

UTAH GEOLOGICAL AND MINERALOGICAL SURVEY  
AFFILIATED WITH  
THE COLLEGE OF MINES AND MINERAL INDUSTRIES  
UNIVERSITY OF UTAH  
SALT LAKE CITY, UTAH

# GEOLOGIC ATLAS OF UTAH

DAGGETT COUNTY

*By*

HOWARD R. RITZMA



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## UTAH GEOLOGICAL AND MINERALOGICAL SURVEY

The Utah Geological and Mineralogical Survey was authorized by act of the Utah State Legislature in 1931; however, no funds were made available for its establishment until 1941 when the State Government was reorganized and the Utah Geological and Mineralogical Survey was placed within the new State Department of Publicity and Industrial Development where the Survey functioned until July 1, 1949. Effective as of that date, the Survey was transferred by law to the College of Mines and Mineral Industries, University of Utah.

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HOWARD R. RITZMA



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## F O R E W O R D

Howard R. Ritzma, author of this bulletin, is a specialist in the geology of the Tri-state region of Utah, Wyoming, and Colorado. The undersigned first became impressed with this fact while attending the Tenth Annual Field Conference of the Wyoming Geological Association in 1955. In the guidebook for this field conference, Ritzma authored the "Late Cretaceous and early Cenozoic structural pattern, southern Rock Springs uplift, Wyoming." As guide and moderator he conducted the examinations and discussions for the region around the northeast flank of the Uinta Mountains.

The profound impression made by Ritzma at the Wyoming field conference was deepened and further expanded when, later in 1955, as editor of the "Guidebook to the Geology of Northwest Colorado," sponsored jointly by the Rocky Mountain Association of Geologists and the Intermountain Association of Petroleum Geologists, he guided this field conference through the eastern Uinta Mountains of northwestern Colorado.

Ritzma's studies of the geology of this Tri-state area began with preparation of his Master's Thesis at the University of Wyoming in 1948 and 1949. This paper, "Geology along the southwest flank of the Sierra Madre, Carbon County, Wyoming" extended the outcrop of the Browns Park formation into south-central Wyoming and related the late Tertiary erosional history of the Sierra Madre with that of the Uintas. His subsequent training and experience as geologist and district geologist for General Petroleum Corporation residing in Rock Springs, Wyoming, and Craig, Colorado, afforded him unusual opportunity for detailed field studies of a regional nature along the entire Uinta Range. These studies have been pursued to the present year.

His background and scholarship marked him as the logical choice to author the Daggett County bulletin for our GEOLOGIC ATLAS OF UTAH series. Two years were spent in trying to get Ritzma to accept the assignment. The multiplicity of his other commitments as a consulting geologist made him hesitate. Finally he did undertake the task. Since that time the Utah Geological and Mineralogical Survey has known that Daggett County "was in good hands" and that when completed this bulletin would be a highlight in our Atlas Series concerning which we would all be proud.

In this bulletin Ritzma has not only produced a treatise that is geologically sound, but one that is also readable by the layman. In it he has chronicled the sequence of explorers, trappers, desperadoes, early settlers, and survey engineers of Browns Park (formerly Browns Hole) and what is now Daggett County. He has given the setting at Diamond Mountain for the international diamond hoax solved by Clarence King of U. S. Geological Survey fame. He has dated the age of the Uinta Mountains, pinpointed the time of their last great northward thrust, and thrown new light on the profound north boundary fault of the Uinta Range. He doubts the Archean age of the Red Creek complex, re-evaluates the geomorphology of the ancient erosion surface and pirated streams, lays out the areal geology of Daggett County in 5 colors, lists a new burial ground of the dinosaurs, spotlights the recreational facilities of the cold water lake back of the new Flaming Gorge Dam, points up the matchless scenery of the biscuitboard topography of the high Uintas, and describes in detail the complete stratigraphy of this pivotal geologic province.

As in the previous bulletin of this series, the GEOLOGIC ATLAS OF UTAH--CACHE COUNTY (UG&MS Bulletin 64), we have prepared a one-page colored areal geologic map of the entire county as a by-product of this study. It will be available at \$1 per map for those who prefer a one-sheet rendition to a series of plates bound within the text.

Arthur L. Crawford, Director  
UTAH GEOLOGICAL AND MINERALOGICAL SURVEY

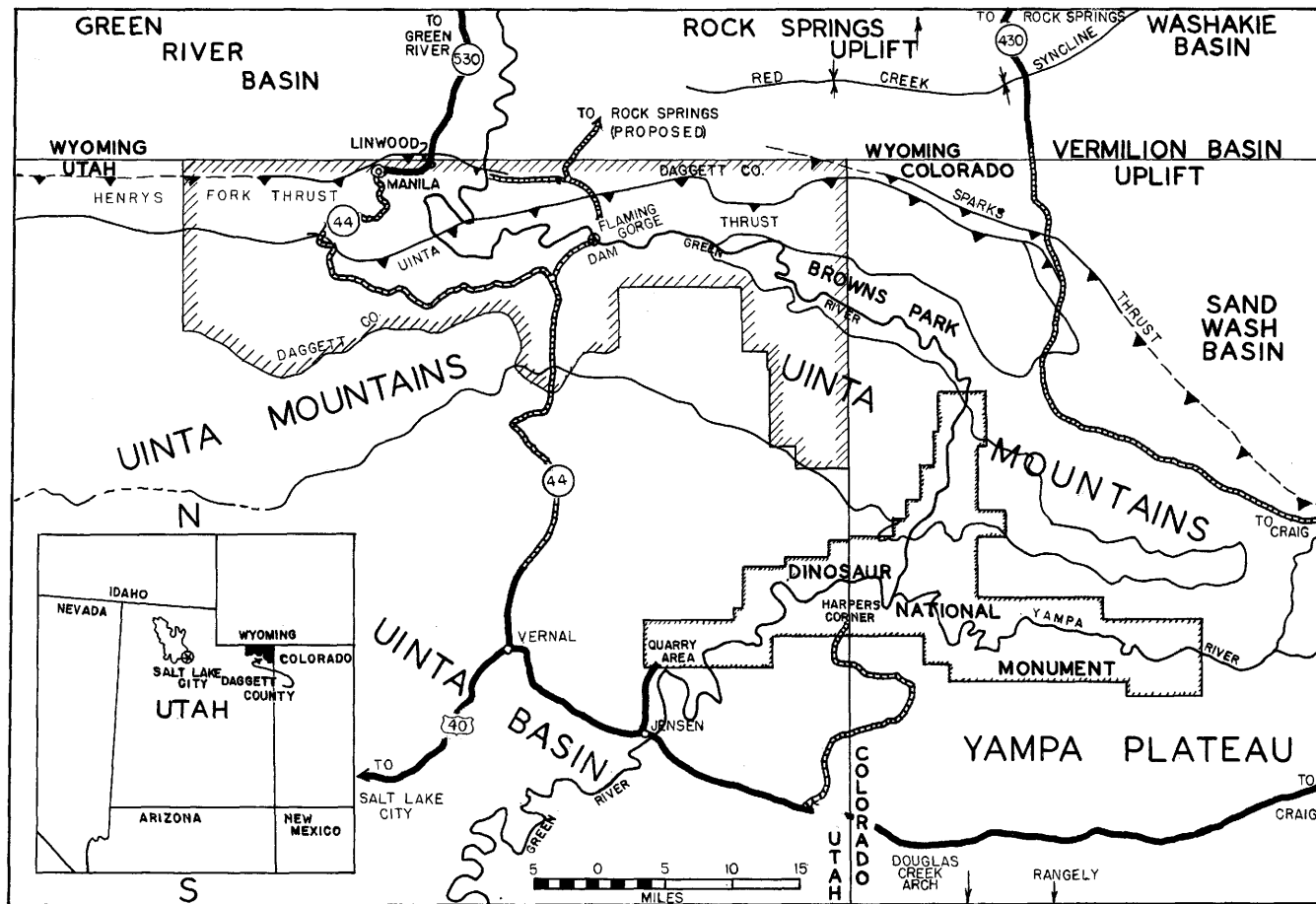


FIGURE 1. REGIONAL INDEX TO THE STRUCTURE OF THE EASTERN UINTA MOUNTAINS SHOWING DAGGETT COUNTY UTAH, IN ITS RELATION TO ITS GEOLOGIC SETTING.

DAGGETT COUNTY<sup>1</sup>By Howard R. Ritzma<sup>2</sup>

## A B S T R A C T

Daggett County is located in northeastern Utah adjacent to Wyoming on the north and Colorado on the east. It is one of the smaller counties of Utah and the least populated.

The general area is of importance in the history of the early West. The first Rendezvous of the fur trappers and traders was held near Linwood in 1825, and the Green River was a focal point for trapping and trading during the 1840's and 1850's with some sparse settlement as early as the 1850's. Early exploration and study by Powell, King, Hayden, Emmons, and others in the late 1860's and 1870's resulted in important advances in the sciences of geology and geomorphology.

The Uinta Mountains and the Green River dominate the geography of Daggett County and its scenery. The Uintas trend from west to east across the southern portion of the county with the southern county boundary following the crest line of the range for much of its distance. The county thus lies almost completely on the north flank of the Uintas, considerably isolated from the rest of Utah. The winding course of the Green first southward, thence eastward through a series of spectacular canyons and open valleys--Flaming Gorge, Horseshoe Canyon, Hideout Canyon, Red Canyon, Little Hole, Browns Park--has further segmented the county and increased its isolation.

Daggett County has a remarkably complete sequence of rock formations. The core of the Uinta Range exposes more than 20,000 feet of Precambrian quartzitic sandstone and argillite, the Uinta Mountain group. It is proposed that the older Precambrian rocks of previous studies, the Red Creek quartzite (or complex), are metamorphosed equivalents of the Uinta Mountain group sediments. The Uinta Mountain group sediments are generally dark red, a color which dominates much of the county's scenic landscape.

Flanking the core of the Uinta Mountains the Paleozoic and Mesozoic rocks form a colorful, spectacular series of hogbacks and strike valleys. On the south flank in Daggett County are small exposures of the Upper Cambrian Lodore formation unconformably overlain by the Mississippian Madison and Deseret limestones. Representatives of the Ordovician, Silurian, and Devonian systems are missing. On the north flank the Mississippian rocks rest directly on the Precambrian Uinta Mountain group quartzites. The Mississippian formations are in ascending order: Madison limestone, Deseret limestone, and Humbug formation. The Mississippian-Pennsylvanian boundary lies within the Manning Canyon formation which overlies the Humbug. The Pennsylvanian system is represented (in ascending order) by the Round Valley limestone, the Morgan formation, and the Weber sandstone. The uppermost Weber beds are probably Permian in age. The Park City formation of Permian age, containing important phosphate beds, overlies the Weber.

The Mesozoic rocks of Daggett County form the most colorful scenery along the Uinta's north flank. The Triassic and Jurassic formations are typical and equivalent of similar formations over extensive areas of eastern and southern Utah. In ascending order these formations are: Triassic-Moenkopi formation, Chinle formation with its basal Shinarump conglomerate, Jurassic-Navajo sandstone, Carmel formation, Entrada sandstone, and the Curtis and Morrison formations. The upper portion of the Morrison is probably Lower Cretaceous in age.

Upper Cretaceous rocks in Daggett County consist of a basal conglomeratic sandstone, shale, and coaly sequence here called the Dakota formation. It is overlain by the 6900-foot thick Mancos shale which is subdivided into the basal Mowry shale member, the thin Frontier sandstone member which in turn is overlain by the main body of the Mancos shale, some 6500 feet thick. Overlying the Mancos is the Mesaverde formation, here about 2000 feet thick. The two formations intertongue, with the lower Mesaverde sandstones tonguing into Mancos shale to the east. The upper Mancos beds and the Mesaverde formation can be related to equivalent formations to the north in the Rock Springs uplift.

<sup>1</sup>The maps for Daggett County used in this bulletin were drawn on a base adapted from outline maps furnished by the Utah State Road Commission. The base, all the colored overlays, and the necessary supplementary drafting were financed by a grant from the University of Utah research fund. Without this grant or without the generous donation of the author's services the preparation of this bulletin would have been indefinitely delayed.

<sup>2</sup>Consulting geologist with the firm of Dan Turner and Associates, Inc., 427 C. A. Johnson Building, Denver, Colorado.

The early Tertiary formations of Daggett County consist of the detrital material from the Paleocene positive area centered at the east end of the Uinta Mountains and the Uinta Mountains proper. The basal formation is the Hiawatha member of the Wasatch formation of Paleocene-Eocene age. Overlying it are the Tipton tongue of the Green River formation, the Cathedral Bluffs member of the Wasatch formation, and the main body of the Green River formation, all of Eocene age. All have complex intertonguing relations coincident with structural episodes of the rising Uinta Arch and fluctuation of the fresh water lake that occupied the Bridger segment of the Green River Basin to the north.

A significant stratigraphic gap occurs between the Eocene and Miocene rocks. Late Tertiary formations (Miocene and Pliocene) are the gravel deposits which cap the Gilbert Peak and Bear Mountain erosion surfaces and the largely wind deposited sandstones and volcanic tuffs of the Browns Park formation.

Quaternary glacial deposits radiate outward from extinct glacial centers in the high Uintas. Quaternary and Recent fluvial deposits are scattered across the county along stream courses.

The Uinta Mountains are the topographic expression of the broad regional Uinta Mountain Arch. This arch coincides closely with the extent and trend of the ancient quartzite-argillite mass known as the Uinta Mountain group and is the manifestation of the movement of this "pod" of sediments as an independent block within the earth's crust. The arch is elongate west to east and in the Daggett County area is strongly asymmetric to the north. Rupture along the north flank has produced two principal northward thrusts, the Uinta and Henrys Fork faults, both aligned west-east. Viewed regionally the Uinta fault is a ramp thrust, steep at its "roots," shallowing northward as it involves less competent beds. Thus, the sole of the fault can vary from nearly horizontal in northerly exposures to nearly vertical in southerly exposures depending on how far erosion has stripped the overthrust sheet back to its "roots." The Henrys Fork fault is less well exposed but is probably of similar habit. The Uinta fault reaches a maximum displacement of 40,000 feet at the Utah-Colorado border. The Henrys Fork fault displaces between 20,000 and 30,000 feet of beds in western Daggett County.

A few subsidiary faults occur north of the Uinta fault and between the Uinta and Henrys Fork faults. An intricate and varied pattern of faults occurs in the quartzite core of the Uinta Mountain Arch. These faults show movement ranging from Precambrian to Quaternary in age.

The Uinta Mountain group of Precambrian age was deposited in a west-east trending trough which ceased to be an active site of deposition in Paleozoic and later geologic time. However, the massive pod of sediments embedded in the earth's crust exerted a strong influence on subsequent structural events. During most of Paleozoic and Mesozoic time the Daggett County vicinity was part of the stable shelf area which included much of the Rocky Mountain region. Marine deposition was greatly accelerated during upper Cretaceous time. This was followed by gentle uplifting focused around the east end of the present Uinta Mountains in uppermost Cretaceous and early Paleocene time. The Uinta "pod" then became structurally active and the broad regional Uinta Mountain Arch was upwarped in a west-east alignment across pre-existing northwest to southeast or north to south folds. The Uinta folding was accomplished mostly through Paleocene time culminating in major thrusting along the northeast and north flanks in early Eocene (Tipton) time. Structural activity then ceased abruptly, and the Uinta Mountains were subjected to extensive erosion.

In later Tertiary time, the Uinta Mountains were buried in their own detrital material high up on their flanks. Wind blown sands and thick blanketing volcanic ash added to the accumulation of encroaching sediment. Erosion surfaces sloped outward from the summits of the range radially into the adjacent basins. Uplift in adjacent areas and the collapse of the Uinta Mountain Arch forced major adjustment of stream patterns. Epirogenic uplift of the region lowered base levels and accelerated erosion by rivers with consequent removal of vast quantities of sediments. A complex sequence of uplift, tilting, differential erosion, and stream piracy enabled the Green River to establish its paradoxical course across the Uintas. Continued regional broadwarping and lowered base levels have resulted in deeply incised canyons and exhumed mountain ranges. Pleistocene glaciation resulted in accelerated erosion and the sculpturing of glacial cirques and valleys in the high Uintas.

Daggett County has no known metallic mineral deposits of commercial value. There are minor occurrences of copper, iron, uranium, manganese, and gold. Natural gas with minor amounts of distillate are produced from the Clay Basin field. Other nonmetallic resources include small locally utilized coal deposits and possibly large undeveloped phosphate rock resources.

Flaming Gorge Dam, a major water storage and hydroelectric unit of the Upper Colorado River Storage Project, is under construction on the Green River in the central portion of Daggett County. The dam undoubtedly will bring sweeping changes in the geography of the entire vicinity. Extensive recreational development--water sports and fishing--and increased commercial and industrial activity are contemplated.

## INTRODUCTION AND ACKNOWLEDGMENTS

The purpose of this bulletin is to provide general information on the geology of Daggett County. It is beyond the scope of this work to delve deeply into scientific profundities or to review the several controversies which have resulted from 90 years of geologic work and publication on the complex geology of the area. However, two new ideas, fundamental to understanding of Uinta Mountain structure and stratigraphy, are presented here: (1) the possibility that the oldest rocks of the Uinta Mountains, the Archeozoic(?) Red Creek complex, are actually contemporary with the Proterozoic(?) Uinta Mountain group but have been greatly metamorphosed by local intrusive action, and (2) the concept of the Uinta Fault as a high-angle reverse fault close to its "roots" shallowing to a low-angle overthrust outward to the north.

Preparation of this bulletin was conceived in 1955 and has continued with many interruptions to this date. During this time, many striking changes have taken place in Daggett County, resulting from construction of Flaming Gorge Dam. Readers and students of this bulletin may find geologic features described here from canyon wall outcrops easily accessible by boat or, perhaps, lost beneath the waters of the lake soon to be impounded behind the dam. Trails, roads, towns, and population will undoubtedly be considerably changed.

The writer has spent parts of five field seasons in geologic work of detailed and reconnaissance nature in almost all parts of Daggett County, coupled with extensive study of the areal geology, stratigraphy, and structure of adjoining portions of Colorado and Wyoming. Most of this work has been related to the field of exploration for oil and gas. Despite this fund of personal knowledge, the writer has been dependent to a great degree on the published geologic literature and various unpublished works, particularly in special geologic fields in which the writer's training and experience is limited. In several instances, mapping and other geological concepts were found to be in considerable conflict, and in these cases the writer has attempted to interpret and reconcile these differences in the light of his own field observations and regional studies.

An index of sources used in compiling the geologic map in this bulletin accompanies the map. An extensive bibliography of the geologic literature concerned with Daggett County follows the text. These publications can be consulted for more detailed information on various geological subjects discussed only generally in this bulletin.

Particularly, the writer wishes to acknowledge use of the extensive published material of Wallace R. Hansen of the U. S. Geological Survey, Denver, Colorado; George G. Anderman, consulting geologist of Denver, Colorado, loaned his unpublished doctoral dissertation to the writer, and several discussions with Dr. Anderman were of great value in resolving important points of controversy.

Many illustrations for this bulletin were obtained from the U. S. Bureau of Reclamation, Salt Lake City, Utah. Others were furnished by John H. Rathbone, Denver, Colorado; Mrs. Heber Bennion Jr., Manila, Utah; and William M. Purdy, Manila, Utah.

The section on Flaming Gorge Dam is largely taken from material furnished by the U. S. Bureau of Reclamation. Information on Sheep Creek Cave was supplied by Dale J. Green, Utah Speleological Society.

Some of the historical research was done by Barbara Robinson Ritzma and the staff of the Western History Section, Denver Public Library. Dale L. Morgan, Bancroft Library, University of California, Berkeley, made helpful suggestions and additions.

The writer also wishes to thank the Muldrow Aerial Surveys Corporation, Midland, Texas, who kindly contributed the controlled base map on which published geologic mapping and air photo reconnaissance mapping was compiled and from which the geologic map in this bulletin was transcribed.

## EXPLORATION AND SETTLEMENT

Daggett County is an area of historic contrasts. In the earliest days of exploration and settlement of the West, the north flank of the Uinta Mountains and the Green River and its tributaries were a focal point for trappers, traders, and explorers. As years passed, however, it became apparent that the Green River had limited use for transport of goods and that its canyon-carved course was not a route of travel. Failure to unearth mineral wealth in the Uinta Mountains diverted the armies of gold and silver prospectors elsewhere. Skirting the Uintas, trails and rails pushed across the Wyoming plains to the north and the basins and mountain passes of Colorado and central Utah to the south. Gradually the area which was to become Daggett County was left in geographic isolation and remained sparsely settled.

The first white men to traverse this area were fur trappers and traders, both British and American, who appeared in the 1820's, possibly as early as 1819. They traveled widely and rapidly, left few marks on the land, and kept scant record of their exploits and explorations. Trappers of the British Northwest Company are known to have been in the upper Green River country in 1819 and again in 1823. By the spring of 1824 Jedediah S. Smith had led the vanguard of the American trappers to streams draining the north slope of the Uintas. This area became the territory of the Rocky Mountain Fur Company and the names of the organizers, Gen. William H. Ashley and Andrew Henry, and many of the "mountain men" who roamed the West as rivals and associates--Bridger, Smith, Jackson, Sublette, Black, Weber, Ogden, and Provo--have left a notable place name heritage in the region.

Late in the summer of 1825 the first "Rendezvous" of the Ashley-Henry group was held in the well-watered valley of the Henrys Fork near its confluence with the Green. The exact spot is not recorded, but the locale appears to be close to the site of the town of Linwood in Daggett County.

Earlier in 1825 Ashley scouted the rendezvous site, and then with a small party descended the Green River through Flaming Gorge, Hideout Canyon, Red Canyon and Lodore Canyon, and southward to Minnie Maud Creek. The voyage was made in bull boats, described as "nothing but a pole frame thirty feet long, with twelve feet of beam, covered with pitch-smearred buffalo skins." In Red Canyon, Ashley inscribed his name and the date 1825, and farther along recorded laborious

portages through Lodore and Split Mountain Canyons. Ashley returned to the "Rendezvous" site on horses purchased from the "Eutah" Indians and from French-Canadian trappers who had penetrated to the Uinta Basin from New Mexico. His return route circled the west end of the Uinta Mountains and thus accomplished the first overland crossing of this region. The Ashley journals went unpublished until 1918, and thus these travels were largely unknown.

The next venture of this kind came in 1849 when gold seekers set out down river hoping for an easy route to the Pacific and California. The adventures of one such party are related by William Manly. In the rehabilitated hulk of a ferry boat, they reached Red Canyon from Green River, Wyoming. Here the clumsy craft foundered and stuck fast. The rest of the remarkable journey to the Duchesne River was made in dugout canoes lashed together into rafts.

John Wesley Powell, famed geologist and explorer of the West, made his first voyage down the Green in 1869. His place names--Flaming Gorge, Horseshoe Canyon, and Lodore--remain today. Finding the inscription "Ashley 1825" in Red Canyon, but knowing only vaguely of his predecessor, Powell misread the date as 1855 and supposed Ashley a trapper or prospector. He named the rapids in the Green at this point Ashley Falls, a name which also survives to commemorate the earlier explorer. These falls will be submerged beneath the reservoir impounded by Flaming Gorge Dam.

Browns Park in eastern Daggett County and adjacent Colorado was the first part of the area to be permanently inhabited. The "park" into which the Green River flows from Red Canyon is a broad, well-watered valley sheltered by encircling cliffs, mountains, and plateaus. Browns Hole, as it was first called, was named for Baptiste Brown who found shelter there in the winter of 1835-36. Philip Thompson and William (David) Craig built Fort Davy Crockett in 1836-37 near the north entrance of Lodore Canyon, in what is now Colorado. It was also dubbed "Fort Misery" and described as "the meanest fort in the West." Kit Carson wintered there in 1837-38 and possibly first named the fort in honor of Crockett. Declining fur trade caused this primitive outpost to be deserted in 1840, and in June 1844 John C. Fremont's eastbound party sojourned briefly near the ruins of Fort Davy Crockett.

Agricultural settlement came slowly. In 1852 Sam C. Bassett arrived, followed by others of his family. The Bassett home ranch was built in 1878 in the Colorado portion of Browns Park. Warren D. Parsons and his wife Annie arrived in 1854--Mrs. Parsons becoming the first white woman settler. Sir Griffeth W. Edwards introduced the first domestic cattle in 1869 and recorded that the trail from Rock Springs traversed "rich, green" country. By the late 1880's several ranches were established in Browns Park and in the Lucerne Valley west of the Green River. Short-lived increases in population resulted from prospecting and timber cutting activity between 1880 and 1910, but few of these people remained.

With jurisdiction split among three states (or, in earlier days, territories) and with splendid isolation and remoteness from law enforcement agencies, Browns Park, Clay Basin, and the rugged canyons and "holes" along the Green River saw much traffic and gained considerable notoriety as hideouts for outlaw bands that roamed widely over the West.

The area also achieved ill-starred international fame briefly in the 1870's with the "discovery" of diamonds and other gems in the Browns Park area. Feverish promotion saw formation of a \$10,000,000 corporation backed by financial and mining interests in San Francisco and New York and reaching as far as European banking and gem interests. Investigations by Clarence King, pioneer geologist of the 40th Parallel Survey fame, quickly proved the "discovery" a crude hoax. The bonanza faded fast, and only place names such as Diamond Mountain, Ruby Gulch, and Diamond Peak survive to commemorate the gaudy swindle.

The north flank of the Uintas has long been a famed outdoor laboratory in which the early day "giants" of geology mapped, studied, and formulated ideas. Here many classical concepts and controversies in American geology had their inception. Notable in these explorations were Powell (1868-75), Hayden (1870), and King, Emmons, and others (1969-72).

Lucerne Valley (Manila and Linwood) was settled from 1880 through the 1890's. Manila, the future county seat, was surveyed in 1898 and derives its name from the events which transpired in the Philippines in that year. Daggett County remained part of Uintah County until 1918 when it achieved separate status and thus became one of Utah's smallest counties in area and the least populated in the state. Uintah and Daggett counties have engaged in several disputes over boundaries, and in 1943 the disagreement was resolved with a major readjustment of the south boundary of Daggett County. The county was named for Ellsworth Daggett, first surveyor general of Utah.

Population has ranged from 250 to 600 (approximate) until recent years. Building of the Pacific Northwest Pipeline brought a brief influx of population and road construction in hitherto rough, remote terrain. With construction of Flaming Gorge Dam and the damsite town of Dutch John, Daggett County has assumed a new importance in the West. New population and roads, growing commercial and industrial activity, recreational facilities and burgeoning tourist trade, undreamed of in the pioneer days so recently past, now seem only a few short years in the future.

## G E O G R A P H Y

Daggett County is located in the extreme northeast corner of Utah and is adjacent to Wyoming on the north and Colorado on the east. The area of the county is 708 square miles, making it 26th in size of Utah's 29 counties. With a population of about 500 in 1955 (364 by 1950 census), it is the smallest county in population in the state and one of the smallest in the nation.

Geographically the county is isolated from the rest of Utah by the Uinta Mountains. Divided by deep canyons and rugged terrain, the county itself is segmented into areas which are sharply isolated from each other and accessible to each other only by circuitous trips through neighboring counties and states.

Lucerne Valley in western Daggett County is the most populous portion and contains Manila, the county seat, and the village of Linwood. It is a broad, fertile, alluvium-floored valley developed

on the soft Mancos shale. Roughly paralleling the Wyoming-Utah line, a hogback of Tertiary sandstone and conglomerate separates the valley from the arid Green River Basin of Wyoming to the north. To the south, curving hogbacks of successively older formations rise sharply into the forested foothills of the Uinta Mountains.

The Uintas reach their maximum height in Daggett County at Deadman's Peak (elevation 12,280') in the extreme southwest corner of the county. Eastward from here for 10 miles to Leidy Peak, the elevation of the range averages over 11,500 feet, with several prominences over 12,000 feet. The mountains are well watered, dotted with lakes, and thickly forested. Eastward from Leidy Peak (elevation 12,013') to the broad pass where Utah Highway 44 crosses the range at an elevation of 8,500 feet, the Uintas rapidly lose elevation and are not as well watered. From the pass eastward the range breaks up into isolated ridges and irregular rocky prominences that rise above rolling plateau country. The plateau surface is modified by the drainage of Pot or Cascade Creek which flows across the plateau to the east into Colorado and by numerous streams that plunge precipitously into the Green River to the north. The country becomes decidedly more arid to the east and the barren mountains reveal more of the somber red hue of their ancient quartzite core.

The Green River, flowing in canyons up to 2,000 feet in depth, sharply divides Daggett County. Prior to the Flaming Gorge Dam construction, only two foot bridges crossed the river, one east of Linwood and the other at the north opening of Hideout Canyon. Ferries have operated across the river in Browns Park and east of Linwood, and a bridge for light vehicular traffic spans the Green in Browns Park in Colorado.

The country northeast of the Green River is a continuation of the hogback and broad strike valley pattern of the Lucerne Valley west of the river. Along the Utah-Wyoming line parallel arcuate hogbacks of Mesaverde sandstone form the feature called The Glades. To the south of these ridges is Antelope Flats, a continuation of the Mancos shale strike valley extending west to east. This broad shale-floored valley is constricted by the overriding thrust mass of Goslin Mountain but widens again into Clay Basin. South of Antelope Flats are sharply upturned ridges such as Boar's Tusk and Dutch John Ridge scuffed up against and under the great Uinta fault. The country is arid and sparsely vegetated and the streams are intermittent. A small community is located in Clay Basin for employees operating the gas field.

Browns Park in easternmost Daggett County is a picturesque, fertile, gravel-floored valley surrounded by somber mountains and plateaus. The Green River issues from Red Canyon into the "Park" from the west and flows out to the south through the slot-like north opening of Lodore Canyon in Colorado. The lowest elevation in Daggett County (5,365') is on the Green River at the Colorado line.

The county is almost wholly devoted to agriculture, principally the raising of cattle, sheep, and horses. The ranches are large and their operations widespread. Livestock are wintered in sheltered valleys at low elevations and trailed or trucked to the high plateaus and mountains for summer grazing. Return to lower elevations in the fall completes the cycle. More than half of the county lies within the Ashley National Forest.

Utah Highway 44 crosses the county north-south and connects with Wyoming Highway 530 north of Linwood. Utah 44 provides access to Vernal to the south and Green River, Wyoming, on the north. The pass to Vernal is generally closed from December to May. Clay Basin is reached from Rock Springs, Wyoming, on the north and is connected with Browns Park by a rough steep road through Jesse Ewing Canyon. Browns Park is accessible over secondary roads from Colorado to the east and from Vernal, Utah, to the south and west.

Construction of Flaming Gorge Dam and the damsite town of Dutch John undoubtedly will bring sweeping changes in the geography of Daggett County with new roads, population, commerce, and industry.

### D R A I N A G E

Drainage in Daggett County is accomplished by the Green River and its tributaries. The Green enters Utah from the north in Daggett County, flowing south and southwest for nine miles. During this course it meanders through Flaming Gorge and Horseshoe Canyon. It then turns southeast through Hideout Canyon, thence generally eastward through Red Canyon, Little Hole, Swallow Canyon, and into Browns Park. In Browns Park it enters Colorado, still flowing in a generally eastward direction. The large streams which enter the Green from the west, southwest, and south rise in the high mountains and have excellent year-round flows. This includes streams such as the Henrys Fork, Birch Spring Draw, Sheep Creek and its tributary Lodgepole Creek, Carter Creek and its tributary Beaver Creek, Skull Creek, and Cart Creek. East of Cart Creek the streams entering the Green from the south plunge precipitously down short canyons from lower mountains and plateau country. Although most have perennial flow from springs, this occasionally becomes feeble by late summer. In this group are streams such as Gorge Canyon and Jackson, Tollivers, Sears, and \*Crouse Creeks.

