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GEOLOGY OF UINTAH COUNTY

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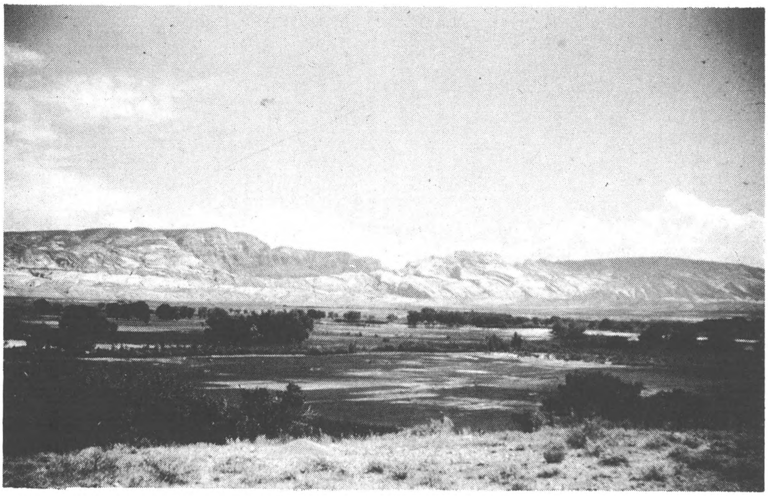
GEOLOGY OF UINTAH COUNTY

by G. E. and B. R. Untermann



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GEOLOGY OF UINTAH COUNTY

by G. E. and B. R. Untermann

ABSTRACT

Uintah County, athwart the geographic center of the Uinta Mountains and the parallel Uinta Basin, embraces a topography that ranges from more than 12,000 feet to less than 4,800 feet. Its land forms vary from those typical of high mountains to the badland terrain of a semi-arid region. The master stream, the Green River, flows from northeast to southwest; its main tributaries, the easterly flowing Duchesne River and the westerly flowing White River, follow the topographic low of the Uinta Basin and join the Green River scarcely two miles apart in the center of the county.

The Uinta Mountains, 150 miles in length, the largest individual east-west range in the western hemisphere, contain the highest elevations in Utah. Structurally, they represent a comparatively flat-topped asymmetrical anticlinal fold with similar minor flank folds.

Formations in Uintah County range from Precambrian (Uinta Mountain group) to late Tertiary (Browns Park, Miocene ?). Tertiary fluviatile and lacustrine sediments fill the Uinta Basin to a depth of more than 10,000 feet. They abut against the Uinta Mountains with angular discordance on eroded pre-Tertiary beds, although at higher elevations Miocene (?) Browns Park beds nonconformably overlie older strata.

Cretaceous time marked the beginning of folding which continued during the Tertiary with intermittent uplift and large-scale faulting. Maximum uplift of 45,000 feet probably at no time raised the range higher than at present -- erosion keeping pace with uplift. There is indication that elevation still continues.

None of the major faults are continuous across the county, but occur intermittently or as en echelon fractures. Latest major displacement, probably early Pliocene and often occurring along pre-existing fault zones, formed the Uinta Mountain graben in the eastern end of the range.

During late Pliocene or early Pleistocene, superposition of the major streams greatly influenced the modern drainage pattern; while continental uplift and tilting with attendant stream piracy and entrenching of meanders, resulted in many of the spectacular scenic features of the entire Uinta Mountain and Basin area.

During Quaternary time Uintah County witnessed active denudation and continued faulting, successive periods of elevation or subsidence, renewal of stream activity, arid climates, and torrential storms and flash floods that accumulated poorly sorted fanglomerate material. During the Pleistocene, glaciation of the higher portions of the Uinta Mountains occurred principally west of Longitude 109° 40' (Ashley Canyon, northwest of Vernal). During recent times, glacial debris, as well as late Tertiary and early Quaternary stream deposits, has been greatly reworked and redistributed farther down the slopes, thus forming terrace gravels of successively younger stages of erosion. The Browns Park (Miocene ?) conglomerates have acted as a source of much of this material.

INTRODUCTION AND ACKNOWLEDGEMENTS

Compilation of this bulletin began in 1957 with the mapping of several areas of Uintah County. As time permitted, this mapping was followed by a reconnaissance of the entire county to familiarize the writers with areas in which they had not made a detailed study. It is hoped that the resulting map and bulletin will aid geologists and the public generally.

Uintah County topography varies from high glaciated mountain scenery, through deeply incised canyon country of the Green River drainage, to highly colored badlands of the Uinta Basin. The county has among its outstanding scenic and geologic features a portion of Dinosaur National Monument, with its visitor center and unusual quarry-in-place exhibit of dinosaur skeletons and other displays (Untermann, 1954, p. 1-221). The vivid colors, the fantastic erosion and spectacular attitude of the formations, readily accessible from Vernal, are such that they elicit enthusiastic comment from practically all visitors.

The writers are greatly impressed by the fine work of early geologists in the West who were handicapped by slower means of travel over great distances and rugged terrain, and are much indebted to them and to more recent geologists, oil companies, and others for their individual published reports and information, without which this compilation would not have been possible.

The writers express their appreciation to Arthur L. Crawford, Assistant Director of the Utah Geological and Mineralogical Survey (under whose direction the project began), to the present Director, William P. Hewitt, to Hellmut H. Doelling for his excellent drafting, and to the Survey's staff for their cooperation. The Survey deserves much credit for its achievements and it is to be applauded for the high quality of its work.

PREHISTORIC SETTLERS

Ancient man arrived in the Uinta Basin and eastern Utah much earlier than is generally believed. A descendant of primitive human immigrants who came to the North American continent across the Bering Strait during late Pleistocene time, he developed in Uintah County, as in most of Utah and the Great Basin, a special culture adapted to an arid region -- the earliest period of which is known as the Desert Culture. It was a time of nomadic life with temporary campsites located along routes where food and water were most easily obtainable. It is believed that later cultures of this region originated from the Desert people, whose techniques were carried over, contributing to those of the Basketmakers and Pueblos and to their modifications called the Fremont, thus bridging the gap between the first hunters and farmers and the Ute Indians who later occupied the area.

Indians of Uintah County are now represented by three principal bands of Utes: Uintahs, White Rivers, and Uncompahgres, numbering approximately 1,700, largely confined to the Uintah and Ouray reservations centering around Whiterocks, Ft. Duchesne, and Ouray. The White River and Uncompahgre Utes were transferred to these areas following the Meeker, Colorado, Massacre of 1879.

EXPLORATION AND WHITE SETTLEMENT

First known white men to enter the Uinta Basin were members of the famous Escalante Expedition of 1776, headed by two Franciscan monks, Fray Silvestre Velez de Escalante, missionary at Zuni in New Mexico, and Fray Francisco Atanasio Dominguez, a contact missionary from Sonora, Mexico. Assigned the task of finding a route through hostile Indian country from Sante Fe, New Mexico, to a new mission at Monterey, then capitol of California, their venture was unsuccessful (Bolton, 1950).

William Henry Ashley, the first of the fur trappers to enter the Uinta Basin, boated down the Green River in 1824. A trading post, established by Antoine Robidoux in 1832 near the site of the present town of Whiterocks (located adjacent to the northwestern boundary of Uintah County), is usually credited as the first "permanent" settlement in Utah. However, an earlier post is claimed by descendants of one of its founders, Jim Reed, to have been established prior to Fort Robidoux and only a few yards to the west. Fort Robidoux survived until 1844 when it was burned by Indians.

Although Mormon pioneers came to Utah in 1847, no attempt was made to colonize the Uinta Basin until late in the summer of 1861, when a scouting party sent out by Brigham Young reported unfavorably on the area. Southwestern Utah was settled instead.

A large part of the Uinta country was proclaimed an Indian reservation by President Abraham Lincoln on October 3, 1861, and Indian agencies were established at various points from Daniels Canyon to Whiterocks between 1864 and 1868. In the early seventies, white personnel from the Indian agency became the first settlers to take up homesteads off the reservation. By 1880 the population justified organization of Uintah County, which then also included the present Daggett County.

PHYSICAL GEOGRAPHY

Uintah* County, centrally located in the extensive Uinta* Mountain and Basin area, is the sixth largest county in Utah, comprising 4,501 square miles. Except for Daggett County adjoining on the north (the Uintah-Daggett county line follows the crest of the Uinta Range), Uintah County occupies the northeastern corner of Utah. Grand County borders Uintah County on the south, Carbon and Duchesne Counties on the west, and the State of Colorado on its eastern border.

Uintah County consists of three geographic provinces which are, from north to south: the Uinta Range, the Uinta Basin, and the Tavaputs Plateau. A discussion of these provinces follows:

The Uinta Range

The Uinta Range, approximately 150 miles long by 50 miles wide, extends eastward from the Heber area to Cross Mountain, Colorado, and southward from approximately the Utah-Wyoming line to the northern boundary of the Basin. Kings Peak (13,498 feet), in Duchesne County, is the highest peak in Utah. There are 11 peaks more than 13,000 feet in the western half of the range, but the highest in Uintah County (Marsh Peak) is 12,219 feet. These peaks are named for famous paleontologists and geologists such as Marsh, Leidy, Emmons, Gilbert, King, Hayden, and others, who worked in the Western Territories following the Civil War.

The south slope of the Uintas is dissected by many deep, steep-walled, north-south trending canyons. The most important of these are the spectacular rugged canyons of the Green River carved chiefly in Paleozoic formations (Whirlpool, Split Mountain and Jones Hole in Dinosaur National Monument), and Brush Creek Gorge, north of Vernal, Ashley and Dry Fork, to the northwest, and Whiterocks and Uinta in the extreme northwest. Most of these are easily reached over improved roads.

The Uinta Mountains are host to a variety of plant types. Edward H. Graham (1937) in a study for the Carnegie Museum, recognized seven zones and more than 1,100 species. Some of these are:

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* The National Board of Geographic Names applies the spelling "Uintah" to political subdivisions, such as counties, reservations, etc., and the spelling "Uinta" to mountains, streams, and other geographic features. The word "Uintah" is believed to mean "that (country) at the foot of long-leaf timber pines, clear stream flowing." (Dillman, 1948, p. 8).

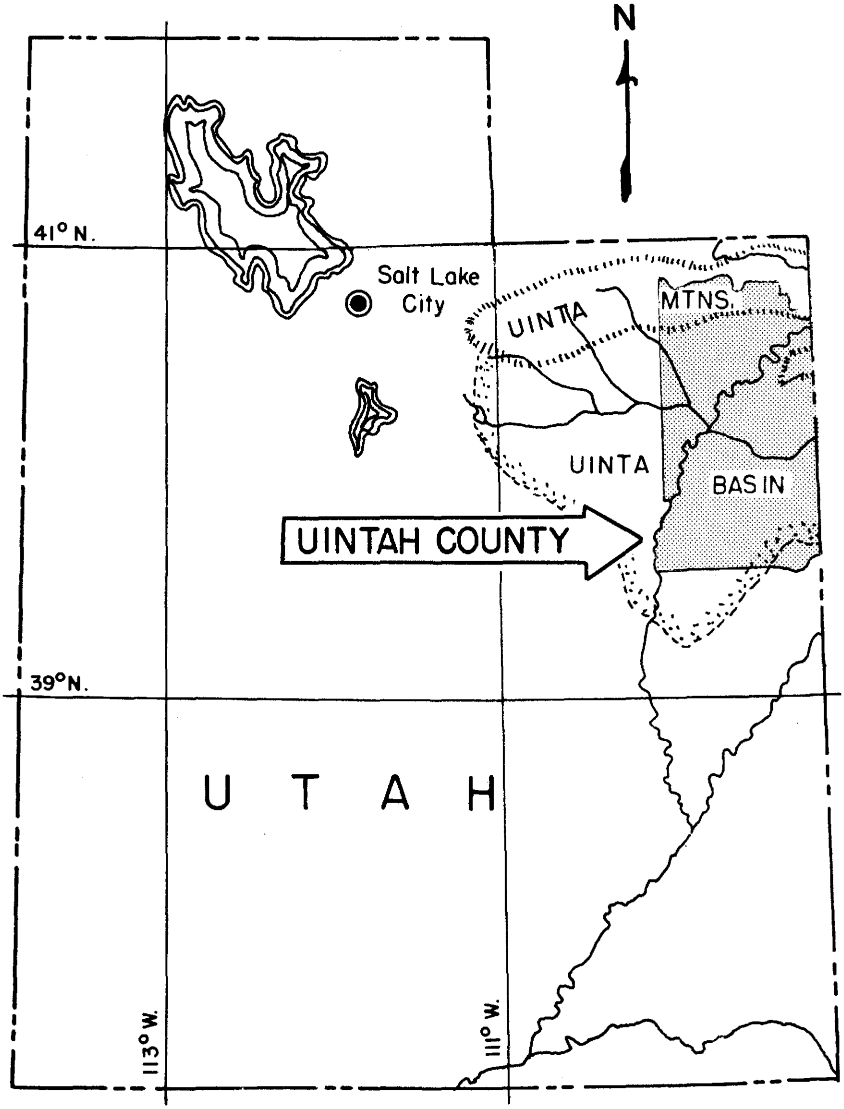

Figure 1. Index Map of the Area.

