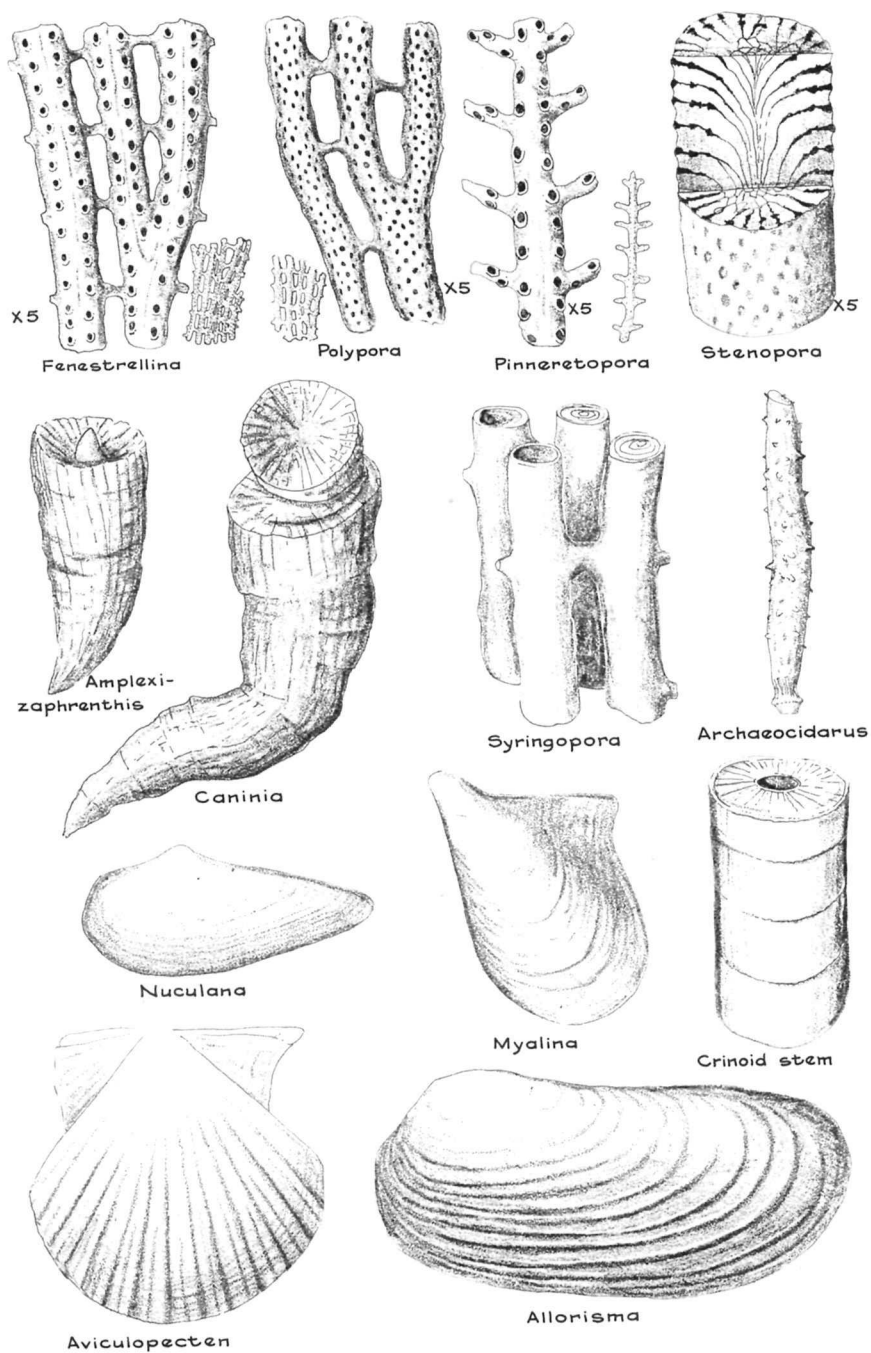
Mile 60.9.—ELEPHANT CANYON ENTERS AS SMALL TRIBUTARY ON THE SOUTH BANK. The natural levees are high here and some are typical of the development at the mouths of some of the longer stream channels. Small Indian granaries can be seen 60 to 70 feet above river level in the overhang of the sandstone, below the terrace on the south side of the mouth of the canyon.

Mile 62.—Excellent exposures here of the Meander anticline are in the limey Hermosa beds on both sides of the canyon.

Mile 62.4.—THE SLIDE constricts the river and was caused by collapse and slumping of the badly brecciated north wall of the canyon. Brecciation is common in the axial zone along the Meander anticline. Fossiliferous Hermosa and Rico beds are exposed in the Slide area. Fast water is produced by the narrowing of the channel (Text-fig. 54).

Mile 63.—First view of the Green River, Colorado River junction. Meander anticline shows very well in Hermosa beds which dip away from the axis of the stream (Text-fig. 53).

Mile 64.—CONFLUENCE OF THE GREEN AND COLORADO RIVERS (Text-figs. 56, 58). Downstream massive sandstone along the rim is the Cedar Mesa Sandstone above the red Rico beds. Rico beds are the reddish cliffs above the lower slope zone in the upper part of the Hermosa Formation. Upstream the marked upflexing of the Hermosa beds in the immediate vicinity of the river, suggest upwarping due to removal of overburden as the canyon was cut. Some of the apparent tilting on the Meander anticline may be due to Salt flowage of Paradox beds into zone of low overburden along the canyon bottom. In



TEXT-FIGURE 54.—Bryozoans, corals, and pelecypods common in the Rico and Formosa formations.