North and east of the Green River the country is much drier and stream flow is irregular. Spring Creek, an intermittent stream, enters Daggett County from Wyoming through Spring Creek Gap, then flows west to the Green across Antelope Flats. Red Creek, which drains a large area in Wyoming, enters the county through Richards Gap, flows through Clay Basin and out to the south through a narrow, sinuous canyon to join the Green. Red Creek has a very irregular surface flow and considerable subsurface volume. Two streams enter Browns Park from the north: Jesse Ewing Canyon and Willow Creek. The first is intermittent. The latter rises in high plateau country near the common corner of Wyoming, Colorado, and Utah and has a good year-round flow.

The extreme southeast corner of the county is drained by Pot (or Cascade) Creek, which flows eastward into Colorado to join the Green.

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\*This stream has been erroneously called "Grouse" on several published maps.

## S T R A T I G R A P H Y

Daggett County contains an unusually complete and well-exposed stratigraphic section ranging from Archeozoic to Quaternary and Recent age. Almost unique in the Rocky Mountains is the thick section of Precambrian metasediments and sediments exposed in the core and flanks of the Uinta Mountains. The Tertiary section exposed within Daggett County and in adjoining Wyoming and Colorado is of great importance in understanding the complex structural history of the Uinta Mountains.

### PRECAMBRIAN STRATIGRAPHY

#### Older Precambrian (Archeozoic?)

##### Red Creek complex

What are presumed to be the oldest rocks in the Uinta Mountains are exposed in Daggett County between Clay Basin and Browns Park and vicinity. Because of their profoundly metamorphosed character and an apparent unconformity between them and the younger Precambrian sediments, they are provisionally classed as Archeozoic in age. These exposures of the "core rocks" of the range along its extreme north edge rather than along the axis of the Uinta Mountain Arch are one of several structural paradoxes unsolved by the available mapping of this large regional fold. These and other aspects of Uinta Mountain structure are discussed at some length under "Structure" in this volume.

The older Precambrian rocks of this area have been known as the Red Creek quartzite since the early geologic exploration of the Uinta region by Powell, King, and others. Because of the diversity of rock types found in the older Precambrian, it is more convenient and accurate to term the whole assemblage the Red Creek complex and to discuss the principal rock types separately. On the geologic map the Red Creek complex has been mapped as a unit with no attempt to differentiate the metasediments, metamorphic, and igneous rock types. Comprehensive study of these rocks is included in papers by Hansen (1955b) (1957) and (1958b) and Hansen and Bonilla (1954).

The most abundant rock type of the Red Creek complex is the quartzite from which the rock group originally was named. This is white to green in color, vitreous, highly fractured, and complexly folded. Often the fractured quartzite has been recemented by silica into highly resistant breccia. Muscovite mica is a common constituent and the quartzite grades into quartzose mica schist with increase in mica content.

Quartzose mica schist is the second most common rock type in the Red Creek complex. This is a varicolored rock exhibiting complex foliation, folding, and crushing. In the schist are several accessory metamorphic minerals. Almandite (red garnet) and staurolite are common over wide areas. Kyanite and anthophyllite have also been noted in more localized occurrences.

Epidiorite is found on the northeast slope of Goslin Mountain in a large pod-like mass imbedded in quartzite and elsewhere in the Clay Basin area in smaller quantity. Amphibolite also occurs in

considerable amount throughout the area of the Red Creek complex with many variants of granitic and gneissic appearance and composition. The amphibolite is regarded as a metamorphosed igneous rock intruded as sills, dikes, and irregular bodies, originally diabasic in nature (Hansen, 1955b).

Other rock types which occur in the Red Creek complex are carbonates and pegmatites. The complex carbonates are hydrothermally derived from epidiorite and amphibolite and occur in vein-like and pod-like masses. The pegmatites are widely but sparsely distributed over the outcrop area of the Red Creek complex. They are of simple composition--quartz, feldspar, and muscovite mica--with very minor amounts of black tourmaline, apatite, and beryl. The pegmatite is the youngest of the Red Creek complex lithologic assemblage and exhibits the least deformation.

### Younger Precambrian (Proterozoic)

#### Uinta Mountain group

The Uinta Mountains are dominated stratigraphically and structurally by the Uinta Mountain group (or Uinta quartzite of earlier studies). The range is essentially a large structural arch with this thick sequence of quartzites, argillites, and shales exposed by erosion along the core or axis of the fold. This immense pod-like mass of relatively homogenous metasediment imbedded in the earth's crust has acted as a single mass or unit in structural movements and accounts for the formation and west-east alignment of the Uinta Range (See Structure). The Uinta Mountain group can be traced from equivalent rocks in the Wasatch Mountains on the west for 200 miles to the east to Juniper Mountain in northwest Colorado. Geophysical data indicate its continuation for at least 15 miles east of these outcrops. The apparent north-south extent of the Uinta Mountain group is a belt about 30 to 50 miles wide.

The Uinta Mountain group rests with apparent unconformity on the contorted and faulted Red Creek complex. Locally the unconformable surface displays relief from a few to 100 feet, and regionally the relief probably is measurable in several hundreds of feet. Hansen (1955b, p.27) presents an excellent analysis of the classic concept of this surface by Powell (1876, p.139) in light of the evidence provided by detailed mapping of the present day.

The Uinta Mountain group consists of tan, pinkish but mainly red and reddish-brown siliceous sandstone, quartzite, and conglomerate with interbedded gray, green, red, and purple micaceous shale and argillite. Most of the sandstones are medium to coarse grained and, with larger grain size, grade into pebble and cobble conglomerates. Locally sandstones may grade into arkose. The Uinta Mountain group is dominantly quartzite and conglomerate in eastern Daggett County, but shale and argillite tongues appear more frequently to the west. The source of the coarse sediment apparently lies to the east and northeast, and material locally derived from the underlying Red Creek complex has been described from conglomerates of the Uinta Mountain group.

The red color of the sandstone and quartzite is due to a coating of ferric oxide which coats the sand grains but does not permeate the whole mass. The Uinta Mountain group is usually a dark red color on weathered surfaces and the entire Uinta Range and the canyons carved

in these rocks (Red, Swallow, and Lodore) are dominated by this somber, often forbidding hue. On fresh surfaces these quartzose sandstones are pinkish, tan, or white.

Excellent exposures of the shales and argillites that interfinger in the Uinta Mountain group can be seen in the bottom of Red Canyon downstream from the overlook near Green Lakes.

The thickness of the Uinta Mountain group was measured by Powell (1876, pp.142-144) and his figure of 12,000 or 13,000 feet as the average of two incomplete sections has been widely quoted. Hansen (1955b, p.27) measured as complete a section as is possible in Daggett County from the Uinta fault on the north to Browns Park on the south and found a thickness of 20,600 feet. The writer's reconnaissance of sections on Cold Spring Mountain, Moffat County, Colorado, a few miles east, indicates the total thickness of the Uinta Mountain group may reach 24,000 feet.

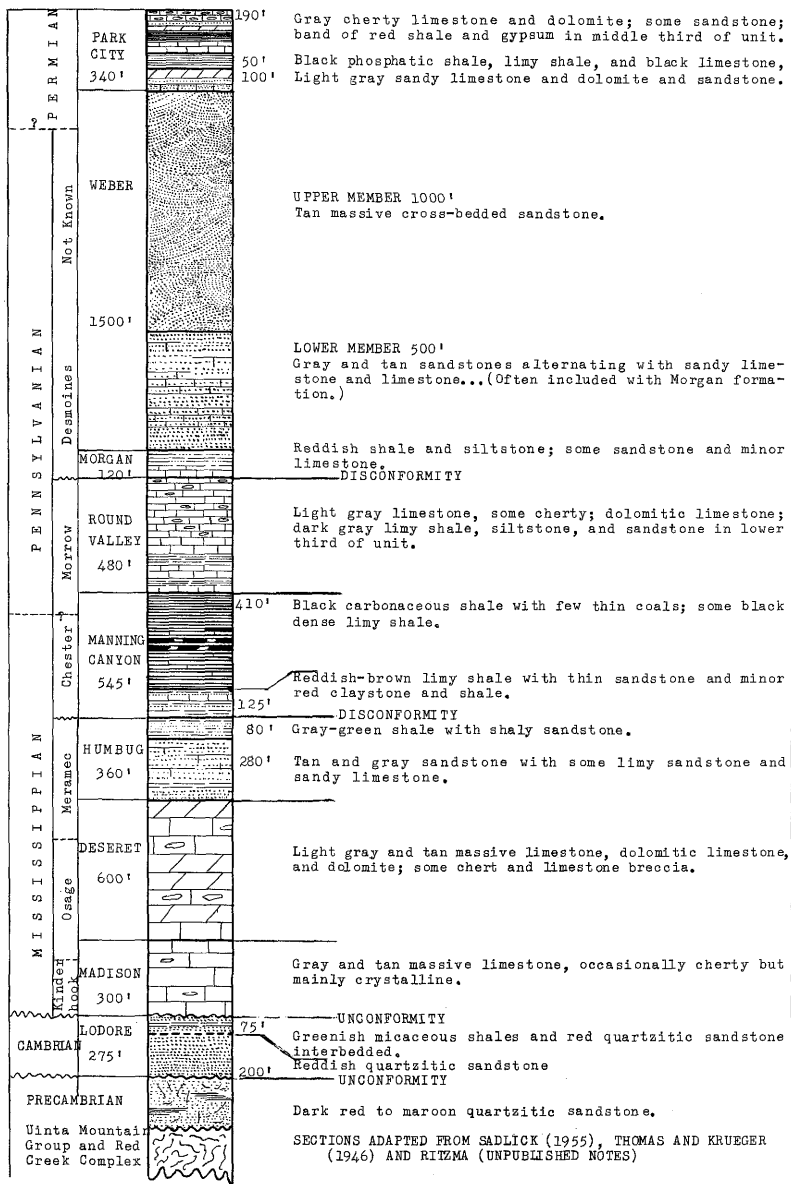
The age of the Uinta Mountain group has been arbitrarily assigned to the Proterozoic or "younger Precambrian" because of its unmetamorphosed state and the apparent unconformity between it and the underlying Red Creek complex. For such ancient sediments the shales and quartzites of the Uinta Mountain group are remarkably unaltered and unindurated. For that reason many early geological maps showed these rocks as Cambrian or often as young as Devonian in age.

In the eastern portion of the south flank of the Uinta Range the younger Precambrian Uinta Mountain group rocks are unconformably overlain by rocks of Middle(?) and Upper Cambrian age. On the north flank the Madison limestone of Mississippian age rests unconformably on the Precambrian.



Plate 1. The Palisades, Uinta Mountain group (lower left), and Madison limestone (upper right) dipping north at Uinta fault. Near Palisade campground on Vernal-Manila Road (Utah Highway 44).

- J. H. Rathbone -



COMPOSITE GENERALIZED SECTIONS OF EXPOSED PALEOZOIC ROCKS  
DAGGETT COUNTY, UTAH  
FIGURE 2

SECTIONS ADAPTED FROM SADLICK (1955), THOMAS AND KRUEGER (1946) AND RITZMA (UNPUBLISHED NOTES)

HRR 1957

## PALEOZOIC STRATIGRAPHY

### Cambrian System

#### Lodore formation

Rocks of Cambrian age crop out only in the extreme southeast corner of Daggett County, where they form a narrow belt of exposures between the Precambrian Uinta Mountain group of the core of the Uinta Mountains and the overlying Madison limestone of Mississippian age. These rocks dip southward toward the Uinta Basin and are the only Paleozoic formation of the south flank of the Uinta Mountains which lies wholly in Daggett County. On the north flank within the county boundaries, Cambrian rocks are not present and the Madison limestone rests directly on the Precambrian.

The Cambrian rocks of Daggett County occupy a position midway between two well-known Cambrian sections described in the geologic literature and are easily correlated. Six miles southeast of the Daggett County outcrops Cambrian exposures in the canyons of Dinosaur National Monument comprise the type section of the Lodore formation. The formation here is 450 feet thick (Untermann and Untermann, 1954) and consists of about 200 feet of basal quartzitic sandstone grading upward into alternating green and red shales and quartzitic sandstones. To the west of the exposures in the Monument, the upper beds were apparently removed by erosion prior to the deposition of the Mississippian Madison limestone; and the Lodore formation becomes progressively thinner with less of the upper shaly portion present. West of the Daggett County exposures Kinney (1951) measured and described 155 feet of Cambrian Lodore formation, consisting entirely of the basal quartzitic sandstone. It is this thin, entirely quartzitic sandstone section that is exposed adjacent to Utah Highway 44 en route from Vernal to Manila. Between the two previously mentioned measured sections, the Daggett County exposures average 275 feet in thickness and include 200 feet of the basal quartzitic sandstone and 75 feet of alternating reddish, rusty glauconitic sandstone and green micaceous, glauconitic shale. The basal sandstone beds are thicker and more massive, but become more thin bedded and shaly upward in the section. They are typically reddish-brown on a weathered surface and pink to tan in fresh exposures. The sandstone derives its rusty hue from surficial weathering of abundant glauconite. The age of the Lodore formation has been established as Upper Cambrian from fossils found in the upper shaly portion in the Dinosaur Monument sections. The lower quartzitic sandstone is presumably the same age but may range downward into the Middle Cambrian. No fossils have been noted in the Daggett County outcrops.

### Mississippian System

Mississippian formations are exposed on the north and south flanks of the Uinta Mountains in Daggett County. The exposures on the south flank are in the extreme southeast corner of the county, are of very small areal extent, and are not discussed here. On the north flank of the mountains, Mississippian formations are exposed in a mile-wide band from the west border of Daggett County eastward for some 15 miles, where they are faulted out against and under the Uinta fault. Because of this fault relationship the section be-

comes abbreviated eastward from Sheep Creek Canyon at Palisade Park where Utah Highway 44 crosses the outcropping Mississippian formations in a series of spectacular exposures.

Absence of rocks representing Ordovician, Silurian, and Devonian systems in Daggett County and the erosional unconformity noted at the top of the Cambrian Lodore formation implies that during this vast span of 100 million years of Paleozoic time the area was part of a low structurally positive area. Beds representing these systems either were eroded off or were not deposited prior to early Mississippian time. Since these units are missing over wide areas of northeast Utah, southern Wyoming, and northwest Colorado, the positive area was widespread. However, there is no marked angular discordance between the Lodore and the basal Madison, and the Madison has no prominent basal sandstone or conglomerate. The implication is that the rate of uplift of the positive area was very slow and that it was of small vertical magnitude. The Madison Sea transgressed across terrain of very low relief.

### Madison limestone

The Madison limestone forms the base of the Mississippian series in Daggett County. It is about 300 feet thick where measured in Sols Canyon and maintains this thickness and a uniform lithologic character throughout the county. The Madison is a light gray to tan massively bedded limestone, usually crystalline, but sometimes containing cherty layers and a little dolomite or dolomitic limestone. It is sparingly fossiliferous in this area but does contain thin beds of limestone consisting mainly of crinoid fragments and a scattering of broken corals. Occasionally specimens of Spirifer centronatus, a diagnostic Madison brachiopod, are found.

To the west of Daggett County, the Madison thickens rapidly, but to the east thicknesses decrease. Along the Uinta fault east of Clay Basin and eastward into Colorado are several masses of limestone dragged up along the overriding thrust sheet. Most of these have been greatly altered from crushing and recrystallization. They have resemblance to the Madison but can only be tentatively identified as such.

The Madison limestone derives its name from the Madison River in Montana and is a very widely recognized rock unit in the Rocky Mountain region.

### Deseret limestone

The Deseret limestone is a unit which closely resembles the underlying Madison and is often separated from it with difficulty. In section 11, T. 2 N., R. 18 E., in Sols Canyon the formation is 600 feet thick and consists of massive beds of light gray to tan limestone, dolomitic limestone, and dolomite. The Deseret typically has a higher percentage of dolomite than the Madison and also contains more cherty beds and limestone breccias.

The Deseret maintains a uniform thickness to the west but thins rapidly to the east of Daggett County in sections in northwestern Colorado. The formation derives its name from the type section exposed on Deseret Peak in the Oquirrh Mountains west of Salt Lake Valley.

### Humbug formation

In Sols Canyon the Humbug formation has been found to be 360 feet thick by Sadlick (1955) and Anderman. Here the formation contains a lower member, 280 feet thick, mainly limy sandstone and sandy limestone, and an upper member, 80 feet thick, which is mainly shale and shaly sandstone. The thin bedding and varied yellow-gray, gray-green and reddish-brown colors of the Humbug are in strong contrast to the underlying gray, massive Deseret and Madison. Some slabby or thin sheet-like beds of the Humbug are beautifully ripple-marked, and a sandy oolitic limestone occurs in the lower third of the section.

There is a minor unconformity evident in the upper beds of the Humbug apparently marking a period when these beds were exposed to sub-aerial erosion before deposition of the overlying Manning Canyon shale commenced.

The Humbug formation was named for the Humbug Mine (now known as Uncle Sam Mine) near Eureka, Utah, in the Tintic District southwest of Salt Lake City.

### Mississippian - Pennsylvanian Systems

#### Manning Canyon formation

Overlying the Humbug formation at Sols Canyon Sadlick (1955) and Anderman measured 545 feet of beds which comprise the Manning Canyon formation. The lower 135 feet of the formation is rusty brown limy shale, thin sandstone, and red clay overlain by 400 feet or more of black carbonaceous shale and black dense shaly limestone. A few thin coal beds occur with the black shale. The Manning Canyon formation appears to straddle the Mississippian-Pennsylvanian age boundary with no discernible lithologic break. Fossil spores from a coal bed 230 feet below the top of the Manning Canyon section in Sols Canyon are Chesterian in age (Sadlick, 1955) thus making at least 60 per cent of the formation Mississippian in age. The Mississippian-Pennsylvanian boundary probably occurs in poorly exposed, unfossiliferous black shales in the upper third of the formation.

The basal 125 feet of the Manning Canyon formation at Sols Canyon and elsewhere in the eastern Uinta Mountains is reddish in color and contains a considerable amount of moderately coarse clastics. Sadlick (1955) postulates that this represents a reworked regolith (fossil soil) and material derived from a regolith (possibly an eroded upland area) which was transported and mixed with clastics and marine limestone deposits to the west. Thus the lower portion of the Manning Canyon has an origin similar to the Molas formation of the Paradox Basin of southeastern Utah and has been correlated by some geologists with the Molas. The Manning Canyon, however, appears to be somewhat older than the Molas and the erosion surface on which the Molas is developed appears to correspond more closely with the unconformity and time break present at the contact of the Round Valley limestone and Morgan formation (Pennsylvanian).

The thin coals present in the section in Sols Canyon were recognized early in the geologic exploration of the region and are notable as one of the few occurrences of coal in the Paleozoic rocks of western United States. This is in sharp contrast to the abundant coal of the Carboniferous (Mississippian-Pennsylvanian) of eastern United States.

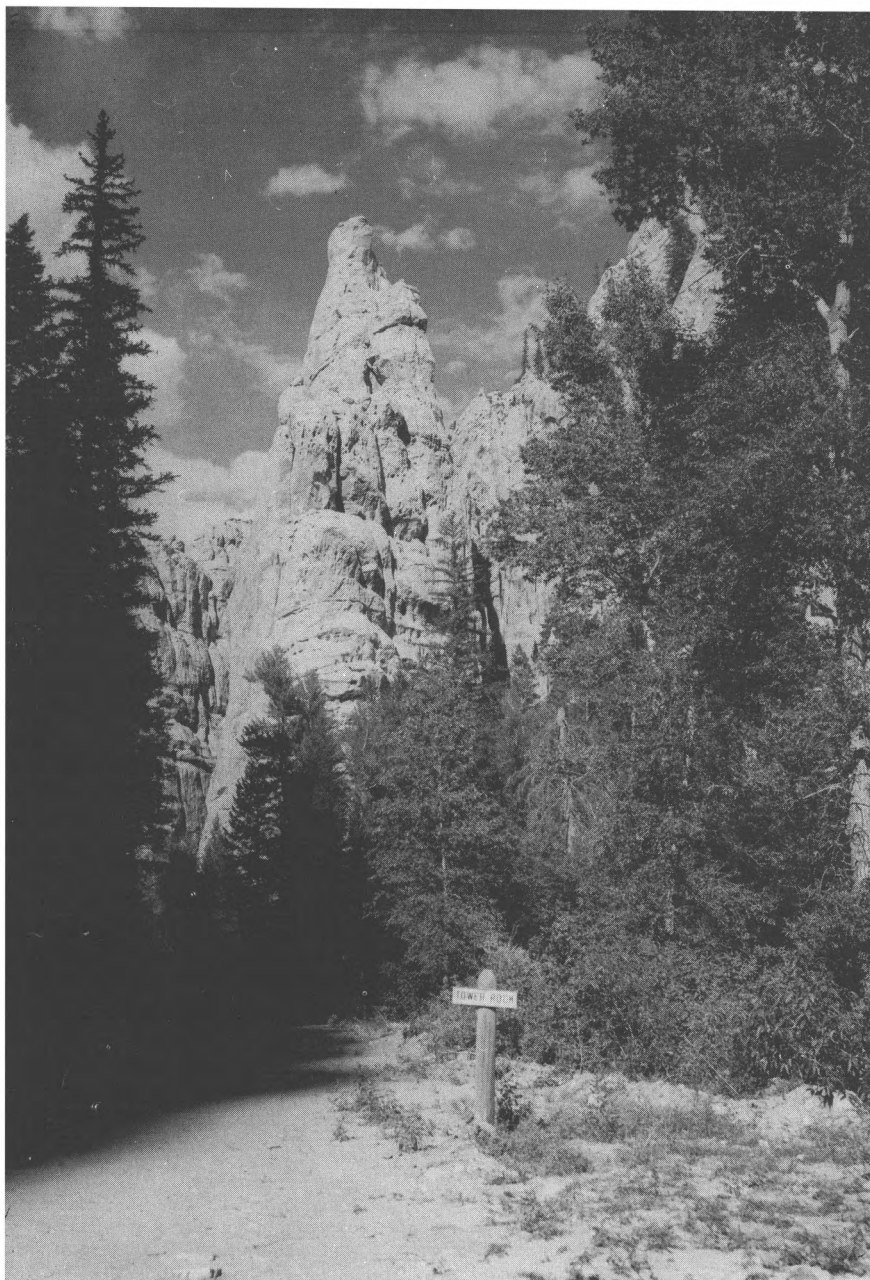


Plate 2. Tower Rock in Sheep Creek Canyon (Weber sandstone)  
Vernal-Manila Road (Utah Highway 44). - U.S. Bureau of Reclamation

The Manning Canyon formation is faulted out against the Uinta fault in section 24, T. 2 N., R. 19 E., and does not crop out east of this point except where tentatively identified in a very large fault slice in sections 29 and 30, T. 3 N., R. 23 E. This block of limestone, black bituminous limestone, and petroliferous limy shale measures 1-1/2 miles long and 1/8 to 1/2 mile in width. Fossils collected by the writer from this fault slice were identified by Mackenzie Gordon, Jr. of the U. S. Geological Survey and classified as probably Chesterian in age. This, in addition to the distinctive lithology, leads to nearly certain identification of the fault slice as Manning Canyon. These rocks are the farthest east identifiable Paleozoic rocks outcropping along the north flank of the Uinta Mountains in Utah. Anderman (1955, p.92) found a fauna in this same fault slice which indicated that it was Round Valley. It is probable that large fragments of both formations are found in juxtaposition.

The Manning Canyon formation derives its name from exposures in Manning Canyon, in the Oquirrh Mountains, five miles northwest of Fairfield, Utah.

### Pennsylvanian System

Pennsylvanian formations in Daggett County are exposed in a broad band from the west boundary of the county eastward for some 25 miles where they are faulted out against and under the Uinta fault. The progressive termination of successively younger Pennsylvanian beds against the fault occurs in a distance of 3-1/2 miles east and north of the Green River at Hideout Canyon.

As has been previously discussed, sedimentation was continuous across the Mississippian-Pennsylvanian boundary and only a tentative delineation can be made in the upper third of the Manning Canyon formation.

### Round Valley limestone

The Round Valley limestone derives its name from its type section in Round Valley east of Morgan, Morgan County, Utah. The unit is readily identified and persistent over wide areas of northeastern Utah and southwestern Wyoming. In the past this limestone has been included in the overlying Morgan formation or has been referred to as a Morrowan age equivalent of several formations present and named in areas distant from the Uinta Mountains. Detailed studies by Sadlick (1955) clarify the position of this unit in the section and justify its classification as a separate formation. As measured in Sols Canyon, the Round Valley is 480 feet thick, about 300 feet of which is dense, light gray limestone that is often cherty and dolomitic. The lower third of the formation contains lesser amounts of limestone and more shale, siltstone, and fine-grained sandstone.

The Round Valley limestone is an apparent lateral equivalent of the Belden formation of northwestern Colorado, and as it is traced eastward the limestone phase of the formation is gradually replaced by limy shale and shale.

Most of the shales of the Round Valley have a gray or gray-green color with small amounts of red or purple present. Some of the limestone beds contain abundant gray and red nodular chert,

and many fossil brachiopods are replaced by jasper and are exceptionally well preserved. Often large numbers of these fossils can be collected in the beds of dry stream courses.

The Round Valley limestone is faulted out against the Uinta fault a short distance west of Hideout Canyon where the fault crosses the Green River. However, one large block of limestone dragged up along the thrust is exposed east of the Green River in NW1/4, section 2, T. 2 N., R. 21 E., and is tentatively identified as Round Valley. Several other blocks of limestone exposed in fault slices farther east may also be Round Valley limestone.

#### Morgan formation

Overlying the Round Valley (Morrowan) and separated from it by a disconformity is the Morgan formation of Des Moinesian age. The absence of beds of Atokan (Lampassan) age between the Round Valley and Morgan marks a widespread break in deposition and, possibly, in some areas, an angular unconformity in northeastern Utah.

The Morgan formation has been the subject of considerable redefinition, and the term has been used over a wide area of northeastern Utah and adjacent states to describe a variable sequence of beds sometimes exceeding 2000 feet in thickness. In Daggett County, the term Morgan in past usage has been applied to the sequence of beds including the Round Valley limestone previously discussed upward through the section to the base of the massive cross-bedded sandstone of the Weber formation and including the lower 500 feet (lower member) of the Weber as defined by Sadlick (1955). Conforming to this redefinition the Morgan is restricted in this report to the 120 foot sequence of reddish shale, siltstone, sandstone, and limestone between the Round Valley limestone and the Weber sandstone.

The type section of the Morgan is near the town of Morgan, Morgan County, Utah.

#### Weber sandstone

The Weber sandstone is named from outcrops in Weber Canyon in the Wasatch Mountains. In Daggett County this resistant unit gives rise to much spectacular scenery, particularly in the narrows of Sheep Creek Canyon southwest of Manila.

The formation comprises some 1500 feet of beds, the lower third of which is alternating tan and cream sandy limestone and sandstone. The upper 1000 feet of the formation is white, cream and tan, massive, cross-bedded sandstone.

The lower member has in the past been included as a part of the Morgan formation, but is here included in the Weber to conform with the most recent correlations of Sadlick (1955). The massive sandstones of the Weber have often been called quartzite, but the high degree of induration and dense character of these rocks are attributable to crystalline calcareous cement and not to metamorphism. Solution of this cement by ground water or stream action leaves the Weber a very soft, friable sandstone. The term sandstone rather than quartzite has acquired nearly universal usage in reference to the Weber in recent years. The Weber sandstone is a complete or partial equivalent of the Tensleep sandstone of Wyoming, the Wells quartzite of western Wyoming and Idaho, and the Coconino sandstone of central Utah.

## Permian System

### Park City formation

The Park City formation is named from its type section exposed at Park City, Wasatch County, Utah. The formation is widely recognized throughout northeastern Utah and adjacent Colorado, Idaho, and Wyoming. The upper two thirds of the Park City formation is equivalent to the Phosphoria formation of Idaho and western Wyoming.

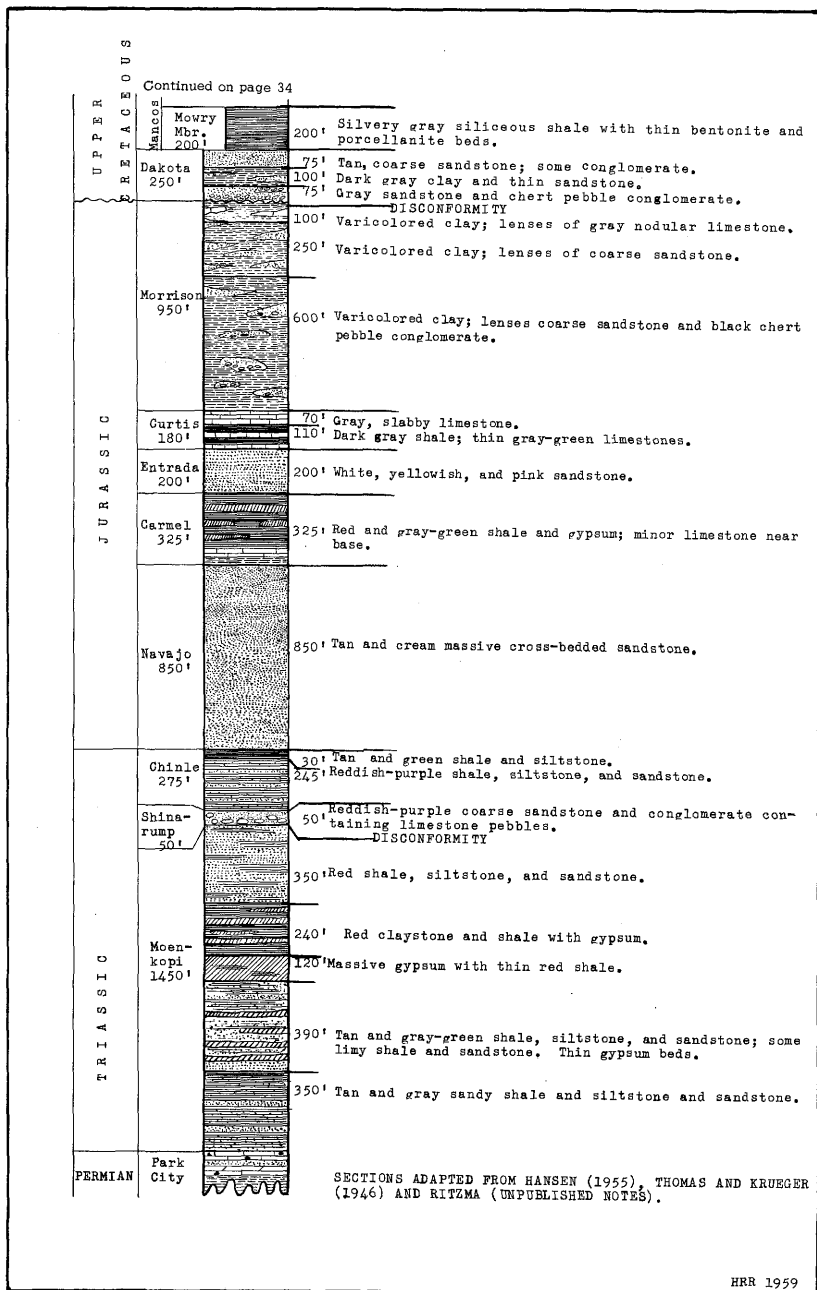
In exposures in Daggett County, the Park City formation is 340 feet thick and contains a great variety of rock types. The lower third of the formation is primarily buff to brown sandstone, some of which resembles the underlying Weber. However, there is a discernible minor erosional break at the base of the Park City formation, and the sandstones above this break contain chert and calcite geodes and display considerable lateral and vertical variation in shaly, calcareous and quartzitic characteristics.