ALPINE ZONE (11,000 feet and above) -- above timber line meadow (especially where Spruce-Fir zone overlaps the zonal boundary), Lichen.

SPRUCE-FIR ZONE (11,000-10,000 feet) -- White Fir, Douglas Fir, Englemann Spruce, Blue Spruce.

LODGEPOLE PINE ZONE (10,000-8,700 feet) -- Lodgepole Pine, some Ponderosa Pine, and overlapping Quaking Aspen.

QUAKING ASPEN ZONE (8,700-8,000 feet) -- Quaking Aspen, some Ponderosa Pine, and overlapping Lodgepole Pine.

LOWER SLOPES AND PLATEAU ZONES (8,000-7,000 feet) -- Submontane Shrub Associations

Artemesia (sagebrush), Amelanchior (serviceberry), Cercocarpus (buck brush - mountain mahogany), Purshia (antelope brush), shrubby cinquefoil, Ribes (wild gooseberry), willows, Ponderosa Pine in parks and moist open areas in canyons.

FOOTHILL ZONE (7,000-5,500 feet) -- dense Piñon-Juniper association (the latter known as Utah "cedar").

Annual precipitation in the mountain zones averages approximately 30 inches. Several feet of snow accumulate during the winter months. Dry years occur occasionally. These greatly reduce the water table and flow of springs, and result in restricted irrigation and livestock use.

The Uinta Basin

The Uinta Basin, a structural depression paralleling the range on the south, comprises the lowland stream bottoms and badland country (4,800 to 6,000 feet) lying between the Uinta Range and the Tavaputs Plateau. Green River, largest tributary of the Colorado, crosses Uintah County diagonally from northeast to southwest. Duchesne River enters the Green River from the west, and White River from the east just below Ouray. These major drainages and their tributaries have produced a highly developed badland terrain dominated by colorful mesas, buttes, cliff-bench topography, and other typical features formed in the younger and softer rock formations of the Basin. Annual precipitation averages about 9 inches. Vegetation is sparse, but comprises many species of some plant families: Artemesia (sagebrush), salt bush types, Chrysothamnus (rabbit brush), and those typical of the Mixed Desert Shrub Zone: cottonwoods, boxelders, willows, and birch dominate stream bottoms; _Atriplex_ (shadscale), _Tetradymia_ (horsebrush), _Sarcobatus_ (greasewood), and _Grayia_ (salt bushes) dominate dry lowland areas (especially alkaline, poorly-drained soils). These together with Artemesia which occurs over a wide range of elevations make excellent brouse for livestock. Following winters of considerable precipitation, wild flowers blossom from May to September in a profusion of brilliant hues.

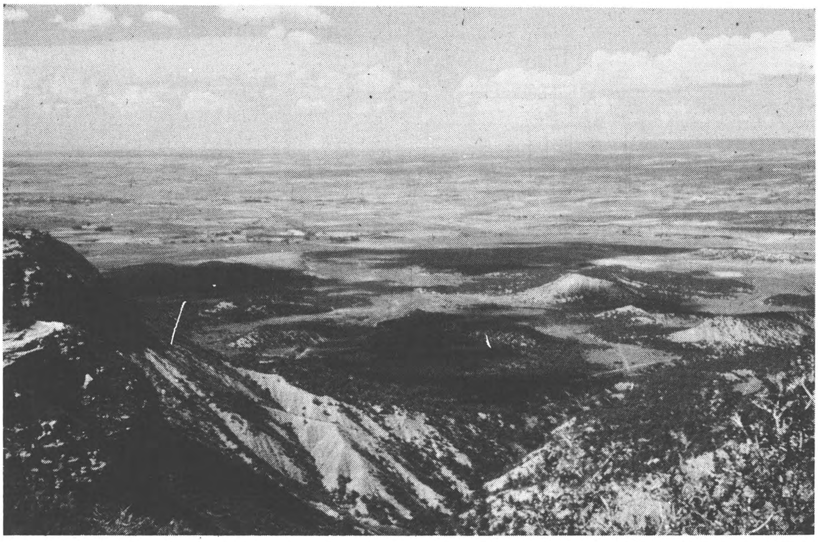

Figure 2. Looking south toward the Uinta Basin from Blue Mountain.

The Tavaputs Plateau

The Tavaputs Plateau extends into southern Uintah County as a northward sloping area, bounded on the south by outward-facing retreating escarpments known as the Roan and Book Cliffs. Elevation at the county line attains 8,000 feet. Vegetation consists of salt bushes, greasewood, shadscale and similar types in the lower reaches and principally sagebrush and juniper-piñon at higher elevations.

FAUNA

The fauna overlap the plant zonal boundaries: deer, porcupines, beaver, and marmots are found in most zones; conies (rock rabbits) are observed in the Alpine zone; goshawks, chipmunks, gray squirrels, pine marten, cougar, bear (quite rare), etc., occupy the Spruce-Fir-Lodgepole Pine zones; mountain sheep may be seen in rugged canyons; sage chickens are common in the Submontane Shrub zone; and prarie dogs, badgers, rabbits, ground squirrels, kangaroo rats, lizards, and snakes are common in the lower zones.

ECONOMIC DEVELOPMENT

Cattle, sheep, dairying and agricultural pursuits, augmented by lumbering, mining, and oil, represent the basic economy of Uintah County (population 12,000). Millions of board feet of timber are cut annually on the Ashley National Forest. Most of this timber lies at elevations between 7,500 and 10,500 feet and is cut for mine props as well as lumber.

From 1888 to 1961, mining was chiefly confined to gilsonite. Early in 1961, however, the development of vast phosphate deposits by the San Francisco Chemical Company began 13 miles north of Vernal. A several hundred year reserve of phosphate ore has been explored on the 14,000+ acres of patented land comprising the property.

The rediscovery of oil on September 18, 1948, in the Ashley Valley Field, 10 miles east of Vernal (first commercial well in Utah) initiated oil and gas production which still has not reached its crest (Crawford, 1963). Red Wash and Ashley fields are now being supplemented by newer discoveries. The impact of the petroleum industry is having a profound beneficial effect on the county's finances.

In 1904 the narrow guage Uintah Railway was constructed from the Denver and Rio Grande Western at Mack, Colorado, over the Book Cliffs to Dragon, Utah, for the purpose of hauling gilsonite to the mainline. In 1911 the tracks were extended down Evacuation Creek to Watson and westward to the mines at Rainbow. The railroad became "extinct" in 1938, after 34 years of operation, because truck transportation of gilsonite over highways paved with bituminous sand from the massive deposits four miles west of Vernal (U.S. Bureau of Mines estimates 2-3 billion tons reserve) became more economical. Furthermore, principal mining operations were now in the Bonanza area and the tracks had never been extended that far. The present auto road over Baxter Pass, out of the Basin to Mack, is partly laid on the old Uintah Railway grade. Rotting ties are still visible along the shoulders.

CORRELATION CHART-UINTA BASIN UTAH

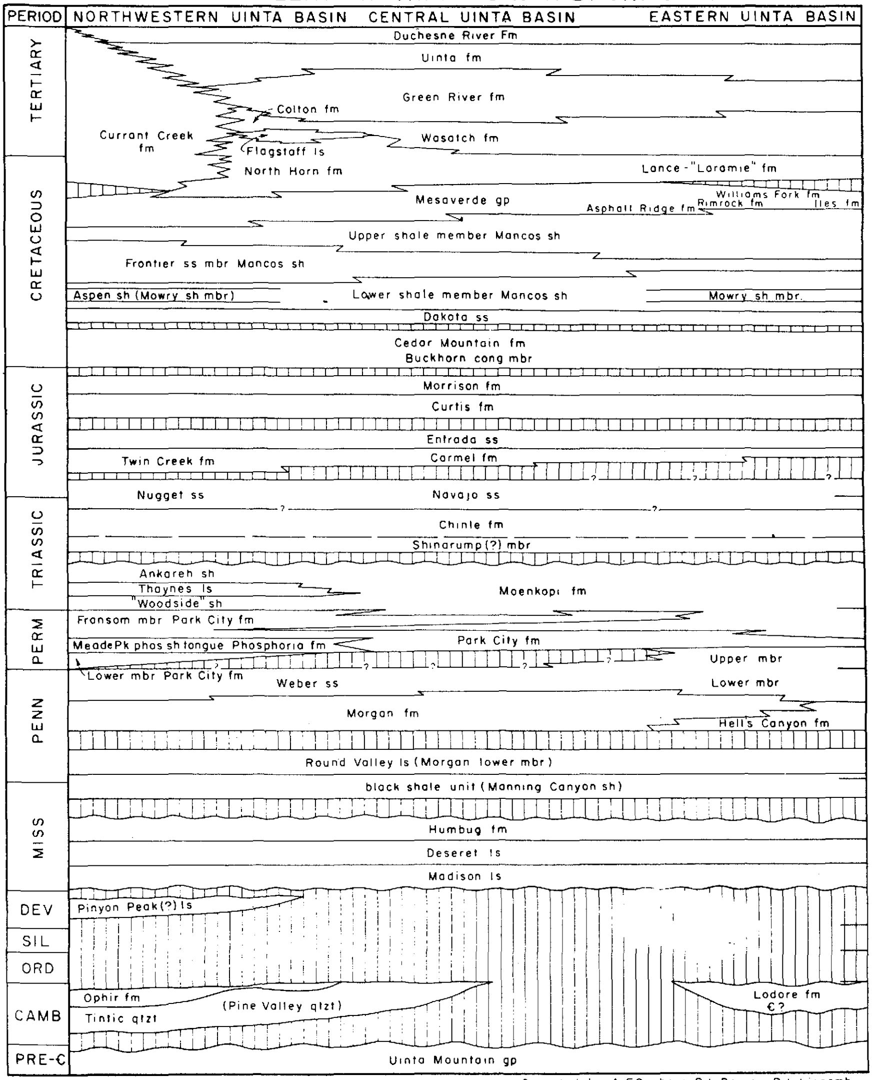

Figure 3. Correlation Chart of the Uinta Basin and Mountain area.

Today Vernal, "metropolis" of the Basin and county seat of Uintah County (population 4,500-5,000), remains more than 100 miles from the nearest railroad. The Uintah narrow-guage never got closer to Vernal than 60 miles. Nearest railheads are now 110 miles to Helper, Utah; 122 miles to Craig, Colorado; 125 miles to Green River, Wyoming; and 130 miles to Heber, Utah. The present development of the phosphate deposits near Vernal might become a modern incentive for introducing a railroad into Uintah County. A route from Craig, Colorado, with its relatively low grades has been proposed, at an estimated cost of $14,000,000. Pipeline transportation of concentrates has also been considered.

STRATIGRAPHY

General Statement

In Uintah County most rock formations are sedimentary, ranging in age from Precambrian to Tertiary. They represent periods of marine and continental (delta, floodplain, lake, eolian, etc.) origin, and of both geosynclinal and foreland character.

In general, the stratigraphic history of the Uinta Mountain and Basin region is one of great regularity and stability. Noticeable unconformities are rare, indicating that throughout the sedimentations which gave rise successively to the immense thickness of Precambrian Uinta Quartzite (Kinney, 1955, p. 22; Hansen, 1956, p. 52) and the deposits of Paleozoic and Mesozoic time, there was little or no orogenic deformation until near the close of the latter. Breaks are mostly faunal and lithologic rather than stratigraphic.