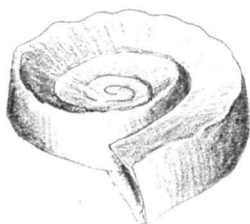
Euphemites



Pharkidonotus



Bellerophon



Amphiscapha



Punctospirifer



Chonetina



Derbyia



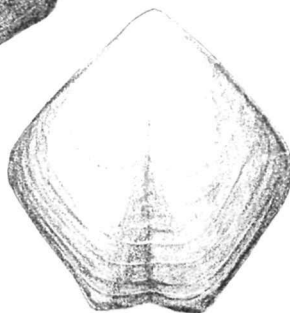
Mesolobus



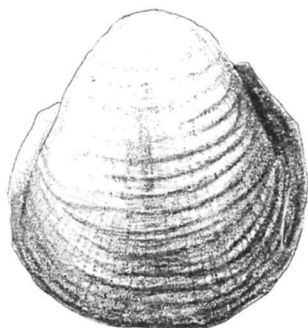
Dictyoclostus



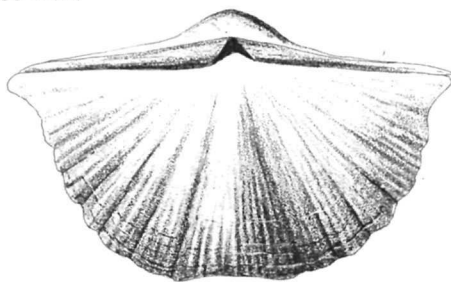
Hustedia



Composita

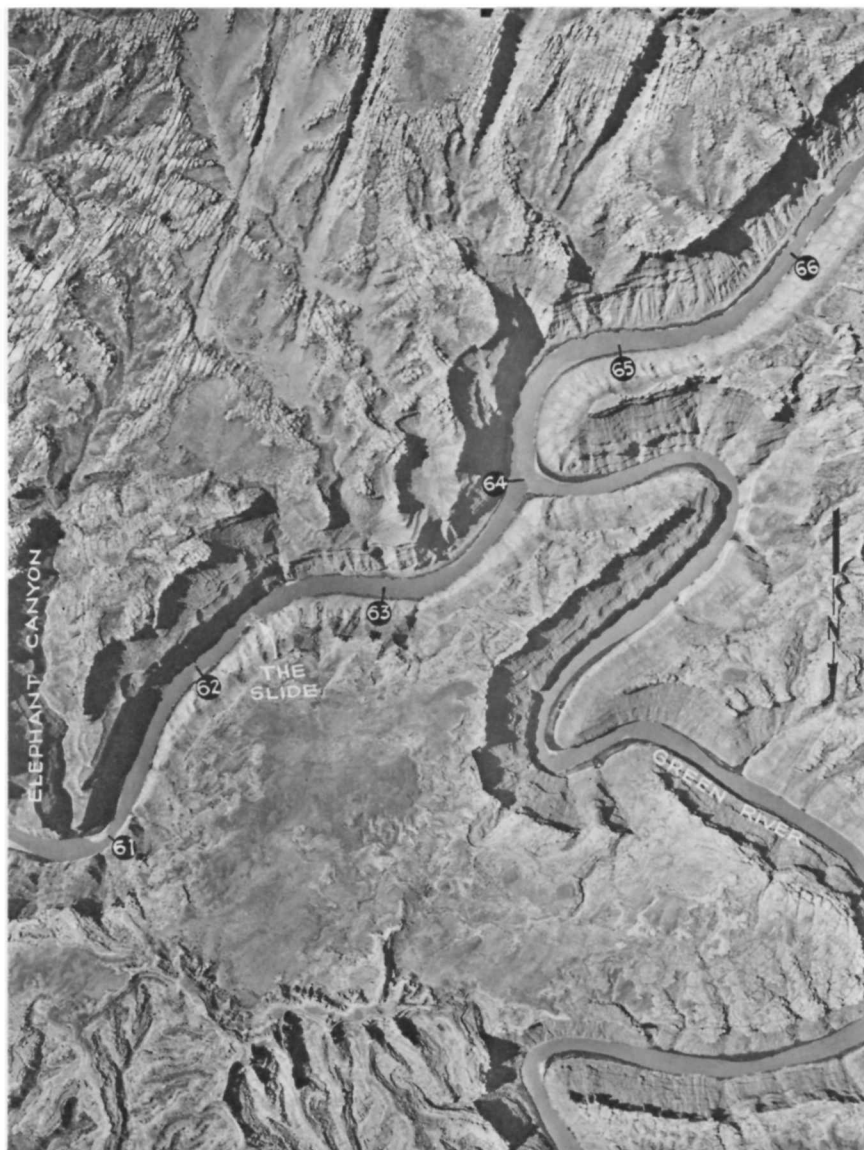


Echinoconchus



Neospirifer

TEXT-FIGURE 55.—Brachiopods and gastropods locally common in the Hermosa and Rico formations.



TEXT-FIGURE 56.—Vertical aerial photograph covering the area between Mile 61 and Mile 66 at the confluence of the Green and Colorado rivers. Jointed light-colored rocks at the rim are Cedar Mesa Sandstone which shows the graben structure of the Needles Section of Canyonlands National Park at the upper margin. Muddy water of the Green River mingles with less muddy water of the Colorado River at the confluence. The Slide is a slump mass from the margin of the gorge. It causes some fast water above the confluence.

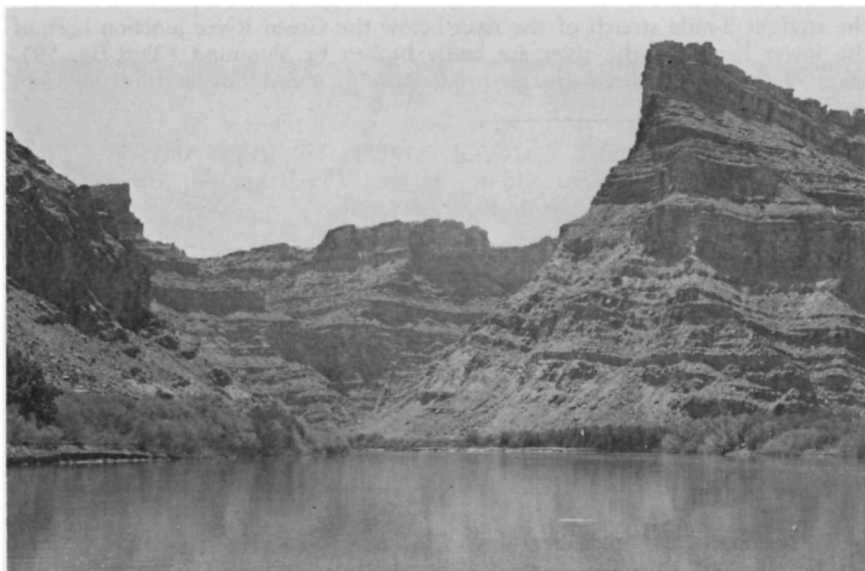
the straight 2-mile stretch of the river below the Green River junction both of the lower banks of the river are badly broken by slumping (Text-fig. 59). Some of this may be breakage due to salt heaving and minor landslide development.