The middle third of the Park City formation contains varicolored shales, siltstone and sandstone, thin gypsum beds, dense cherty limestone, black limy and carbonaceous shale, and black oolitic phosphate rock. This sequence is extremely variable and individual beds cannot be traced along the outcrop for any great distance. This portion of the Park City formation is correlative with the lower part of the phosphatic shale member of the Phosphoria formation of western Wyoming (Cheney, 1957a).

The upper third of the Park City formation consists of limestone and dolomite with some gray shale and bedded chert. The limestones and dolomites are very cherty, dense, and resistant with the chert occurring as nodules or layers, or disseminated throughout. Where steep dipping, this portion of the unit forms knife-edge hogbacks, and with less steep dips forms jointed slabby dipslopes. The upper limestones are abundantly fossiliferous and often coquina. Cheney (1957a) has correlated the upper third of the Park City formation of Daggett County with the Rex chert member of the Phosphoria formation of southwestern Wyoming and southeastern Idaho.

The alternating resistant and nonresistant bedding of the formation leads to a characteristic tier-like profile on cliffs with the resistant beds forming ledges and the less resistant soft slopes.

Phosphate rock in the Park City formation has been studied extensively for possible economic development. The Daggett County area does not appear to have beds of phosphate rock of sufficient concentration and thickness to support commercial mining at present in competition with areas closer to transportation and market and where the phosphate content of the rock is as great or greater.



COMPOSITE GENERALIZED SECTIONS OF EXPOSED MESOZOIC ROCKS, DAGGETT COUNTY, UTAH  
FIGURE 3-A

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## MESOZOIC STRATIGRAPHY

Mesozoic rocks are exposed in a broad band from west to east across nearly the entire length of Daggett County. The most complete exposures are present along a north-south line through the county seat of Manila and can be seen along the route traversed by Utah Highway 44. Geological markers have been set along this road as a convenient guide to the geology of the area.

Westward from Manila, the younger Mesozoic formations are faulted out by the Henrys Fork fault, and to the east the older formations are faulted out against and under the overriding Uinta fault. The youngest Mesozoic formation, the Ericson sandstone member of the Mesaverde formation, disappears under the low-dipping Uinta fault a short distance east of Clay Basin.

Nomenclature of the Mesozoic rocks of Daggett County has always presented difficult problems, and formation names have been imported from all sides to describe the outcrops. The names used have been strongly influenced by the direction in which the adjoining correlative areas lie; and, because of the geographic isolation of the Daggett County outcrops, correlations have necessarily been extended across long distances with no outcrops and only sparse deep well data intervening.

The terminology used here for Triassic and Jurassic formations is that which is in common usage in northeastern Utah along the south flank of the Uinta Mountains and in east-central Utah. Cretaceous formation names are a synthesis of terminology used in northeastern Utah and in the adjacent Rock Springs uplift of southwestern Wyoming.

### Triassic System

#### Moenkopi formation

The Moenkopi formation is about 1450 feet thick as measured in the Manila area. This thickness remains constant to the west, but to the east the formation was only 895 feet thick where penetrated in the Clay Basin gas field.

The Moenkopi is composed mainly of shale, siltstone, and fine-grained sandstone with considerable amounts of interbedded gypsum and gypsiferous shale. The lower half of the formation in Daggett County is notable for its lack of red color, this portion being gray, gray-green, buff, and brown. The upper Moenkopi beds are typical of the colorful Triassic red-bed sequences that are so much a part of the scenery of western United States.

The Moenkopi is a soft, often poorly exposed formation except for the resistant upper sandstone and siltstone member. Often it is involved in complex, small scale faulting, particularly in gypsiferous parts of the section. Where resistant beds above the Triassic form a protective capping, the Moenkopi may be the lowest portion of a spectacular colorful cliff. It is from this type of exposure that the Flaming Gorge was named.

The lower drab-colored portion of the Moenkopi is correlative with the Dinwoody formation of Wyoming, and the whole formation of

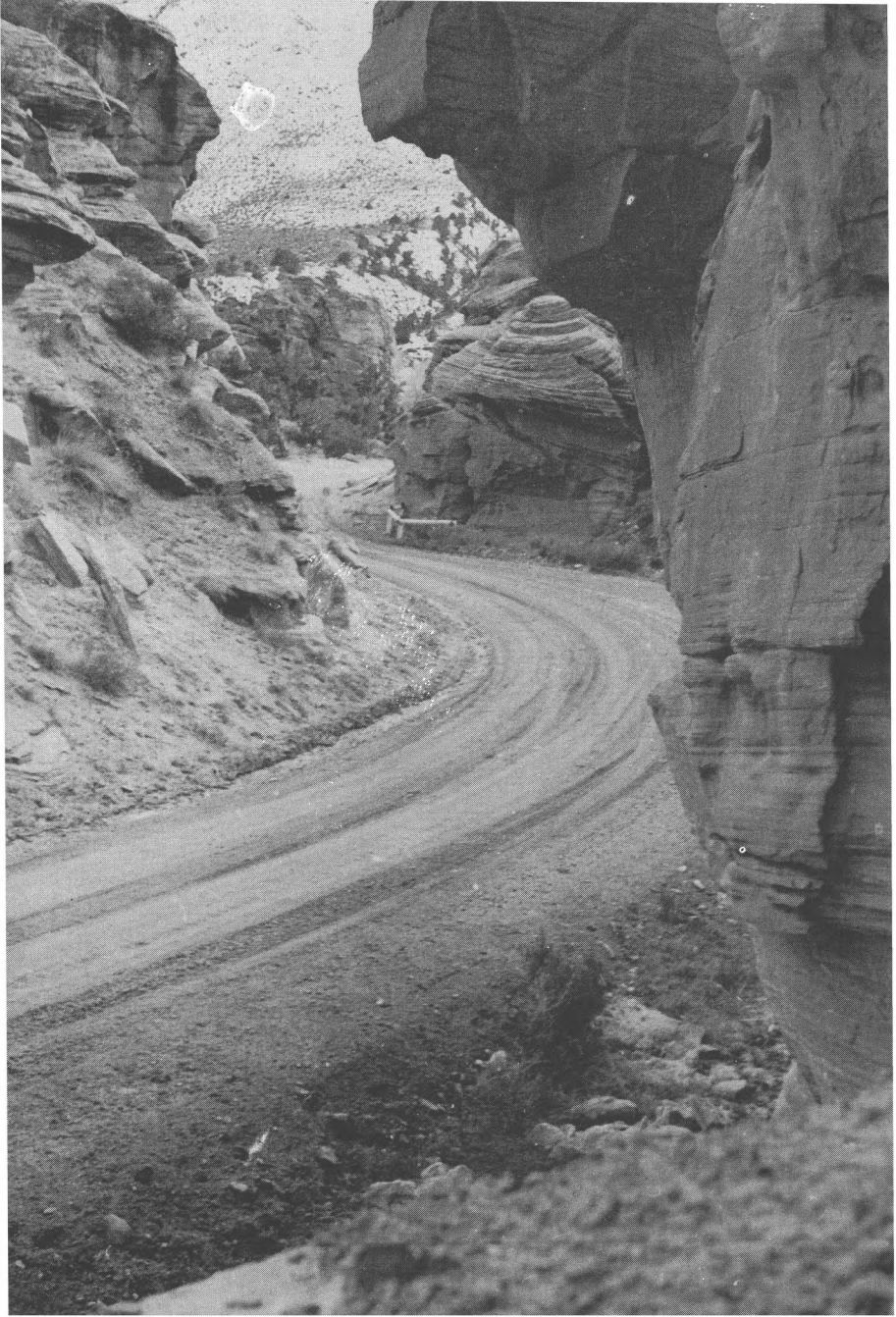


Plate 3. Navajo sandstone in Sheep Creek cut, Vernal-Manila Road (Utah Highway 44).

- J. H. Rathbone -

the Manila area has been called Woodside in some geological reports. The Moenkopi derives its name from the type section at Moenkopi Wash, Grand Canyon, Arizona.

#### Shinarump conglomerate member of Chinle formation

In Daggett County, the Shinarump conglomerate is a tan to purple, medium- to coarse-grained sandstone with lenses of limestone, quartz, and shale pebble conglomerate which varies in thickness from ten to nearly one hundred feet. Occasionally small concentrations of silicified fossil wood and carbonaceous matter can be found, but not in the abundance for which the Shinarump became noted in the uranium areas of southern Utah.

The surface on which the Shinarump was deposited displays considerable relief, and the wide thickness variation is accounted for by lenses of sandstone and conglomerate deposited in channels cut into the underlying Moenkopi. Most of the pebbles and small cobbles in the conglomerates are limestone, generally angular blocks, slabs, and chips with slightly rounded edges.

Although extensively prospected, the Shinarump of this area has yielded only minor indications of uranium mineralization.

#### Chinle formation

The Chinle formation consists of dark red, reddish-brown, and purple-red claystone, shale, siltstone, and sandstone with thin stringers of purplish shale chip and quartz and limestone pebble conglomerate. The formation is 275 feet thick in the Manila area and was 230 feet thick where penetrated at Clay Basin. The upper 15 to 35 feet of the Chinle is conspicuously tan, gray-green and apple-green in color. These beds immediately beneath the massive porous Navajo sandstone have been leached of their iron minerals by waters circulating through the sandstone. This "leached zone" or the "apple-green marker" is similar in appearance and genesis to beds at the top of the Chinle throughout wide areas of the West, particularly in the uranium country of southeastern Utah.

Like the Moenkopi and Shinarump, the formation name Chinle was first applied to rocks in southeastern Utah. In the Manila area, particularly in Flaming Gorge, this formation forms a striking vertical cliff below the massive Jurassic Navajo sandstone.

#### Jurassic System

##### Navajo sandstone

Some of the most spectacular scenery in Daggett County has been carved from the cliff and ridge forming Navajo sandstone. The formation is 850 feet thick in the vicinity of Flaming Gorge, thickens to nearly 1000 feet in the west of the county and was found to be 775 feet thick where penetrated at Clay Basin to the east.

In areas of gentle dip such as Flaming Gorge, the Navajo forms a massive cliff, and eastward, where steep dipping, it forms the curved knife-like Boar's Tusk ridge. Still farther east the Navajo stands vertical where turned up against the Uinta fault and forms the eight mile long, wall-like Dutch John Ridge.

The Navajo is a nearly pure sandstone consisting of fine-grained, well-sorted, rounded, clear quartz grains loosely cemented by calcareous clay. On fresh faces the formation is white or creamy colored, and on weathered surfaces tan with a pale brownish-pink cast. Coatings of desert varnish (manganese oxide) often impart a streaked polished mahogany hue to weathered faces. The Navajo is massively cross-bedded, but this characteristic is often masked by jointing, strong dissection on dipslopes and surficial staining from weathering. Massive cross-bedding, absence of fossils, and complete lack of any evidence of water-laid deposition point to a desert sand dune mode of deposition.

#### Carmel formation

Above the Navajo sandstone and forming a colorful separation between the Navajo and Entrada sandstones is the Carmel formation, about 325 feet thick in the Manila area. The Carmel formation is an eastward extension of the thick marine Twin Creek limestone of western Wyoming and north-central Utah, but only the lower 50 feet of the formation in the Manila area is typical of the marine Twin Creek lithology. This portion of the section consists of gray, oolitic and coquina, blocky and slabby limestone interbedded with dark-gray, clayey shale. The limestones are resistant and often form a slabby cap on the underlying Navajo sandstone. Fossils in the limestone indicate a Middle through basal Upper Jurassic age.

The upper 275 feet of the Carmel consists of red, green, and gray-green silty gypsiferous shale with several thick beds of gypsum and reddish gypsiferous shale. This upper portion of the Carmel is soft and nonresistant, poorly exposed and, because of its structural incompetency, is involved in small-scale faulting, squeezing, and flowage between the massive sandstones above and below.

The Carmel-Navajo contact is in places marked by a sandstone-limestone pebble conglomerate with sandy limy cementation, apparently marking a local disconformity. Elsewhere the contact is sharp but not marked by angular discordance or evidence of erosion. To the east, the Carmel thins rapidly and was only 110 feet thick where drilled at Clay Basin. The marine phase was almost entirely absent here.

#### Entrada sandstone

The Entrada is a massive, very fine to fine-grained sandstone unit about 200 feet thick in the Flaming Gorge area. Although more thinly bedded than the Navajo, it is strongly cross-bedded and apparently represents a return of desert conditions of deposition after a brief invasion of the Twin Creek (Carmel) Sea. The Entrada is more colorful in appearance than the Navajo, with a range from cream color through yellow, pink, reddish-orange, and red. Coloration is not uniform and seldom persistent. Beds are often mottled and variations of color grade laterally through units and often across bedding planes. Color in the Entrada appears to be a secondary feature formed by the leaching out of coloration and cement and redeposition and recementing of the sandstone by circulating ground water. However, the uppermost sandstone of the Entrada, 80 to 85 feet thick, is almost everywhere a colorful reddish-orange hue and is the only regionally persistent unit of the formation. To the east, the Entrada has decreased to a thickness of only 100 feet where penetrated in the Clay Basin gas field. To the west, it

is the lithologic equivalent of the thick Preuss formation of northern Utah and southeastern Idaho.

### Curtis formation

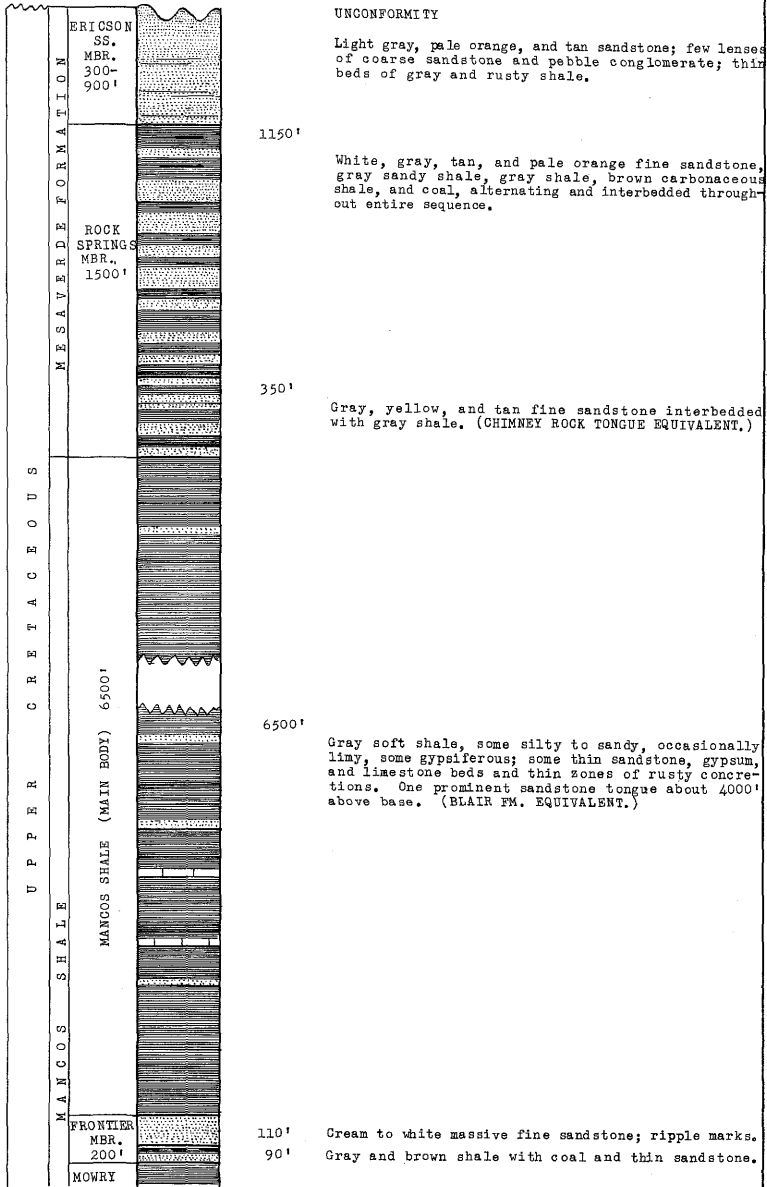
A sharp color and lithologic change marks the Entrada-Curtis contact and a return to Jurassic marine deposition. The Curtis formation is the lithologic equivalent of the Stump formation of western Wyoming and southeastern Idaho.

Throughout Daggett County the Curtis maintains a uniform thickness of about 180 feet and is divisible into two distinct members on the basis of lithology and weathering characteristics. The lower 110 feet consists of thin-bedded siltstone and fine-grained sandstone alternating with lenses and thin beds of nodular concretionary limestone. The color of this member ranges from gray-green through dark olive-green, and it is abundantly glauconitic. Also very abundant throughout the unit is the tapered cigar-shaped fossil "cuttle bone" of the Jurassic belemnite, Pachyteuthis densus. This lower member is nonresistant and forms a soft debris-mantled slope.

The upper 70 feet of the Curtis is a light gray, blocky, thick-bedded, often sandy limestone which sometimes takes on a greenish hue from abundant glauconite. Interbedded with the limestone are thin beds of greenish, fine-grained glauconitic sandstone. The brachiopod Kallirhynchia myrina is found very abundantly throughout this upper limestone, with lesser occurrence of the pelecypod, Camptonectes ballistriatus. The upper unit is quite resistant and forms flatirons and sharp hogback ridges between the Curtis sandstone-siltstone unit below and the soft clays of the Morrison formation above.

### Morrison formation

In the Manila area the Morrison formation is 950 feet thick and consists of banded varicolored clays, mainly pastels of red, lavender, purple, green, and olive-green with discontinuous lenses of sandstone, pebble conglomerate, and some fresh water limestone. The formation along the north flank of the Uintas is not dissimilar from typical Morrison lithology throughout vast areas of the Rocky Mountains and is readily recognized by the distinctive varicolored outcrops and miniature badland topography carved in the soft clays. The uniform character of the Morrison over a truly vast area implies depositional environment of remarkable stability over a great length of geologic time. The lithology suggests a vast flood plain with moderate rainfall, temperate to sub-tropical climate and gentle relief. The sandstone and conglomerate lenses represent the channel deposits of streams that meandered across this vast plain and the occasional limestones represent sedimentation in fresh water lakes that waxed and waned from time to time on the surface of the plain. The vegetative and animal life that flourished in this environment is evidenced by frequent finds of fossil wood and dinosaur remains in the Morrison. Such fossil remains are usually silicified and found as litter or "lag" of chert, jasper, or agate fragments on slopes of weathered clay. Some nearly complete silicified dinosaur skeletons have been found in places in South Valley near Manila in what appears to be a small scale dinosaur "graveyard" similar to the spectacular Dinosaur Quarry remains northeast of



Continued from page 28

COMPOSITE GENERALIZED SECTIONS OF EXPOSED MESOZOIC ROCKS  
DAGGETT COUNTY, UTAH  
FIGURE 3-B

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Vernal, Utah, in Dinosaur National Monument. Gastroliths, dinosaur "gizzard stones," are often found weathered out of the upper half of the Morrison in Daggett County. These rounded, highly polished stones apparently were swallowed by dinosaurs and utilized as grinders in their massive digestive systems.

Most of the conglomerate in the Morrison occurs in the lower half of the section and consists of lenses of loosely cemented black and gray chert pebbles from a few to a hundred or more feet thick. The upper half of the formation contains most of the sandstone lenses. Limestone occurrences are uncommon and are limited to the upper 150 feet. The thickness of the Morrison decreases to the east and was only 650 feet where drilled at Clay Basin.

Stokes (1955, p.84) has considered the upper third of the Morrison as defined here as Lower Cretaceous in age, possibly equivalent to the Cedar Mountain formation of east-central Utah.

### Cretaceous System

The Cretaceous rocks of Daggett County mark a gradual shift in depositional environment from the flood plain sediments of the Morrison through the nonmarine sediments of the Dakota and into the 6900-foot thick dominantly marine Mancos shale sequence. Generally, the Dakota represents a transition from nonmarine to marine sedimentation with the overlying Mowry member of the Mancos marking the beginning of a long period of marine shale deposition broken only by a relatively thin sequence of sandstone, coal, and carbonaceous shale in the Frontier member immediately above the Mowry.

An extensive belt of growing mountains lie, in general, to the west and had intermittently advanced eastward across Nevada and western Utah through Triassic and Jurassic time. The sands, coal, and carbonaceous shale of the Frontier member of the Mancos shale represent a tongue of coarser sediments swept eastward from this upland area as a pulse of regional uplifting gave rise to a brief period of offshore marine, shallow-water marine, and nonmarine deposition. There followed a long period of marine shale deposition represented by the 6500-foot thick main body of the Mancos shale. Further mountain building episodes to the west caused the Cretaceous seas to regress eastward and another tongue of nonmarine sediments transgressed eastward. These are the sandstones, shales, and coals of the Mesaverde formation. Only the lower portion of the Mesaverde has been preserved in Daggett County, the upper portion having been eroded off and unconformably overlapped by younger Tertiary beds. Study of outcrops and well samples of these absent formations where they are present in adjacent Wyoming and Colorado indicates that Cretaceous marine deposition in the Daggett County area ceased with the Ericson sandstone member of the Mesaverde and that after that time coarse clastics and coal were deposited in a nonmarine environment. The source of the sediment lies to the west in an uplifted area in what is now the Western Wyoming Fold-Thrust Belt and the Wasatch Mountains of north-central Utah.

### Dakota formation

The Dakota formation in the Manila area is about 250 feet thick and consists of a basal conglomeratic sandstone, a middle claystone and shale unit, and an upper sandstone. Superficially this threefold

subdivision resembles the Dakota-Fuson-Lakota formational subdivisions of the Cloverly group of Wyoming, and this terminology has been applied to this rock sequence at Clay Basin and elsewhere in the vicinity.

The basal member of the Dakota formation is a grayish, medium-to coarse-grained, cross-bedded sandstone containing abundant lenses of chert pebble conglomerate and layers of soft gray gypsiferous claystone and shale. The sandstone and conglomerate is often quartzitic, vitreous, and porcellaneous, and contains abundant fragmental wood and finely disseminated charcoal. This lower unit varies greatly in thickness and rests disconformably on the underlying Morrison. Relief on this contact may exceed 50 feet where the conglomerate has been deposited in channels cut into the Morrison.

The middle shale member of the Dakota consists of soft gray gypsiferous and bentonitic claystone and shale with interbedded shaly sandstone. This unit contains abundant charcoal disseminated throughout as a sooty film or specks and as flattened twig and stem impressions. The upper member is a cream to tan, medium- to coarse-grained, cross-bedded sandstone containing occasional lenses of conglomerate and zones of rusty "cannonball" concretions.

The entire Dakota formation, and particularly the two sandstones at base and top, forms a prominent ridge or hogback along most of its length of outcrop. Regional correlation tied to the recent restudy by Reeside (1955) of the Vermilion Creek section in nearby northwestern Colorado indicates that the Dakota formation of Daggett County is wholly Upper Cretaceous in age. Stokes (1955, p.84) has proposed that the upper third of the Morrison formation of this area is lower Cretaceous in age.

The formation maintains an average thickness of 200 to 250 feet along the outcrop and thins to less than 200 feet at Clay Basin. Here natural gas is produced from the upper sandstone member at an average depth of 5760 feet.

#### Mancos shale

Mowry shale member: Above the Dakota and separated from it by a sharp, well-defined contact is the distinctive Mowry member of the Mancos shale. The bulk of this member is dark-gray to black, thin-bedded, splintery, platy, siliceous shale alternating with occasionally thick beds of bentonite and porcellanite and thin dense vitreous sandstone. The Mowry contains abundant fish scales and weathers to a characteristic silvery-gray color. Slopes of Mowry shale are almost devoid of vegetation.

In the Manila area the Mowry is 200 feet thick with a marked thinning eastward to Clay Basin, where the unit was only 140 feet thick.

Frontier sandstone member: The Frontier member of the Mancos averages about 200 feet in thickness in the Manila area and thins to the east. About 160 feet of beds attributable to the Frontier have been drilled in the Clay Basin gas field where the upper sandstones are productive of gas.

In the Manila area the formation consists of a lower shaly portion about 90 feet thick and an upper sandstone portion about 110 feet thick. The lower shaly portion weathers to a brown color and

is carbonaceous and sandy. A coaly zone occurs about 15 feet below the upper sandstone. The upper unit consists of white to tan fine-grained, well-bedded sandstone that weathers blocky or platy. Many of the bedding planes are prominently ripple-marked.

The Frontier member of the Mancos shale in Daggett County is a thin correlative of the thick Frontier formation of western Wyoming and is apparently correlative with the Ferron sandstone of east-central Utah. It grades upward into the main body of the Mancos shale.

Main body of Mancos shale: The main body of the Mancos shale, about 6500 feet thick in Daggett County, is a monotonous sequence of gray to black, soft shale of marine origin. Much of the shale is gypsiferous, and weathered slopes are often covered with glistening platy gypsum crystals. Throughout the Mancos silty and sandy zones are encountered and some portions of the formation are quite limy.

The Mancos shale forms a broad strike valley one to three miles wide across Daggett County from Manila on the west to Clay Basin on the east. The valley is known by various names--Lucerne Valley, Antelope Flats, and Clay Basin. Except where overlain by gravels or deeply weathered and reworked by streams, the Mancos shale supports scant vegetation.

One prominent sandstone is present in the Mancos about 4000 feet above the base. At the Green River this unit is about 100 feet thick. It thickens westward and thins to a feather edge six miles east. This sandstone unit is probably equivalent to the basal sandstone tongue of the Blair formation of the Rock Springs uplift.

#### Mesaverde formation

The Mesaverde formation in Daggett County is divisible into two members, the lower Rock Springs member about 1500 feet thick, and the upper Ericson sandstone member from 300 to 900 feet in thickness.

The Mesaverde formation and the underlying Mancos shale have an intertonguing relationship, and the contact between the two cannot be drawn everywhere at the same horizon. The top of the Mancos migrates upward toward the base of the Ericson sandstone from west to east across Daggett County and is drawn at the base of the Ericson at Clay Basin. The Rock Springs member, therefore, is seen to inter-tongue with the Mancos with a transition from nonmarine sandstone, shale, and coal in the west to marine shale in the east. The base of the Ericson appears to be nearly constant, and variation in the thickness of the member is largely due to the top of the formation being an unconformity.

The Rock Springs member contains a prominent, massive, fine-grained sandstone at the base which is correlated with the Chimney Rock sandstone tongue of the formation in its type area to the north. This sandstone is about 450 feet thick at the Green River, 350 feet thick at Spring Creek gap, tongues out rapidly eastward, and is not recognized at Clay Basin. The Chimney Rock tongue forms the crest of the south ridge of the arcuate double hogback known as The Glades, east of the Green River. The upper 1150 feet of the Rock Springs consists of thin shaly sandstones interbedded with soft brown shale and bituminous coal. This nonresistant portion of the section forms the floor or trough of The Glades.

The Ericson sandstone member of the Mesaverde consists of gray, tan and brownish-orange, massive sandstone broken by a few shaly and coaly intervals. Largely of fluvial origin, the Ericson is medium- to coarse-grained and contains a small amount of pebble conglomerate.

Study of the content of these conglomerates indicates that their source was to the west in a structurally positive area where Jurassic limestones (Curtis and Carmel) and possibly older formations were exposed to erosion. The Ericson forms the crest and back slope of the north ridge of The Glades.

The upper boundary of the Ericson is an unconformable surface overlapped by the Hiawatha member of the Wasatch formation of Paleocene-Eocene age. Over the county this erosion surface has about 600 feet of relief, but only locally in eastern Daggett County are there strong discordant dips between the Ericson and Wasatch. Elsewhere the two formations display remarkably conformable dip. Relief on the unconformity seldom exceeds 100 feet within a mile, although locally large channels have been scoured deeply into the top of the Ericson and filled with gritty sandstone and conglomerate constituting the basal conglomerate of the Hiawatha member of the Wasatch.

The Mesaverde formation is exposed from a point 1-1/2 miles west of the Green River for 20 miles to the east along the Utah-Wyoming border. The outcrop terminates at the west end against the Henrys Fork fault and the formation disappears to the east beneath the low-dipping Uinta fault.

## CENOZOIC STRATIGRAPHY

Cenozoic rocks are exposed widely over Daggett County and may be subdivided into three main classifications: early Tertiary, late Tertiary, and Quaternary. The early Tertiary rocks range in age from Paleocene through mid Eocene and consist of the Wasatch and Green River formations. These rocks are the detrital material deposited on the flanks of the rising Uinta Mountains mixed with the flood plain and lake sediments of the adjacent Green River basin. The late Tertiary formations are the Bear Mountain erosion surface (late Miocene?) and its thin veneer of sands and gravels and the Browns Park formation proper which was deposited on the Bear Mountain surface. The Browns Park (late Miocene or Pliocene) consists of a variety of lithologies: locally derived conglomerates, siltstone, tuffaceous sandstone, and tuff. The tuffaceous material originated as airborne volcanic ash. Quaternary deposits include glacial moraines and outwash deposits in the upper reaches of high mountain valleys and a great variety of alluvium, bench gravels, talus and landslide debris, dunes, alluvial fans, and other deposits throughout the county.

### Tertiary System

#### Paleocene and Eocene - (Early Tertiary)

The Paleocene and Eocene rocks of Daggett County and adjoining areas of Colorado and Wyoming have been subdivided as follows:

#### EOCENE

Bridger formation  
Laney shale member of Green River formation  
Cathedral Bluffs member of Wasatch formation  
Tipton tongue of Green River formation  
Hiawatha member of Wasatch formation (upper portion)

#### PALEOCENE

Hiawatha member of Wasatch formation (lower portion)  
"Fort Union formation"

A complex interfingering relationship exists between the Bridger formation and the members of the Green River and Wasatch formations. This interfingering complexity results from three factors which acted in combination throughout Paleocene and Eocene time: (1) intermittent and gradual growth of the Uinta Mountains with (2) accompanying downwarp of the Green River Basin adjacent to the growing mountain range, and (3) the fluctuation of the large fresh-water lake that persisted in the Green River Basin through much of Eocene time. The complex relationship of these formations has been graphically depicted in Figure 4.

The boundary between the Paleocene and Eocene cannot be drawn on the basis of lithology, a pronounced break in deposition or angular discordance. It is apparent that deposition was nearly continuous throughout this span of geologic time.