The most conspicuous erosional surfaces prior to Laramide folding are between the Precambrian (Uinta Mountain group) and Cambrian (Lodore formation), between the Mississippian (Manning Canyon shale) and Pennsylvanian (Morgan), and between Moenkopi and Shinarump formations of the Triassic. Even the absence of three periods (Ordovician, Silurian, and Devonian) does not reveal a profound erosional unconformity.

Following the Devonian, Carboniferous sediments of shallow shelf origin derived from the southeast and contributed by the rising Uncompahgre Range of the Ancestral Rockies (Eardley, 1950, p. 120), intertongued westerly with thicker marine deposits. During Pennsylvanian time, vast quantities of clear quartz sand, derived from the northwest and shed from "Cascadia" (Heaton, 1933, p. 138) were distributed over western Montana and Wyoming, eastern Idaho, northern Utah, and northern Nevada. The Weber sandstone and equivalents may owe their origin to this source.

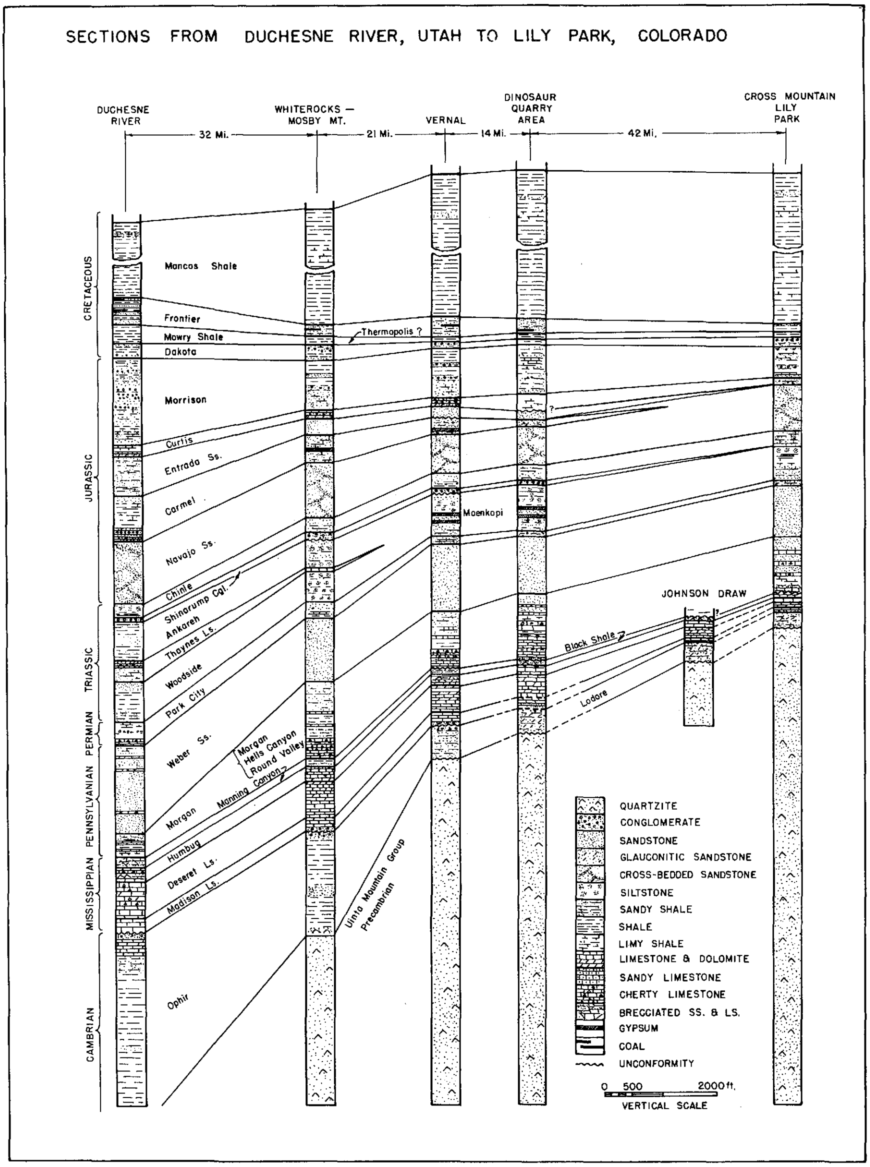

Figure 4. Correlation Sections from Duchesne River Area to Lily Park, Colorado.

Under similar conditions Triassic sediments furnished from highlands to the east (Ancestral Rockies) graded into marine facies which thicken westerly; whereas during the Jurassic, the rising of the "Nevada Mountains" on the west and southwest probably supplied much of the sediments which resulted in the widespread accumulation of coarser clastics of the Upper Jurassic and Lower Cretaceous series. Thick Upper Cretaceous marine deposition to the southeast graded laterally into coarser sediments (Current Creek) derived from the west.

South and north of the Uinta Range, downwarping of the Uinta and Bridger basins developed small Paleocene and Wasatch lakes, which in time became extensive fresh-water bodies wherein accumulated thousands of feet of fine sediments. These are now believed to be a source of some of the oil of the region. The lake basins were gradually filled by streams, creating extensive flood plains on which additional thousands of feet of conglomerate, sandstone, and shale accumulated to form the Bridger and Washakie (north of the Range) and the Uinta and Duchesne River formations (south of the Range) which have been the source of vast quantities of fossil material, including mammal, reptile, bird, insect, and plant remains.

Later Tertiary and Quaternary deposits consist of sandstone and coarse gravels, chiefly of stream origin, with some glacial debris in the western half of the Uinta Range.

Approximate maximum total deposition of known sediments from Precambrian to Tertiary time, inclusive, amounts to 45,000 feet in eastern Uinta Mountain and Basin areas, and 63,000 feet in the western part of the region.

The Uinta geosyncline, an east-west arm of the Wasatch trough, remained fairly stable until late Cretaceous time. Receiving sediments from the surrounding highland areas, this marine basin had its deepest parts in the west, shallowing eastward, producing a broad foreland shelf on which sediments of increasingly shallow marine character graded into continental deposits derived from the east or southeast. Conversely, during the Upper Cretaceous thick marine Mancos shales intertongue westward with shallow-water sandstones and conglomerates derived from the rising mountains to the west.

The only igneous rock observed in Uintah County is a gabbroid dike, with a maximum width of 60 feet, cutting the Precambrian Uinta Mountain group in the northwestern corner of the county and outcropping intermittently from Lake Shore Basin at the south foot of Leidy Peak westward to the head of Uinta River in western Duchesne County.

PRECAMBRIAN

Uinta Mountain Group

The oldest rocks exposed in Uintah County are dark-red to buff, cross-bedded, medium- to coarser-grained quartzitic sandstones, red and green phyllitic shales, and conglomerates, some of which become arkosic westward (Untermann, 1954, p. 187-192). Metamorphism, accomplished chiefly through the addition of silica and ferruginous cements, has been less intense than in the Red Creek metaquartzite on the northeast side of the range. These quartzites retain their grain outline (Untermann, 1954, p. 23). Vertical joints give a blocky character to the formation and desert varnish commonly coats columnar masses. Where thin-bedded it becomes ledgy, and often has a darker color than beds of the overlying Cambrian formation (Lodore) from which it is difficult to distinguish.

Powell (1876, p. 144) estimated a thickness of more than 13,000 feet, but recent work by Hansen (1956) indicates greater than 20,000 feet for the Uinta Mountain group. It outcrops chiefly along the crest of the main Uinta arch, and is exposed down dip in the upper canyons for some distance along the mountain slopes. In the western

Figure 5. Lodore Canyon, Green River. Upper Precambrian, Uinta Mountain Group.

part of the county, the formation is overlain directly by Mississippian limestone. Kinney observed that the upper shale member of the Uinta Mountain group thinned eastward from 3,000 feet in Uinta Canyon to 265 feet north of Diamond Mountain and was entirely missing farther east at Lodore Canyon; that sandstones in the thick shale unit in Whiterocks Canyon are glauconitic, and therefore probably of marine origin (Kinney, 1955, p. 21-22). No fossils have been found.

Conglomerates increase in thickness and coarseness to the east, where Hansen (1957, p. 52) believes a highland source occurred. Marine conditions probably prevailed to the west (Kinney, 1956, p. 22) with offshore sub-aerial conditions occurring to the east. Williams (1953, p. 2737-2738) correlated the Uinta Mountain group with the Big Cottonwood series of the Wasatch Mountains.

CAMBRIAN SYSTEM

Lodore Formation

In the Jones Hole area, near Whirlpool Canyon in the northwestern corner of Dinosaur National Monument, the writers studied 450 feet of Lodore white to red quartzitic sandstone, greenish-gray siltstones and sandstones, frequently glauconitic, and interbedded green to red silty shales containing mudcracks, ripple marks, and occasional fossils. A few trilobites were found (Untermann, 1954, p. 25, 129-132) and identified as upper Cambrian age. Some of the sandstones contain minor amounts of feldspar and white mica. At the base of the formation is a red to white, ledgy, shelf-making quartzitic sandstone, 150+ feet thick, containing white "vermicelli" (worm borings?); also purple to green sericitic and ripple marked shale partings and a basal conglomerate. The contact between the Cambrian and the underlying Uinta Mountain group (Precambrian) is one of pronounced erosion with slight angular discordance of 4 to 5 degrees (Untermann, 1954, p. 133). The Lodore formation appears to thin to the west. West of Brush Creek, it was not observed (Kinney, 1955, p. 22); but, still farther west, in the Rock Creek area of Duchesne County, Huddle collected poorly preserved fossils of Late Cambrian age from sandy shales above the Pine Valley conglomerate (Kinney, 1955, p. 23).

EARLY PALEOZOIC SYSTEMS

In Uintah County, Ordovician, Silurian, and Devonian time is marked by a great hiatus, and these rocks are absent (Untermann, 1954, p. 17-18).

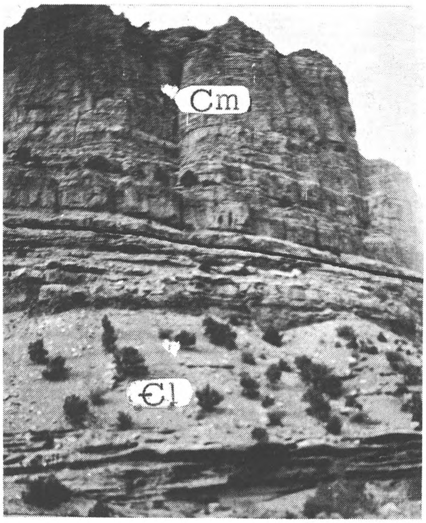

Figure 6. Mississippian (CM) and Cambrian upper Lodore (Cl) formations. Mouth of Jones Hole Creek near confluence with Green River.

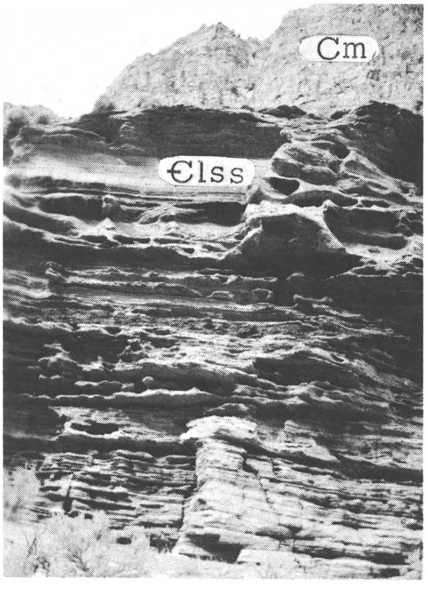

Figure 7. Basal Cambrian, Lodore sandstone (Clss). Mouth of Jones Hole near confluence with Green River.

CARBONIFEROUS SYSTEMS

Mississippian (Lower Carboniferous)

General Statement

Mississippian formations directly overlie Upper Cambrian (Lodore). These consist of limestone and dolomite at the base. Believed to be Lower Mississippian (Madison), they are overlain by limestones, calcareous sandstones, and black shales which may be equivalent to the Upper Mississippian Deseret and Humbug formations and Manning Canyon shale (Baker, et al., 1949, p. 1161-1197), and outcrop along the south flank of the Uinta Mountains where the section comprises between 1,000 and 1,500 feet of marine sediments laid down in a shallow-water near-shore environment. The entire Mississippian system increases in thickness from less than 900 feet in the eastern part of Uintah County to 1,231 feet at Whiterocks River in the western part.