Mile 67.1 (505.5).—THE CANYON OPENS UP INTO SPANISH BOTTOM, a broad valley ahead and to the west (Text-figs. 60, 61). Miles in parentheses are miles below Green River, Wyoming.

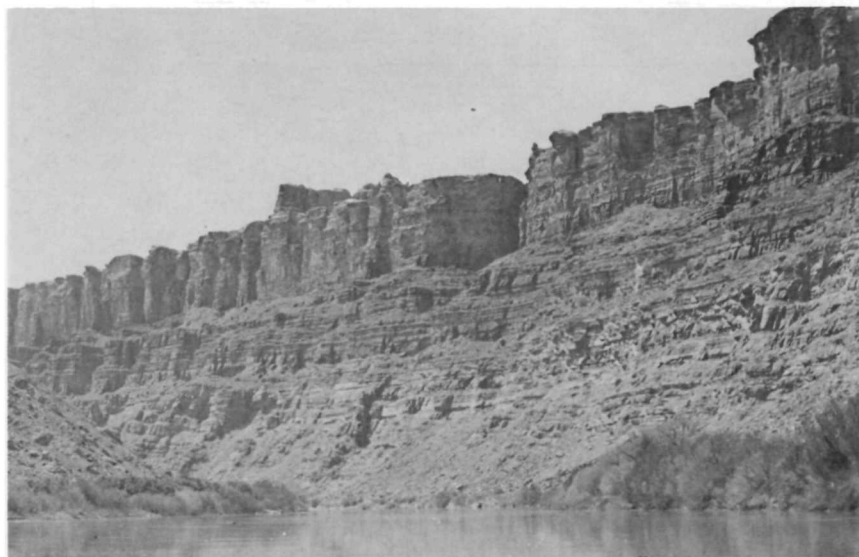
Mile 67.3 (505.7).—Gray Paradox Formation is exposed as a gypsiferous plug on the immediate east side, north of the mouth of Lower Red Lake Canyon (Text-fig. 62).



TEXT-FIGURE 57.—Oblique view down the Colorado River from approximately Mile 63 toward the confluence of the Green and the Colorado rivers. Note the muddy water of the Green River entering from the right. Cedar Mesa Sandstone forms the prominent light-colored upland along both drainages. A trail out of the river gorge leads up from near the junction around the shoulders of the small canyon in the lower left. Spanish Bottom is at the major bend where the river disappears in the middle distance.



TEXT-FIGURE 58.—View downstream near the confluence of the Green and Colorado rivers. The prominent fin on the skyline to the right separates the Green and Colorado gorges.



TEXT-FIGURE 59.—Canyon wall at approximately Mile 65.5. Massive Cedar Mesa Sandstone forms the upper cliff with reddish gray Rico beds overlying the lighter colored greenish-gray Hermosa rocks near river level.



TEXT-FIGURE 60.—Vertical aerial photograph of the Colorado River covering the area from approximately Mile 66 to Mile 71 in the upper part of Cataract Canyon. Prominent exposures near the mouth of Lower Red Lake Canyon in Spanish Bottom are of a gypsum plug of Paradox beds. Prominent jointing and faulting in The Needles Section of Canyonlands National Park shows in the upper left, as the long linear graben in broken Cedar Mesa Sandstone.

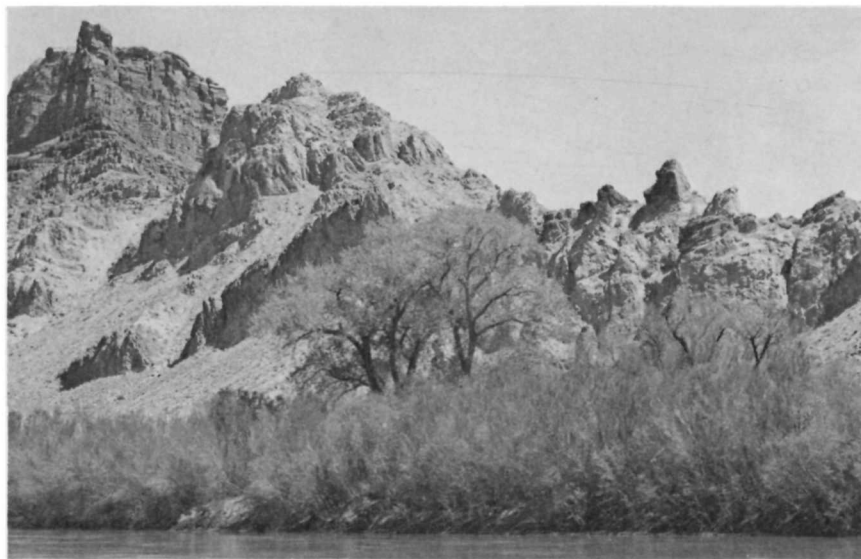


TEXT-FIGURE 61.—View southeast across Spanish Bottom to the mouth of Lower Red Lake Canyon. Dark exposures above the plant fringe on the point bar are gypsiferous Paradox beds.

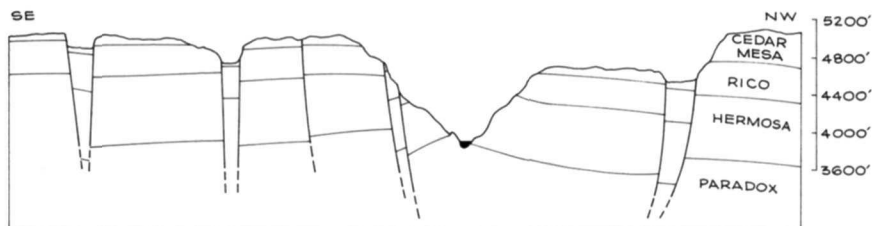
Mile 67.6 (506).—The point bar at the mouth of lower Red Lake Canyon is typical of bar formation along the river. A ridge and swale sequence begins at the river margin and extends eastward to the clay flat at the base of the canyon slope and presents a sequence of vegetation which reflects the changes in the environment backwards from the river.