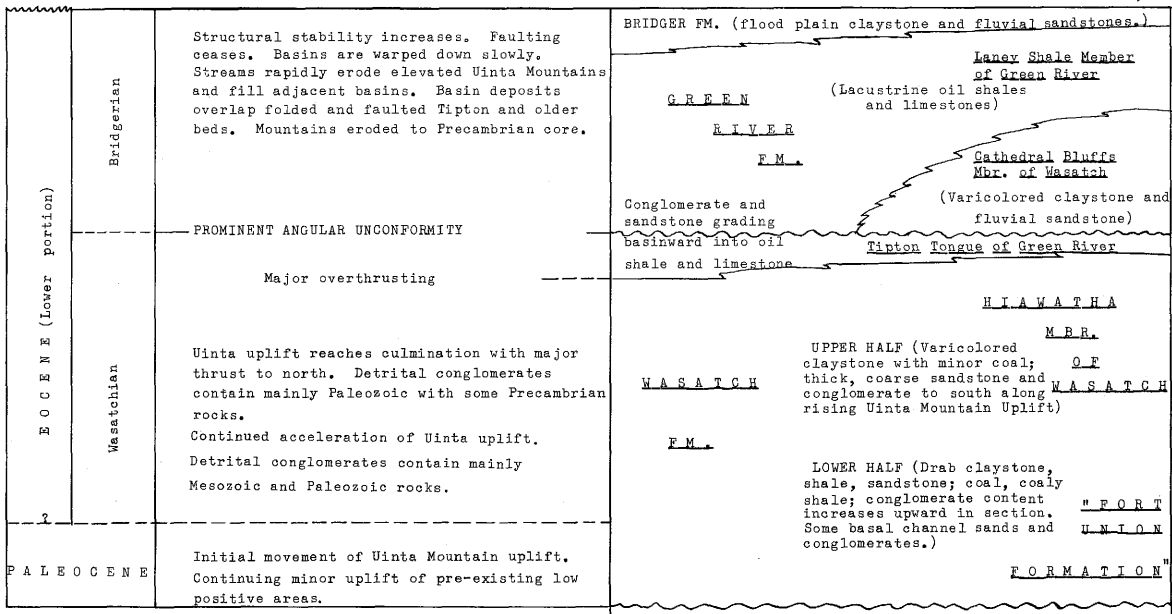
YOUNGER EOCENE ROCKS  
NOT PRESENT

STRUCTURAL AND STRATIGRAPHIC EVENTS

WEST OF  
MANILA

FORMATIONS AND LITHOLOGY  
NORTH OF CLAY BASIN

VERMILION CREEK  
MOFFAT CO., COLO.



CRETACEOUS - MESAVERDE FORMATION

HRR 1959

DIAGRAMMATIC SECTION SHOWING RELATIONSHIP OF EARLY TERTIARY FORMATIONS

AND STRUCTURAL EVENTS ALONG NORTH FLANK OF UINTA MOUNTAINS.

FIGURE 4

Hiawatha member of the Wasatch formation: The Hiawatha, as exposed in Daggett County and in adjacent Wyoming, consists of up to 3500 feet of beds of considerable diversity. The lower 1200 to 1800 feet of the Hiawatha is drab colored and consists of gray to grayish-yellow claystone, siltstone, and lenticular sandstone and conglomerate. Coarse sandstones and conglomerates are found filling channels scoured in the top of the Ericson sandstone member of the Mesaverde in several localities, but this basal Wasatch conglomerate is not everywhere present. Coarse sandstone and conglomerate becomes more common upward in the drab portion of the Hiawatha, indicating an increase in the tempo of the growth of the Uintas. The drab portion of the Hiawatha also contains considerable carbonaceous shale and small amounts of low-grade coal.

The upper half of the Hiawatha member of the Wasatch is more colorful in appearance and is marked by massive lenticular conglomerates. Transition from drab colored Wasatch to brightly colored Wasatch is generally gradual and occurs through about 400 to 500 feet of section. Often the transition is marked by an abrupt change to massive channel sands and conglomerates. One such sandstone-conglomeratic zone of distinctive brownish-orange color is particularly well developed around the north flanks of Clay Basin anticline where it forms the bulk of the upper portions of Richards and Tepee Mountains. Over all, the upper half of the Hiawatha is composed of varicolored, often strikingly banded, claystone, mainly in shades of red with lesser amounts of gray-green, green, orange, and yellow. Massive lenses of coarse, poorly sorted sandstone and conglomerate occur haphazardly throughout the variegated portion of the Wasatch. These sandstones and conglomerates originated in stream channels or as alluvial fans built out from the growing Uinta Mountains.

Fossils indicate that the lower half of the Hiawatha is at least partly of Paleocene (Fort Union) age and that the upper portion ranges upward into lower Eocene time (Wasatchian). The formation receives its name from the type section in Echo and Weber Canyons in the Wasatch Mountains, northeastern Utah. The term Hiawatha comes from the Hiawatha gas field, Moffat County, Colorado, 25 miles east of Daggett County.

Tipton tongue of the Green River formation: The Tipton tongue is a prominent member of the lacustrine Green River formation recognized widely in southwestern Wyoming and northwestern Colorado. It derives its name from Tipton station on the Union Pacific Railroad in Sweetwater County, Wyoming. The Green River formation receives its name from the exposures at Green River, Wyoming, 35 miles to the north.

The Tipton was deposited during a relatively brief but widespread expansion of the fresh-water lake that occupied the western portion of the Green River (Bridger) Basin of southwestern Wyoming. The relation of the Tipton to the Wasatch members above and below and the main body of the Green River formation is depicted in Figure 4.

Two areas of Tipton outcrop are present in Daggett County. One small patch in section 3, T. 3 N., R. 25 E. in the extreme northeast of the county is a part of more extensive Tipton exposures in adjacent Colorado and Wyoming. Here the Tipton is mainly limy sandstone of probable beach origin. Several beds of algal

and calcareous tufa concretions also suggest shallow shore line deposition. Considerable cobble and boulder conglomerate is interbedded with the lacustrine and beach beds, thus indicating that the shore line of the Tipton Lake lay close to the foot of the mountains. The Tipton here is about 180 feet thick.

In western Daggett County the Green River formation is broken by a prominent unconformity. The beds below the unconformity are tentatively identified as the Tipton tongue of the Green River and the beds above as the main body of the Green River formation which here is equivalent to the Cathedral Bluffs member of the Wasatch and Laney shale of the Green River as mapped farther east. This relationship is shown in Figure 4. The Tipton in western Daggett County is very conglomeratic and contains boulders up to five feet in diameter. Thickness ranges from 50 to 300 feet.

Cathedral Bluffs member of Wasatch: The Cathedral Bluffs member of the Wasatch consists of varicolored, but mainly red, claystone and siltstone with lenticular sandstones and conglomerate. It represents the replacement of lake deposits with flood plain deposits as the Tipton stage of the Green River Lake shrank in size and retreated westward into the Green River (Bridger) Basin. This relationship is shown in Figure 4. The Cathedral Bluffs as such does not crop out in Daggett County, but rocks equivalent to this member occur in the Green River formation west of Manila. The Cathedral Bluffs member is structurally significant since the core of the Uinta Mountains was generally breached to the Precambrian during the early stages of its deposition. The Cathedral Bluffs is marked by a notable flood of cobbles and boulders of the Precambrian Uinta Mountain group quartzites, and the striking red coloration of the member and its equivalents undoubtedly was derived to a large degree from these reddish source rocks.

Green River formation (main body): The Green River formation derives its name from its type section at Green River, Wyoming, 35 miles north of Daggett County. At the type section the Green River formation is primarily a lake deposit and contains thick sequences of thinly laminated oil shales. In Daggett County the environment in which the Green River formation was deposited was the shore line of the lake with the high, structurally active Uinta Mountains rising sharply from the lake shore. The Green River formation here consists of generally light colored, but sometimes reddish, massive conglomerates with interbedded quartzose sandstones and thin oolitic and concretionary limestones. Also present in small amounts are lignitic and gypsiferous shales. The conglomerates occasionally contain boulders up to 10 feet in diameter. The sandstones and limestones of the Green River are abundantly fossiliferous, containing typical clam and snail faunas of the Green River formation.

The conglomeratic nature of the Green River in the Manila area indicates that the margin between the lake shore and the mountain front was narrow and fluctuating. The conglomerate facies disappears rapidly to the north and is replaced by typical flood plain and lake deposits of the basin. The total thickness of the Green River formation in the Manila area (not including the Tipton tongue) exceeds 2500 feet. The great conglomerate mass of Phil Pico Mountain, considered by many writers to be Bridger formation equivalent, is included here in the Green River formation, conforming to the correlation of Anderman (1955, p.131).

The Green River formation of the Manila area contains the equivalents of the Cathedral Bluffs member of the Wasatch formation and the Laney shale and Morrow Creek members of the Green River formation of southern Wyoming.

**Bridger formation:** The Bridger formation, a drab sequence of gray-green claystone, shale, tuffaceous sandstone, and thin clayey limestones, does not crop out in Daggett County. It covers extensive areas north of Manila in Wyoming where it has been carved into drab badlands. The Bridger formation represents a shift to structural stability in middle Eocene time, and the establishment of broad low-lying flood plains. It is the youngest Eocene formation in the area.

#### **Miocene and Pliocene (Late Tertiary)**

Succeeding the depositional pattern of early Tertiary time with its episodes of mountain building and basin down warping, late Tertiary time was a period of relative structural stability during which the Uinta Mountains were extensively eroded, and gently sloping erosion surfaces (pediments) and flood plains extended outward for long distances from the remaining isolated mountain masses into the adjacent basins. Great volumes of volcanic ash, presumably from the then active volcanic areas of the Pacific Northwest, Idaho, and Nevada, drifting with the prevailing west winds, blanketed the basins of the Rocky Mountain area and buried the mountain ranges nearly to their summits.

**Gilbert Peak erosion surface:** The oldest and most extensive of the late Tertiary erosion surfaces on the north flank of the Uintas is the Gilbert Peak surface of Oligocene or Miocene age. This great pediment surface sloped from the highest peaks of the Uinta Range outward into the adjoining basins, and on its surface was deposited the widespread Bishop conglomerate. Many remnant areas of this surface occur in Daggett County, but the Bishop conglomerate, as such, is not present. Thin gravel and quartzose sand veneers many areas of the Gilbert Peak surface, but generally the surface has developed only a sparse mantle of sandy soil.

The Gilbert Peak surface occurs in Daggett County along the crest of the high Uintas from Deadman Peak at an elevation of 12,200 feet and forms the crest of the range from that point eastward for 25 miles. Here the peneplain has descended to elevations of 9500 to 9800 feet. Most of the mountain tops along this crest line are nearly flat or gently rolling and are well-preserved remnants of the ancient topography of Miocene time. Only a few knobs such as Leidy Peak and Trout Peak rise several hundred feet above the old surface.

Other remnants of the Gilbert Peak surface occur in Daggett County north of the Green River on Goslin Mountain, Mountain Home, and the Owyukuts Plateau between Clay Basin and Browns Park. No areas of the Gilbert Peak surface have been shown on the geologic map of the county accompanying this bulletin. The surface receives its name from Gilbert Peak along the crest of the Uintas some 18 miles west of Daggett County.

**Bear Mountain erosion surface:** In late Miocene time, a second extensive erosion surface developed along the flanks of the Uinta. This was the Bear Mountain surface which truncated the Bishop con-

glomerate, the Gilbert Peak surface, and cut more deeply into the older rocks of the Uinta Mountains. Like the Gilbert Peak surface, it is variably veneered with gravel and sand and supports only sparse soil cover. Development of the Bear Mountain surface came as a response to changing climatic conditions (Bradley, 1936).

Remnants of the Bear Mountain surface occur across Daggett County from its western to easternmost extremities. All of these are shown on the geologic map accompanying this bulletin and are taken largely from the definitive work of Bradley (1936) with additions from Hansen (1955). The surface was named by Bradley from its development on Bear Mountain north of Red Canyon. Areas of Bear Mountain surface in southeast Daggett County are from reconnaissance mapping and air photo interpretation by this writer. Relating these areas with Bear Mountain surface was suggested by Bradley (1936, p.181) who stated: "The Browns Park and Summit valleys seem to be the counterparts of the long valleys which, in the central and western parts of the range, were cut below the Gilbert Peak surface and opened out onto the Bear Mountain surface where its pediment portion was extensively developed." The erosion surfaces and conglomerates south of Summit Valley have been correlated with the Gilbert Peak surface and the Bishop conglomerate (Kinney, 1955). It appears, however, that the situation is quite complex with the Gilbert Peak surface and the Bishop conglomerate present but truncated in part by the Bear Mountain surface which is overlain in turn by the Browns Park formation with its basal conglomerate and a variable thickness of light colored tuffaceous sandstone. One or more younger erosion surfaces are developed on top of the whole sequence. The erosion surface in southernmost Daggett County is the Bear Mountain surface veneered by younger gravel and lag gravels and with a few remnant patches of Browns Park tuffaceous sandstone.

Browns Park formation: The Browns Park formation was deposited on the Bear Mountain erosion surface apparently as a response to another climatic change. At about the same time, a great volume of volcanic ash borne on westerly winds from Nevada, Idaho, northwestern Wyoming, and the Pacific Northwest drifted into the area. It filled topographic depressions, blanketed the old erosion surfaces and flood plains, and buried the mountains nearly to their summits.

The Browns Park and its equivalent formations are widely distributed in discontinuous patches in adjacent southern Wyoming and northwestern Colorado. Most extensive deposits are where the formation has been protected by capping gravels or lava flows or where it has been faulted down into a protected trough. From these protected outcrops where thicknesses as much as 1800 feet are known, it can be readily concluded that the Browns Park formation once blanketed the entire region and that it accumulated to a considerable thickness. Throughout northeastern Utah and adjacent Colorado and Wyoming, the Browns Park is principally light colored volcanic ash (tuff) and ashy (tuffaceous) sandstones with many local assemblages of other rock types such as limestone, quartzites, and conglomerates. To a great degree the formation was wind-deposited with minor lake and stream deposits admixed.

In Daggett County, the Browns Park formation, as such, is confined to Browns Park proper although the gravel and conglomerate veneer of the Bear Mountain surface might possibly be considered as part of the basal conglomerate of the formation. Bradley (1936, p. 184) states: "This basal conglomerate may be only in

part the shifting gravel mantle that covered the surface while it was being cut. Probably the greater part of it, like the Bishop conglomerate, was a deposit formed in response to a shift in the climate toward greater aridity. But, unlike the Bishop conglomerate, it was followed by further deposition, which continued until the rest of the Browns Park formation had been laid down."

Within Browns Park the formation was deposited under complicated circumstances, and the formation at its type locality is much more diverse than in other areas of outcrop. The Park itself was a pre-existing topographic basin or valley in which was deposited lake beds, river sands and gravels, valley fill, and alluvial fan and landslide deposits built out from the valley edges. All are intimately mingled with wind-blown volcanic ash and dune sand. At the same time, the valley itself was the focal point of the collapse of the Uinta Mountain Arch and was being complexly down-faulted. Deposition continued, in fact it was accelerated by these structural events and attendant drainage disruptions and changes. A "hodge-podge" of lithologies resulted with numerous unconformities within the formation.

Most common lithologies observed are: drab clays and siltstones, some finely laminated, some loess-like in texture and weathering characteristics; pale orange friable siltstone and sandstone; yellow and chalky white tuff and tuffaceous sandstone; conglomerates with fragments ranging from pebbles to large boulders in size. Hansen (1957) states: "The tuffs and clays retain remarkable uniformity over considerable distances, but the sands and conglomerates thin markedly from the sides toward the axis of the valley."

One sizeable unconformity within the Browns Park formation can be observed in Browns Park in Daggett County and traced eastward into Colorado. It is apparent the older Browns Park beds were faulted, folded, and down-warped and that younger beds were quickly deposited unconformably on top of the older beds. The process possibly took place several times or was more or less continuous throughout the time of Browns Park formation deposition.

The age of the Browns Park formation is not known from fossil evidence in the Daggett County area, but age determination based on fossils found in Colorado and Wyoming place the age as early through medial Miocene (Carey, 1955).

#### Quaternary System

Since the deposition of the Browns Park formation in Miocene time, erosion with extensive removal of older rocks has been the principal geological process. The process was greatly accelerated by the work of glaciers in Pleistocene time.

#### Pleistocene glacial deposits

During the Ice Ages, the Uinta Mountains were extensively glaciated. Prior to that time the mountains had approximately the same elevation as they do today, but their slopes were much gentler and their summits more subdued. Apparently in the high Uintas the rolling terrain of the old Gilbert Peak and Bear Mountain erosion surfaces had been preserved with only minor modification. The

glaciers formed in the headwaters of the major drainages and in these catchment areas the ice accomplished most of its erosive work. Into the old rolling upland terrain of the High Uintas, the glaciers scooped large amphitheater-like basins or "cirques" and scoured long U-shaped valleys that descended basinward. Along the valley sides the glaciers deposited elongate ridges of ill-sorted rock and soil debris called "lateral moraines." Where the glaciers of two or more basins joined, the lateral moraines coalesced to form "medial moraines." At the end of the glacier, "terminal moraines" were formed. The melt water of the glacier-fed streams swept great volumes of sediment and debris down the valleys, and these deposits are termed "outwash." Moraines are a poorly sorted mixture of clay, sand, gravels, and boulders and form rough, hummocky terrain. Outwash is generally well-sorted stream-laid clay, silt, sand, and gravel.

The principal catchment areas for glaciers in Daggett and adjacent Summit Counties now form the headwaters of Burnt Fork, Sheep Creek, and Beaver and Carter Creeks. Eastward from that point the elevation of the Uinta Range apparently was not great enough to support the conditions needed to supply and sustain glaciers.

Atwood (1909) found evidence for two periods of glaciation in the Uinta Mountains; but later, Bradley (1936) found three distinct stages which he termed, from oldest to youngest: Little Dry, Blacks Fork, and Smiths Fork. The Blacks Fork stage corresponds to Atwood's "older epoch" and the Smiths Fork stage to Atwood's "younger epoch." The oldest or Little Dry stage of glaciation is represented

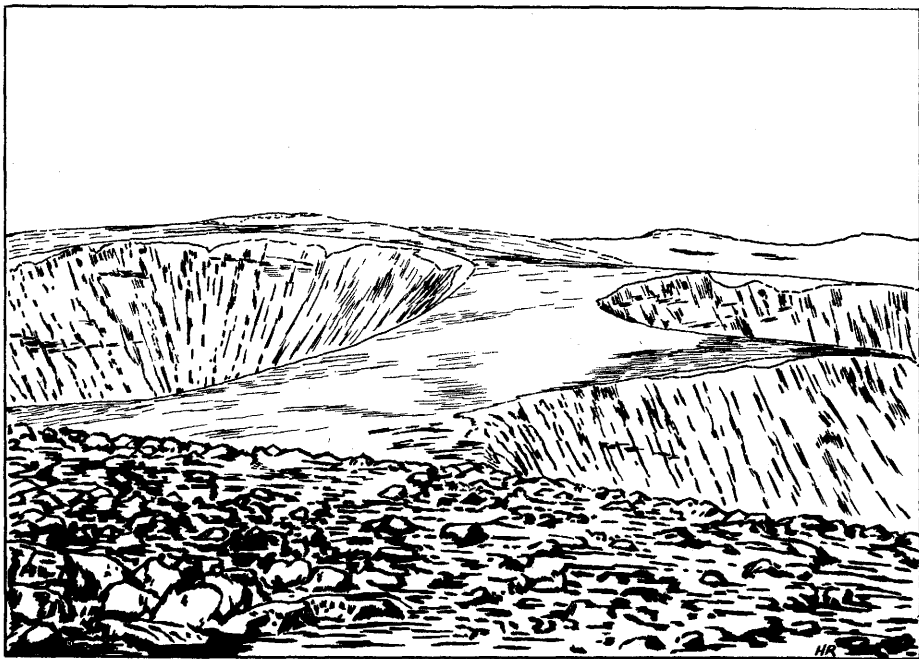


Plate 4. Glacial cirques cut into gently rolling Gilbert Peak erosion surface, an excellent example of "biscuit board" topography. Headwaters of Sheep Creek, southwest Daggett County.

- After photograph-Atwood, U.S.G.S. Prof. Paper 61 -

in the vicinity in only one place by what Bradley (1936, p.194) described as, "This great accumulation of moraines between Burnt Fork and the Middle Fork of Beaver Creek, which makes up the greater part of a barren group of hills locally known as the 'Bald Range,' appears to be the combined deposit left by glaciers of the Little Dry stage that came down Henrys Fork, the West and East Forks of Beaver Creek, and Burnt Fork." This is in sections 17, 18, 19, and 20, T. 3 N., R. 17 E., Summit County.

The catchment area and valley of the Burnt Fork glacier system show evidence of both the Blacks Fork and Smiths Fork stages of glaciation. The other drainage areas show evidence of only the Smiths Fork stage. It is possible that all areas supported glaciers during both of the latter stages but that the glaciers of the Smiths Fork stage erased the evidence of earlier glaciers in the Sheep Creek and Beaver-Carter Creek drainages.

Atwood (1909, p. 66) summarized the glaciated areas of Daggett County as follows:

NAME OF CANYON	Burnt Fork	W. Fork Sheep Cr.	E. Fork Sheep Cr.	Beaver- Carter Cr.
Size of catchment area (Square miles)	9.00	4.00	4.00	6.50
Average elevation of floor of catchment area	10,500'	10,500'	10,000'	10,000'
Average elevation of ice action in catchment area	11,500'	11,300'	10,500'	11,000'
Average elevation of bounding walls of catch- ment area	1,000'	600'	500'	700'
Average thickness of ice in catchment area	500'	500'	600'	600'
Maximum thickness of glacier	700'	800'	1,000'	600'
Length of glacier (miles)	11.00	6.25	7.50	6.00
Elevation of lower limit of glacier	8,800'	8,500'	8,000'	8,200'

#### Other Pleistocene and Recent deposits

Quaternary deposits other than those of glacial origin are the many diverse kinds of alluvium, valley fill, bench gravels, alluvial fans, and flood plain deposits found along the Green River and its tributaries in Daggett County. Deposits formed of talus and landslide material are found along hillsides and valley walls at many places in the county. Stationary and active sand dunes are found at several localities on the flood plain of the Green River. On the map accompanying this bulletin these separate types have not been differentiated and only the larger areas have been shown.



Plate 5. Flaming Gorge from the north looking down the Green River.  
- U.S. Bureau of Reclamation -

## S T R U C T U R E

The location of Daggett County along the north flank of the Uinta Mountains brings the structural configuration of the rocks in the county almost completely under the influence of the large regional Uinta Mountain Arch. Only a few traces of the structural features which existed before the rise of the Uintas are discernible today, and the structural features younger than the Uinta Mountain Arch are actually those which took shape as the gigantic arch "relaxed" or collapsed.

### FOLDS AND FAULTS

Figure 5 shows the most important folds and faults in Daggett County. The structure of the areas north of the Uinta fault is exceptionally well exposed and readily mapped. South of the Uinta fault most significant exposures are confined to the beds of the Precambrian Uinta Mountain group. In the eastern half of the county the attitude of these beds is easily seen on the surface and in aerial photographs, and the structure here is known in considerable detail. Forest cover and glacial deposits have prevented similar detailed coverage of the western area of Precambrian exposures.

#### Folds

##### The Uinta Mountain Arch

The axis of the Uinta Mountain Arch extends across Daggett County from west to east in a gently curving arc which trends more to the southeast as it passes into Colorado. That the oldest rocks in the Uinta Range, the Red Creek complex, are not exposed along the axis of the Uinta Mountain Arch but rather on its northern flank is a structural paradox that may be related to a combination of the following factors: complex thrust relationships between the Red Creek complex and the Uinta Mountain group, profound thickness changes in the Uinta Mountain group, and the possibility that the Red Creek complex may not be older than the Uinta Mountain group but may be a part of the Uinta Mountain group strongly altered by localized intrusions.

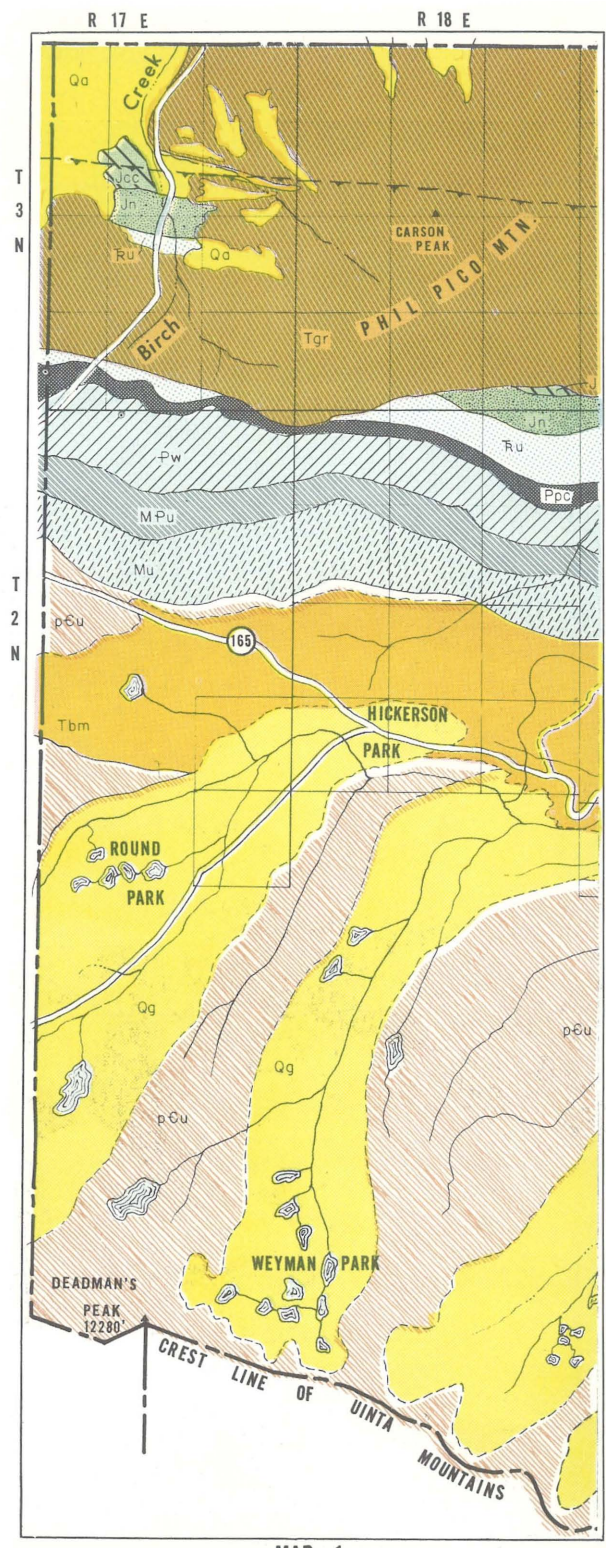
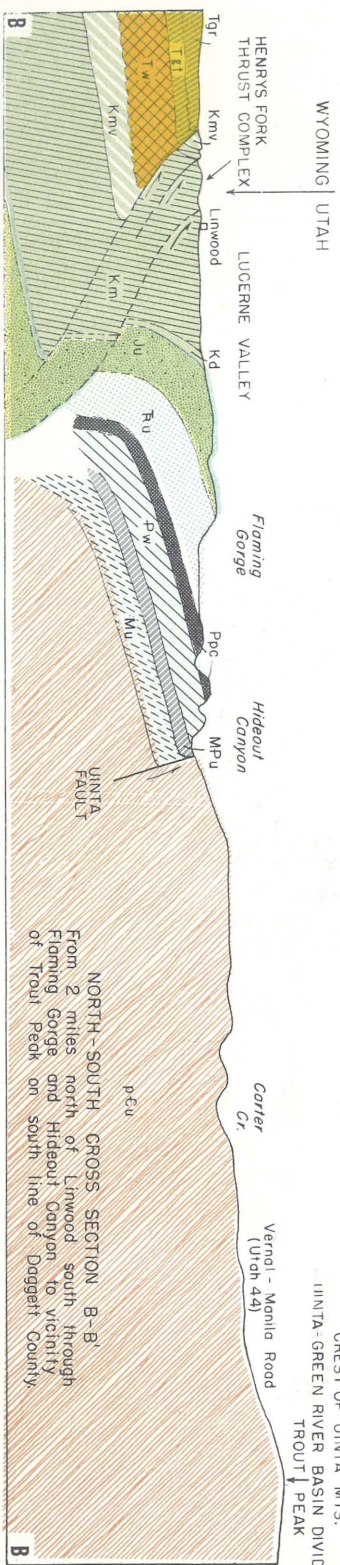
A considerable body of evidence is accumulating to support the latter view, that the Red Creek complex is composed of metamorphic equivalents of the Uinta Mountain group. The salient points of this evidence are summarized as follows:

1. The basal contact of the Uinta Mountain group, rather than being generally obscure, is more a gradational contact with an almost imperceptible change from unmetamorphosed quartzose, micaceous sandstone (Uinta Mountain group), through intermediate gradations to vitreous quartzite and mica schist (Red Creek complex) which also grade one into the other. The gradational zone varies from a few to more than 100 feet in width.
2. Within areas of Red Creek complex outcrop, the succession of rock types is generally from quartzite to mica schist to epidiorite and amphibolite, or from least metamorphosed to most metamorphosed to igneous rocks in the inner "core" of the metamorphosed area.





Colored Scene No. 1. Looking southwest up Sheep Creek Canyon from face of enclosing hogback about two miles west of where hogback is breached by the stream to form Sheep Creek Gap.



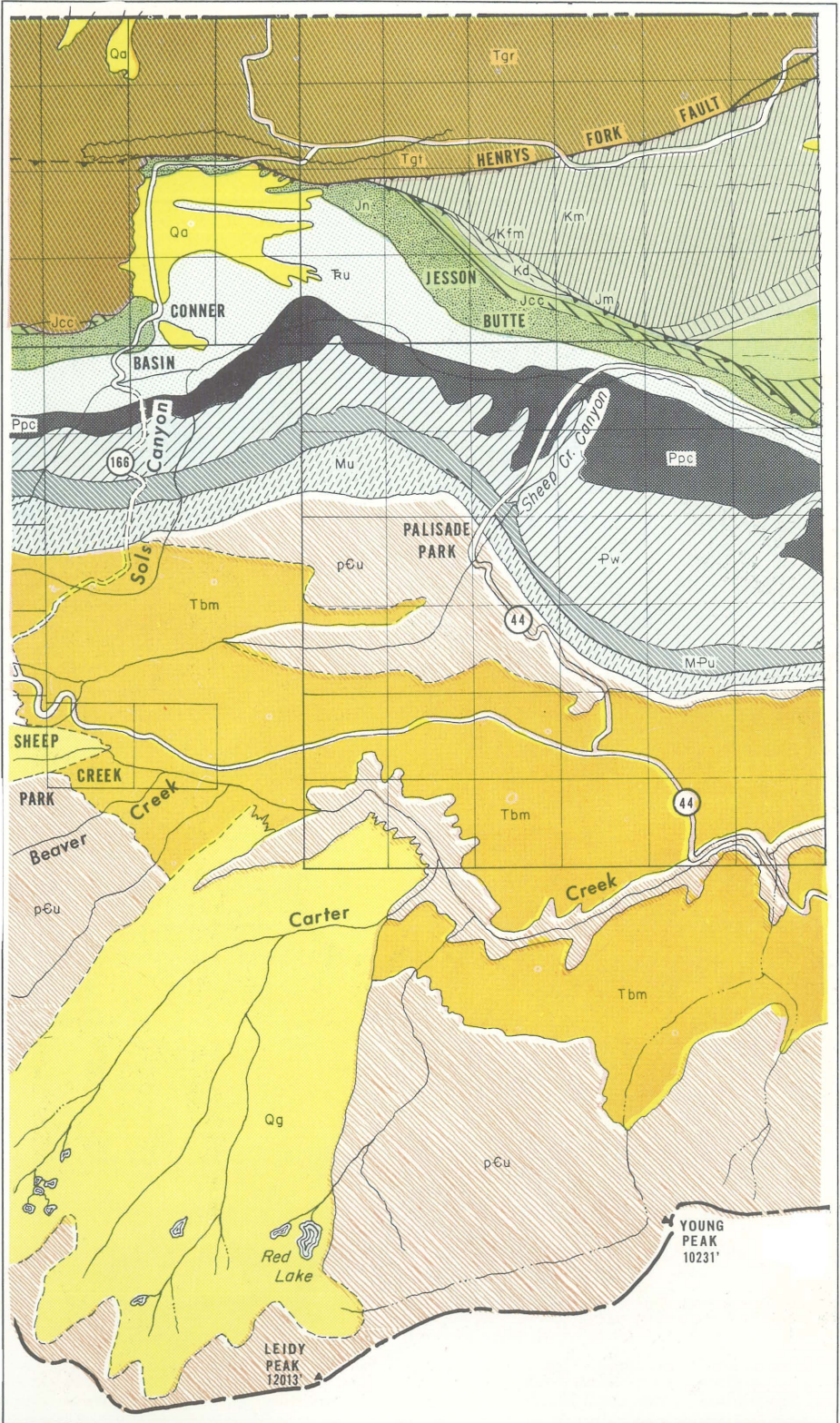
MAP 1

R 18 E

R 19 E

T 3 N

T 2 N



MAP 2



Colored Scene No. 2. Hieroglyphics on north rim of South Valley, Benview ranch near Msnila, Utah--looking north.