Strike ridges of gray cliff-forming limestone show long southward dipping "scalloped" rocky slopes, which at a distance appear massive in canyon walls, but upon closer examination are quite thin-bedded. Where brecciated, they produce much angular talus. In contrast, the Manning Canyon shale is a slope-forming unit.

Madison Limestone

The Madison consists of thin-bedded, light- to dark-bluish gray, dense, fine-grained limestones, in part dolomitic. Fossil corals, brachiopods, Euomphalus-type gastropods are occasionally found, and Kinney (1955, p. 30) identified a "typical Madison limestone assemblage..." from the west side of Whiterocks River. In Dinosaur National Monument, the lower 20 or 30 feet of the Madison is sandy, ripple-marked, minutely crossbedded, with poorly sorted pink quartz pebbles, less than one-half inch in length, apparently derived from the underlying Lodore. There is a gradation upward into gray limestone. In the Jones Hole-Whirlpool Canyon area, it is 175 feet thick (Untermann, 1954, p. 127-129).

Deseret Limestone

The massive Deseret limestone, usually exposed in buff, columnar-appearing cliffs of porous, light-colored, intricately-banded sandy limestones and dolomites (the latter more numerous in the upper part) contains small crinoid stem plates, cup corals, and other fossil forms. Dark gray-and-white banded chert nodules and lenses are common along bedding planes. At Jones Hole, there is approximately 450 feet of these beds.

Humbug Formation

The Humbug, a tan-weathering, pink, gray, or brownish formation, is composed of marly, calcareous beds with dense gray limestone. It is commonly brecciated, ripple-marked, and crossbedded. Light-colored cherts occur in round or elliptical nodules and lenses. Calcite veins and cavities lined with dog tooth spar are common. At Jones Hole there is approximately 250 feet of these beds, or a total of 875 feet of pre-Manning Canyon Mississippian limestone in eastern Uintah County.

Figure 8. Pennsylvania (Morgan) upper center distance. Mississippian and Cambrian below and right. Mouth of Jones Hole Creek, near confluence with Green River.

Manning Canyon Formation

This predominantly black, slope-forming formation occurs along the south flank of the Uinta Mountains and is 279 feet thick at Whiterocks Canyon in western Uintah County (Baker, et al., 1949, p. 1177-1178). It thins eastward to 185 feet at Whirlpool Canyon (Untermann, 1954, p. 31), where the main shale member is 87 feet thick. Underlying the shale member is 35 feet of white to yellow cross-bedded quartz-sandstone, in places friable, and containing black shale laminae. These beds are underlain by 3 feet of heavily hematitized gravelly sandstone and 20 feet of quartz-sandstone which locally exhibits evidence of erosion. Beneath is a thin limestone layer which overlies 30 feet of red to brown angular conglomeratic sandstone. Facies thin and become coarser in an eastward direction. In eastern Uintah County, a persistent marker bed locally carries noncommercial concentrations of iron and copper oxides and other minerals (Untermann, 1954, p. 31-32). Sadlick has identified spores from the Manning Canyon (personal communication).

Pennsylvania (Upper Carboniferous)

General Statement

The Pennsylvanian formations of Uintah County are as follows: from oldest to youngest, the Morgan formation, which is divided into three members, the Round Valley (Morrow), the Hells Canyon (Atoka), and the upper Morgan (Lower Des Moines); and the Weber sandstone.

Morgan Formation

The Morgan, conformably overlying the Manning Canyon shale and grading upward into the Weber sandstone, is 1,384 feet thick at Whiterocks Canyon (Baker, et al., 1949, p. 1181-1182), 1,266 feet at Whirlpool Canyon, and is divisible at the latter place, lithologically and faunally, into three members: from top to bottom, Lower Des Moines (660 feet), Atoka (372 feet), and Morrow (234 feet). (Untermann, 1949, p. 219-232; 1954, p. 33). At the Whirlpool Canyon locality, Sadlick placed contacts at somewhat different positions, obtaining 489 feet for the upper Morgan, 258 feet for Hells Canyon (Atoka), and 313 feet for Round Valley (Morrow). He has shown that the Hells Canyon formation interfingers westward with the Morgan, and he proposes that the Hells Canyon, Morgan, and overlying Weber formations, which represent shelf deposits with gradational facies change deposited in response to "basin formation and rising highlands", be included in the "Durst group" (Sadlick, 1957, p. 61, 70, 74).

The upper part of the Morgan contains thin layers of compact, fossiliferous gray limestone, often cherty, which weathers reddish; alternating with massive, fine-grained, buff to red sandstones that are slightly crossbedded and non-fossiliferous. On a basis of studies of the fusuline fauna of these limestones by Lloyd G. Henbest (Untermann, 1949, p. 225), they are placed in the lower half of the Des Moines section. West of Whiterocks River (Kinney, et al., 1955, p. 40), 1,084 feet of Pennsylvanian beds lie below the Weber. In this sequence, calcareous, fine- to medium-grained sandstones, overly intercalated beds of red sandy shale, fine-grained sandstone, and argillaceous limestone.

The Middle mauve-colored member (Hells Canyon) consists of argillaceous limestone, shale, and light- to dark-gray, dense to coarse limestone, red-weathering, abundantly fossiliferous, and frequently cherty. At Whirlpool Canyon the basal beds are a dark-colored limestone containing vari-colored chert and a thin black pebble-conglomerate.

The lower part (Round Valley) consists of gray to black fine- to medium-textured, occasionally dolomitic thin-bedded limestones, and mauve to gray argillaceous limestones and shales containing fossils of Morrow age. In the Whiterocks area it is thin to thick bedded and contains gray to red chert.

Sadlick (1957, p. 72, 75) placed the contact between the Morgan and the overlying Weber at the base of the gray-buff sandstone-limestone beds, above the first red sandstones of the upper Morgan, as in the type section in Weber Canyon, east of Morgan, Utah; whereas the writer's placed it above the limestones at the base of the massive sandstones. The Morgan formation (unrestricted), as it occurs in the Uinta Mountain area, is at least in part equivalent in age to the Amsden and Quadrant formations of Wyoming, Maroon of Colorado, Wells of Idaho, and Paradox of southern Utah.

Figure 9. Morgan formation, Whirlpool Canyon (center) and Wild Mountain (distance). Capped by Weber in center and foreground.

At its type locality in Weber River Canyon, northern Utah, it was named Weber Quartzite by Clarence King (1876, p. 477-480). Although locally a quartzite, it is more often a fine-grained, massive to thin-bedded quartz sandstone with calcareous cement (Untermann, 1954, p. 36, 37). In the upper portion, it is strongly crossbedded, possibly wind deposited, and is often concretionary and coarse. Calcite seams are numerous in places. Though unfossiliferous in Uintah County, the transitional nature of the Morgan (lower Des Moines, Pennsylvanian) into the overlying Weber, and the latter's position beneath the Park City formation (Permian) suggests that the Weber is of upper or middle Des Moines age. In Duchesne County, J. Stewart Williams (1943, p. 604) found Desmoinesian fossils near the top of the Weber in Duchesne River Canyon. In western Uintah County, the Weber is 1,200 feet thick, but thins eastward to 1,000 feet at Split Mountain. East of Duchesne County, Sadlick describes a lower member of sandstone interbedded with less than 10 to 20 per cent limestone, and an upper member of crossbedded sandstone with bedding planes that truncate the crossbeds. A similar two-fold subdivision is in evidence at the type locality in Weber Canyon (Sadlick, 1957, p. 76).

Erosion produces deep steep-walled gorges which are among the outstanding scenic features of the county. The Ashley Valley oil field produces from the upper part of the formation.

PERMIAN SYSTEM

Park City Formation (Phosphoria)

Type locality is the Park City mining district east of Salt Lake City, Utah (Boutwell, 1912, p. 443-444). In western Uintah County the basal member of the Park City consists of greenish-gray beds rich in rock phosphate that lie on Weber sandstone, and it thins eastward from about 22 feet at the site of the San Francisco Chemical Company's mining operations on Brush Creek to a few inches on the north side of Split Mountain and about one inch on the south slope. The upper calcareous member, about 195 feet thick in the Whiterocks area (Kinney, 1954, p. 50), consists of interbedded light-gray cherty limestone and shale. Within the shale are two thin tongues of red silty sandstone known as the Mackentire "red beds" tongue. In the Red Mountain-Brush Creek area, 100 feet of cherty limestone are separated in the upper part of the formation by a 27-foot "red beds" layer, and at the base by a 17-22 foot bed of shale and commercial oolitic fossiliferous phosphate rock. Eastward the Park City, composed of light gray to yellow calcareous shale with small nodules and seams of chert, diminishes to 40-60 feet in thickness; the Mackentire tongue lenses out between Brush Creek and Split Mountain; and the lower part of the formation consists of gray, thinly bedded, cherty, fossiliferous limestone, calcareous sandstone, and nodules and vugs of calcite. The chert is light-gray to light blue. Calcite and blue-, purple-, and green-chalcedony geodes are characteristic.

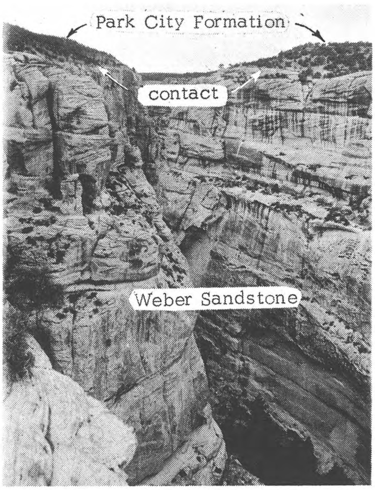

Figure 10. Park City (Ppc) and Weber (Cpw) formations. Brush Creek area, north of Vernal.

The eastward-thinning marine Park City formation generally forms the lower juniper-covered mountain slopes, and where well exposed, exhibits "flat-iron" erosion with Weber sandstone exposed in intervening canyons. The color transition in the "flat-irons" -- from gray to yellow of the upper Park City into red of the overlying Moenkopi formation -- is a striking physiographic feature formed by erosion (Untermann, 1954, p. 38-39).

TRIASSIC SYSTEM

General Statement

The gradational nature of the Permian and overlying non-fossiliferous Triassic beds makes the Paleozoic-Mesozoic boundary difficult to recognize. Cherty limestones grading upward through yellowish gray shales to red arenaceous beds were deposited over an area of low relief by an eastward-shallowing sea. Subsequently, the area was not exposed to rapid erosion at the close of the Permian, and deposition of shallow-water on-shore, near-shore deposits continued into early Triassic time. The boundary was drawn arbitrarily between the buff cherty Park City limestones and the Moenkopi-like variegated shales. In eastern Uintah County (Untermann, 1954, p. 41-45) Moenkopi has been applied to the lower and middle Triassic (?) (Stewart, 1957, p. 442), and Shinarump and Chinle to the upper Triassic. Triassic beds, 1,100 feet thick at Whiterocks River and 1,200 feet at Island Park, were measured. Source for these beds is believed to have been the Ancestral Rockies to the southeast, and highlands to the south and southwest (Stokes, 1950, p. 98).

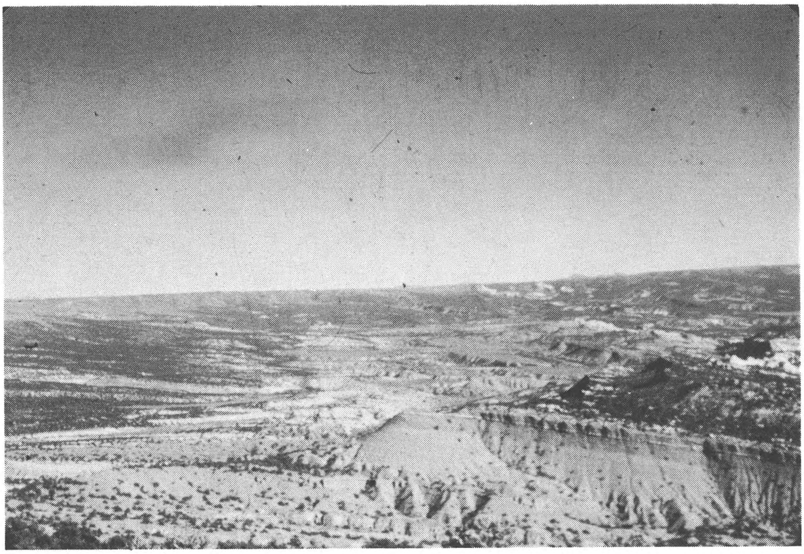

Figure 11. Permian, (left), and Triassic (right) formations. Lookin east from Highway 44, north of Vernal. Diamond Mountain rim in background.