Mile 68.6 (507).—**BROWN BETTY RAPIDS (4) AT THE HEAD OF CATARACT CANYON** followed by two other rapids (3, 2), 10-foot drop. All three of these rapids are caused by debris falls from both sides of the canyon. Hermosa rocks have been faulted down to the river as slump blocks. In some instances the rocks have moved 400 or 500 feet. Black, bedded limestone and dolomite can be seen displaced in both canyon walls. Minor rapids continue with total of 20-foot drop.

Mile 69.8 (508.2).—A prominent linear tributary enters from Surprise Valley on the north. The straight, long, western edge of Surprise Valley and the tributary are probably controlled by the same fault (Text-fig. 63). The low



TEXT-FIGURE 62.—Heavily vegetated margin of the point bar north of the mouth of Lower Red Lake Canyon towards gypsiferous Paradox beds in the distance. Tamarix occurs in the foreground, in front of a large Fremont poplar in the center.



TEXT-FIGURE 63.—Cross-canyon profile showing the relationship of stratigraphic units and the long, narrow, graben trenches to linear valleys like those seen in Text-figure 60.



TEXT-FIGURE 64.—Vertical aerial photograph of the Colorado River from approximately Mile 71 to Mile 75. Small debris fans at the mouths of the several steep tributaries produce minor rapids. The broken hummocky upper surface on the upper edge of the canyon is produced by complex faulting.

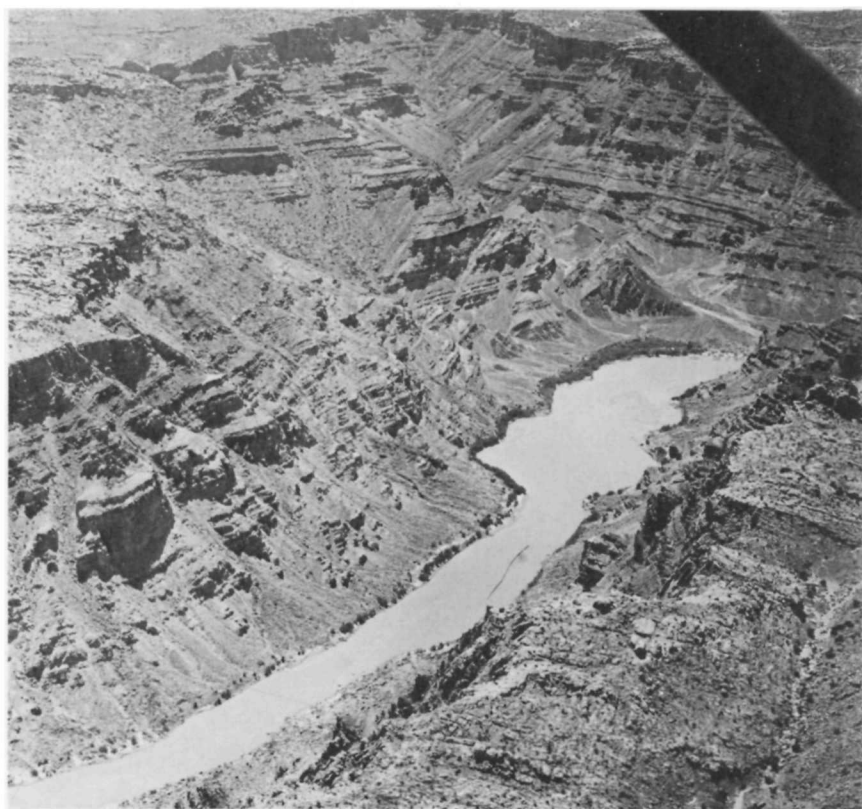
rapids at 69.8 (508.2) is produced by debris from the tributary and banked against massive landslide material which has moved down both sides of the main canyon.

Mile 71.1 (509.5).—Gypsiferous Paradox beds are exposed near river level on the east bank below strongly jointed Hermosa rocks.

Mile 71.6 (510).—Several small rapids (3 to 6) here are produced by landslide and slump masses of Rico and Hermosa beds. Toes of the masses are spectacularly truncated by river erosion.

Mile 71.9 (510.3).—Y CANYON (TILTED RAPID - 1, 2) enters from the southeast (Text-fig. 64). Paradox beds are well exposed in the small conical hill to the south, at the mouth of Cross Canyon. Paradox beds are also well exposed in unfaulted relation with the overlying Hermosa beds up Cross Canyon beyond the conical hill.

Mile 72.0 (510.4).—CROSS CANYON ENTERS FROM THE SOUTHEAST



TEXT-FIGURE 65.—Oblique view downstream to approximately Mile 73 where exposures of Paradox beds occur near the mouth of a small unnamed canyon near a major bend of the river. Upland is in the Cedar Mesa Sandstone.



TEXT-FIGURE 66.—Vertical aerial photograph of the Colorado River covering the region from approximately Mile 75 to Mile 81 in Cataract Canyon. The frequent rapids in this section are produced predominantly by slumps of canyon wall instead of debris fans at the mouths of the small canyon.

and unites with Y Canyon to produce a broad alluvial fan and minor ripples on the river. Paradox beds are exposed on both sides of Cross Canyon.

Mile 73.0 (512.0).—Minor Paige Canyon from the south produces alluvial fan and a minor rapid (2) with a 3-foot drop. This is a good place to camp. Paradox Formation is exposed in the light gray hills east of the canyon mouth but is badly faulted (Text-fig. 65).

Mile 75.1 (513.5).—Broad apron of alluvial debris reaches high up the canyon wall to the north, blanketing the less intensely broken beds of limestone.

Mile 75.4 (513.8).—Minor canyon from the north drains The Fins section of Ernies County in Canyonlands National Park.