-Mrs. Heber Bennion Jr. -



Colored Scene No. 3. Dutch John, the town constructed by the Federal Government and its contractors as a base for the construction of the Flaming Gorge Dam and for the operation and maintenance facilities needed after its construction--view looking southwest.

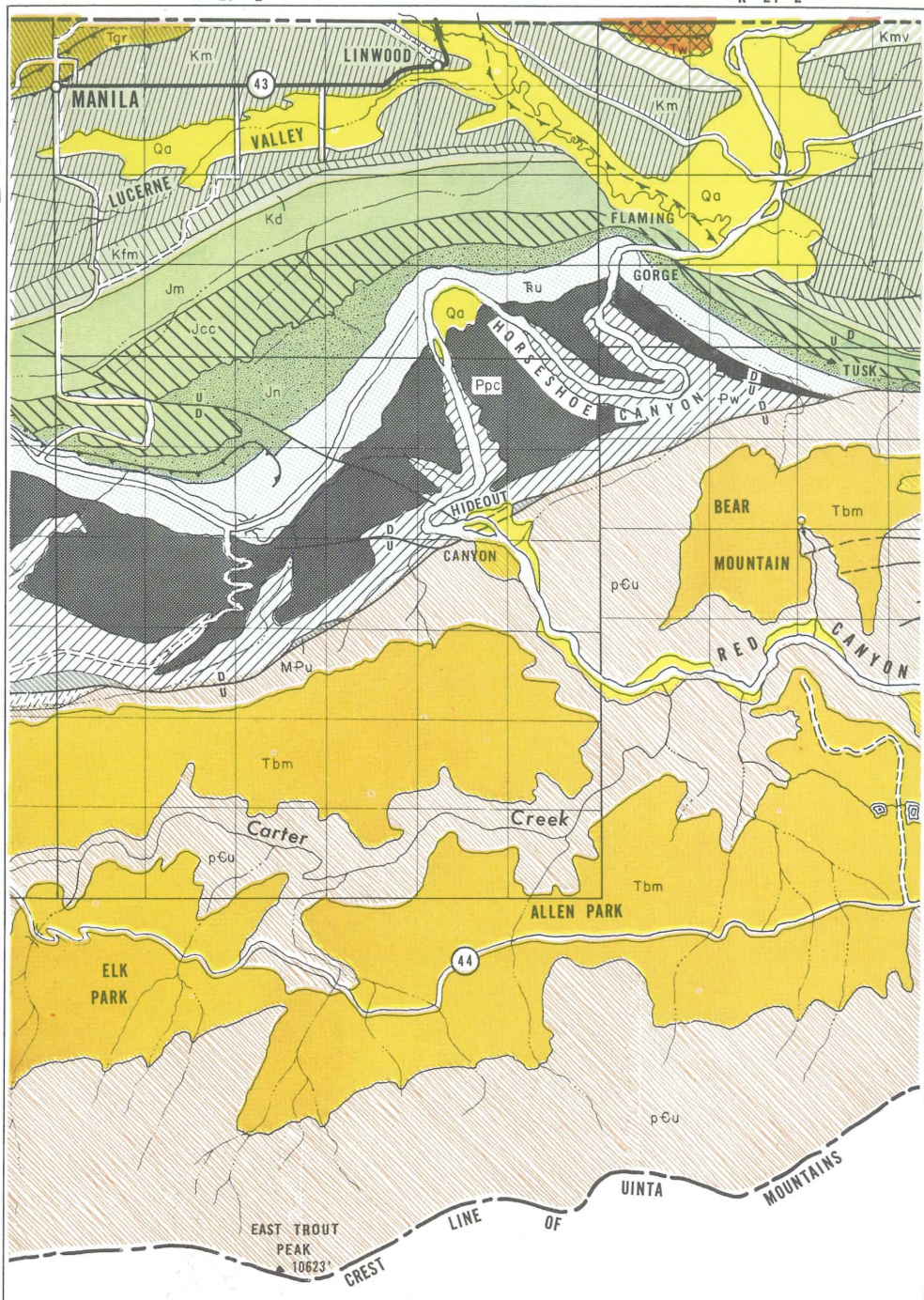
-Mrs. Heber Bennion Jr.-

R 20 E

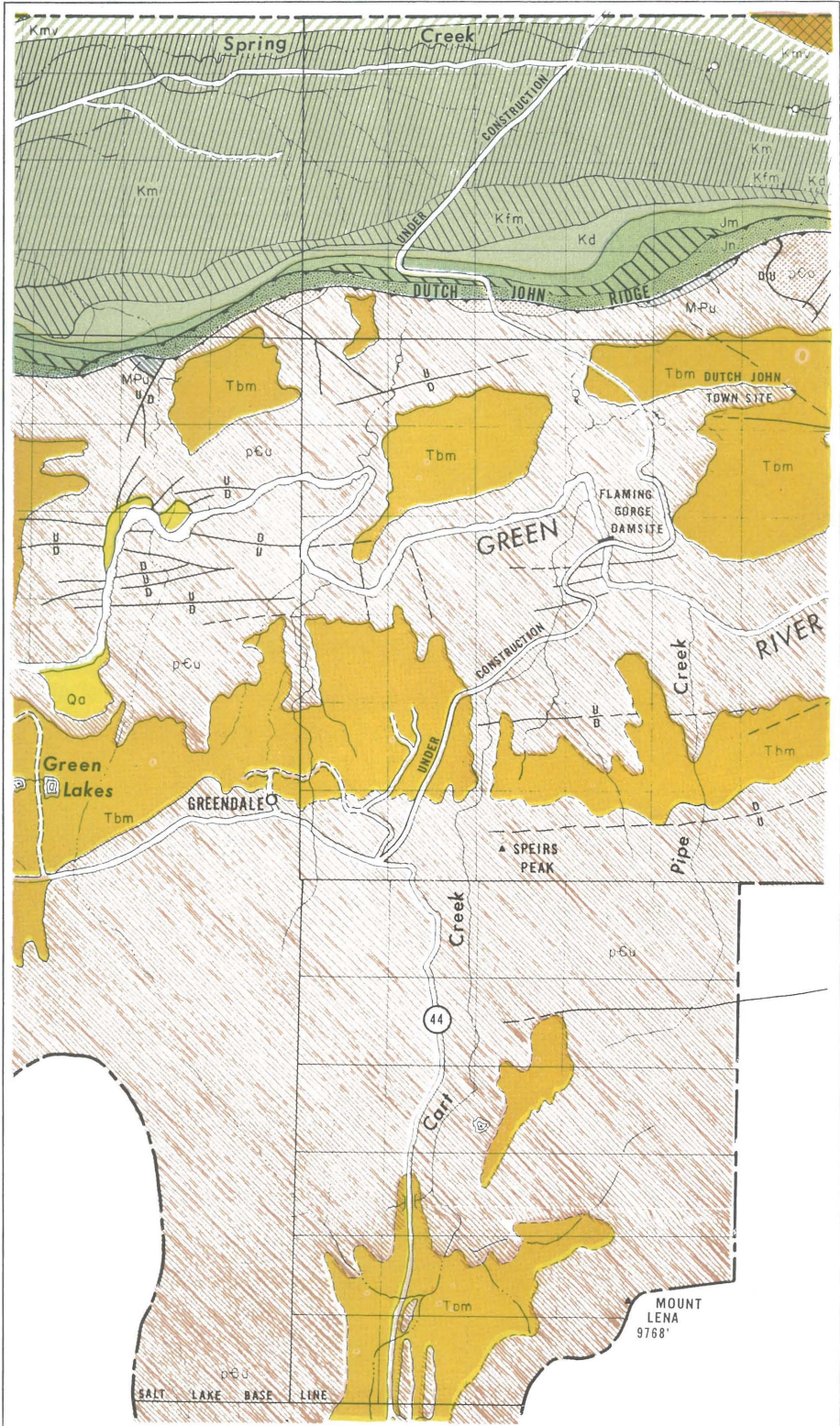
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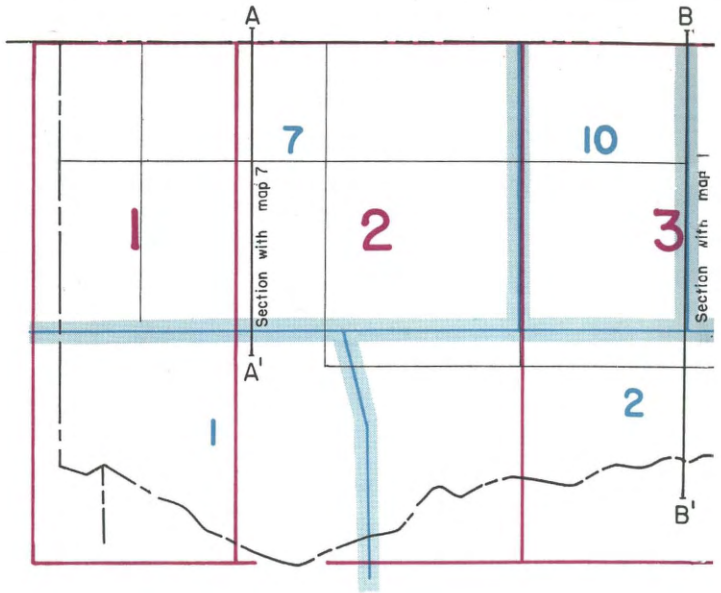
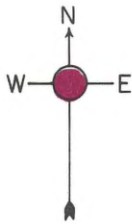
T 2 N



MAP 3



MAP 4



INDEX TO  
**GEOLOGIC ATLAS OF UTAH**  
**DAGGETT COUNTY**

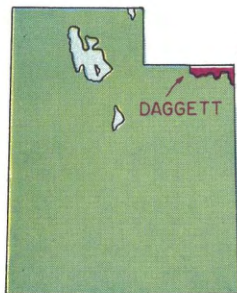
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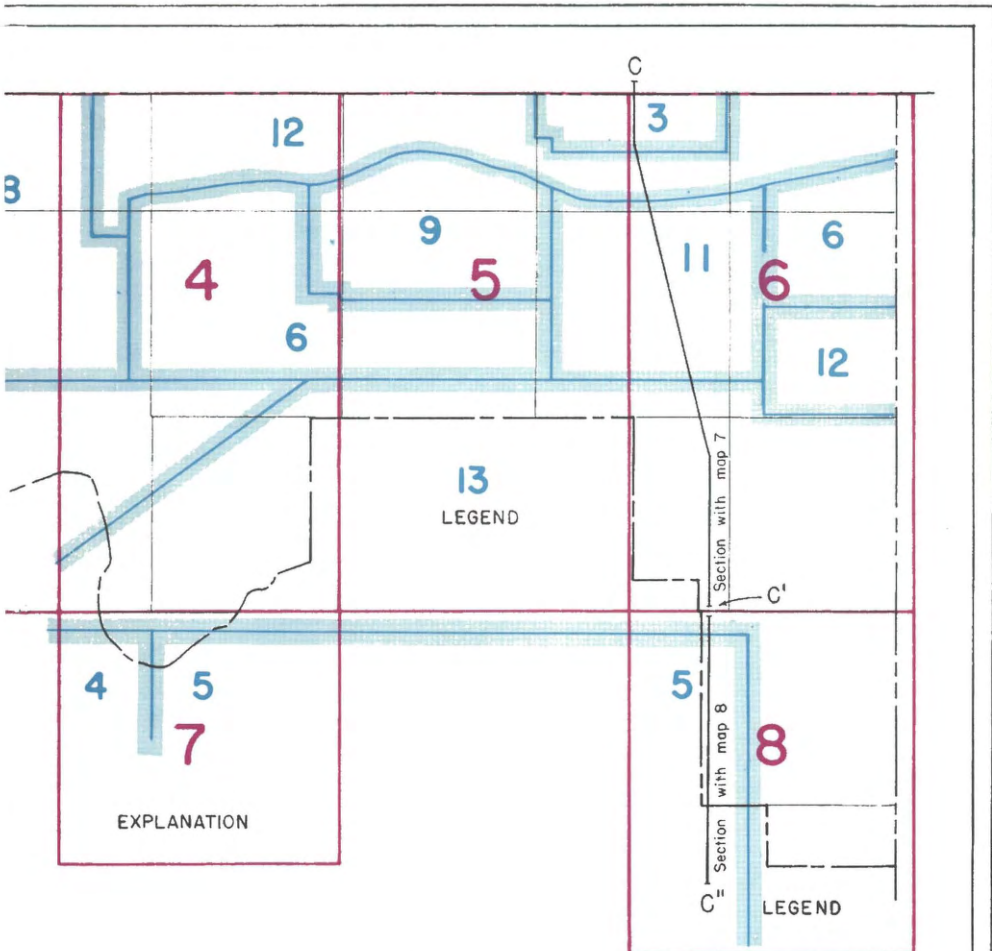
Scale of index:  $1'' = 3 \text{ Miles}$



Red numbers correspond to  
 map numbers.



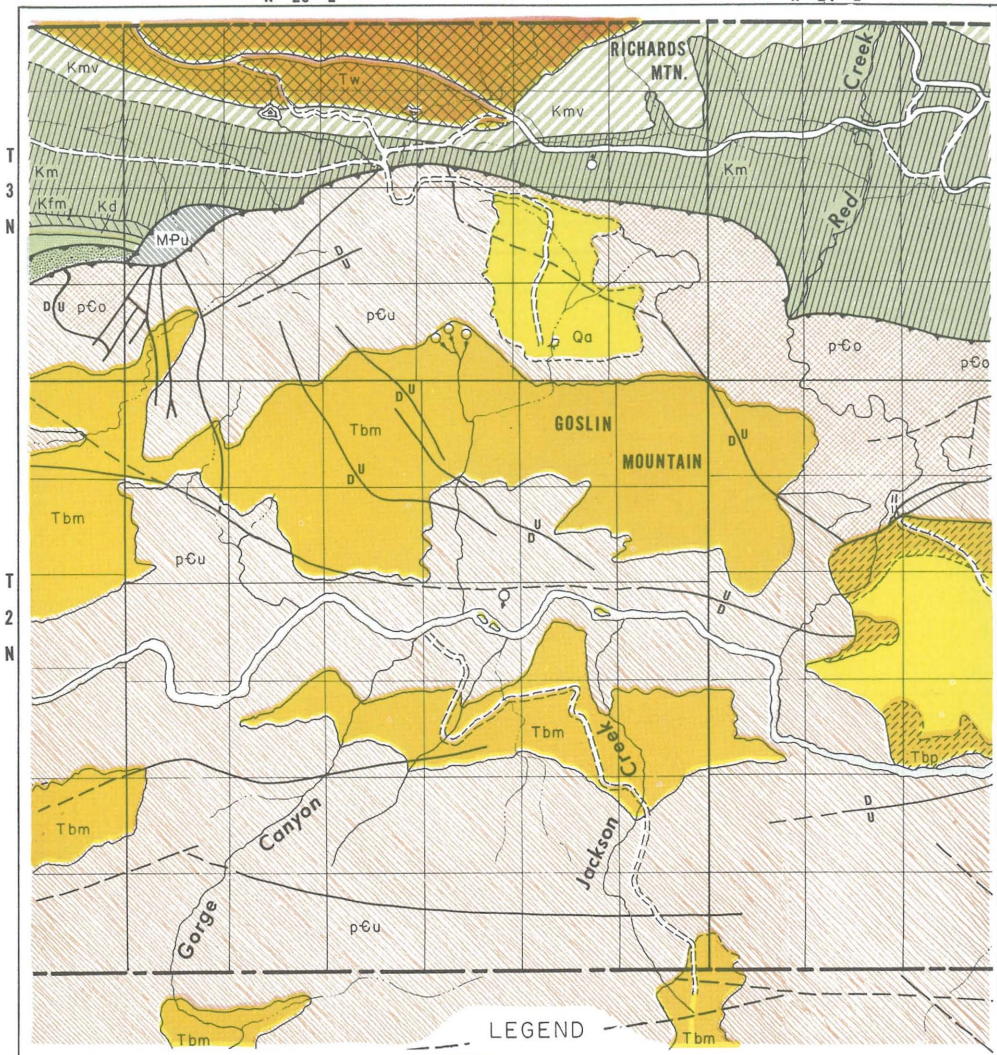
Blue numbers correspond to  
 sources of information.



SOURCES OF INFORMATION

1. ATWOOD (1909), and elsewhere on map where glacial geology is shown.
2. BRADLEY (1936), and elsewhere on map where late Tertiary erosion surfaces and formations are shown.
3. DOBBIN and DAVISON (1945)
4. KINNEY and ROMINGER (1947)
5. KINNEY (1951)
6. HANSEN and BONILLA (1954)
7. ANDERMAN (1955a, 1955b)
8. HANSEN (1955a)
9. HANSEN (1955b)
10. HANSEN and BONILLA (1956)
11. HANSEN (1957)
12. RITZMA - air photo and detailed surface mapping (this bulletin).
13. RITZMA - air photo and surface reconnaissance (this bulletin).

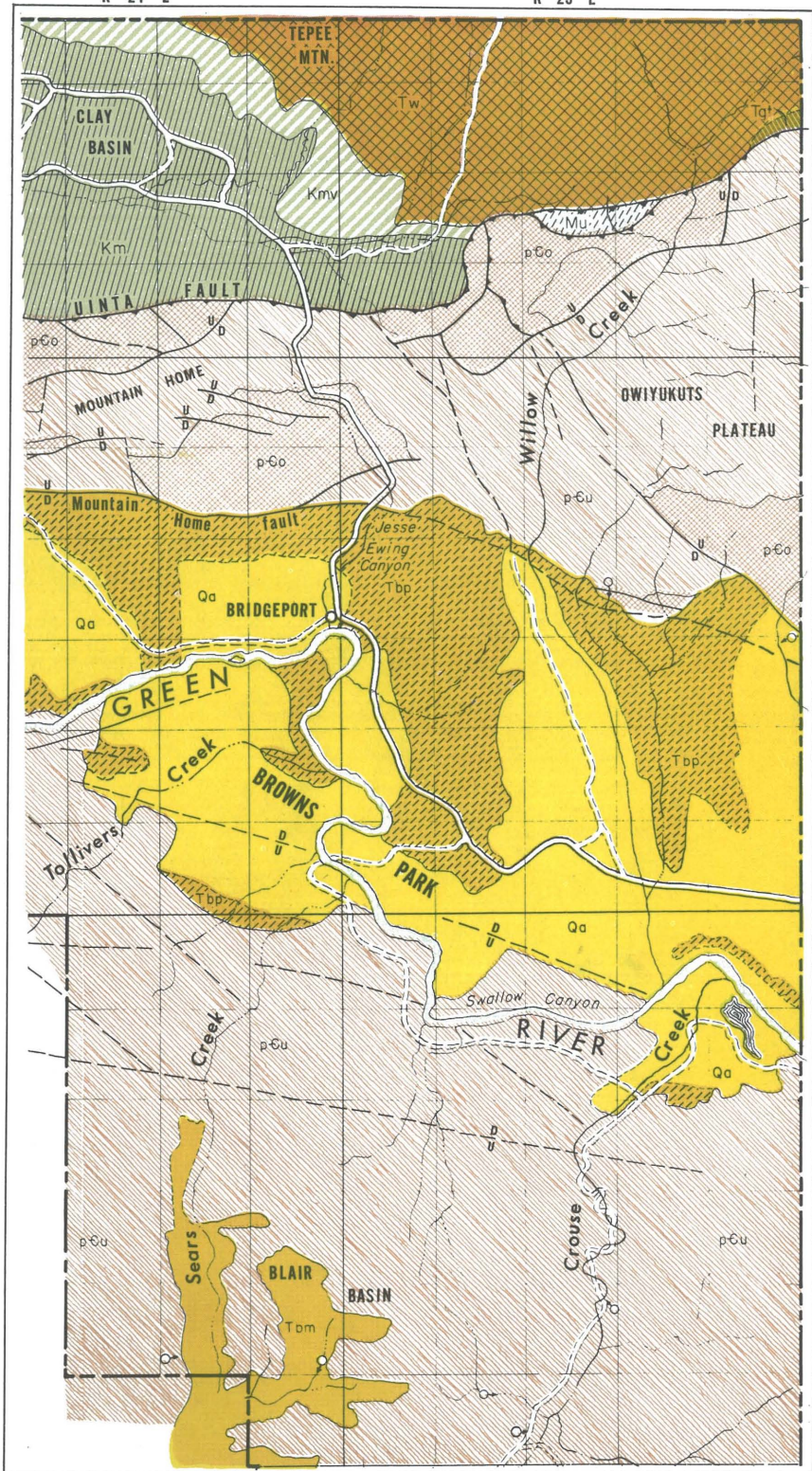
Legend with maps 5 and 8, explanation with map 7.



LEGEND

CENOZOIC	Quaternary	Quaternary alluvium	Qa	MESOZOIC	Cretaceous	Mesaverde formation	Kmv
		Glacial deposits, outwash & moraines	Qg			Mancos shale	Km
	Browns Park formation	Tbp	Frontier and Mowry members of Mancos sh.			Kfm	
	Bear Mountain surface	Tbm	Dakota formation			Kd	
	<i>MAJOR UNCONFORMITY</i>						
	Tertiary	Green River formation	Tgr		Jurassic	Morrison formation	Jm
		<i>LOCAL UNCONFORMITY</i>					
		Tipton tongue of Green River formation	Tgt			San Rafael gp. { Curtis fm. Entrada ss. Carmel fm.	Jcc
		Hiawatha member of Wasatch formation	Tw			Navajo sandstone	Jn

Legend continued on map 6.



MAP 6

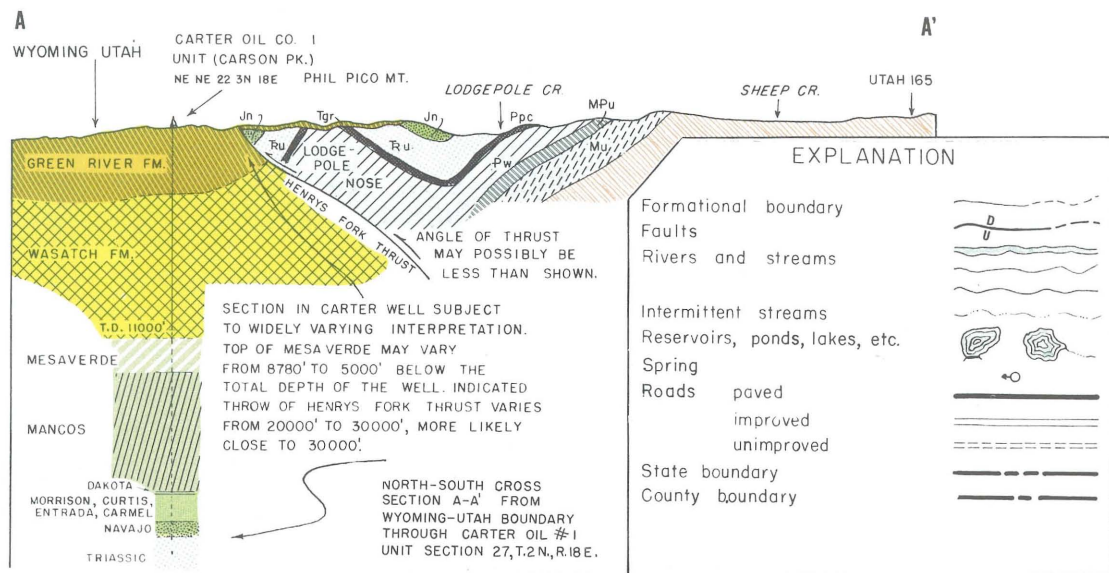
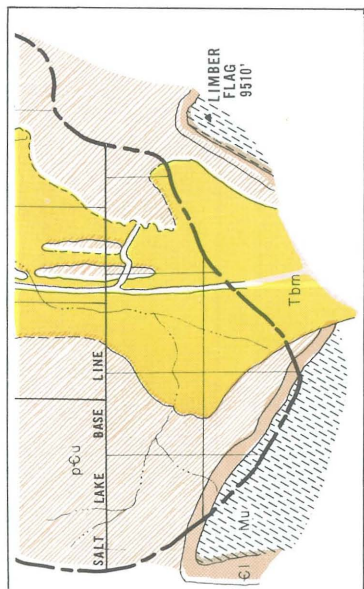
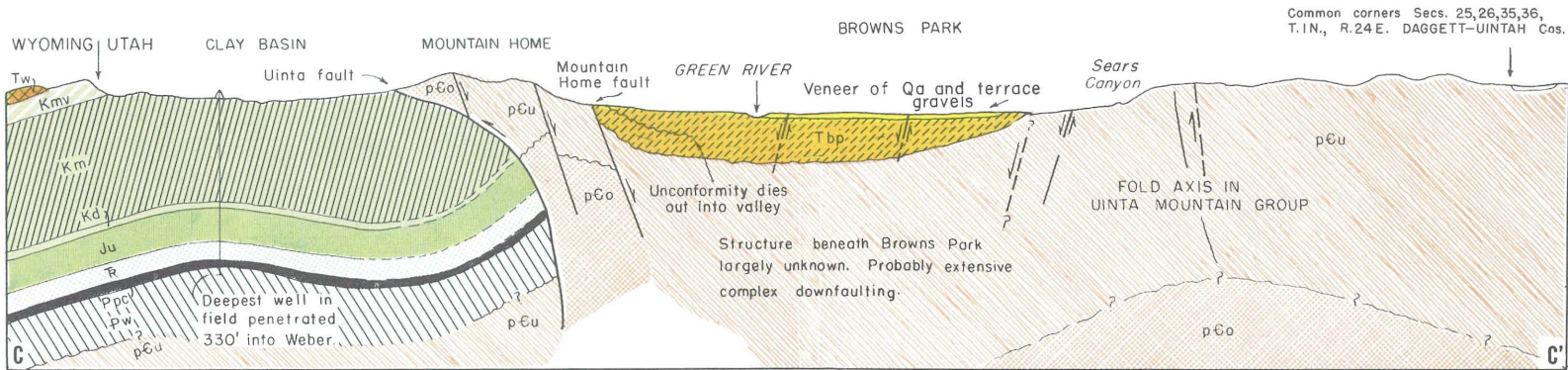


Colored Scene No. 4. Sheep in Lucerne Valley, near Manila, Utah, with typical upturned strata forming Jessen Butte hogback in distance--view looking west.  
-Mrs. Heber Bennion Jr.-



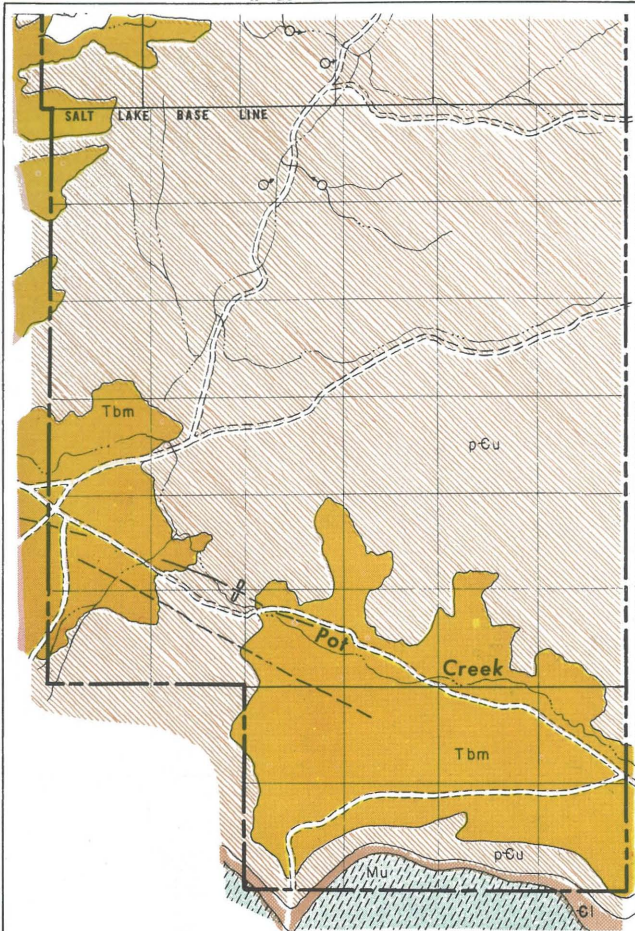
Colored Scene No. 5. Ashley Falls in Red Canyon situated two and one-half river miles above the Flaming Gorge Dam. General William Henry Ashley (General in the Missouri Militia and president of the Rocky Mountain Fur Company) with his party floated down the river in "bull boats" in 1825. Ashley inscribed his name on the rocks at this point. Major John Wesley Powell, not knowing of his predecessor, misread the inscription as "1855" and supposed Ashley to be a trapper or prospector.

-William M. Purdy-



R 25 E

T 1 S

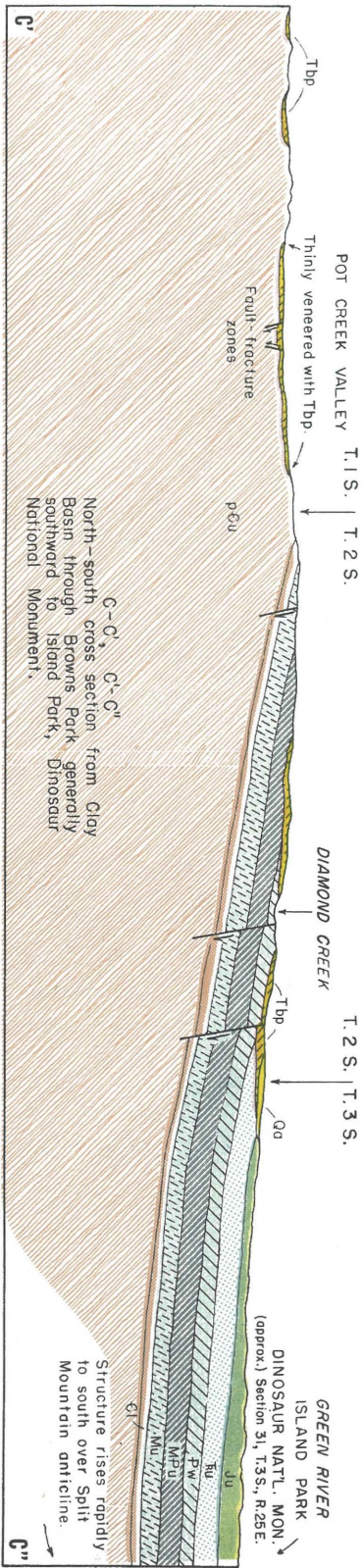


Legend continued from map 5.