Moenkopi Formation

In the Whiterocks River area, a three-fold division (Woodside, Thaynes, and Ankareh), consisting of fine-grained sandstone and shale, separated by a fossiliferous limestone, changes to a series of red silty shales and gypsiferous fine-grained sandstones for which the name Moenkopi has been used.

In eastern Uintah County, the Moenkopi, up to 950-feet thick, consists of calcareous shales, siltstones, and fine-grained sandstones, commonly micaceous; the lower half brick-red, the upper half a darker red. The formation grades downward into alternating red and grayish-yellow beds at the base. Gypsum, prevalent throughout the formation as thin veins and as layers as thick as 4 feet, indicates evaporative basin environment. It is believed that gypsiferous beds near the middle of the series correspond to the marine Thaynes limestone unit west of Whiterocks River (Kinney, 1955, p. 56); the upper part of the Moenkopi in Uintah County corresponds to the Ankareh farther west; the lower portion to the Woodside.

Footprints and trackways of a reptilian vertebrate, possibly Chirotherium ("hand reptile"), similar to those found in southern Utah and northern Arizona, have been found interbedded in light gray-green shales and red sandstones at Brush Creek, north of Vernal (Peabody, 1948).

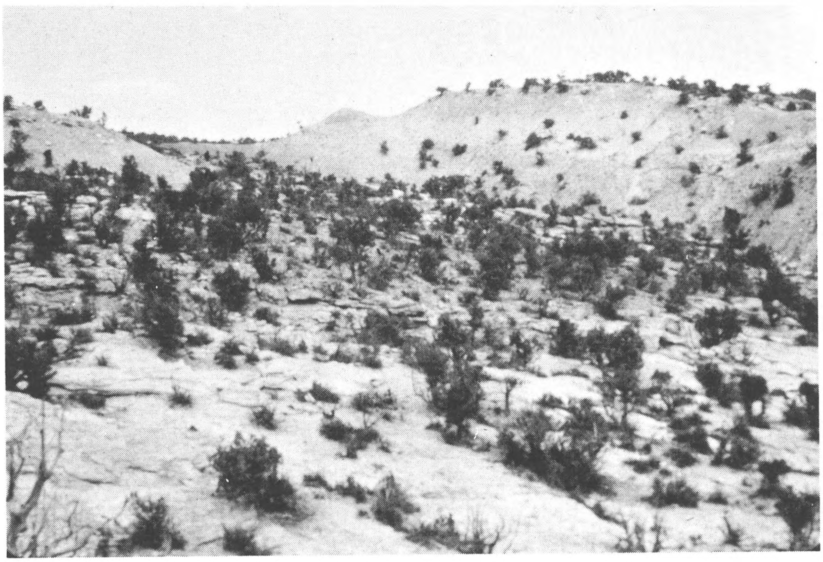

Figure 12. Chinle formation with Shinarump in foreground. Island Park area.

Shinarump Conglomerate

In the Whiterocks area Kinney (1955, p. 64-65) measured 93 feet of Shinarump, 53 feet of grayish tan crossbedded sandstone above, and 40 feet of tan conglomeratic sandstone below. In eastern Uintah County, the Shinarump varies from 35 to 75 feet of buffish, poorly sorted, conglomeratic quartz sandstone, containing varicolored "sugary" quartz pebbles up to 2 inches in length, strongly cross-bedded and lensy, whereas eastward it thins and appears to grade into fairly resistant fine-grained red sandstone, resembling the Chinle. It forms strike ridges and long dip-slopes, on which pot-holes and oval basins are locally well developed.

The Shinarump often fills channels on the Moenkopi with which it appears otherwise conformable, as it is also with the overlying Chinle, for which it has been interpreted as a basal conglomerate (Untermann, 1954, p. 43; Stewart, 1957, p. 411-446). Its uniformity over thousands of square miles indicates flood plain subaerial conditions with a possible pre-Cambrian quartzite highland source (Gregory, 1917, p. 41). A slight elevation to the east could have brought to a close the evaporating-basin environment of Moenkopi time, renewed stream gradients and covered the area with the thin subaerial gravelly sands of the Shinarump. Twenhofel (1950, p. 61) is of the opinion this formation originated in possibly the middle or lower areas of a piedmont environment under desert conditions.

Silicified wood, belonging to a primitive conifer, probably Araucaria, up to 40 feet long and 3 feet in diameter, is abundant. It is similar to that found in the Chinle formation, but less colorful.

Chinle Formation

The upper two-thirds of the Chinle consists of red calcareous shales, siltstones, and sandstones. Ripple marks and mud cracks are common. Mud pebbles and thin mud-silt conglomerate lenses occur. Thin seams of aragonite are abundant locally. In the Red Mountain area, the writers observed 4-toed dinosauroid tracks.

The lower third is composed of varicolored calcareous silty shales, at the top of which is a prominent mustard-yellow layer grading downward into blue and purple beds and containing botryoidal geodes lined with calcite. The purple shales contain light-gray sandstone lenses bearing reptilian teeth and amphibian bone fragments. Quartz-lined geodes, reddish silicified wood, and manganiferous iron oxide nodules occur in the lower 10 feet. Where the wood is absent, banded jasper is often present. Analcite was also found in small amounts by W. D. Keller (Untermann, 1954, p. 45) in the ocherous beds at Brush Creek. The Chinle formation varies from 276 feet at Red Mountain, northwest of Vernal (Kinney, 1955, p. 70) to 235 feet in the eastern part of the county (Untermann, 1954, p. 116). The formation is slope-forming and probably of shallow lake, delta and stream origin.

JURASSIC SYSTEM

General Statement

The Jurassic, initiated by arid conditions, includes the Navajo sandstone, the Carmel formation, the Entrada sandstone, the Curtis and Morrison formations. Two marine invasions followed the Navajo and are represented by the Carmel (Twin Creek) and Curtis (Sundance, in part) and separated by the continental Entrada and equivalents. The Jurassic period was closed by deposition of the extensive lake, flood-plain, delta, and lagoonal sediments of the Morrison formation. The source of most Jurassic sediments in Uintah County appears to have been highland areas to the west and southwest. Western marine equivalents grade into terrestrial facies to the east in the Uinta Mountain region.

An unconformity probably separates the Jurassic from the Triassic, but is not generally apparent. Chinle beds are truncated locally by Navajo (Untermann, 1954, p. 47) north of Vernal. The Colorado plateau formations, Wingate and Kayenta, may extend northward mid way under the Uinta Basin. Deep wells east of Green River in the Hill Creek area penetrate undifferentiated Glen Canyon sediments. Southwest terminology and correlation (Baker, et al., 1936, p. 41, and correlation table number 6) are here used. Jurassic sediments total 2,693 feet near Whiterocks and 2,211 feet in the Dinosaur headquarters area.

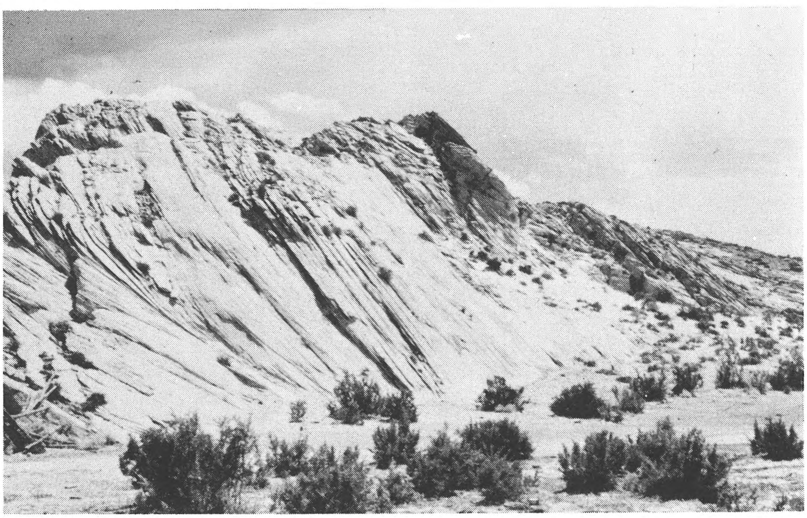

Figure 13. Navajo sandstone showing tangential crossbedding. Cliff Creek area, east of Jensen, Utah.

The Navajo, 1,028 feet thick in the mouth of Whiterocks Canyon (where it is impregnated with bitumen), thins eastward to 700 feet at Dinosaur National Monument and to 577 feet at Island Park. It is massive, locally thin-bedded, uniformly light-gray to buff, red, fine- to medium-grained, generally well sorted and poorly cemented. It breaks down readily into an unconsolidated fine sand which is frequently redeposited by wind in the form of small dunes and sand "flats" on lower surfaces. The Navajo is a good aquifer. Springs often occur along its contact with the overlying impervious Carmel. The Navajo exhibits large-scale tangential crossbedding. West of Little Brush Creek is a 6 to 8 feet lentil of gray sandy limestone in the middle of the formation (Kinney, 1955, p. 74). Navajo weathering produces rounded backs, isolated domed masses, and sheer walls. Iron and calcareous sandy concretions are common, and pitted quartzite ventifacts occur in places at the top of the formation.

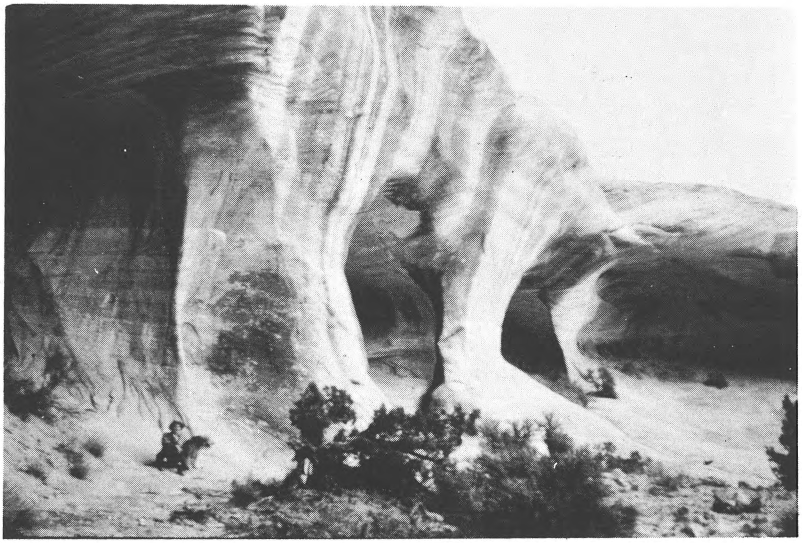

Figure 14. Navajo sandstone, showing caves formed by wind and water erosion. Steinaker Draw, north of Vernal.

Carmel Formation

Topographically, the Carmel occupies depressions between ridges of Navajo and Entrada. Near Whiterocks it consists of 383 feet of soft reddish-brown sandy shale and fine-grained sandstone, interbedded light-gray calcareous mudstone, with light-gray fossiliferous limestone of Middle and Upper Jurassic age at the base (Kinney, 1955, p. 77). In eastern Uintah County, the Carmel is 125 feet thick. North of Vernal it contains a 4-foot gypsum layer. Trigonia quadrangularis Hall and Whitfield, Arctica cf. A. occidentalis Whiteaves, and Natica cf. N. williamsi Cragin are common fossils.