Mile 75.6 (514.0).—BEGIN MILE LONG RAPIDS (5 to 8) NEAR THE MOUTH OF RANGE CANYON (Text-figs. 66, 67). The rapids are more or less continuous from Mile 75.6 on downstream some distance with a total drop of 30 feet. They are mainly produced by landslide masses. Faulted Her-



TEXT-FIGURE 67.—View downstream to the mouth of Range Canyon. The numerous rapids are almost uniformly produced by debris slumps in from the canyon margin. The upper rim of the canyon is in massive Cedar Mesa Sandstone.

mosa beds are at river level with thin Rico and thick Cedar Mesa beds above to the canyon rim.

Mile 76.0—CAPSIZE RAPIDS (9).

*Mile 77.6 (516.0).—*Small islands in the center, keep to the right against the northwest wall. Rico beds are at river level. Rapids (5).

*Mile 77.9 (516.3).—*Alluvial fan and debris apron with rapids (4) at the mouth of Calf or Teapot Canyon, beginning of One-Mile Rapids.

Mile 78.4 (516.8).—KOLB OR BIG DROP RAPID (9-10) (Text-fig. 68). Big Drop Rapid is the result of debris fans and aprons of talus coming from both the east and the west walls of the canyon. Tributaries apparently produce only relatively minor rapids in contrast to some of the major landslide masses which produce the most rigorous rapids. The rapid at Big Drop is produced by landslide debris moving down both the canyon walls, constricting the channel (Text-fig. 69). In this area the Hermosa Formation forms a massive wall of limestone overlain by the alternating red and green sandstone and limestones



TEXT-FIGURE 68.—Rough white water at the Big Drop Rapids at Mile 78.4. Slump debris like that in the background, from both walls of the canyon, produce the rapids.



TEXT-FIGURE 69.—View upstream from approximately Mile 78 near the mouth of Calf Canyon, at the left, to Range Canyon near the bend of the river in the distance.

of the Rico beds. The upper one quarter of the canyon wall is carved in lighter colored Cedar Mesa Sandstone.

Mile 78.6 (517.0).—End of the continuous rapids (3 - 4). The canyon here has nearly vertical walls of the massive limestone of the Hermosa Formation in the lower half of the canyon wall. Thin, well-bedded sandstone of the overlying Rico beds are overlain by massive light-colored sandstone of the Cedar Mesa rocks which extend to the skyline. The canyon now is deep and narrow with aprons of slump debris extending from the base of the cliff right to river level. This will be at headwaters of Lake Powell when it is full, at 3700 feet.

Mile 79.9 (518.3).—A suitable campground is on sandbars above one major bend in the river. Paradox beds are exposed above the sandbar to the east.

Mile 80.4 (518.8).—Alluvial fan to the south is produced by the stream which drains Imperial Valley. The fan constricts the narrow channel and produces a minor rapid (2 - 4). Faulting in the Hermosa beds is well exposed with down-to-the river movement. Paradox beds are exposed at river level on the south and east in normal contact relations with the Hermosa beds above. There may



TEXT-FIGURE 70.—Vertical aerial photograph of the Colorado River covering from approximately Mile 83 to Mile 87. The large slump mass opposite the mouth of Gypsum Canyon shows as a low hill and produces the rapids at the mouth of the canyon. This area will be the approximate upper end of Lake Powell when the lake is full and at an elevation of approximately 3700 feet.

be removal of underlying Paradox salt by solution which results in continuous slumping.

Mile 81.6 to 83.6 (520 to 522).—Almost continuous rapids (2 - 3, 1971), result from large landslide masses and slumps of Rico and Hermosa debris moving down into the canyon. The confined river has fast rough water (Text-fig. 70). Slumping is particularly evident on the east side where the badly broken Hermosa and overlying beds form breccia pinnacles and spires. More or less continuous rapids (2 - 3) extend downstream for some distance, particularly by Waterhole Canyon (6) at Mile 82.2 (520.0), where alluvial fan debris has swept out to narrow the channel (Text-fig. 71).

Mile 83.1 (521.5).—Excellent examples of slumping can be seen downstream on the right (west) side of the canyon upstream from Gypsum Canyon. Large



TEXT-FIGURE 71.—Downstream from approximately Mile 80.5 past the mouth of Waterhole Canyon. The rather characteristic profile of the lower part of Cataract Canyon shows with an upper, massive, light gray Cedar Mesa Sandstone, an intermediate terrace and cliff zone on the Rico beds, and the lower, massive, light colored Hermosa limestone extending to river level.



TEXT-FIGURE 72.—View downstream at the mouth of Gypsum Canyon at approximately Mile 84.5. The massive landslide block opposite the mouth of Gypsum Canyon has moved down into the canyon floor several hundred feet below the normal position of the rock units high on the west canyon wall.

blocks of Hermosa Formation have moved down several hundred feet to river level (Text-fig. 72). These blocks contain intact an almost complete sequence of Rico and Cedar Mesa beds. Pinnacles and spires across from the sandbar upstream from Gypsum Canyon are in the Cedar Mesa and Rico beds above the greenish Hermosa and Paradox rocks. Paradox beds are exposed on the east side of the canyon, and on the walls of Gypsum Canyon one can see massive crystalline gypsum.

Mile 84.4 (522.8).—GYPSUM RAPIDS (7), 10-foot drop. Mouth of Gypsum Canyon to the east. Gypsiferous Paradox beds are particularly well exposed on the south side of the mouth of Gypsum Canyon beneath the thick, dark gray limestones of the Hermosa Formation. Paradox beds in Gypsum Canyon show remarkably little distortion compared to the gypsum plugs seen at Spanish Bottoms and Y Canyon. Last of major rapids in Cataract Canyon (1971). A broad, sandy flat is present at the mouth of Gypsum Canyon. Willow, tamarix, and baccharis line the river bank (Text-fig. 73). The dry, sandy portion east of the bank is covered with species of prickly pear cactus, and the slopes eastward are covered with shrubs typical of the canyon.

Mile 85.1 (523.5).—Mouth of Palmer Canyon. A broad alluvial fan here constricts the channel to produce a minor rapid. Considerable slumping can be seen along the canyon walls where Hermosa beds have been let down over Paradox beds. Ocean Point is to the north.