MESOZOIC	Permian	Triassic	Chinle formation		Tru
		Shinarump cgl. mbr.			
			Moenkopi formation		Tm
PALEOZOIC	Penn.		Park City formation		Ppc
			Weber sandstone		Pw
	Miss.		Mississippian-Pennsylvanian undifferentiated		MPu
			Mississippian undifferentiated		Mu
DISCONFORMITY					
PRECAMBRIAN	Younger Cambrian		Lodore formation		El
			Uinta Mountain group		pCu
	Older		Red Creek complex		pCo

Possibly represents metamorphosed equivalents of Uinta Mountain group. Contact possibly is intrusive or "melt" contact.

MAP 8



C

MAP 8



Colored Scene No. 6. Looking east-northeast across Beaver Creek at the contact (about two-thirds the way up Cold Spring Mountain) between the overlying maroon quartzite of the Uinta Mountain group and the Red Creek complex below. The Utah-Colorado state line passes north and south between the viewer and the contact. Quartzite dips north into contact.

- Howard R. Ritzma-

3. The bedding of the Uinta Mountain group and the alignment of bedding, foliation, schistosity, and other structural trends in the Red Creek are often in remarkable agreement. Several isolated patches of Uinta Mountain sediments appear to be "roof pendants" partially founded into the "halo" of metamorphosed rock close to an intrusive body.

4. At two localities small inclusions of relatively unaltered Uinta Mountain group quartzite are found "floating" in the white vitreous quartzite of the Red Creek complex. The relations of these rocks suggest that these are xenoliths which sank into and were partly assimilated into a molten mass.

5. The rock types of the Red Creek are all types which could be derived from the metamorphism of a lithologically simple quartzose terrane such as the Uinta Mountain group.

If additional field work can prove that the Red Creek complex is actually composed of metamorphosed Uinta Mountain group sediments admixed with a small amount of igneous and metamorphosed igneous rock, it would appear that the area between Clay Basin and Browns Park exposes the uppermost part of a pluton, possibly of Tertiary age, a stock or small batholith with a "halo" of fused quartzite extending outward from the thermal source into unaltered country rock.

Acceptance of the idea would resolve the paradox of exposure of the "oldest" rocks of the Uinta Mountain Arch on its north flank and greatly simplify the tenuous explanations for older rocks caught in fault slices between younger rocks along the Uinta fault (Hansen and Bonilla, 1954, pp. 17, 21).

The Uinta Mountain Arch is reflected in the quartzite, quartzitic sandstones, and slaty shales of the Uinta Mountain group and the Paleozoic and Mesozoic rocks farther down the flanks. In the vicinity of Daggett County the arch is about 25 to 30 miles wide from the Uinta fault on the north to the point on the south flank where the Tertiary beds of the Uinta Basin overlap the flanking hogbacks of the Uinta foothills.

The arch is strongly asymmetric. Dips on the south flank are mostly in the range of  $12^{\circ}$  to  $25^{\circ}$  and rarely exceed  $35^{\circ}$ . On the north flank formations dip mostly in excess of  $30^{\circ}$  and range up to strongly overturned dips. For the east end of the Uinta Arch in Utah, it can be generally said that the whole arch was subjected to stronger compressive forces from the south with resulting asymmetry of folding to the north. The folds ruptured with major overthrusting of the north flank from south to north outward into the Green River Basin.

#### Folds in the Precambrian

Three anticlines and two complementary synclines are exposed in the Precambrian Uinta Mountain group beds in the east half of Daggett County. The easternmost anticline is the broad nose known as Dutch John nose which plunges northwesterly across the Green River, a short distance west of Browns Park. To the southwest of this fold is a smaller parallel anticlinal nose which extends across the mouth of Gorge Canyon. An east-west trending closed anticline

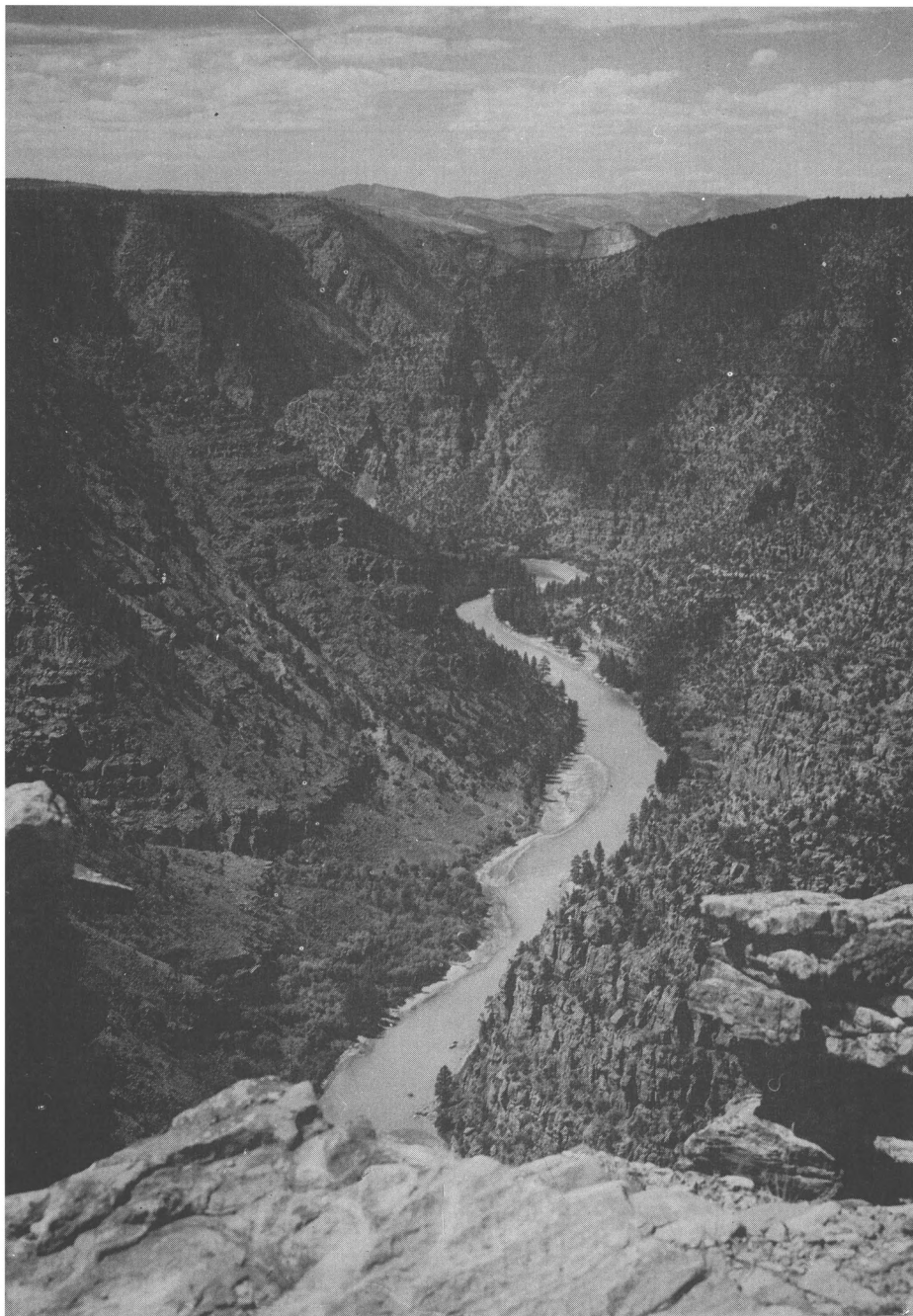


Plate 6. Red Canyon exposing Uinta Mountain group sediments from Green Lakes overlook.

- U.S. Bureau of Reclamation -

named Red Canyon anticline is exposed in the Uinta Mountain group beds in Red Canyon between Bear Mountain and Greendale west of Flaming Gorge dam site.

### Flanking folds

Three large flanking folds are separated from the Uinta Mountain Arch by the Uinta fault. From east to west these are Clay Basin anticline, Spring Creek nose, and Linwood nose. Farther west, beyond the termination of the Uinta fault, the Lodgepole nose plunges north with no fault interruption from the Precambrian basinward toward the Henrys Fork fault where the axis turns due west parallel to the fault, apparently as a result of down-dragging of beds along the fault. All four flanking folds have certain characteristics in common: all axes trend northwesterly, all are strongly asymmetric to the northeast, and each is separated from its companion fold by a shallow, strongly asymmetric syncline which is often faulted.

The farthest west of these folds, Lodgepole nose, exposes Precambrian rocks in its core but is not interrupted by faulting, at least to Jurassic formations. Linwood and Spring Creek noses culminate against or under the Uinta fault. The Pennsylvanian Weber sandstone is the oldest formation exposed north of the Uinta fault on Linwood nose, and the Jurassic Nugget sandstone is the oldest formation similarly situated on Spring Creek nose. Clay Basin anticline, a doubly plunging fold with about 400 feet of closure, exposes the Upper Cretaceous Mancos shale at its crest and along its culmination against and under the Uinta fault.

Lodgepole nose is separated from Linwood nose by a strongly asymmetric syncline and the associated Sheep Creek and South Valley faults. Linwood nose is, in turn, separated from Spring Creek nose by a strongly asymmetric syncline and somewhat less important faulting. Spring Creek nose is separated from Clay Basin anticline by a shallow asymmetric syncline without visible faulting.

It is apparent that these four flanking folds are arranged in stair-step fashion from west-southwest to east-northeast. The highest structural fold is on the west and the intensity of deformation lessens with decreasing structural elevation of the folds from west to east.

### Relations of folds

The folds north of the Uinta fault and those exposed in the Precambrian rocks south of the fault appear to be related. Dutch John nose and Spring Creek nose appear to be structural counterparts, as do Red Canyon anticline and Linwood nose. Clay Basin anticline appears possibly to have a fold counterpart in the Precambrian beds of Cold Spring Mountain to the east of Daggett County in Colorado. In each case there is an offset of two or three miles where the axis of these folds could be expected to meet at the fault. In the case of the unfaulted Lodgepole nose in western Daggett County, the offset appears to have been accomplished by plastic deformation of the beds rather than rupture and offset by faulting. This plastic deformation causes an abrupt change in the direction of plunge of Lodgepole axis from northwest to west. Much of the offset can be accounted for mathematically by simple gap-offset relations in these axes by a fault displacing them at angles normal or oblique to these axial trends. However, appreciable twisting of

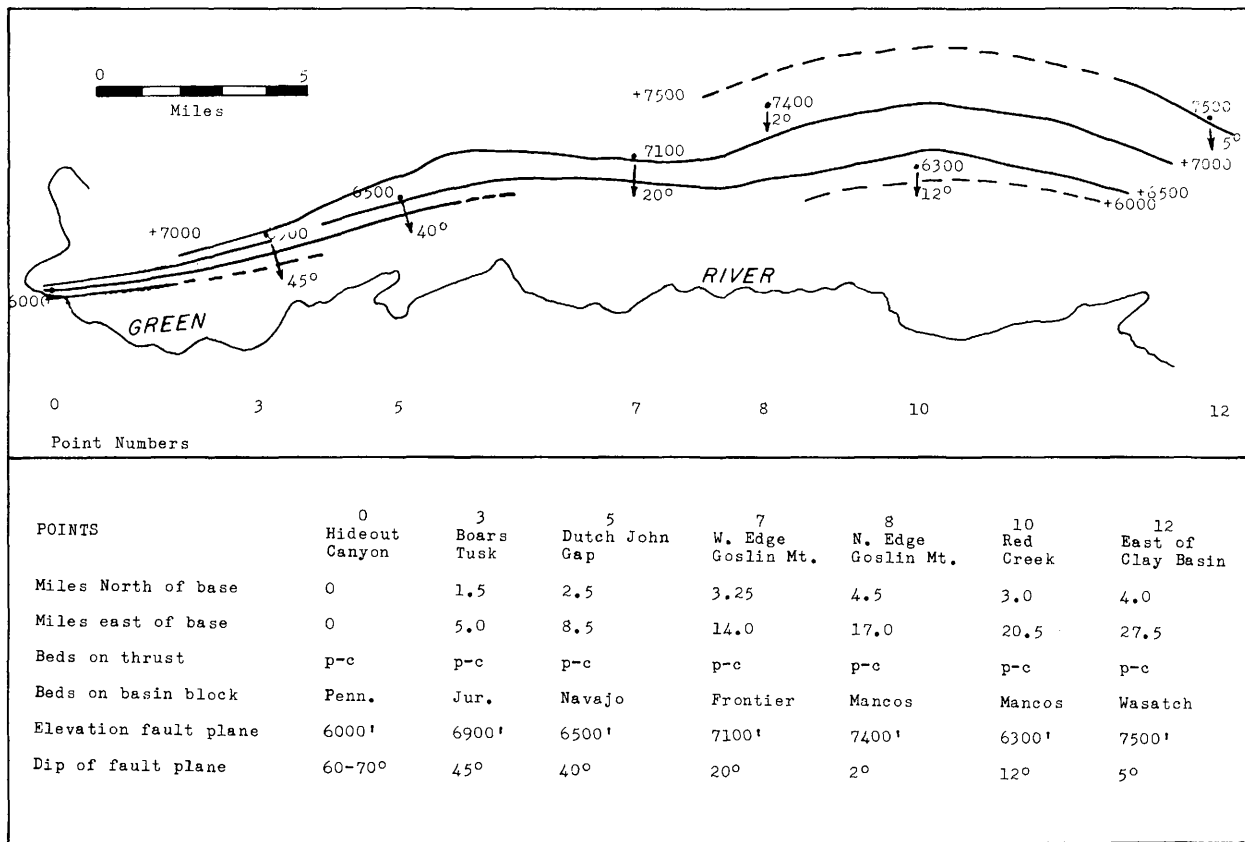


FIGURE 6 GENERALIZED STRUCTURE CONTOUR MAP ON THE PLANE OF THE UINTA FAULT  
IN EASTERN DAGGETT COUNTY, UTAH

the axes which indicates cumulative offset of five to six miles can be accounted for only by considerable strike-slip movement along the Uinta fault.

From the trend of the four large flanking folds and their counterparts in the Precambrian it is obvious that these are old fold axes aligned northwest-southeast in general conformity with the rest of the Rocky Mountain region. The Uinta Mountain Arch and its attendant faulting appears to have been superimposed across these older folds, modifying them greatly. The Uinta Mountain Arch not only rose vertically but was also thrust outward to the north and south by compression forced by subsidence of the Green River Basin adjacent to the Uintas on the north and the Uinta Basin on the south flank. In addition, the entire Uinta Mountain Arch appears to have been propelled eastward, causing strike-slip movement along the flanking Uinta fault.

### Faults

#### The Uinta fault

The Uinta fault is but one of many faults of a complex system that bounds the Uinta Mountain Arch along its north flank. It is not the longest nor the largest of these faults in measurable displacement, but it is the best and most spectacularly exposed and hence the best known.

Trace, dip, and displacement: The western termination of the Uinta fault is in section 8, T. 2 N., R. 19 E., in western Daggett County, where it passes into a sharp monoclinial flexure and dies out in beds of the Manning Canyon formation. Eastward from this point the plane of the fault is nearly vertical or dips steeply to the south at angles from 70° to 85°. The fault here involves highly competent Precambrian and lower Paleozoic rock units, and the displacement from the zero point at its western termination increases to more than 5,000 feet at Hideout Canyon some ten miles east. Here the Precambrian is faulted against the Pennsylvanian Morgan formation and the fault dips south at 60° to 70°. The fault here begins to trend to the northeast and the Precambrian is thrust over successively younger formations. At Boars Tusk five miles northeast, the fault juxtaposes Precambrian against Upper Jurassic. Displacement is probably 12,000 feet and the fault plane appears to dip south at 45°. Eastward from this point, the fault and the strike of the Jurassic formations on the down-faulted block nearly coincide and the "scuffed-up" Navajo sandstone forms the impressive eight-mile-long Dutch John Ridge. East of Dutch John Ridge in section 30, T. 3 N., R. 23 E., the trace of the fault turns northward abruptly and the Precambrian is thrust over the strongly "dragged-up" remaining Jurassic formations, the Dakota, and the Mowry and Frontier members of the Mancos shale. Viewed at right angles to the west-east strike of the fault at this point, the sole of the Uinta fault is seen to flatten rapidly as the fault involves Precambrian quartzite against and over incompetent Mancos shale. The fault here dips less than 10° to the south and may be almost flat-lying on the northernmost tip of the thrust sheet on Goslin Mountain. Fault movement here appears to have been mostly skidding of the thrust sheet with the shale as lubricant. Displacement is probably about 30,000 feet. Another point of measurement of the fault plane is at Red Creek where this stream canyon cuts a V-shaped re-entrant into the thrust sheet.



- A. Bear Mountain erosion surface on top of Goslin Mountain.
- B. Red Creek complex (pC) in overthrust mass of Goslin Mountain. Sparsely forested.
- C. Low dipping Uinta fault.
- D. Debris-coated Mancos shale. Forested on gravels.
- E. Red Creek flowing south into Red Creek Canyon (F). Point IO, Figure 6.
- G. Clay Basin eroded in Mancos shale: Brush covered; few trees.
- H. Gently arched Mesaverde on northwest flank of Clay Basin anticline.
- J. Vertical to overturned Mesaverde scuffed up by Uinta fault.
- K. Richards Mountain.

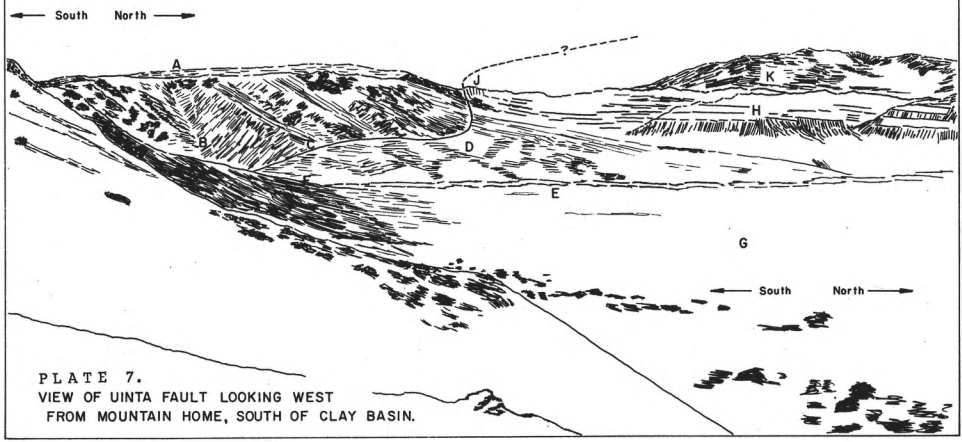


PLATE 7.  
VIEW OF UINTA FAULT LOOKING WEST  
FROM MOUNTAIN HOME, SOUTH OF CLAY BASIN.

Plate 7. View of Uinta fault looking west from Mountain Home, south of Clay Basin. Photo above; sketch of same below.

- H. R. Ritzma -

Here the sole of the thrust dips south at about  $12^{\circ}$ . From Goslin Mountain eastward the fault continues to involve Precambrian against Mancos until in section 32, T. 3 N., R. 25 E., the fault trace turns sharply north and northeast and the Precambrian is thrust over "dragged up" Mesaverde, Hiawatha, and Tipton beds. Again viewed at right angles to the west-east strike of the Uinta fault, the fault plane is seen here dipping south at  $5^{\circ}$ . In this easternmost portion of Daggett County, the Uinta fault involves beds which were being laid down as the fault was active. Within the Hiawatha member of the Wasatch formation (Paleocene and Eocene) and the Tipton tongue of the Green River (upper lower Eocene) are many local unconformities that die out basinward; and the clays, sands, and boulder conglomerate of these orogenic deposits were apparently deposited, faulted, broken up, and redeposited many times during the millions of years involved in the folding and faulting of the Uinta Mountain Arch.

Displacement on the fault is probably at a maximum near the Utah-Colorado boundary and is estimated at 40,000 feet.

The Uinta fault continues eastward into Colorado for about eighteen miles, where it passes into a monoclinial flexure on the northeast flank of Cold Spring Mountain and presumably dies out in the Mancos shale. Where the fault dies out to the east it is replaced by another large parallel thrust, the Sparks fault, a segment of the regional fault system that bounds the Uinta Mountain Arch on its north flank. Another large fault of this regional system, the Henrys Fork fault, similarly replaces the Uinta fault near its western termination.

Classification of the fault: Since faults are classified according to the dip of the fault plane in relation to movement, the classification of the Uinta fault has presented many perplexing, although unnecessary problems. Observation of the fault by the pioneering geologists of the late 1800's was along the Green River near Hideout Canyon where the fault is definitely a high angle reverse fault. Powell unfortunately depicted the fault as nearly vertical. These observations were incorporated into subsequent geologic studies and generalized extensively for the entire length of the fault without the benefit of additional critical field observation. Ver Wiebe (1930) and de Lyndon (1932) postulated a lower angle for the Uinta fault and described it correctly as an overthrust. These opinions were not widely held in the profession. Hansen (1955) shows the fault plane as  $35^{\circ}$  in a cross-section near Hideout Canyon and about  $45^{\circ}$  east of Boars Tusk. In other cross sections to the east, however, he (Hansen, 1957) depicts the fault plane as  $60^{\circ}$ .

The writer's own critical observation of the fault along its entire length has led him to the following conclusions. The Uinta fault is a reverse fault of nearly east-west strike throughout its entire length. The plane of the fault is steep at the roots of the fault but shallows out rapidly as the fault block is thrust upward and outward over the adjoining basin in a "lipping-over" or mushrooming effect. An important factor is the competency of the rocks involved, for the fault plane inevitably steepens toward the roots of the fault where the rupture involves more competent beds. Thus, where Precambrian quartzite is thrust against Paleozoic rocks west of the Green River the fault plane is steep to vertical. To the east, as the fault involves Precambrian quartzite over increasingly less competent beds, the sole of the fault shallows out to nearly horizontal.

In a fault of this type the dip of the fault plane at a particular locale is a function of the degree to which erosion has stripped back the overthrust block to its roots. A structure contour map of the Uinta fault plane shows it to be an undulating, somewhat irregular surface striking N. 85° E. with an average 6° south dip, but abruptly steepening to the south as the "root" of the thrust is approached. Figure 6 illustrates this concept.

The low angle overthrust nature of the Uinta fault has been confirmed by geophysical surveys conducted in the course of exploration for oil and gas. In at least five locales known to this writer, seismic profiles continued south of the surface traces of the Uinta, Henrys Fork, and Sparks faults continued to record reflections from the beds of the "basin block," thus indicating their continuity for a considerable distance beneath the overthrust sheet.

#### Henrys Fork fault

The Henrys Fork fault begins in section 3, T. 2 N., R. 23 E., as a branch of the Uinta fault and is traceable to the northwest in the strongly overturned beds of Boars Tusk Ridge. It continues northwest across the Green River, its trace nearly coincident with the alluvium-floored valley of Henrys fork. A short distance east of Linwood, the fault is joined by another fault from the east and together they continue northwest into Wyoming, then swing southwest back into Utah. Displacement increases rapidly. It is significant that a few miles south the Uinta fault is rapidly decreasing in displacement. Thus the Henrys Fork fault appears to take up where the Uinta fault leaves off. In section 22, T. 3 N., R. 18 E., an 11,000-foot test drilled for oil and gas by Carter Oil Company bottomed in beds which were possibly basal Wasatch. A short distance south of the well the Jurassic Navajo sandstone is thrust against and over Green River (Eocene) beds. The indicated displacement of the Henrys Fork fault at this point is between 20,000 and 30,000 feet, and this displacement appears to continue to the west. The trace of the fault is obscured by overlapping upper Green River (Eocene) beds a short distance west of the Daggett-Summit County boundary, but geophysical information obtained in oil exploration indicates that the fault continues westward for 40 miles or more along the north flank of the mountains.

#### Other faults north of Uinta fault

The Sheep Creek fault in Ts. 2 and 3 N., Rs. 19 and 20 E., is a branch of the Henrys Fork fault. It extends southeast toward the Uinta fault for some ten miles. Like the Uinta and Henrys Fork faults, the Sheep Creek fault is a reverse fault with beds thrust from south or southwest in a northerly direction. The fault parallels the trend of the axis of Lodgepole nose and is actually a rupture of the beds on the steep to overturned north flank of this fold. Displacement is difficult to determine southeastward from the Henrys Fork fault where displacement mainly involves the Mancos shale. The fault where exposed at Sheep Creek Gap and along Utah 44 displaces Jurassic beds about 350 feet. The fault plane is concave upward with a low dip to the south. Associated with the Sheep Creek fault are many minor faults and folds involving the easily deformed gypsiferous sequences of the Carmel and Moenkopi formations.

A small fault branching from the Uinta fault near the mouth of Hidecut Canyon dies out about two miles west. At its east end, the upthrown side is on the north. Toward the west, the upthrown side is on the south (Hansen and Bonilla, 1954, p. 19).

The South Valley fault is a normal fault with an average of 200 feet displacement. It is well exposed north of Sheep Creek Gap along Utah 44 where it has nearly 300 feet of throw. The fault is about five miles long and joins the Uinta fault north of Hidecut Canyon. Its trace parallels the Sheep Creek fault and it appears related to a relaxation of compressive forces in the syncline between Lodgepole and Linwood noses.

Along the great Uinta fault, particularly to the east of the Green River, are several parallel branches of the overthrust. Several enclose fault "slices," blocks of resistant rock caught and dragged up along the Uinta fault between the overthrust sheet and the beds on the down-faulted side. Faults of this type extend along the north side of Dutch John Ridge at the east and west ends of the ridge. It is apparent that the thrust sheet moving upward and outward to the north dragged up the massive competent 800-foot-thick Navajo sandstone and warped it up in a vertical position. Both ends of this massive eight-mile-long block of upwarped sandstone broke away from its "roots" and were forced by the thrust block outward (northward) across the younger Jurassic rocks for a short distance. Much of the skidding and attendant squeezing was accomplished in the gypsiferous shales of the Carmel formation.

#### Faulting south of Uinta fault

South of the Uinta fault, within the broad area of outcrop of the Uinta Mountain group, a great number of faults and fractures are mappable on the surface or can be inferred from aerial photographs. These range in age from displacements of Precambrian age confined to the ancient rocks of the Red Creek complex and Uinta Mountain group to normal faults which pass from Precambrian rocks into Quaternary river deposits. Some displace the river deposits, and the relatively undissected scarps suggest movement in geologically Recent time. The faults appear to fall into three groups.

The first group of faults south of the Uinta fault is an intricate set of faults and fractures of variable trend confined to the Red Creek complex and the Uinta Mountain group. These faults which are of limited significance in regional structure have been mapped in considerable detail on Goslin Mountain and between Clay Basin and Browns Park by Hansen (1955b) (1957) (1958b), Hansen and Bonilla (1954), and Wilmarth (1953).

The second group of faults and fractures are east-west in trend and closely parallel the trend of the Uinta Mountain Arch and other folds within the Arch. These faults appear to be connected with lessening or release of compressive forces. This release eventually led to the collapse of the eastern end of the Uinta Mountain Arch into a series of grabens of regional extent. One such set of faults and fractures is traceable on the surface and on aerial photographs for twenty miles along the axis of the Uinta Mountain Arch across the eastern half of the county and into Colorado. Other sets parallel the axes of Dutch John nose and Red Canyon anticline. Of this latter group of faults Hansen, (1954, p. 21) states, "Faulting in Red Canyon east of Bear Mountain appears

to be associated with collapse of the Red Canyon anticline; at any rate the net result.....was a slight lowering of the crestal part of the fold relative to its limbs." Several possibly related faults of the same trend cross the Green River just below the Flaming Gorge Dam site. The age of this faulting is probably mostly Late Tertiary. The Bear Mountain erosion surface appears to have been dropped down several hundred feet by faults of this type on the south side of Red Canyon north of Speirs Peak and to the east. Another set of faults of this trend cuts across the extreme southeast corner of Daggett County and continues westward for ten or so miles up the valley of Pot (or Cascade) Creek. These faults are apparently related to many other faults and fractures of similar trend on the south flank of the Uinta Mountain Arch.

In the vicinity of Browns Park is a group of faults closely related to those discussed in the previous paragraph which has accomplished the downfaulting of Browns Park into a large graben. On the north side of the Park this has been accomplished by Mountain Home, Beaver Creek, and several unnamed faults, all major normal faults, down-dropped to the south. The Mountain Home fault is exceptionally well exposed at the south entrance of Jesse Ewing Canyon. The down-faulting of the south side of the Park is distributed across several miles and at least three faults, all of which displace the Precambrian and at least one of which extends into the Browns Park formation and Recent river deposits. Presumably other faults are concealed beneath the alluvium-covered floor of the Park.

The latter group of faults has had great significance in the Late Tertiary structure of Daggett County and the surrounding region. The down-faulting of Browns Park with its attendant drainage changes and canyon cutting has left a profound mark on the geology and geography of northeastern Utah and adjoining states. The faulting which parallels Summit Valley and Pot (or Cascade) Creek apparently controlled the formation of this valley and the course of Pot Creek. The well-developed drainage pattern of the Bear Mountain erosion surface was completely disrupted.

## STRUCTURAL HISTORY

The structural history of the Daggett County area is, of course, the structural history of the Uinta Mountains. This range has had a complicated and unusual history. Detailed geologic study on a regional basis is necessary for complete comprehension of the several phases of Uinta structure and the stratigraphic ramifications in the beds deposited in the basins surrounding the mountains on the north, east, and south. Such a study is beyond the scope of this work. What follows is a generalized account of the structural development of the Uinta Mountains as they exist today.

### Structural Framework

#### Precambrian

The Uintas had their inception in Precambrian time with the development of a narrow deep arcuate trough generally coinciding with the present west to east trend of the Uintas across northeast Utah and northwest Colorado. Into this trough a thick sequence of conglomerate, sandstone, and shale was deposited which makes up the 20,000 or more foot-thick Uinta Mountain group exposed in the core of the range for its 175-mile length. Equivalents of the Uinta Mountain group are present in an east-west band across the Wasatch Range, thus giving the trough an indicated length of more than 200 miles. The trough apparently averaged about 35 to 40 miles in width, and the Uinta Mountain group sediments are presumed not to extend to the north or south beneath the adjacent basins for any considerable distance.

The Uinta Mountain group was presumably deposited on an ancient metamorphic terrane represented by the Red Creek complex, although there is considerable evidence that the rocks of the Red Creek complex may actually be metamorphic equivalents of the Uinta Mountain group. The source of the Uinta Mountain group sediments lay to the north and east.

The Uinta Mountain group formed a massive, thick "pod" of relatively homogenous and competent rocks embedded in the wafer-thin layer of the earth's crust. In later crustal movements, this "pod" has tended to act as a single unit.

#### Paleozoic and Mesozoic

The Paleozoic Era covers a span of some 400 million years of time during which remarkable stability existed in the Uinta Mountain area. About 500 million years ago, in Upper Cambrian time, the sea transgressed slowly across a surface of low relief on which were exposed the ancient Precambrian rocks. The Cambrian rocks are widespread across the area and were probably deposited uniformly across the region. The Cambrian seas then withdrew and a long period of nondeposition and/or gentle erosion ensued, resulting in the absence of Ordovician, Silurian, and Devonian rocks in the Daggett County area. During this span of some 150 million years Daggett County was a part of a broad, low-lying positive area over which these sediments were either not deposited or were deposited and later eroded away. In a small area of northeast Utah and adjacent northwest Colorado, including most of Daggett County, the older Cambrian rocks also were apparently removed by this gentle uplifting and erosion. The unconformity is very slight and the

discordance in dip between the Cambrian and overlying Mississippian rocks is measurable only in terms of 30 to 50 feet per mile. Over this nearly featureless terrain the temperate shallow Mississippian seas transgressed with widespread deposition of carbonate units such as the Madison, Deseret, and Humbug.