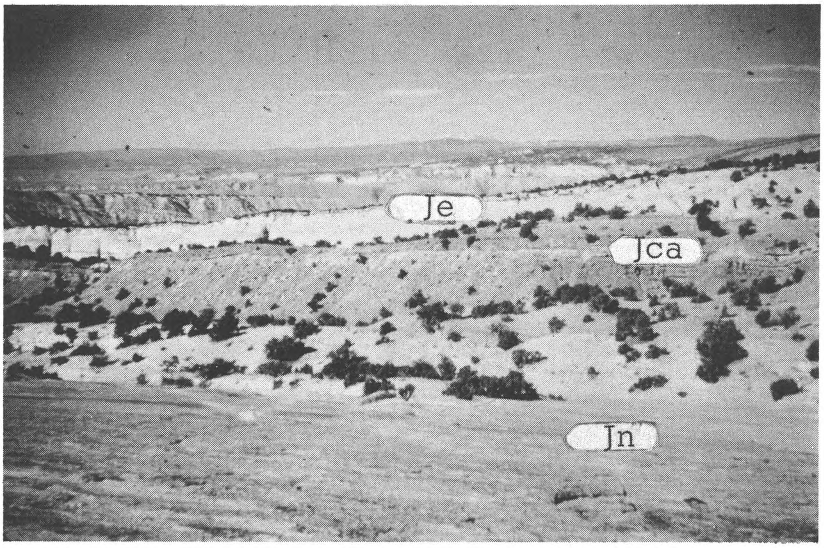

Figure 15. Navajo (Jn), Carmel (Jca), and Entrada (Je) formations in foreground. Curtis and Morrison, left center. Uinta Range in distance. Cub Creek-Bonnie May Ranch road, northeast of Jensen.

Entrada Sandstone

The unfossiliferous, gray to buff, locally reddish medium-grained, clear quartz Entrada sandstone forms conspicuous strike-ridges and weathers into smooth rounded backs and knobs. It is 240 feet thick (Kinney, 1955, p. 82) to the west, thins to 165 feet in the Split Mountain area, and to 135 feet at Island Park (Untermann, 1954, p. 115). The Entrada grades upward into the fossiliferous Curtis sandstone, but occasionally the boundary is marked by a thin mud-pebble conglomerate and a slight wavy line.

The Curtis consists of a basal sandstone member, overlain by an upper series of interbedded bluish-weathering gray carbonaceous shales, thin-bedded to platy, sparingly glauconitic sandstones, and gray to brownish gray oolitic sandy limestones. Near Whiterocks it is 150 feet thick; at Split Mountain, 262 feet. Near the top of the Curtis, in the eastern part of Uintah County 10 to 15 feet below the Morrison contact, occurs a persistant coral-pink to white, minutely concretionary 3- to 6-inch calcareous bed that makes an excellent marker. It lies above a platy glauconitic sandstone which contains Rhynchonella gnathophora (?) Meek, a small brachiopod (Untermann, 1954, p. 52). The writers placed the contact (apparently gradational) between the Curtis and the overlying Morrison at the top of the thin, platy sandstones above the coral marker bed. The abundant marine invertebrate fossils including Belemnites densis (Meek) are of middle Upper Jurassic age (Reeside, 1925, p. 43-44).

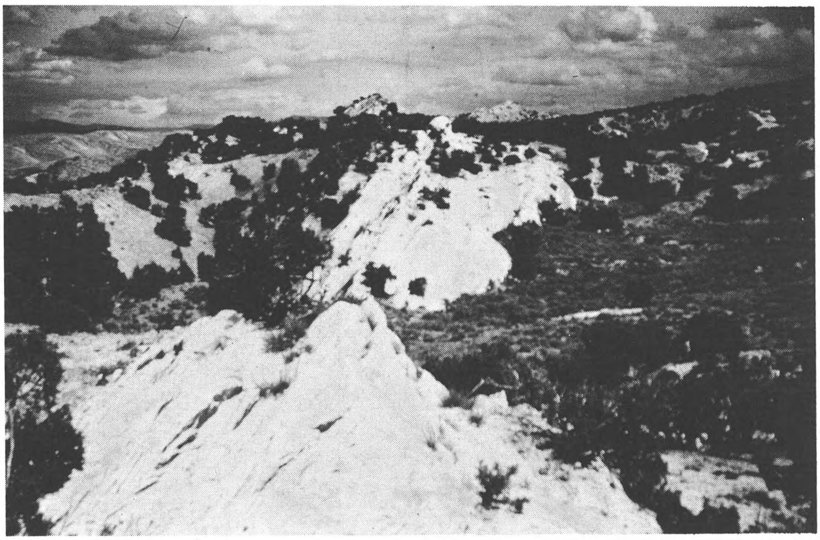

Figure 16. Basal Curtis sandstone — Entrada sandstone contact, center. Gray upper Curtis shale (left), Carmel (right). South of Island Park road.

Morrison Formation

This colorful series of strata of Upper Jurassic age (Baker, et al., 1936, p. 63) contains the world-famous assemblage of dinosaur fossils at Dinosaur National Monument Quarry, 7 miles north of Jensen, Utah. Here the Morrison is a succession of pink to white lensing sandstones, containing silicified wood, in part bentonitic;

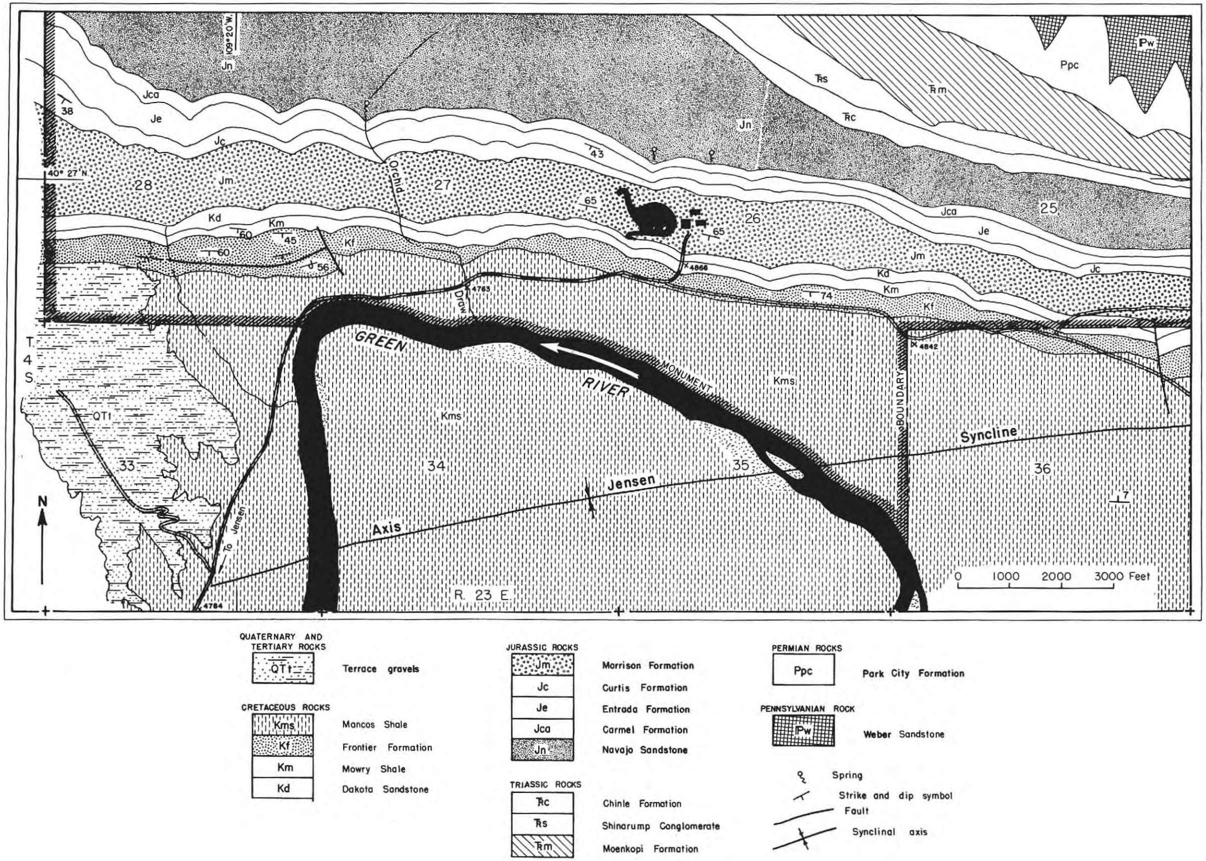

Figure 17. Geologic Map of Dinosaur Quarry, Dinosaur National Monument, Utah.

varicolored soft-weathering calcareous and bentonitic mudstones; claystones; and shales containing interbedded fossil-bearing brown to green conglomeratic sandstones and conglomerates. An abundance of aragonite, often in large concretions, is a common constituent. These beds represent lagoonal, deltaic, lacustrine, and fluviatile sediments deposited near sea level on a broad, uneven plain formed by gradual elevation of the floor and withdrawal of the Curtis sea. The climate may have been somewhat arid (Stokes, 1944, p. 975-976). Some streams had sufficient velocity to transport relatively coarse gravel -- pebbles occasionally up to 4 inches, but generally less than 1 inch (Untermann, 1954, p. 54).

The conglomerates consist largely of subangular light-to-dark-gray, occasionally red or black, quartzite, and some black flint pebbles. Occasional orthoquartzites grade into more widespread calcareous sandstones and jasperoid facies cemented by amorphous silica. Weathered-rock surfaces are frequently dark brown or black due to a coating of desert varnish. The upper conglomerate, which at Dinosaur National Monument Quarry, occurs between two thick bentonitic claystone and shale beds, is the principal dinosaur bone-bearing layer. It has produced an abundance of well preserved skeletal remains representing many species. At the present writing, 26, more or less, complete skeletons have been recovered from the vast quantities of bone material. The following is a list of the fauna recovered from the quarry:

CLASS REPTILIA

Order Saurischis (Dinosaurs)
- Apatosaurus (Brontosaurus) louisae Holland
- Barosaurus sp.
- Camarasaurus lentus (Marsh)
- Camarasaurus sp.
- Diplodocus longus Marsh
- Pleurocoelus sp.
- Antrodemus (Allosaurus) valens Leidy
- Ceratsaurus sp.
- Coelurus sp. (an Ornitholestes type)

Order Ornithischia (Dinosaurs)
- Camptosaurus medius Marsh
- Dryosaurus altus Marsh
- Laosaurus gracilis Marsh
- Stegosaurus ungulatus Marsh

Order Crocodilia
- Goniopholis sp. (Goniopholidae)
- Hoplosuchus kayi Gilmore (Aetosauria, Stegomu-suchidae, a thecodont, Gilmore, 1926; Atoposuridae?, Romer, 1945, p. 597).

Order Chelonia (Turtles)
- Glyptops utahensis Gilmore

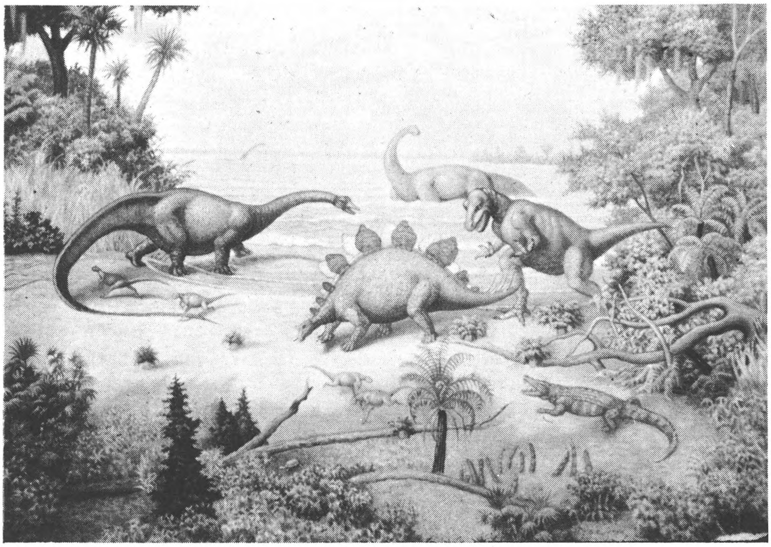

Figure 18. Dinosaurs and other reptiles typical of those found in the Morrison formation at Dinosaur Quarry, Dinosaur National Monument. Painting by Ernest Untermann, Sr.