TEXT-FIGURE 73.—View northeast through tamarix woods along the bar at the mouth of Gypsum Canyon towards cliffs in Cedar Mesa Sandstone along the skyline.

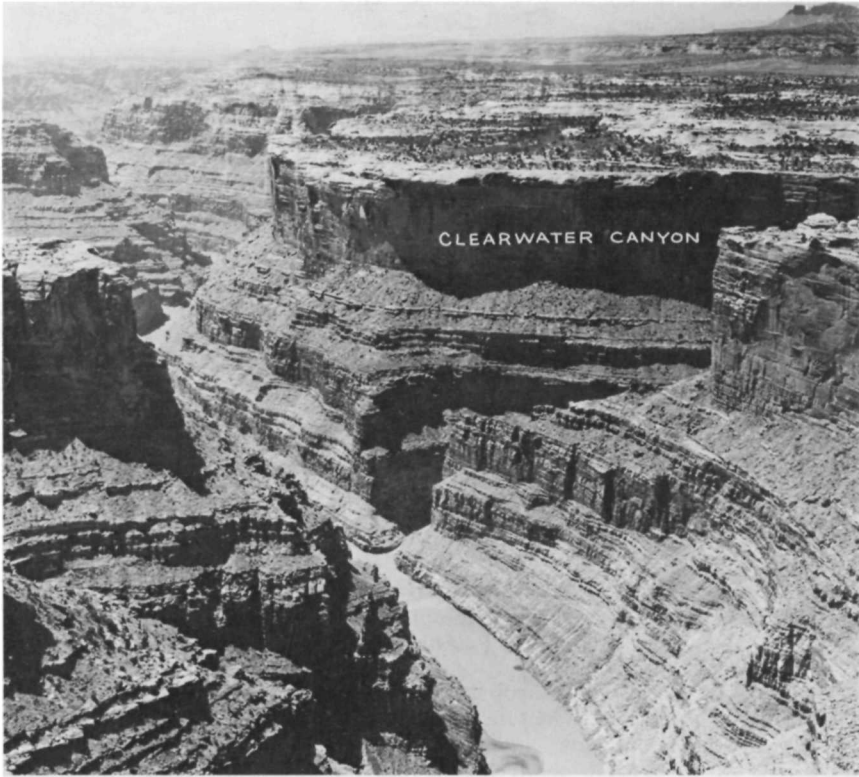
Mile 86.1 (524.5).—Paradox beds disappear below river level. Near Palmer Canyon the lower massive limestones of the Hermosa Formation form the narrow gorge at river level. Red sandstones of the Rico Formation form the middle part of the canyon wall and are capped by massive, white-weathering Cedar Mesa Sandstone.

Mile 87.1 (525.5).—Basal beds of the Hermosa Formation are laminated dark limestones and dolomites. These beds are particularly well exposed on the north wall near the mouth of the small canyons opposite Bowdie Point. Limestones near river level are abundantly fossiliferous. Large coral colonies are particularly well exposed on the lowest ledges on the south side of the alluvial fan built by the tributary.

Mile 88.6 (527.0).—MOUTH CLEARWATER CANYON. GOOD DRINKING WATER (Text-figs. 74, 75). The canyon here is about 2,000 feet deep



TEXT-FIGURE 74.—Vertical aerial photograph of the Colorado River covering from approximately Mile 87 to Mile 93 in the lower part of Cataract Canyon. Drinking water is normally available in Clearwater Canyon, shown in the lower part of the map. Headwaters of Lake Powell have submerged the rapids which Powell encountered in the lower part of Cataract Canyon. From here on toward Hite the water is relatively smooth.



TEXT-FIGURE 75.—A view downstream of the upper part of Lake Powell at the mouth of Clearwater Canyon. The tip of Red Point, carved in the younger rock units, forms the skyline in the upper right.

with the lower half carved in the Hermosa Formation below the reddish ledge-and-slope zone of the Rico Formation. Massive, light gray Cedar Mesa Sandstone caps the skyline on both canyon walls. Thick sandstone lenses in the Rico Formation appear similar to the Cedar Mesa Sandstone and probably represent intertonguing of Rico beds with the Cedar Mesa Sandstone toward the south. These light-colored sandstones in the Rico sequence are particularly evident high on the east rim, downstream.

There are small pools of clear water along the floor of the limestone canyon that can be reached by a short walk up the canyon bottom over a waterfall area. A single Indian ruin of 3 small rooms occurs at the cliff base on top of the alluvial fan on the north side of the mouth of the canyon.

Mile 90.1 (528.5).—Small alluvial fan now largely submerged beneath Lake Powell has developed at the mouth of Bowdie Canyon. The rocks now dip gently downstream, and the massive light-colored Cedar Mesa Sandstone is thicker. The inner gorge is still carved mainly in Hermosa beds.

Mile 92.6 (531.0).—The narrow inner gorge is composed almost totally of

Hermosa beds beneath massive sandstone cliffs of the Rico Formation and Cedar Mesa Sandstone.

Mile 93.7 (532.1).—Small canyon to the south is fault-controlled in Hermosa beds. A cove is carved in the bottom of cliffs in the Hermosa Formation which is overlain by a slope zone of the Rico beds beneath a vertical cliff of massive Cedar Mesa Sandstone.

Mile 94.4 (532.8).—COVE CANYON ENTERS FROM WEST.

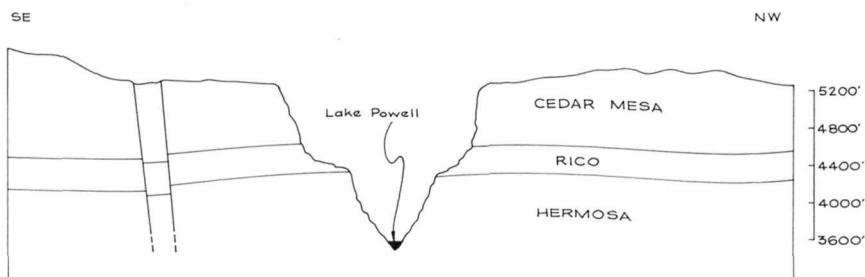
Mile 95.4 (533.8).—The canyon broadens with a narrow fault-controlled tributary coming in from the northeast. The prominent slope zone is low in the Hermosa Formation. The Rico Formation has graded almost totally to pink, massive sandstone beneath the white Cedar Mesa Sandstone. Downstream, the prominent cliff zone in the middle of the canyon wall is in the upper Rico Formation (Text-fig. 76).