Throughout the remainder of Paleozoic and much of Mesozoic time--a span of perhaps 200 million years--Daggett County was part of this remarkably stable shelf area which separated the Cordilleran geosyncline to the west and intermittently active positive areas to the east and south. The seas advanced and retreated across this shelf area and, during periods of emergence, thick deposits of desert sand--the Weber, Navajo, and Entrada--and extensive continental deposits shifted across its surface. Breaks in deposition are of a minor nature and the boundaries of the Mississippian and Pennsylvanian, Pennsylvanian and Permian, Paleozoic and Mesozoic, and Jurassic and Cretaceous are ill-defined. Formations from Cambrian through Cretaceous show remarkable conformity in strike and dip.

Thickness studies of the Paleozoic and Mesozoic rocks reveal that the east end of the Uinta Mountains showed considerable positive tendencies throughout Paleozoic and Mesozoic time. The following table is a generalization of this study showing the marked thinning of formations from west to east.

SECTION	MANILA AREA DAGGETT COUNTY		CLAY BASIN DAGGETT COUNTY		VERMILION CREEK MOFFAT CO., COLO.	
	Thick- ness	% of Base	Thick- ness	% of Base	Thick- ness	% of Base
Upper Cretaceous Mowry and Dakota	450'	100%	375'	88%	250'	55%
L. Cret. (?)--Jurassic Morrison-Navajo	2505'	100%	1760'	70%	1660'	66%
Triassic Chinle-Moenkopi	1775'	100%	1150'	64%	1010'	57%

The Permian Park City formation thins from 340 feet to 325 feet to 65 feet along a line through these same three sections, decreasing from 100 to 95 to 19 per cent of the base section. The Weber sandstone at Vermilion Creek is less than half as thick as it is near Manila.

The table indicates marked positive tendencies for the extreme eastern Uinta Mountain area in Late Paleozoic time with a "hinge point" between thicker and thinner deposits located between the Vermilion Creek and Clay Basin areas. The "hinge point" appears to migrate westward after Permian time to a position between Clay Basin and Manila, then again to the east in post-Morrison time. Significant in interpretation of the latter shift is the disconformity found in the Vermilion Creek section (Reese, 1955) which showed a considerable hiatus in the pre-Frontier Upper Cretaceous rocks due to erosion and/or nondeposition. The low positive structural feature responsible for this disconformity influenced the eastern Uinta Mountain area, the south end of the Rock Springs uplift, and large areas of western and northwestern Colorado. It

appears to have been the forerunner of a similar structural positive area which arose later in Late Cretaceous time.

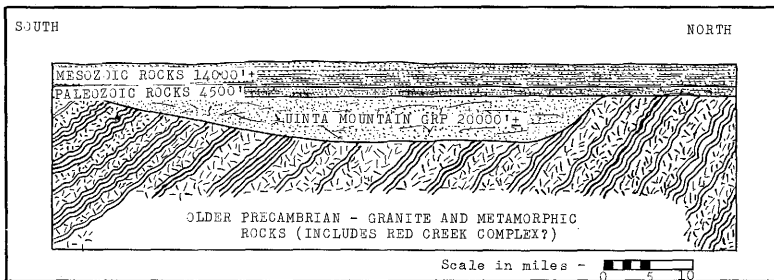
By Medial Cretaceous time (post-Frontier) a reversal of the structural pattern in western United States had taken place. The site of the Paleozoic and Early Mesozoic seaways in the west were uplifted and were the site of active mountain building. The pulses of this structural activity were moving steadily eastward toward the old stable shelf. The Cretaceous seas lay to the east and north, and these seas transgressed and regressed across the shelf area in response to the pulsation of mountain building to the west. Each episode of orogenic activity caused a tongue of conglomerate, sandstone, and siltstone to be built eastward into marine shales and limestones. The site of the present day Uintas appears, rather strangely, to have lost its mildly positive character during this span of Cretaceous time. Minor positive areas protruded through the Cretaceous seas to the north and south, and the orogenic mountain-building belt lay not distant to the west; but the Daggett County area accumulated an abnormal thickness of marine shale throughout the post-Frontier to pre-Mesaverde depositional interval. The Mesaverde formation represents the first tongue of clastic sediments that spread over the area generally, marking the end of marine deposition on the site of the Uinta Mountains.

The steadily increasing tempo of mountain-building activity to the west began to affect the Daggett County area even more directly as Cretaceous time drew to a close. A low fold in the forefront of this orogenic belt began to rise along a north-south line parallel to the Utah-Colorado border from the Uncompahgre uplift of central western Colorado. It crossed the site of the Uinta Mountains at its eastern end, continued north to the south end of the present Rock Springs uplift, then turned northwest toward the La Barge-Big Piney area of western Wyoming. This fold is referred to here as the Douglas Creek-Big Piney foreland fold. Uppermost Cretaceous rocks--Lance and Lewis--were either not deposited or were stripped from the crest of this fold for most of its length. Elsewhere erosion cut as deep as the Ericson sandstone member of the Mesaverde formation. Where this fold crossed the site of the Uintas there was a marked structural culmination, the cumulative effect of older uplifts--pre-Mississippian, Early Mesozoic, Early Late Cretaceous--plus the effects of the Douglas Creek-La Barge folding plus the first stirrings of the Uinta Mountain Arch which was to come. Hansen and Bonilla (1954, p.11) and Hansen (1957) have shown that locally, at least, in the Clay Basin area, the Mowry shale, and possibly the Dakota and Morrison formations, were exposed to erosion in Paleocene time. Recognizable fragments of these formations appear in conglomerates in the lower portion of the Hiawatha member of the Wasatch formation. Regional studies of the Paleocene and earliest Eocene deposits of the area show, however, that the Uinta Mountains, as such, had not yet become a major structural feature.

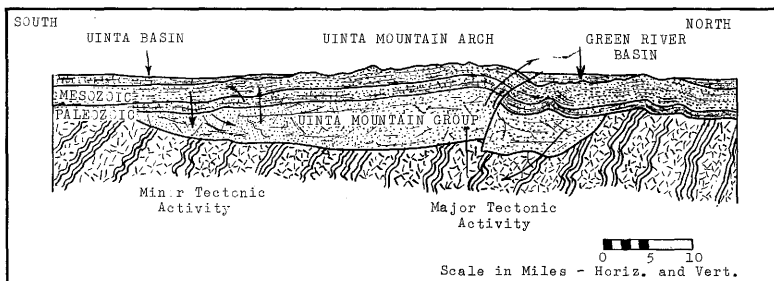
### The Growth of the Uinta Mountains

#### Regional tectonics

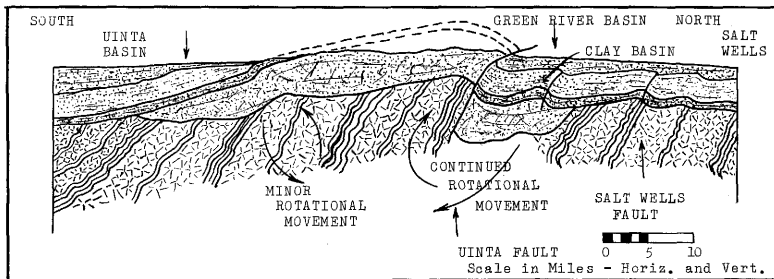
In late Paleocene and earliest Eocene time the Uinta Mountains became a major structural feature and began to influence the sediments in the surrounding basins. The Uinta Mountain Arch was largely controlled in its configuration by the "pod" of Precambrian



UPPERMOST CRETACEOUS (LANCASHIRE FORMATION) - NO APPRECIABLE GROWTH OF  
UINTA ARCH



MID - PALEOCENE (FORT UNION FORMATION) - SUBSIDENCE OF UINATA AND GREEN RIVER BASINS  
TO SOUTH AND NORTH WITH CONSEQUENT GROWTH  
OF UINATA ARCH



EARLY EOCENE (TIPTON TONGUE OF GREEN RIVER FORMATION) -  
PROBABLE MAXIMUM GROWTH OF UINATA ARCH

DIAGRAMMATIC SECTIONS SHOWING STAGES OF  
GROWTH OF UINATA MOUNTAINS  
FIGURE 7

sediments, largely quartzite, which had been imbedded in the earth's crust. The rise of this great regional arch and the mountain range formed by it was triggered by forces acting around it, beneath it, and at its west end. This has been graphically described by the writer (1956b, p. 124) as: "A homely comparison might liken the 'pod' to a bottle imbedded at shallow depth in a tub of crushed ice. If one presses down on the ice adjacent to the bottle, the bottle will be displaced upward. Or, if pressure is applied close to one end, the bottle will be propelled forward. The Uinta 'pod' appears to have responded in similar fashion to the forces acting around it. As Paleocene and early Eocene basins of deposition took shape and began to depress themselves into the earth's crust, the 'pod' rose as a complementary response. As more debris was dumped into the downwarping troughs, the adjacent mountain mass was pushed up higher. The process continued until equilibrium was reached."

In late Paleocene time and early Eocene time the Uinta Basin to the south of the Uintas, the Green River Basin to the north, and the Sand Wash Basin to the northeast began to subside. The Uinta Mountain Arch rose in response. The deepest parts of these basins are located close to the flanks of the Uintas and may, in some cases, lie beneath the great faults which were thrust upward and outward from the margins of the rising arch. It is difficult to say whether the depression of the trough adjacent and subjacent to the mountain mass (underthrusting) was more active or important than the mountain mass floating up and riding out over its own debris (overthrusting). The two processes were contemporaneous and complementary (see Figure 7).

Where the arching and thrusting impinged against the competent mass of the older Douglas Creek-Big Piney foreland fold, the thrusting produced a series of deep-seated, west-east, cross-folded "wrinkles." These are asymmetric to, and often overthrust on, the flank away from the forces which produced them. These "wrinkles" include Middle Mountain anticline and the dual Salt Wells and North Salt Wells anticlines to the north and Split Mountain, Section Ridge, Blue Mountain, and Rangely anticlines to the south.

The strike-slip movement of the Uinta fault has also been graphically depicted by the writer (1956b, p. 125): "The Uinta 'pod' was subjected to a west to east push applied at its west end. The force was the Mesozoic orogenic belt of continental proportions which had moved steadily from Triassic to early Eocene time from Nevada on the west and into western Wyoming on the east. Based on displacement of the older north-south pre-Uinta fold axis (Douglas Creek-Big Piney foreland fold) from the Douglas Creek Arch north through Rangely, thence displaced east to Skull Creek and projected in an arc through patches of Precambrian exposed in Dinosaur National Monument, the Uinta 'pod' appears to have been shoved eastward about six miles. This does not disagree too violently with calculated displacement on the Sparks overthrust, where the east end of the Uintas is thrust over the deepest portion of the Sand Wash Basin (in north-western Colorado)." This figure also agrees with the estimated displacement of complementary anticlines on the north flank of the Uinta Mountains in Daggett County (see Structure, Relations of folds).

Figure 7 depicts in diagrammatic sections progressive stages in the development of the Uinta Mountain Arch and its bounding faults and folds.

## The age of the Uinta Mountains

The Uinta Mountains, as such, came into being in latest Paleocene or early Eocene time. Their rise is marked in the Hiawatha member of the Wasatch formation which in this area is Paleocene and Eocene in age. The lower 1200 to 1800 feet of the Hiawatha is drab-colored, coaly, and contains a small amount of conglomerate. The content of these conglomerates indicates that by late Paleocene time Jurassic rocks, perhaps as old as the Curtis or Navajo, had been exposed to erosion. This uplift was localized at the east end of the site of the Uintas and was due mainly to the cumulative uplift of the Douglas Creek-Big Piney foreland fold. The upper half of the Hiawatha member (earliest Eocene) becomes increasingly conglomeratic and more colorful and loses its coaly content. It is apparent that the tempo of mountain building along the length of the Uintas was increasing and that the low-lying coal swamps had given way to deposits of debris from the rising mountains. The contents of the conglomerates are mainly boulders and cobbles of Paleozoic rocks with a small amount of Precambrian Uinta Mountain group quartzite. The core of the range had been breached even more deeply. The Tipton tongue of the Green River formation is a widespread but thin unit and represents a brief span of early Eocene time. Conglomerates built into these lake deposits retain the pattern of the Hiawatha, primarily Paleozoic rocks with a small amount of Precambrian.

Regional studies (Ritzma, 1955; Ritzma, 1956a; Anderman, 1955a, b) show that the Tipton marks the end of major folding and thrusting along the north flank of the Uinta Mountains. The Tipton is involved in most of the strong folding and thrusting; but the beds above, the Cathedral Bluffs member of the Wasatch, are less strongly folded and often truncate and overlap the strongly folded and faulted older Eocene beds without visible disturbance. In western Daggett County, Green River beds equivalent to the Cathedral Bluffs truncate and overlap younger Green River beds north of the Henrys Fork fault and eventually overlap and obscure the fault completely.

The Uinta Mountains stood high at the end of Tipton time but active folding and faulting appears to have ended. Erosion attacked the mountains, and the range was generally breached to its Precambrian core. Conglomerates in the Cathedral Bluffs member of the Wasatch and its equivalents contain abundant material from the Precambrian Uinta Mountain group, and the strong red hues of this member appear to have been derived in a large part from the red of the ancient quartzite and shales.

The building of the Uinta Mountains thus is bracketed within the latest of Paleocene time and the earliest vertebrate faunal zone of the Eocene, the Wasatchian. This span of time which could range from five to ten million years is more than adequate for mountain building when placed beside the time scale of structural events in California and elsewhere in the world.

## Late Tertiary Structure

A very important factor in the structural configuration of this area was a widespread gentle upwarping of the entire Rocky Mountain region. This epeirogenic movement which uplifted basins

and mountains together occurred intermittently through Oligocene, Miocene, and Pliocene time and had profound effect on the entire region. Climate became more arid as elevation increased. Vegetation and animal life changed in response. River gradients steepened and the base level to which they could erode lowered. The processes of erosion were greatly accelerated and rivers were capable of carving deep canyons and transporting tremendous volumes of sediments away from the region in the course of their excavation.

In Miocene time an apparent relaxation of the compressive forces which produced the Uinta Mountain Arch caused a major collapse of the arch, particularly at its eastern end. In eastern Daggett County a set of normal faults and fractures parallel to the axis of the arch extends from west to southeast for 20 miles and continues eastward into Colorado. Another set of similar trend crosses the southeast corner of the county. A closely spaced set of faults has down-dropped the crest of Red Canyon anticline within the arch.

Browns Park is the western termination of the large regional graben which was formed when the east end of the Uinta Mountain Arch collapsed. This graben extends for 70 miles to the southeast, and some ramifications of the collapse-type structure exist for 20 or more miles to the vicinity of Craig, Colorado. Normal faults bound the park on its north and south sides, and the Browns Park formation dips into and has been faulted into the down-dropped block. The collapse took place during the deposition of the Browns Park formation in early and medial Miocene time. To a very minor extent, some faults related to these Late Tertiary movements have continued to be active into geologically Recent time.

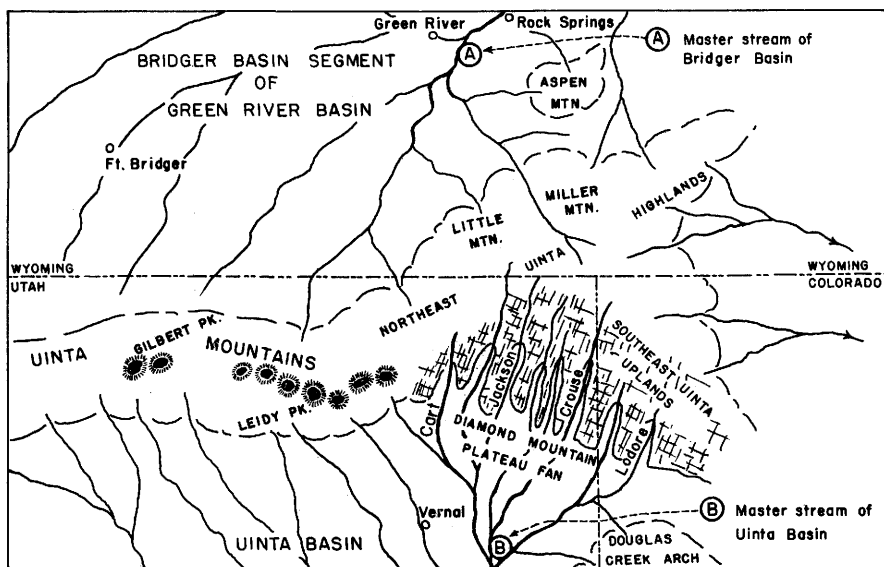


FIGURE 8A. PROBABLE ORIGINAL DRAINAGE PATTERN OF GILBERT PEAK EROSION SURFACE. Shading shows outcrop area of Precambrian Uinta Mountain quartzite. Note: NNE-SSW drainages controlled by joint system in quartzite and radial drainage from vicinity of "Three Corners."

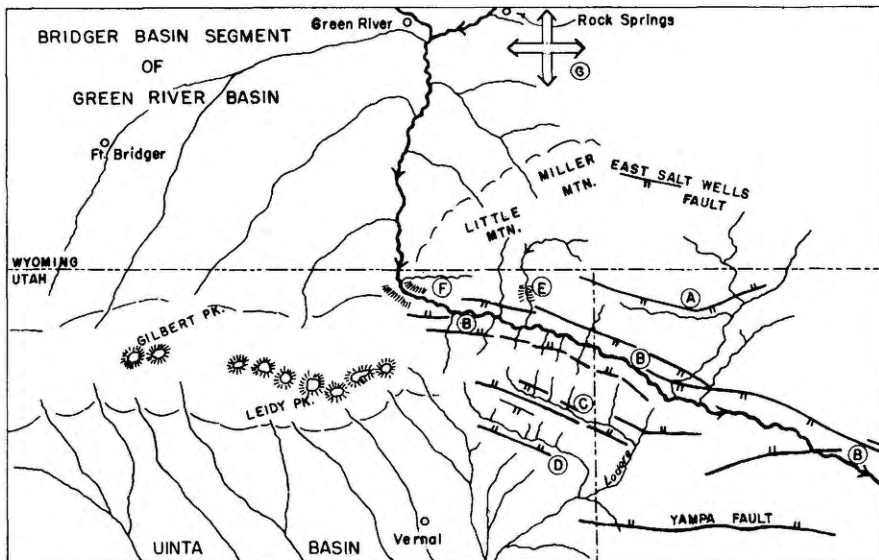


FIGURE 8B. POST-GILBERT PEAK STRUCTURAL TRENDS AND DRAINAGE CHANGES. Structural trends: (A) Talamantes fault zone, (B) Browns Park graben, (C) Pot Creek fault zone, (D) Diamond Culch fault zone, (E) NNE-SSW drainages disrupted and diverted eastward by (B) (C) (D). Capture of Red Creek at (E). Capture of master drainage of Bridger Basin at (F) in Flaming Gorge area. Growth of positive structural area (G) and others to north assist in southward diversion of master drainage. Hachures on down side of faults.

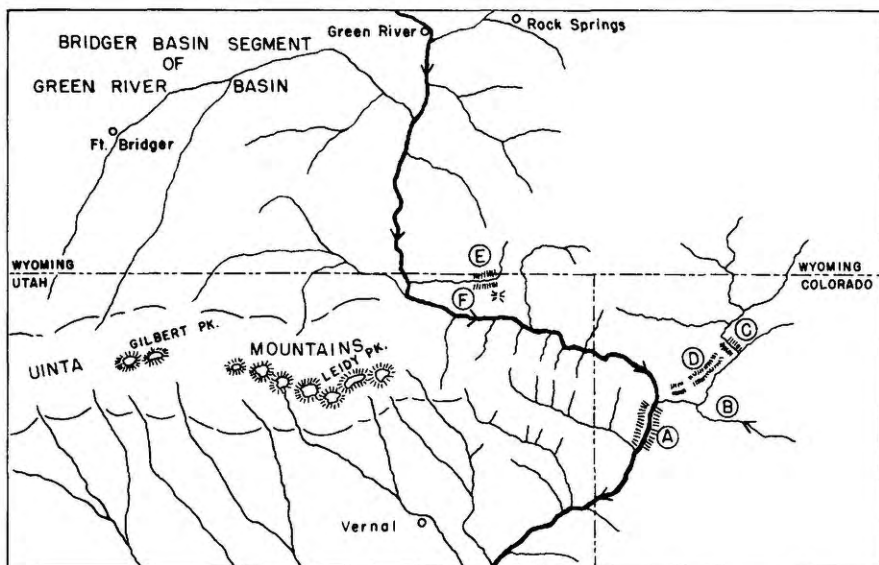


FIGURE 8C. FINAL DRAINAGE PATTERN AFTER LAST MAJOR STREAM PIRACY THROUGH LODORE CANYON. Headward erosion by Lodore Canyon stream (A) captures master drainage, diverting it southward. Reversal of drainage of Vermilion Creek and Douglas Draw (B). Capture of headwaters of Vermilion Creek (C) strands Irish and Bull Canyons as "wind gaps." Capture of (E) by headward erosion of Spring Creek diverts drainage westward, stranding Dutch John Gap (F) as "wind gap." Numerous adjustments in Bridger Basin drainage shown in generalized way.

## G E O M O R P H O L O G Y

### INTERPRETERS OF SCENERY

The course of the Green River through the Uinta Mountains is a paradoxical one. The river flows southward through Wyoming across the floor of the Green River Basin, plunges headlong into the Uinta Mountains at Flaming Gorge, continues a circuitous, meandering course southward through Horseshoe and Hideout Canyons, turns east, and winds sinuously through Red Canyon, Little Hole, Swallow Canyon, and Browns Park. For these 35 miles of general eastward direction the river's course is only slightly north of the structural crest of the Uinta Mountain Arch. At the east end of Browns Park the Green turns abruptly and again plunges across the Uintas at right angles through Lodore Canyon, thence west and south through Whirlpool and Split Mountain Canyons to emerge onto the floor of the Uinta Basin at Jensen, Utah. It is little wonder that this paradoxical course of this river generated unusual thought, imagination, and speculation on the part of the first geologists to visit the Uintas in the middle of the nineteenth century.

The most comprehensive studies of the eastern Uinta Mountains were those of Major John Wesley Powell. Beginning with his exploratory descent of the Green and Colorado Rivers in 1869, three of Powell's expeditions traversed the region, the latter two concentrating specifically on its geologic problems. In 1874 Powell, traveling mainly by pack train, explored in detail a strip 10 to 30 miles wide on either side of the Green River from Green River, Wyoming, to the north portion of the Uinta Basin of Utah. In 1875 his circuit of exploration led southeast from Green River, Wyoming, across the southern Rock Springs uplift to Vermilion Creek and Browns Park and up the Green to Flaming Gorge and back to Green River, Wyoming. Two geologic works resulted from these expeditions (Powell, 1875, 1876); the first an account of the river expedition and the second a classic in the study of land forms. In this second work, Powell defined such terms as consequent, antecedent, and superimposed as they applied to valleys, and with them he attempted to solve the riddle of the course of the Green. Powell (1876) credited Marvine, an associate of Hayden, with developing the fundamental idea of superposition of streams which Marvine had introduced in a Hayden Survey Report in 1874, but he failed to mention Hayden's ideas of antecedency published in 1872 and 1873.

Powell (1875, p. 163) weighed the evidence gathered in his travels and observations of the Green and the Uintas and concluded "the drainage was established antecedent to the corrugation or displacement of the beds by faulting and folding. I propose to call such valleys . . . antecedent valleys."

The Hayden Survey or Geological and Geographical Survey of the Territories conducted from 1867 to 1878 touched the Daggett County area in 1870 when F. V. Hayden spent from September 16 to October 18 in a rapid reconnaissance of the north flank of the Uintas from the head of Bear River to Browns Park. He was impressed and puzzled by the geology and regretted that time did not permit closer study. One succinct observation (1872, p. 62) was that the streams "cut their way through ridges at right angles." Further surmise and study led to Hayden's concept of antecedent streams mentioned in a report in 1873.

Clarence King of the Geological Survey of the Fortieth Parallel (1869-1872) worked in the area intermittently from 1869 through 1872. The excellent reports of King and his associates, J. D. Hague, Arnold Hague, and S. F. Emmons, appeared in print in 1877 and 1878. In Chapters II and III in Descriptive Geology, Emmons (1877) made a significant contribution to the geomorphology of the eastern Uintas by stating that the course of the Green River was due to superposition. Since the idea of superposition was proposed by Marvine in 1874 and acknowledged by Powell in 1875, the ideas of Emmons, perhaps formulated in 1870, antedate those of the former writers by several years.

Later students of Uinta land forms include Atwood (1909), who authored a definitive work on glaciation; Rich (1910); Sears (1924); and Bradley (1936). The latter work is the definitive work on the land forms and drainage of the eastern Uintas. In it the Gilbert Peak and Bear Mountain erosion surfaces are described and the course of the Green River explained as the result of a complex combination of uplift, faulting, tilting, differential erosion, and stream piracy. For the most part, Bradley's terminology and sequence of geomorphic events is recounted here. More complete topographic mapping completed since 1936 and aerial photographs have made necessary only minor modifications.

## POST EOCENE TO PLEISTOCENE

### The Erosion Surfaces

#### Gilbert Peak Surface

There is only fragmentary knowledge of the pattern of the ancient streams that drained the east end of the Uintas from late Eocene time to the cutting of the Gilbert Peak erosion surface and the deposition of the Bishop conglomerate in Miocene time.

Bradley (1936, p. 177) describes this period: "The Gilbert Peak surface was formed at a time when the Tertiary sediments in the Green River Basin had not been dissected and so filled the basin to a higher level than they do today. Slightly eroded remnants of these Tertiary sediments (beneath the remnants of the Bishop conglomerate) indicate that they once lapped high against the flank of the Uinta Range. The altitude of these highest remnants suggests, moreover, that the upper part of the Bridger formation probably lapped up against the east end of the range and was continuous with contemporaneous Tertiary beds filling the basin to the south. Apparently this Bridger cycle of Tertiary sedimentation was followed by a long interval of time, during which the streams of the region flowed on this great plain of aggradation. During this interval the climate seems to have grown progressively more arid, and the great depositional plain was gently warped, so that the structure of the Bridger Basin and the Rock Springs uplift were mildly accentuated."

Bradley (p. 177) surmises that the master stream of the region received the flow of tributary streams that gravitated northward from the Uintas and "must have flowed eastward or northeastward out of the Green River Basin and perhaps connected with the ancestral Platte River or some similar stream that flowed to the Mississippi."

The topographic crest of the Uintas and the axis of the Uinta Mountain Arch apparently were coincident as far east as Leidy Peak (Figure 8A). At this point the topographic crest of the Range trended northeast into Wyoming while the structural axis continued eastward and then turned southeastward into Colorado. The topographic crest may have been controlled in part by latent growth tendencies of the positive area of the south portion of the Rock Springs uplift (Ritzma, 1955, 1956) or Clay Basin anticline. Streams radiated northward from the Clay Basin vicinity (Bradley, 1936, p. 187) and southward across the axis of the Uinta Mountain Arch which apparently had a very subdued topographic expression. The southward flowing streams, for the most part, trended in a S 15° W direction along remarkably parallel valleys probably controlled by jointing and fracturing. The valleys were separated by ridges of the same trend, and rectangular drainage controlled by the dominant right angle joints in the Uinta Mountain group quartzite was probably well developed. In eastern Daggett County the NNE to SSW drainage was disrupted by later faulting and stream piracy, but the valleys are still discernible and are occupied in part (between Browns Park and Summit Valley) by Cart Creek, Jackson Creek, Tollivers Creek (Warren Draw), Sears Creek, Crouse Creek, and in Colorado by Davis Draw and the Green River in Lodore Canyon. Many of these have counterpart valleys north of Browns Park, Beaver Creek lining up with Crouse Creek and Willow Creek with Sears or Tollivers Creek. All but Davis Draw appear to have flowed southward across present Summit Valley into the Uinta Basin. The streams from Crouse Creek west to Cart Creek converged somewhat to the south and discharged across a large fan into the Uinta Basin. This fan survives as the gravel-capped Diamond Mountain Plateau.

#### Bear Mountain Surface

After the cutting of the Gilbert Peak surface and deposition of its shifting gravel mantle (the Bishop conglomerate) the drainage pattern of the area underwent a marked change. Streams began to cut and trench the Gilbert Peak surface and the Bishop conglomerate. In time these streams reached their new grade and widened their valleys extensively. A new plane of erosion, the Bear Mountain surface, was thus formed several hundred feet below the older Gilbert Peak surface.

Quoting Bradley (1936, p. 180): "While the basinward portion of the Gilbert Peak surface was being dissected and the Bear Mountain surface developed, two rather large valleys, each roughly parallel to the axis of the Uinta Mountain Arch, were being cut out in the postmature highland along the east end of the range. The larger of these, the Browns Park Valley, extends from the east side of Henrys Fork at a point about 5 miles south of the Utah-Wyoming boundary eastward about 80 miles to the east end of the Uinta Range. In its west end the position of the valley was apparently determined by an ancient subsequent stream, which flowed eastward along the south side of the strike ridge made by the carboniferous limestone beds where they are turned up along the Uinta flexure."

"South of the Browns Park Valley and about 1500 feet higher is another broad, rather flat-bottomed valley comparable to the Browns Park Valley, though smaller. Powell names this 'Summit Valley'."

### Collapse of the Uinta Mountain Arch

The above valleys described by Bradley undoubtedly were initiated and accentuated by jointing and faulting. The exact sequence is not known, but they apparently were developed at right angles to the old south flowing streams of the Gilbert Peak surface. It was approximately at this time that the east end of the Uinta Mountain Arch began to collapse. This collapse took place along lines of faulting of west-northwest to east-southeast trend, closely paralleling the trend of the axis of the Uinta Mountain Arch and the similar prominent joint trend in the Uinta Mountain group quartzites. Four prominent fault-fracture zones of this geologic age and general trend are recognized in the vicinity of Daggett County (see Figure 8B). Of these, the Browns Park graben and the Pot Creek fault zone are most significant. Both strongly accentuated pre-existing valleys.

As these fault zones became more prominent, particularly the down faulting of Browns Park, the drainage patterns of the Gilbert Peak and Bear Mountain surfaces were disrupted and the streams adjusted themselves quickly to the new tectonically formed valleys and zones of weakness. The major drainages now flowed southeast. The conglomerates of Diamond Mountain Plateau were broken by faulting, and drainage was diverted southeast along the present course of Diamond Gulch. Pot (or Cascade) Creek followed a fault-controlled course southeast and entered the stream which occupied the course of present Lodore Canyon. It then continued its southerly course into the Uinta Basin. The stream in Browns Park Valley meandered widely across the graben floor and continued to the southeast around the east end of the Uinta Mountains.

### Other Structural Events

Several continuing structural events at this time also had profound influence on the Daggett County vicinity. The Rock Springs uplift, a post-late Eocene domal fold, continued to be upwarped, probably across the course of the master stream which drained northeast out of the Green River Basin. In post-Gilbert Peak time portions of the north end of the Rock Springs uplift were particularly uplifted (Ritzma, 1956) and considerable lava was extruded across this part of Wyoming. The northeast course of drainage out of the Green River Basin possibly was made even more difficult. The Vermilion Basin uplift of extreme northwest Colorado was also upwarped through this post-late Eocene to Miocene interval (Ritzma, 1956), but its effect on geomorphic events is local and is not assessed here.