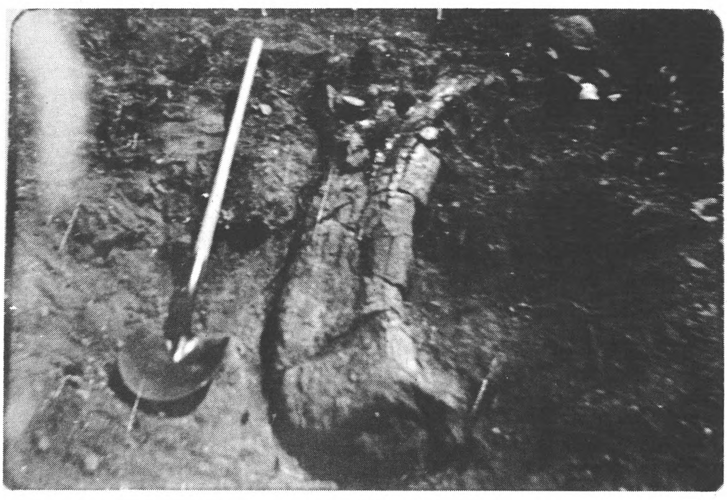

Figure 19. Dinosaur femur (thigh bone). Morrison formation.

A few invertebrate forms also are present. Most abundant are the fresh water bivalve, Unio cf. felchi White and other species of this genus. A very small gastropod, closely resembling Valvata scabrida Meek and Hayden, was found by the writers at the base of the shale bed overlying the main bone-bearing layer.

Near the base of the shale-claystone unit referred to above is a 3- to 5-foot bed of multicolored chert (agate, flint, jasper, opal and other varieties of the quartz family). Associated silicified fossil bone varies in color. Frequently the bone is black, dentoing burial under swamp conditions. Usually this is confined to the lower conglomerate lenses, is softer, and in part is replaced by calcite, barite, or limonite.

The lower portion of the Morrison in Uintah County is predominantly finely arenaceous material probably the equivalent of the Salt Wash member of east central Utah (Stokes, 1944, p. 987). The upper two-thirds largely represents the Brushy Basin member. No sharp erosional contact separates it from the Lower Cretaceous beds in this area. The contact was placed by the writers (1954, p. 56) between the yellow quartzitic sandstone (Buckhorn) and the underlying varicolored shales and claystones. Near the Utah-Colorado line the Morrison has been let down against Navajo and Triassic beds along the Miners Draw Fault. In this locality, remnants of a gray conglomerate layer cap the low-dipping varicolored shale, claystone, and quartzite unit. A short distance to the south, the writers noted up to 75 feet of quartzite pebble-conglomerate, in a light gray sandstone matrix. The bed passes locally into a crossbedded, pebbly sandstone. This conglomerate is believed to represent a lens in upper Morrison and not Buckhorn (Lower Cretaceous--Lakota) as the latter outcrops a short distance to the west where it is less coarse and is of a contrasting yellow color.

Kinney (1955, p. 91) measured 892 feet of Morrison at Mosby Mountain. The writers measured 859 feet in Dinosaur National Monument and 745 feet at Island Park.

LOWER CRETACEOUS SYSTEM

General Statement

The Cretaceous is represented by three units: a lower sandstone (in places conglomeratic), a middle shale, and an upper conglomeratic sandstone. These resemble in lithology and stratigraphic position the Lakota (Buckhorn), Fuson shale (Cedar Mountain), and Dakota, respectively.

Buckhorn Conglomerate (Lakota)

Overlying a varicolored Morrison shale and claystone bed which contains a thin white ortho-quartzite layer that grades upward into gray and yellow soft shale near the contact, the Buckhorn is a fine- to coarse-grained, locally conglomeratic and moderately crossbedded "sugary" sandstone, composed of subangular quartz, feldspar, and gray to black chert. It is yellow to buff, frequently weathering brown. The cementing material is usually siliceous, but becomes clayey or limonitic. White well-silicified fossil wood occurs in some areas. The thickness is 18 feet in the Dinosaur National Monument and 32 feet at Island Park (Untermann, 1954, p. 83, 112).

Cedar Mountain Shale (Fuson)

This unit is a soft, dark-gray to brown or greenish-gray and maroon clay-shale that weathers gray. Near the top occurs a thin fine-grained green sandstone bed. The thickness is 36 feet at Dinosaur National Monument; 41 feet at Island Park.

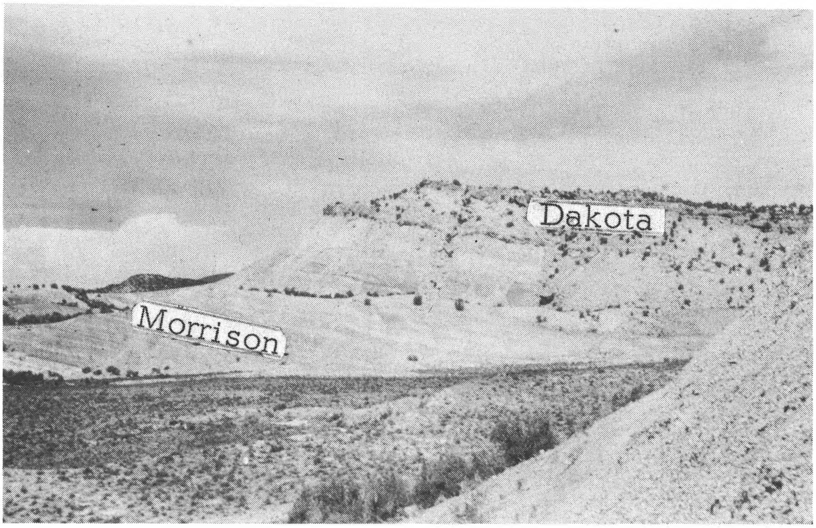

Figure 20. Morrison and Dakota formation.

Dakota Sandstone

The Dakota consists of crossbedded, ripple-marked sandstone lenses, often becoming a pebble conglomerate at the top. Typical yellow to white, light-gray or reddish, it is frequently brown-weathering. It is cavernous, blocky, ridge-forming, and is composed of varying amounts of cherty material. Igneous pebbles occur infrequently. The sandstone lenses are often limonitic and concretionary. More siliceous phases contain quartz veinlets. Clayey portions disintegrate readily. Silicified wood is common. The thickness is 48 feet in the Dinosaur area; 50 feet at Island Park; 34 feet at Mosby Mountain.

UPPER CRETACEOUS SYSTEM

General Statement

Eastward thinning Upper Cretaceous, fluviatile and marine sandstone tongues are the Frontier (Ferron), Emery (Walton, 1957, p. 98), and Mesaverde. Shale tongues are Mowry (Aspen); a middle shale underlying the Frontier sandstone; and a very thick upper shale, the Mancos (Hilliard, in part). These members comprise the Mancos group (Walton, 1944). They are accorded formational status, being persistent and mappable units over extensive areas.

Mowry Shale (Aspen, in Part)

The Mowry is a prominent ridge- and slope-forming bed of hard, gray, silver-weathering siliceous shale. It cleaves into thin plates that contain cycloid fish-scales and small bones of teleost types. Carbonized wood fragments are fairly common. Leaves are rare. A persistent brown-weathering, limestone layer, 18 inches to 2 feet thick with cone-in-cone structure occurs near the middle of the formation. In the eastern part of Uintah County, the writers found one small ammonite, the identity of which was established by Lloyd G. Henbest and J. B. Reeside as <u>Neogastroplites wyomingensis</u> Reeside and Weymouth. Selenite and 2 to 6 inch bentonite layers can be seen where road cuts or quarries expose good sections of this formation. At the base of the Mowry a few feet of soft brownish gray shale, quite unlike the Mowry, may represent an equivalent of the Thermopolis formation of Wyoming which occupies this stratigraphic position. Kinney (1955, p. 100) reported 123 feet of Mowry in the Deep Creek area, west of Vernal, 90 feet north of Vernal, and 31 feet to the northeast at Little Brush Creek. The writers measured 125 feet at Dinosaur National Monument Quarry and 95 feet at Island Park in the eastern part of Uintah County. This irregularity in thickness may represent an erosional unconformity between the Mowry and the Frontier.

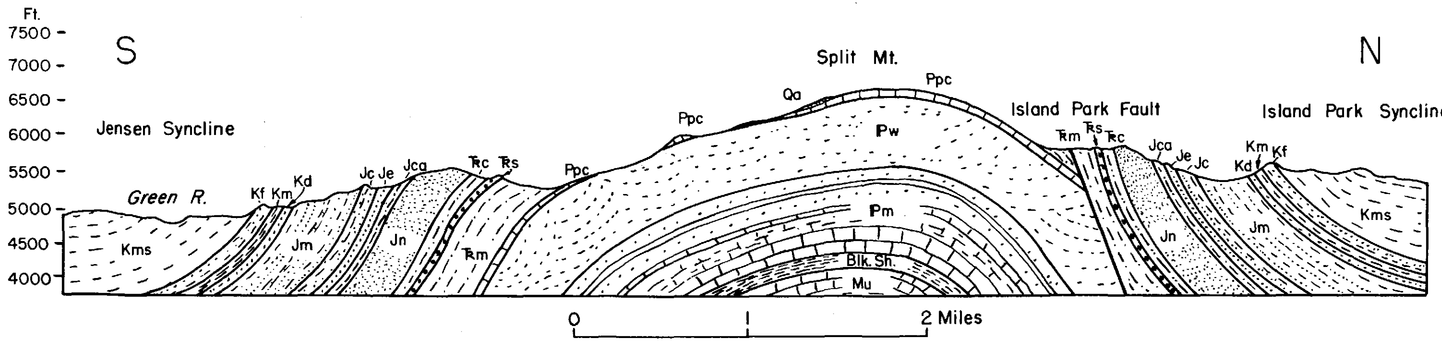

Figure 21. North-south cross-section facing westerly, through Split Mountain and the Jensen and Island Park synclines.

Because of its siliceous composition, scattered yellow (Ponderosa) pine often follows Mowry shale outcrops, even at elevations far below its normal zone (Untermann, 1954, p. 61).

Frontier Sandstone

The Frontier, the oldest eastward-lensing sandstone member of the Mancos group and a prominent ridge and slope-forming unit, is gray, tan, or white, uniformly fine- to medium-grained, calcareous, and slightly arkosic. Brown-weathering, frequently ripple marked, and lightly crossbedded, it lends itself to cavernous weathering. Limonitic iron often forms intricate thin, hard bands, and seams. The uniformity of the sandstone in some places makes for good building stone. The lower part of the formation thickens westward from 37 feet in the eastern side of the county to 87 feet at Dinosaur quarry and to 92 feet north of Vernal. Above this basal sandstone bed occurs gray to brownish carbonaceous, lignitic, and sandy shales, and thin lensing coal seams which reach 15 to 50 feet in the western part of the area. Coal seams from 18 inches to 6 or 7 feet were mined for many years prior to the discovery of oil and gas. The coal varies from soft to hard bituminous varieties; but is difficult to mine because of the thin interbeds of clay and sand. Numerous formerly-worked mines occur north and west of Vernal, and to the east in the Brush Creek area (see mineral section of this paper; and Pruitt, 1961). The coal is overlain by an upper fossiliferous sandstone bed which ranges in thickness from 25 to 50 feet in the eastern part of the county and contains large "cannon ball" limestone concretions, many of which are more than 10 feet in diameter and contain a nucleus of invertebrate fossils, such as bivalves, gastropods, and ammonites (Untermann, 1954, p. 80, 111). Shark teeth and small oyster shells are common in some layers.

The Frontier sandstone, as exposed on the north side of the Uinta Basin, correlates with the Ferron on the south side (Walton, 1957, p. 98) but is slightly older, containing fossils of Greenhorn age, while those of the Ferron are of Carlisle age. The tan, silty Middle Shale member of the Mancos was mapped by the writers as Frontier. These eastward thinning sediments represent an environment varying from littoral to brackish-water swamp conditions. At Island Park, the writers measured 138 feet of Frontier sandstone, and 125 feet of the Middle shale; at Dinosaur National Monument, 146 feet of Frontier, and 80 feet of the shale. Kinney and Rominger measured 94 feet of Frontier sandstone and 177 feet of the Middle Shale northwest of Coal Mine Basin in the Deep Creek area.