Mile 96.6 (535.0).—Broad alluvial fan that formed at the mouth of the small canyon which enter from the east is now largely submerged.

Mile 97.8 (536.2).—DARK CANYON ENTERS FROM THE SOUTH-EAST (Text-figs. 77, 78). Dark Canyon Rapids are now submerged beneath headwaters of Lake Powell. Dark Canyon is a narrow opening in the massive limestones of the upper part of the Hermosa Formation. The mouth of Dark Canyon is almost completely closed by low bars of very fine silt. The terraces at the mouth of Dark Canyon support a native western redbed, much of it destroyed by rising waters of Lake Powell.

Mile 98.0 (536.4).—The canyon turns almost due west below Dark Canyon and continues in massive limestone of the Hermosa Formation beneath red and light-colored sandstone cliffs and slopes of the Rico beds (Text-figs. 79, 80). Massive Cedar Mesa Sandstone forms the rim.

Mile 101.3 (539.7).—The canyon continues with very steep walls. The greenish fossiliferous Hermosa limestone disappears beneath river level near Freddy's Cistern with the water level at an elevation of 3,545 feet. The canyon is dominated by the light tan Cedar Mesa Sandstone on the high rim above an inner gorge carved in more evenly bedded pink and gray Rico beds. Freddy's Cistern enters from the north.



TEXT-FIGURE 76.—Cross-canyon profile near Cove Canyon, at approximately Mile 94.5, showing the distinctive profile of the lower part of Cataract Canyon.



TEXT-FIGURE 77.—Vertical aerial photograph of the Colorado River covering from approximately Mile 91 to Mile 100.

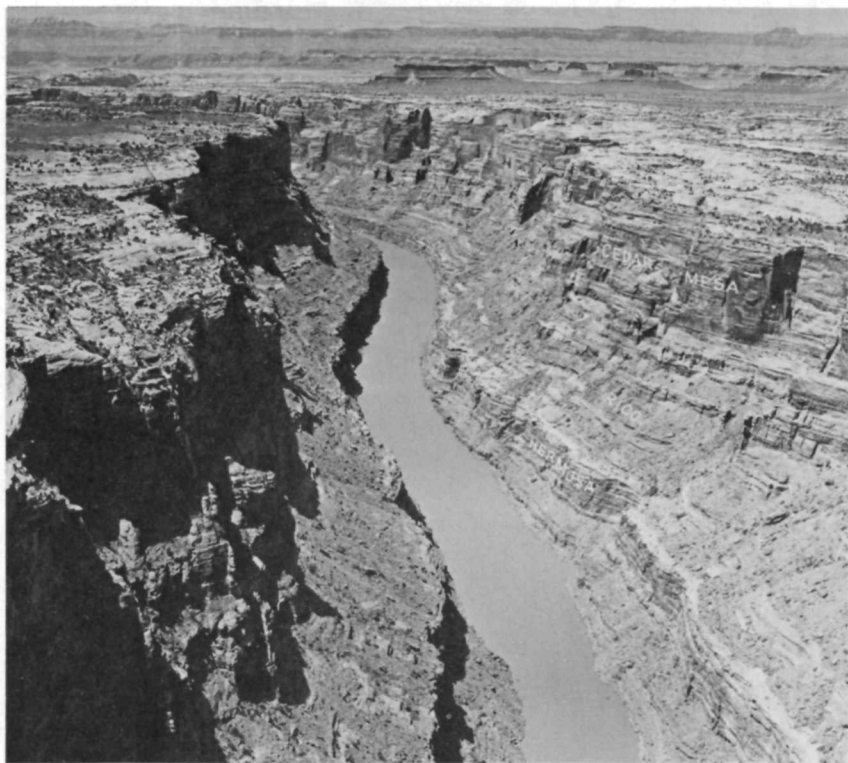


TEXT-FIGURE 78.—Low oblique aerial photograph looking downstream at the mouth of Dark Canyon. Massive Cedar Mesa Sandstone forms the upper cliff. The intermediate slope and lower cliff are in Rico beds and the lower cliff zone is in Hermosa beds.

Mile 101.6 (540.0).—The river makes an abrupt bend toward the south around the east side of Mille Crag Bend. The complex, jointed castellated surface of the bend shows well on the west side in broken massive sandstone fins and towers of the Cedar Mesa and Rico formations. Rico beds are at river level.

Mile 103.4 (541.8).—A small tributary canyon enters from Dry Mesa on the east. Margin of Dry Mesa shows the jointed Rico and Cedar Mesa beds. Steep, joint-isolated blocks produce spectacular scenery on the west side of the canyon in the center of Mille Crag Bend.

Mile 103.6 (542.0).—SHEEP CANYON ENTERS FROM THE EAST (Text-fig. 81). This is the point where Powell's men shot a couple of sheep to supplement their meager rations. This is a suitable camp area. In this general area, with water level at an elevation of 3,545 feet, only approximately 100 feet of



TEXT-FIGURE 79.—View downstream from approximately Mile 99 of the headwaters of Lake Powell.

the red Rico Formation is now exposed in the hills to the southeast. Most of the canyon now is in Cedar Mesa Sandstone.

Mile 104.2 (542.6).—Toward the west, beds continue to dip downstream around Mille Crag Bend. At a water level of 3,600 feet (1969) only a few feet of Rico beds are exposed at the bend.

Mile 104.6 (543.0).—The river bends abruptly to the north along the west side of Mille Crag Bend. Rico beds are exposed as reddish sandstone low on the cliff face. Most of the canyon gorge is in Cedar Mesa Sandstone. The jointed nature of Cedar Mesa beds on Mille Crag meander core is evident to the north and east. The dark brown surface on the light gray Cedar Mesa beds is desert varnish, a natural coating of iron or manganese oxide.