### Browns Park formation

At this same time, the Browns Park formation was also being deposited. Largely wind blown volcanic ash and sand, it tended to fill topographic depressions and was extensively reworked by streams, redeposited in temporary lakes, and admixed with local fan deposits, landslide debris, and the like. It blanketed the region to great depth, and one or more prominent erosion surfaces were developed on top of the Browns Park formation, particularly on the south flank of the Uinta Mountains near Vernal (Kinney, 1955) and extensively throughout northwest Colorado and south-central Wyoming. Along the north flank of the Uintas these younger surfaces have been completely effaced, making it difficult to

assess their role in the geomorphic scene. It is obvious, however, that the Browns Park formation had a "choking" effect on drainage and that it and the surfaces developed on it were major factors in the changing lines of drainage. It is likely that Emmons' in 1877 was at least partially correct in proposing that the course of the Green River was due to superposition from these now effaced surfaces.

### Resulting stream piracy

The major stream draining Browns Park continued to develop its broad valley on the down-faulted valley floor. A tributary entering Browns Park from the north, eroding headward, captured the headwaters of Red Creek and diverted them south. Similar headward erosion by a western tributary captured the master stream of the Green River Basin and diverted it southward into the Browns Park Valley near Flaming Gorge (See fig. 8B).

Quoting Bradley (1936, p. 188): "When the Green River first entered the Browns Park Valley, it flowed on the uppermost beds of the Browns Park formation and apparently followed the course of the ancient Browns Park stream eastward beyond the east end of the Uinta Mountains. . . . but soon after it was diverted sharply southward, so that it came to run directly across the axis of the Uinta Mountain Arch along the present site of Lodore Canyon."

Thus, the headward erosion of the Lodore Branch of the ancient Green River effected the final drainage diversion. With this capture of the entire drainage of the old Browns Park Valley, the present course of the Green was established. The readjustment of drainage lines briefly summarized here had ramifications over broad areas of northeastern Utah and adjacent Colorado and Wyoming, amply attested by numerous reversed drainages, "barbed" tributaries, wind gaps, and paradoxical canyons cut through mountain uplifts (See fig. 8C).

### Carving the Canyons

With the course of the Green established, the cutting of the canyons commenced. During late Tertiary time the entire Rocky Mountain region was affected by a continental broadwarping or epeirogenic uplift which elevated mountains and basins simultaneously. Erosion was greatly accelerated as streams sought to adjust to their new base levels. Vast quantities of sediment were removed from basins and the mountains were "exhumed" from the blanket of sediment which had buried them, in some cases nearly to their summits. This tremendous load of silt and sand was a potent erosive tool as the streams steadily incised their canyons across the ranges and broadened their flat-floored courses across the basins.

### PLEISTOCENE AND RECENT

#### The Ice Ages to the Present

The Pleistocene epoch, covering the span of time from a million years ago to perhaps 25,000 years ago, was the period of the great continental and mountain glaciers, most generally known as the Ice Age.

During this time extensive mountain glaciers formed in the high Uintas, gathering in the headwaters of the major drainages and flowing outward down the valleys. This glaciation has been discussed at length by Atwood (1909) with additions and modifications by Bradley (1936). Much of this information has been recounted in this volume under Cenozoic Stratigraphy, Quaternary System.

The principal effect of the glaciers on the scenery is visible in the high mountain valleys. Here the catchment areas of the glaciers can be seen, the great amphitheater-like, rock-walled cirques dotted with lakes. The glacial ice, scooping these cirques in the gently rolling upland topography of the ancient Gilbert Peak erosion surface, produced a terrain aptly called "biscuit-board" topography. This is well developed in the headwaters of Sheep Creek (see Plate 4) and other drainages in the high Uintas. When two or more cirques coalesce, knife-edge ridges (arêtes) and pyramidal peaks (matterhorns) commonly form. The glaciers of the eastern Uintas apparently did not possess sufficient erosive power to carve these mature alpine glacial land forms in the highly resistant quartzite core of the Uinta Range. In contrast to the alpine scenery of the Wasatch Mountains, the Uinta peaks are rounded and the divides between glacial cirques wide and rarely sharp crested.

The cirques and the valleys that lead out from them are typically U-shaped and occupied by chains of lakes that fill the lowest parts of the rocky basin floors. These rock basin or "tarn" lakes often have no visible outlet, but water percolates through the dams formed by bouldery moraines and rock falls into streams at lower levels. The high glacial valleys and cirques of Daggett County are somber in appearance due to the dark reddish hue of the quartzite from which they are carved. Annually great quantities of snow collect in these basins, and perennial snow fields exist in some today.

Outward from the cirques the valley edges are strewn with bouldery lateral moraines and the blocky material of rock falls and talus slides. Some terminal moraines persist across valleys, but most have been destroyed by meltwater of the retreating glaciers. The moraines are recognizable by typical hummocky terrain and chaotic masses of boulders. They often are densely forested. Farther down the valleys, beyond the limits of the glaciation, the coarse debris becomes less extensive and gives way to cobble and gravel glacial outwash and finally to alluvium along stream bottoms.

With the Ice Ages of the Pleistocene, erosive processes were accelerated by the great volumes of glacial meltwater in combination with sand, silt, and finely ground glacial "flour" swept far downstream. The general effect has been a continuation of the gigantic erosive process begun in Miocene and Pliocene time. Regional uplift (epeirogeny) apparently slowed and has possibly halted, but rivers have persisted in their downcutting and carving. The process continues today, accelerated on one hand by careless use of land and forests, checked on the other by conservation practices and great engineering works such as Flaming Gorge Dam.

### Sheep Creek Cave and Lost Creek

(The following material on Sheep Creek Cave is taken from information furnished by Dale Green, Utah Speleological Society.)

In Sheep Creek Canyon, specifically in the NW of section 16, T. 2 N., R. 19 E., a major cave is exposed in the west wall of the canyon a short distance from Utah Highway 44. Big Spring flows from the lower level and is locally said to be the resurgence of Lost Creek fourteen miles to the west. Geologically the cave is in vertical to overturned Madison limestone (Mississippian) a few hundred feet south of the Uinta fault.

Many exaggerated tales of the size of the cave have been told, although it had not been explored beyond a large room 600 feet from the entrance until late 1956. The first 300 feet of the cave is a confusing array of dry, dusty passages over, between, and under large blocks fallen from the ceiling. The next 300 feet of passage is much wetter and ends in an impressive room measuring 130 by 70 feet. Beyond this are two smaller rooms connected by small passageways. The presently known end of the cave is 1100 feet from the entrance where the ceiling nearly meets the stream.

According to Green, Sheep Creek Cave "exhibits many of the typical features of caverns originating beneath the water table. The present stream and the large amount of block breakdown have modified the original pattern. There are almost no speleothems (stalactites and stalagmites) present."

The Lost River mentioned by Green as a possible source of the stream is shown on the map in this bulletin as Lost Creek. It is located in sections 7 and 18, T. 2 N., R. 17 E., in eastern Summit County at the extreme west edge of the area mapped. Atwood (1909, p. 37) in his discussion of glaciation in Burnt Fork Valley mentions this stream as follows:

The lateral moraines in the main canyon have blocked a number of tributary streams, both on the east and on the west. On the west two streams that were blocked have worked their way out in post-glacial time. On the east, just south of one of the big hogback ridges, there is a stream (Lost Creek) whose history has been somewhat unusual. The lower portion of its course is indicated on Pl. IV (topographic map which is, in part, U. S. Geological Survey Gilbert Peak Quadrangle) by a depression contour. The stream was blocked by Burnt Fork glacier and by the east lateral moraines of that glacier. This valley received much wash from the margin of the ice and became in part filled with this alluvium. The ice, and afterwards the moraine, caused a ponding of the stream, but not sufficient to give the water of the lake a surface outlet. Some water may have seeped through the moraine, but the main outlet was at the bottom of the lake, near the limestone strata that form the hogback ridge. This underground outlet drained the waters of the lake, and the stream, following this course, has developed a valley in the alluvium fully one mile long, 40 to 50 feet deep at the lower end, and 100 to 200 feet wide at its mouth. The valley ends abruptly as in a great sink hole, and the stream now enters the limestone through an opening 10 feet wide and 5 feet high.

All the material excavated in the development of the valley must have been carried away through this underground outlet. The point of exit of the stream from this limestone is not positively known, although a spring, comparable in size to the stream, issues on the north side of the hogback ridge at a point 700 feet below the place where the stream enters the rock. Other springs, farther east, are said to fluctuate with this stream, and as they lie along the strike of the limestone they may be outlets.

## E C O N O M I C   G E O L O G Y

### METALLIC MINERALS

Daggett County has not shared in the important metal mining tradition of the rest of Utah. Exploitation of the few deposits of metallic minerals present has seldom progressed beyond the exploratory stage, and there is little to indicate that important metallic mineral resources are present.

#### Copper and Iron

The country to the north and northwest of Vernal, Utah, on the south flank of the Uintas was the site of considerable mineral prospecting and small-scale commercial mining in the period from 1890 to 1915. Iron and copper, with minor amounts of gold, silver, and lead, were mined from small but relatively rich ore deposits in the Mississippian and Pennsylvanian carbonates. Attempts to locate similar deposits on the north side of the Uintas were unsuccessful. The mines on the south flank failed to develop into "bonanzas," and prospecting and mining efforts along the Uintas declined completely. Only a few dim pits and rotting timbers on the Daggett County side of the mountains mark the labors of now forgotten claims and prospects.

In eastern Daggett County small copper and iron deposits occur in the canyons and on the divides between Red Creek, Jesse Ewing Canyon, and Willow Creek in the area between Clay Basin and Browns Park. These were recorded by Powell (1876) and Emmons in 1877 in their studies of the eastern Uinta Mountains. The deposits consist of copper and iron sulfide, oxide, and carbonate ores in fissure veins occupied by dioritic and pegmatitic dikes and irregular quartz veins. The ore is commonly associated with the quartz veins or is disseminated for a short distance into the quartzite and schist wall rock or the diorite dikes. The principal copper sulfides are chalcopyrite and chalcocite, and other copper minerals include bornite, azurite, and malachite. Pyrite and hematite are the main iron minerals. The ore occurs in the Red Creek complex of Archeozoic (?) age.

No commercial production has been reported and small-scale prospecting and mining has been at best sporadic. The district has been termed the Red Creek or Yellow Canary area and most recent interest has stemmed from discovery of uranium ore in the abandoned copper prospects.

## Uranium

Feverish uranium prospecting in the late 1940's and early 1950's triggered a systematic search for uranium occurrences similar to the extensive deposits discovered on the Colorado Plateau in sedimentary formations such as the Morrison and Shinarump. These and other formations were tracked in all directions from the Colorado Plateau over vast distances from Montana to Mexico. The spectacular knife-edge hogbacks and colorful cliffs of Jurassic and Triassic formations along the north flank of the Uintas saw intensive prospecting activity. Many radioactive "shows" were recorded, myriad claims were staked and hundreds of pits dug, but no sizeable mineral concentrations were uncovered.

In eastern Daggett County an unusual deposit of uranium ore stirred considerable interest during this period. Carnotite had been noted as early as 1920 in the Red Creek area by B. S. Butler and F. L. Hess (Butler, et al, 1920) but little interest developed until 1948 when claims were staked in what was called the Yellow Canary area. Active prospecting and development began in 1950. The principal uranium ore is tyuyamunite with lesser amounts of carnotite, volborthite, and other uranium minerals (Wilmarth, 1950). The ore is sparsely and spottily disseminated in fractures in the strongly folded and faulted Archeozoic (?) Red Creek complex and is closely associated with the copper deposits previously described.

The occurrence of the ore in Precambrian rocks stirred much interest and study. Unfortunately the ore body proved to be small and erratic in nature and very limited development has taken place.

## Gold

Gold in small amounts in the form of "flour" has been recovered by panning and small-scale sluicing of sand and gravel in the Green River in Browns Park and Red Canyon. As far as is known, no organized operation has ever been undertaken.

## Manganese

Several pockets of manganiferous sandstone and conglomerate in the Morrison formation have been found. Two such deposits located three miles south and southwest of Manila have been described by Heim and Allsman (1950) and Anderman (1955). The deposits appear to be of small value. Except for small amounts of ore removed for sampling and assay, no production has been recorded.

## NONMETALLIC MINERALS

### Gas and Oil

Daggett County produces large quantities of natural gas from the Clay Basin gas field. The basin from which the field received its name is a striking topographic hollow eroded in the soft Mancos shale. Cliffs of Mesaverde sandstone half circle the basin from west through north to east, and the salient features of the struc-

ture are readily discernible in these outcrops. On the south reddish and varicolored foothills of the Uintas rise abruptly. The basin is drained by Red Creek and tributaries.

Clay Basin is a doubly plunging anticline with about 400 feet of closure. The axis trends about N 70° W, slightly oblique to the east-west trend of the Uinta Mountain Arch and the Uinta fault. The north flank of the fold falls off rapidly and the northwest end plunges rapidly away from the central area of closure into the Green River structural basin. The south and southeast flanks of the anticline are obscured, but apparently there is several hundred feet of reversal across a shallow syncline before the Mancos shale turns up sharply against and under the Uinta overthrust.

The first well, P. C. Spencer #1 Gov't, was drilled in 1924 to a depth of 500 feet and was abandoned. The discovery well, Producers and Refiners Corporation #1 R. D. Murphy, was completed in 1927 for 3,275 mcf gas per day from the Frontier sandstone. The well was shut in for lack of market. In succeeding years leases covering the area of the structure were unitized, and in 1935 a second test was drilled by the unit operator, Mountain Fuel Supply Company. This well, #2 Murphy, discovered the large gas reserve in the Dakota formation and was completed for 32,000 mcf gas per day. A pipeline connection to Salt Lake City was completed in 1937. Eleven wells have been drilled in the field, of which ten are producers. The Dakota is the principal producing sand at an average depth of 5760 feet. Deeper drilling has proved the Entrada, Navajo, and Shinarump formations water-bearing, and a large volume of inert gas was tested from the Weber sandstone.

Clay Basin has produced 88,035,000 mcf gas (1937 through 1958). All wells produce varying amounts of condensate. Production in 1958 was 1,779,000 mcf gas and 1,844 bbls. of condensate. Published maps and reports on the field are as follows: Dobbin and Davison (1945), Fidler (1949), Fidler (1950), and Hansen (1957).

Two "wildcat" tests for oil and gas have been drilled in Daggett County. In 1956 a dry hole by Ohio Oil Company in section 34, T. 3 N., R. 22 E., tested the culmination of Spring Creek (Dutch John) nose against the Uinta fault. The well spudded in Morrison and bottomed in Weber sandstone at 3277 feet.

A dry hole was drilled by Carter Oil Company in 1954 in section 22, T. 3 N., R. 18 E. This well spudded in conglomerates of the upper Green River formation and bottomed in what is possibly the upper few hundred feet of the Mesaverde formation at a depth of 11,000 feet. The well was a highly significant stratigraphic test and indicated a great thickness of Tertiary beds immediately north of the Henrys Fork fault.

Oil and gas prospects appear to be good in Daggett County. Thick Paleozoic and Mesozoic formations of marine origin and a thick Tertiary section with many richly organic beds of swamp and lacustrine origin insure adequate sources for hydrocarbons. Many excellent reservoir sandstones and limestones are present through the stratigraphic column. Complex folding and faulting immediately north of the Uintas gives rise to many diverse but difficult to locate structural traps. Stratigraphic trap possibilities in lensing sandstones in the Morrison, Dakota, Mancos, and Mesaverde also are good. Exploration for these oil and gas traps is in the challenging period of pioneer effort.

## Coal

The coal resources of Daggett County are considerable. Important reserves are found in the Mesaverde formation (Upper Cretaceous) with minor deposits in the Frontier member of the Mancos shale (Upper Cretaceous) and the Manning Canyon shale (Mississippian-Pennsylvanian).

Most Mesaverde coal occurs in the upper three fourths of the Rock Springs member in the soft interval between the basal Chimney Rock sandstone tongue of the Rock Springs and the overlying massive Ericson sandstone member. This portion of the section consists of brown carbonaceous shale and bituminous coal interbedded with soft sandstone, gray claystone, and gray shale. The coals are irregular in occurrence and thickness ranging from beds a few inches thick to lenses of limited areal extent 10 to 12 feet thick. Coaly zones are persistent, but individual beds are discontinuous and broken by shale, claystone, and sandstone partings. The thickest and most numerous coals are found in the west of the band of Mesaverde outcrop near Linwood. Most of the mines here are a short distance north of the Wyoming border. The band of coaly sediments crops out for about eight miles to the east before it swings north again into Wyoming. Eastward the Rock Springs member tongues out into the marine Mancos shale, and the amount of coal becomes progressively less until none is present.

Several coaly zones are present in the Ericson sandstone member, and small openings have been worked near Spring Creek Gap and at Richards Gap north of Clay Basin, both a short distance into Wyoming.

Daggett County coal has not been mined extensively because of remoteness of markets and the difficult topographic and structural situations encountered along the outcrop. Most of the mines are small and production is for local use. The coal is of bituminous rank.

Coal in the Frontier and Manning Canyon formations is of very limited areal extent and thickness and has been little prospected. The occurrence of coal in the Manning Canyon shale is notable as one of the few coal occurrences in the Carboniferous (Mississippian-Pennsylvanian) rocks of western United States.

## Phosphate Rock

Reserves of phosphate rock in Daggett County are an important resource for possible development in future years. The phosphate occurs near the middle of the Park City formation (Permian) as phosphatic shale, mudstone, limestone, and dolomite. Highest phosphate content is found in oolitic shaly limestone or limy shale. The entire phosphatic sequence is soft and has a characteristic sooty gray to black appearance. The phosphatic portion of the Park City formation is 44 feet thick as measured at Horseshoe Canyon, of which about 20% is classified as commercial phosphate rock. The commercial zone thickens appreciably from west to east across the county from a few feet at Sols Canyon to about nine feet at Horseshoe Canyon.

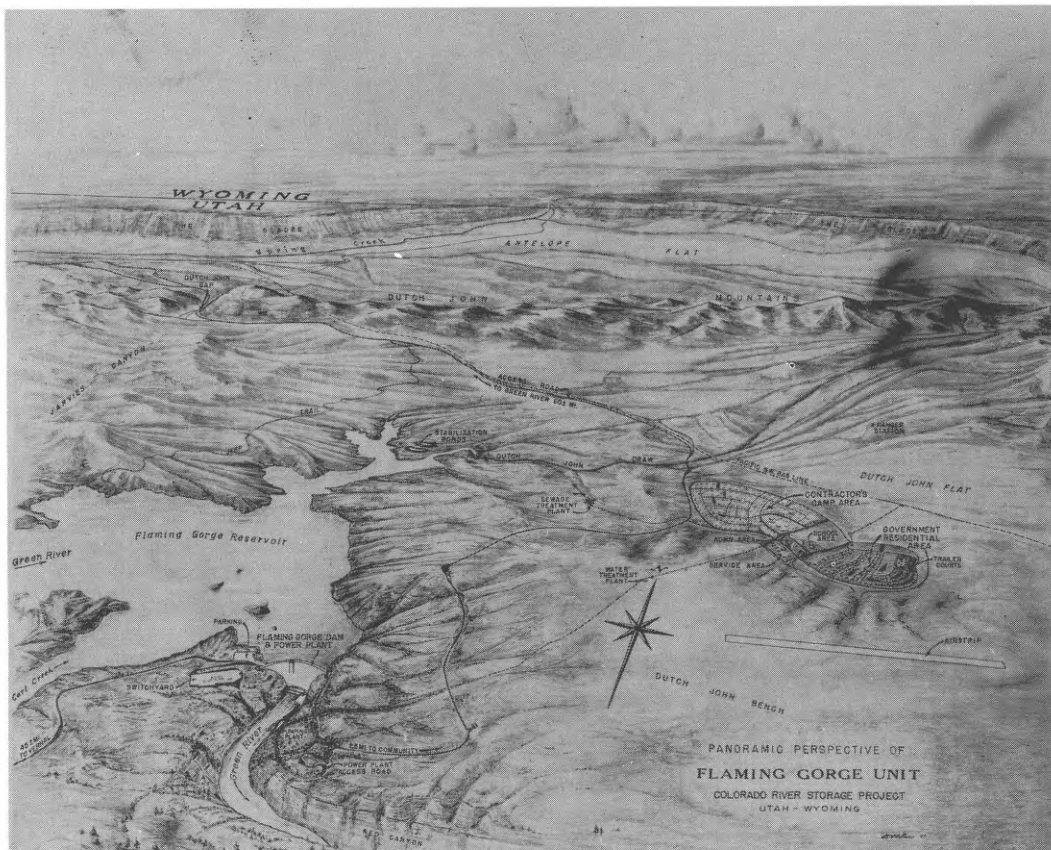


Plate 8. Panoramic perspective of Flaming Gorge Unit.  
- U.S. Bureau of Reclamation -

At present extensive deposits in the Phosphoria formation (Park City equivalent) in Idaho, western Wyoming, and Montana provide most of the West's minable phosphate. The Daggett County deposits, if developed, will require underground mining, and considerable topographic and structural complexity will doubtless be encountered.

#### Miscellaneous

Other nonmetallic resources present in Daggett County are: gypsum in the Carmel formation, bentonite in the Mowry shale, abundant limestone and dolomite, and considerable building stone. The value and potential of these are largely unrealized.

Very extensive quantities of sand, gravel, and rip-rap occur over the entire county. Until recently they have found only small local use. Construction of the Flaming Gorge Dam and related projects will, undoubtedly, bring about important use of these resources.

#### Gem Stones and Collectors' Items

Within Daggett County only a few occurrences of gem stones are known. In the micaceous schists of the Red Creek complex between Clay Basin and Browns Park, abundant almandite (red garnet) is found. cursory examination has indicated a small number of semi-precious quality stones. Many of the garnets are of large size and exhibit nearly perfect crystal form. Other interesting minerals found in these schists are staurolite and kyanite. Pegmatite dikes in the same area have yielded a single occurrence of beryl (Hansen, 1957).

The copper-uranium prospects of the Red Creek area and vicinity have yielded small quantities of opal, malachite, and azurite.

Agate and jasper occur in considerable quantity and great variety in the many gravel deposits in the county. The gravels which veneer high erosion surfaces in the Uintas have a variety of agate types. Bench gravels and alluvial gravels along the Green River in Browns Park yield agate and jasper and slabs of silicified wood and silicified snail shell coquinas derived from outcrops of the Eocene Green River formation upstream in Wyoming. Jade fragments are occasionally found in Browns Park, apparently derived far upstream from the Wind River Mountains of Wyoming. Slope wash on outcrops of the Morrison formation often yields silicified wood and dinosaur bone and gastroliths, the well-known dinosaur "gizzard stones."

#### F L A M I N G G O R G E D A M

(The following was prepared from material furnished by Mr. Neil Murdock, Bureau of Reclamation, Salt Lake City)

The construction of the Flaming Gorge Dam in Daggett County has brought striking changes in the life and landscape of north-eastern Utah. Sparsely settled Daggett County has seen a great influx of population and business. Dutch John, the newly built town two miles north of the damsite, already has a population three to

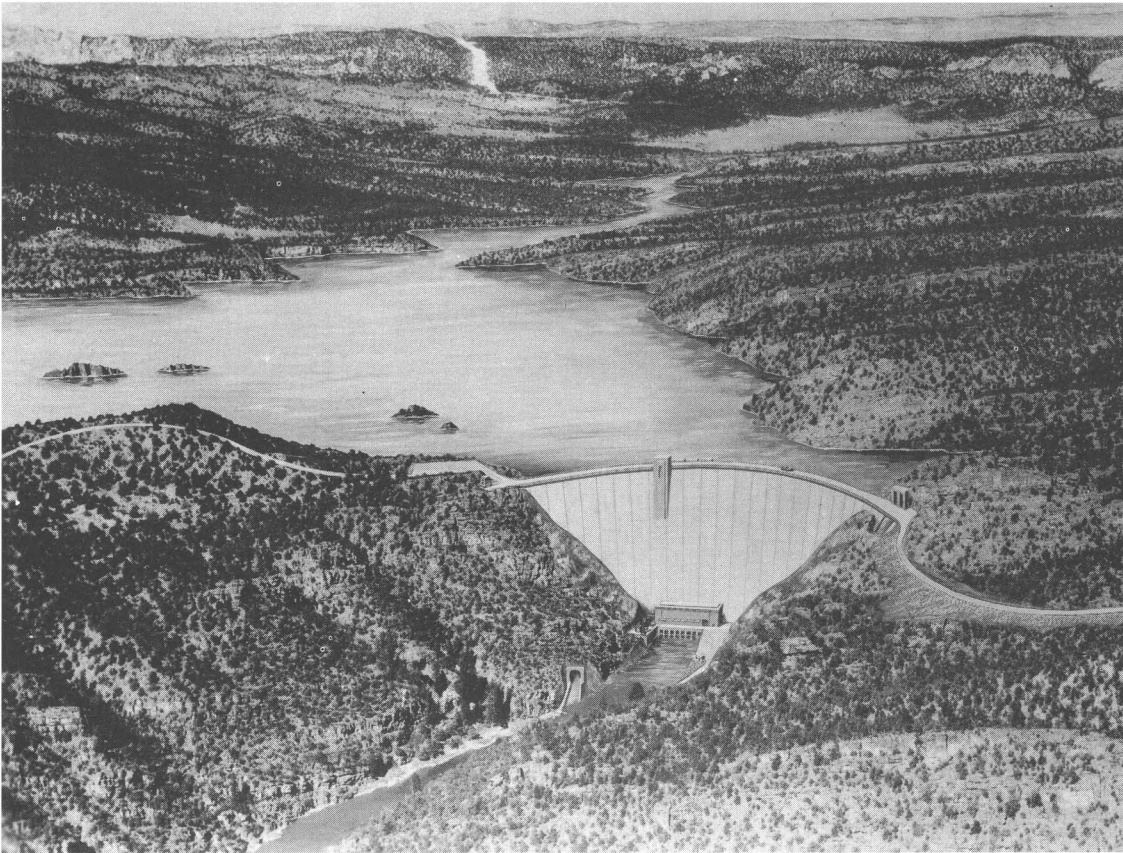


Plate 9. Artist's conception of Flaming Gorge Dam.  
- U.S. Bureau of Reclamation -

four times that of the rest of the county. The town and the dam-site are located in what was once the most inaccessible and least visited portion of Daggett County. Fifteen miles of hard-surfaced road have been built from Linwood to Dutch John. A temporary timber bridge spans the Green east of Linwood, providing the first vehicular link to exist between the east and west segments of the county. Utah 44 linking the damsite with Vernal has been vastly improved and is being kept open through the year.

Completion of the dam will bring even more striking changes. The dam will carry a roadway across its curving crest, providing a scenic road connection between Vernal, Utah, and Rock Springs, Wyoming, and the only vehicular crossing of the Green in its 150-mile course between Green River, Wyoming, and Jensen, Utah. Part of the access road and the timber bridge east of Linwood will be submerged and Linwood townsite also will go under the waves. The reservoir to be impounded by the dam will create a large new recreation area, particularly boating and excellent fishing in the deep, cold waters of the reservoir and its inlets and bays.

Flaming Gorge Dam will be a concrete arch structure rising about 495 feet above foundation and 450 feet above the river. The dam will be about 150 feet wide at the base and about 30 feet wide at the crest. The length of the dam along the arc of the crest will be 1180 feet. A 27-foot wide roadway will cross the crest. The elevation of the crest will be 6047 feet and at maximum the elevation of the surface of the water in the reservoir will be 6040 feet. The structure will rank as the seventh highest concrete dam in the nation.

Flaming Gorge Dam is a unit of the Colorado River Storage Project. The lake to be impounded by the dam will be the first storage reservoir on the Green River to provide control and regulation of river flows. The reservoir will extend 94 miles upstream nearly to the town of Green River, Wyoming, will cover some 68 square miles, and will store 4,400,000 acre-feet of water. The reservoir will be 14th in size in the nation.

The damsite has been thoroughly explored by diamond drill and horizontal drifts and is considered by the Bureau of Reclamation to be well adapted to concrete arch construction. The foundation and abutments are in the sandstone and quartzite of the Precambrian Uinta Mountain group. A small amount of shale and siltstone is interbedded with the quartzite and sandstone but is considered unimportant.

Structurally the dip and strike of the Uinta Mountain group strata is ideal to receive the thrust of an arch dam. It dips 16° north and strikes 60° east. Folding in the area has produced some shearing in the brittle rock. A prominent system of transverse joints parallel to the fold axis is plainly evident. These joints are nearly vertical and spaced two to four feet apart. Some secondary cementation has partially healed these fractures and made them fairly tight. Grouting with cement under pressure should strengthen the rock, fill the fractures, and make them completely watertight.

During construction of the dam the Green River will be carried through a diversion tunnel under the right (south) abutment of the dam. This tunnel will be 23 feet in diameter, 1100 feet long and fully lined with concrete.

Also under construction with Flaming Gorge Dam is a power plant to be located at the toe of the dam. Three generators will be housed in the plant with a capacity of 36,000 kilowatts. The combined capacity of all three will be 108,000 kilowatts providing initially 430,000,000 kilowatt hours of salable power annually.

The town of Dutch John, so named for the many geographic features of the same name in the area, is construction headquarters for the dam and will be the permanent headquarters for operating and maintenance personnel after completion. The town will house more than 2000 people at the peak of construction activity. The name Dutch John is derived from a pioneer settler in the area.

Preliminary work on access roads and the town of Dutch John began in 1957 and was completed in 1958. The office of the Flaming Gorge Storage Unit moved from its temporary location at Vernal to Dutch John on May 15, 1958. The town is expected to be essentially complete early in 1959 with surfaced streets, temporary and permanent residences, utilities, schools, shopping area, offices, warehouses, and garages. The entire project is expected to be complete in 1963 or 1964.

TOPOGRAPHIC MAPS OF DAGGETT COUNTY AND VICINITY  
PUBLISHED BY U. S. GEOLOGICAL SURVEY

1:250,000 Western United States (Army Map Service)

NK-12-9 Rock Springs, Wyo. (1958) 41° to 42° N - 108° to 110°W  
NK-12-12 Vernal (1958) 40° to 41° N - 108° to 110° W

1:125,000 30' Series

Gilbert Peak Quadrangle (1905)  
40° 30' to 41° 00' N - 110° 00' to 110° 30' W  
Marsh Peak Quadrangle (1906)  
40° 30' to 41° 00' N - 109° 30' to 110° 00' W

1:24,000 7.5' Series

Blair Basin Quadrangle (1950)  
40° 37' 30" to 40° 45' N - 109° 15' to 109° 22' 30" W  
Burnt Cabin Gorge (1950)  
40° 37' 30" to 40° 45' N - 109° 22' 30" to 109° 30' W  
Clay Basin (Home Mtn.) (1952)  
40° 52' 30" to 41° 00' N - 109° 07' 30" to 109° 15' W  
Dutch John Mountain (1952)  
40° 52' 30" to 41° 00' N - 109° 22' 30" to 109° 30' W  
Dyer Mountain (1950)  
40° 37' 30" to 40° 45' N - 109° 30' to 109° 37' 30" W  
Flaming Gorge (1952)  
40° 52' 30" to 41° 00' N - 109° 30' to 109° 37' 30" W  
Goslin Mountain (1952)  
40° 52' 30" to 41° 00' N - 109° 15' to 109° 22' 30" W  
Swallow Canyon, Utah-Colo. (1952)  
40° 45' to 40° 52' 30" N - 109° 00' to 109° 07' 30" W  
Warren Draw (1952)  
40° 45' to 40° 52' 30" N - 109° 07' 30" to 109° 15' W  
Willow Creek Butte, Utah-Colo.  
40° 52' 30" to 41° 00' N - 109° 00' to 109° 07' 30" W

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