Mile 106.0 (544.4).—The river turns abruptly toward the west at the northwest end of Mille Crag Bend. The canyon is dominated by a thick cliff of Cedar Mesa Sandstone with minor reddish beds of the Rico sequence near river level (Text-fig. 82). Major prominent joints control canyons on the northern end of Mille Crag Bend. The Henry Mountains are the peaks on the skyline down



TEXT-FIGURE 80.—Vertical aerial photograph of the Colorado River covering the area from approximately Mile 99 to Mile 107. Mille Crag Bend, in the center of the photograph, is named from the castellate and pinnaced exposures of broken Cedar Mesa Sandstone. Sheep Canyon, at the lower left, was named by Powell after his men shot two sheep here to supplement their meager rations on their first trip down the river. Note the strong structural control of aligned joints with a nearly east-west trend and the parallel east-west trend of the lower part of Cataract Canyon and Narrow Canyon.



TEXT-FIGURE 81.—View down Sheep Canyon towards the tip of Mille Crag Bend. Most of the canyon wall is now carved in the Cedar Mesa Sandstone.

The lakeshore is newly formed and the normally bordering plant fringe has not had time to develop. Rise of Lake Powell has submerged the fringe earlier established along the river.

the canyon. Units from the Organ Rock tongue of the Cutler Formation up to the Wingate Sandstone can be seen in the cliff in front of the Henry Mountains.

Mile 106.6 (545.0).—Small tributary canyon enters from the north.

Mile 108.6 (547.0).—Many of the mesas to the south and north have a Cedar Mesa Sandstone cap from which the softer overlying Organ Rock member of the Cutler Formation has been eroded. Some local areas of differential cementation have produced irregular cave-like and honeycomb-like openings on the weathered surface of Cedar Mesa Sandstone. This part of the canyon was named Narrow Canyon by Powell (Text-fig. 83).

Mile 109.6 (548.0).—Small canyon enters from the north. The canyon rim of Cedar Mesa Sandstone lowers downstream. Cross-bedding is well expressed in the Cedar Mesa Sandstone in the immediate vicinity. The high bridge over



TEXT-FIGURE 82.—Downstream along Narrow Canyon from approximately Mile 107 towards the Hite Marina which is at the base of the cliff in the distance.

the Colorado River can be seen downstream in front of the younger Permian and Triassic rocks (Text-fig. 84).

Mile 110.1 (548.8).—PASS BENEATH THE HIGH RIVER BRIDGE. Upper and lower divisions of the Cedar Mesa Sandstone can be seen on the south, separated by a slope zone. Directly ahead, downstream, can be seen a stratigraphic section which extends upward from Cedar Mesa Sandstone to jointed Wingate Sandstone on the horizon.

Mile 111.1 (549.5).—THE FREMONT OR DIRTY DEVIL RIVER JOINS THE COLORADO RIVER. Castellated Organ Rock beds can be seen directly ahead beneath the White Rim Sandstone. These red beds also form some of the towers and pillars up the Fremont River to the north and northwest. Kayenta beds cap the cliff with Chinle and Moenkopi formations in the slope zone below. White Rim Sandstone caps the brick-red Organ Rock beds above the light-colored Cedar Mesa Sandstone. Last exposures of Cedar Mesa Sandstone are on the point between the Fremont and Colorado river.

Mile 111.6 (550.0).—HITE MARINA. End of log.



TEXT-FIGURE 83.—Vertical aerial photograph of the Colorado River covering the area between Miles 107 and the Hite Marina, at approximately Mile 112, just beyond the lower end of Narrow Canyon and the junction of the Fremont (Dirty Devil) River.



TEXT-FIGURE 84.—Low angle oblique photograph along the lower end of Narrow Canyon to beyond the high river bridge. Narrow canyon in the foreground is in Cedar Mesa Sandstone, with rocks as young as Wingate Sandstone exposed in the background as the jointed cliffs in the upper left. The base of the Henry Mountains shows beyond the Wingate cliffs on the skyline. The arrow in front of the dark cliffs marks the position of the Hite Marina and the end of the river trip.

Selected References

- Baars, D. L., 1962, Permian System of Colorado Plateau: *Bull. Amer. Assoc. Petrol. Geol.*, v. 46, p. 149-218.
- Baker, A. A., 1933, Geology and oil possibilities of the Moab district, Grand and San Juan counties, Utah: *U.S. Geol. Survey Bull.* 841, 95 p.
- Baker, A. A., 1946, Geology of the Green River Desert-Cataract Canyon region, Emery, Wayne, and Garfield Counties, Utah: *U. S. Geol. Survey Bull.* 951, 122 p.
- Gregory, H. E., 1917, Geology of the Navajo country—a reconnaissance of parts of Arizona, New Mexico, and Utah: *U. S. Geol. Survey Prof. Paper* 93, 161 p.
- Hunt, C. B., assisted by Averitt Paul, and Miller, R. L., 1953, Geology and geography of the Henry Mountains region, Utah: *U. S. Geol. Survey Prof. Paper* 228, 234 p.
- Lewis, R. Q., and Campbell, R. H., 1965, Geology and Uranium deposits of Elk Ridge and vicinity, San Juan County, Utah: *U.S. Geol. Survey Prof. Paper* 474-B, 65 p.
- McKnight, E. T., 1940, Geology of area between Green and Colorado rivers, Grand and San Juan counties, Utah: *U.S. Geol. Survey Bull.* 908, 147 p.
- Moore, R. C., 1926, Significance of incised meanders in the physiographic history of the Colorado Plateau country: *Jour. Geology*, v. 34, 97-130.

- Powell, J. W., 1875, Exploration of the Colorado River of the West and its tributaries: Smithsonian Institute, Washington, U.S. Govt. Printing Office, 291 p.
- Welsh, S. L., and Ratcliff, W., 1971, Flowers of the Canyon Country: Brigham Young Univ. Press, 55 p.
- Wengerd, S. A., and Matheny, M. L., 1958, Pennsylvanian System of Four Corners region: Amer. Assoc. Petrol. Geol. Bull. v. 42, p. 2048-2106.