Emery Sandstone

This medial sandstone member was not observed by the writers, but was recognized by Walton (1957, p. 98) in the well logs of Uinta Basin oil wells. Its best development is in the Wasatch Plateau area, where it carries an Eagle Fauna and is therefore of Montana age.

Mancos (Upper Shale) Formation

The Mancos, a soft clay shale formation that weathers typically light-gray in the lower part and yellow buff in the upper part, conformably overlies the Frontier. Near Jensen, Walton (1944, p. 105) measured 1,235 feet of dark-blue to bluish gray clay in the lower one-fourth, followed by 730 feet of drab clay shale, 2,360 feet of yellowish gray, sandy clay shales, and 747 feet of drab to yellow clay shale containing numerous thin beds (less than 7 foot) of brown, hard, fine-grained calcareous sandstone. The total of 5,072 feet is probably maximum for this area. Calcite geodes and selenite seams are abundant in many beds. The shales erode easily and lend themselves to "badland" development. The rich agricultural lands of the Ashley and Jensen valleys are formed on Mancos shale. Because of the high alkali content, particularly in places where drainage is poor, vegetation on the Mancos is chiefly greasewood, shadscale, horsebrush, with some sagebrush and rabbit brush, producing good winter grazing for livestock.

The Mancos contains numerous types of marine invertebrates, most characteristic of which are species of Inoceramus, Baculites, and Scaphites, of Benton, Niobrara, and lower Montana age (Walton, 1944, p. 105). The absence of the lower Carlile shale equivalent (Reeside, 1944, map 5) suggests that a stratigraphic break may be present between Frontier sandstone and Mancos shale, although no physical evidence for such a break is known (Kinney, 1955, p. 108). The overlying Mesaverde group is largely Niobrara in age in the western part of the Uinta Basin and post-Niobrara in the eastern part.

Mesaverde Group

The Mesaverde in this area consists of a lower series of marine sandstones, the Asphalt Ridge and Rim Rock members, and an upper succession of sandstones, sandy shales, carbonaceous shales, and oal-bearing beds of chiefly brackish- and fresh-water origin -- the /illiams Fork formation. These beds thin toward the east where ıey interfinger with Mancos shale.

Asphalt Ridge Member: The Asphalt Ridge, basal member of the Mesaverde, consists of gypsiferous, yellow to white, poorly cemented sandstone that is approximately 100 feet thick. It somewhat resembles the Trout Creek (?) sandstone of the Axial Basin area to the east in western Colorado (Walton, 1944, p. 116). This unit does not contain bituminous material, but sandstone beds both above and below it are saturated. Except for a local occurrence of thin-bedded argillaceous sandstone below, the Asphalt Ridge member itself lies directly on Mancos.

Rim-Rock Sandstone: The Rim Rock sandstone forms a prominent hogback from Asphalt Ridge to the Utah-Colorado line, a distance of 30 miles. It represents a near-shore facies of gray poorly-cemented crossbedded sandstone that frequently has a speckled appearance due to the presence of numerous minute chert fragments. At Asphalt Ridge, four miles southwest of Vernal, the Rim Rock member is 112 feet thick. It attains a maximum thickness of 416 feet 9 miles east of Green River, from which point it gradually thins eastward. Asphaltic bitumen of commercial value saturates much of the Rim Rock sandstone. It is separated from the underlying Asphalt Ridge member by a thin tongue of shale. The Rim Rock sandstone along Asphalt Ridge is partially overlapped by Tertiary formations, the Duchesne River and Uinta north and west of Green River and by Uinta, Green River and Wasatch east of the river. As beds both above and below the Tertiary-Cretaceous boundary are saturated with bituminous material, there is apparently a definite relationship between the saturation and this unconformity along which the asphaltic material has migrated.

Williams Fork Formation: The Upper portion of the Mesaverde (Williams Fork) is composed of varicolored shales; buff, gray and brown sandstones; and coal beds. East of Green River at the junction of State Road No. 45 (Bonanza Road) and U.S. Highway 40, it is approximately 1,000 feet thick. About 60 per cent of the formation is shale. Both brackish- and fresh-water fossils have been found. Extensive swamps, formed near the end of this period, produced coal deposits of considerable economic value (Pruitt, 1961). Burning of some of the coal layers has given rise to reddish indurated shales. Regional correlation of the coal-bearing beds, undertaken by Reeside and others, places the Adaville formation of southwestern Wyoming in the same faunal zone as the Blackhawk and lower Price River (upper Pierre) of the Book Cliff-Wasatch Plateau area (Walton, 1944, p. 116-117), whereas Walton states that the lithologies of the Williams Fork in this region, the Blackhawk, and the lower part of the Price River are similar, and on that basis these three formations may be correlated and are believed to occupy the same stratigraphic position. It is also believed that the Mesaverde of this area includes, in addition to the Williams Fork, beds equivalent to the Iles formation at the base and Lewis (?) shale, which is possibly Fox Hills in age, at the top.

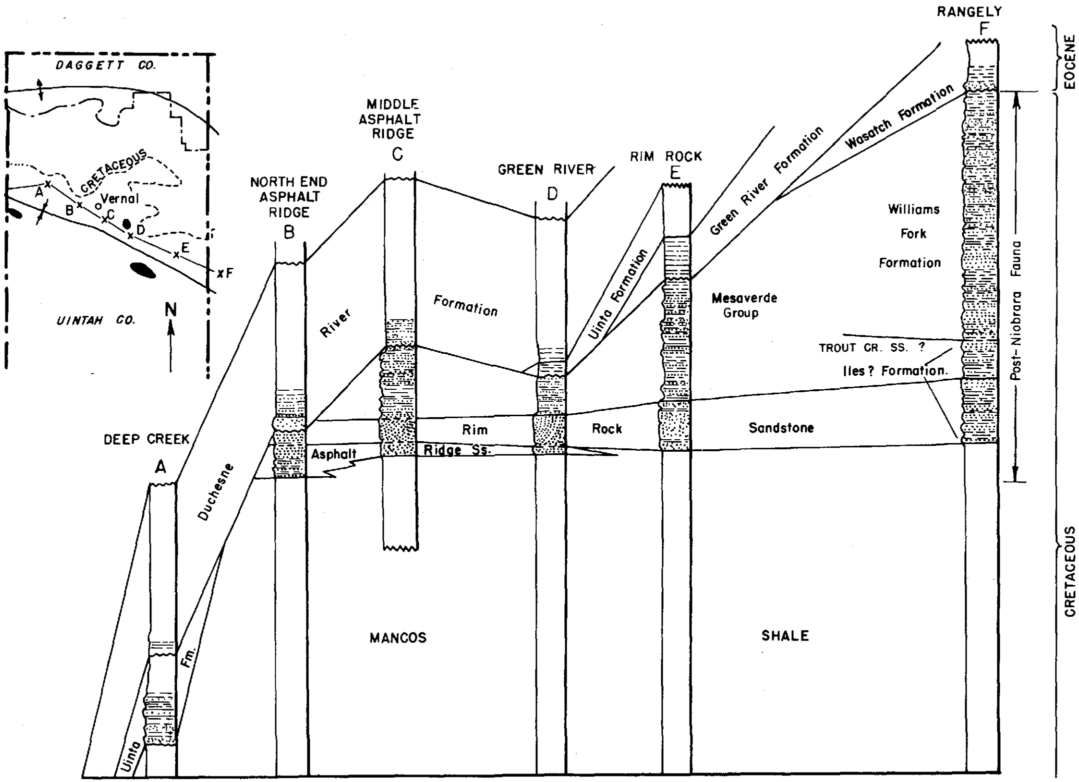

Figure 22. Sections showing Tertiary-Cretaceous relationship along north side of Uinta Basin. (Modified from P. T. Walton.)

West of Vernal, the Mesaverde outcrops in various places. Thus, at Red Creek, near the western boundary of Duchesne County, it has a thickness of 3,000 feet which may be divided into a lower series of massive marine sandstones 879 feet thick, and an upper series of fresh- to brackish-water sandstones, sandy shales, and coal beds, 2,132 feet thick. From several wells in the southern part of the Uinta Basin, shales of dark-gray color similar to the Lewis (?) are known to interfinger with the upper part of the Williams Fork, but are several hundred feet lower in the section than the Lewis shale of the Axial Basin area in western Colorado. In some of the wells, shales overlying the Lewis (?) are believed to be equivalent to the North Horn formation of late Cretaceous and early Paleocene age which outcrops in the southwestern part of the Uinta Basin.

During Upper Cretaceous time, the thickest marine deposition (Mancos shale) took place to the southeast and spread westward grading laterally into coarser sediments of post-Colorado age, and of continental origin.

TERTIARY SYSTEM

General Statement

As a result of the initial uplifting of the Uinta Range, the Cretaceous sea withdrew from northeastern Utah and marine shales grade laterally and are interbed with continental sandstones, shales and coal seams of flood-plain and lagoonal character. Fluviatile sediments, the Currant Creek, North Horn, and Colton formations to the west and southwest, representing both late Cretaceous and early Tertiary, cross time boundaries and interfinger with their Paleocene and Wasatch equivalents to the east.

Two periods of lacustrine sedimentation, the Flagstaff limestone and the Green River formation, followed the early flood-plain deposition. Of these, the latter, deposited by Lake Uinta, is the more extensive. That Lake Uinta (estimated to have existed for 8 to 10 million years) underwent many fluctuations is indicated (Bradley, 1931, p. 55) by the complex interfingering of marginal fluviatile and deltaic beds with those of lacustrine origin in the central part of the Uinta Basin. Thus, above the Wasatch (Colton) tongue, a second lacustral facies, a delta facies, an oil shale facies, and a saline facies at the top comprise the Green River formation. In its later stages, the lake, whose greatest depth was in the west-central part of the Basin, increased in salinity, and finally gave way to an interfingering of fluviatile and lacustrine sediments during Uinta, Eocene time.

Deposition of the Duchesne River formation, Eocene (?) - Oligocene, followed as downwarping ceased and the Basin filled with fluviatile sediments as streams again became the dominant agents of deposition.

In Uintah County the Tertiary formations, derived by erosion from older rocks of the Uinta Mountain area, progressively overlap the upturned and eroded edges of the pre-Tertiary formations along the south flank of the Uinta Range. Here maximum warping has produced the Uinta Basin synclinal axis where dips on the north limb vary from 10^{o} to 35^{o}, but flatten to 2^{o} to 4^{o} on the south limb of the syncline.

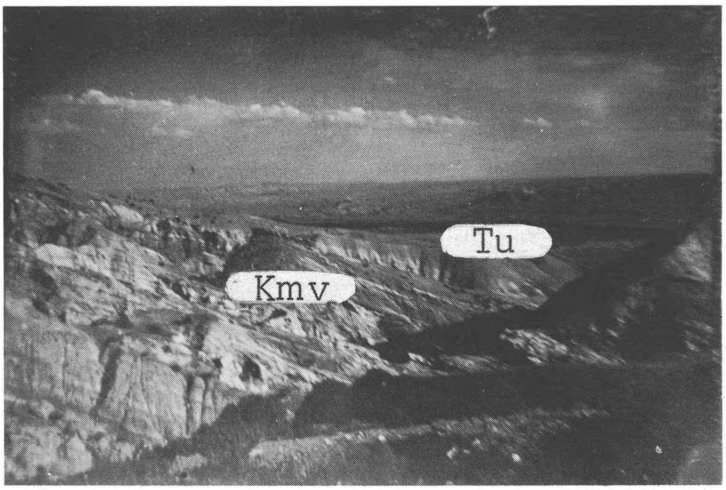

Figure 23. Mesaverde formation, Cretaceous, (left) partially overlapped by Uinta, Eocene (center right).

Eocene Series

Paleocene-Wasatch Formation

The Wasatch, predominantly a red-bed formation of fluviatile origin, ranges in age from late Paleocene to early Eocene. Inplaces it unconformably overlies the Mesaverde (Upper Cretaceous). Elsewhere the contact is gradational (Abbott, 1957, p. 103). Its upper portion interfingers with or grades into the overlying Green River formation, the base of which is generally marked by the presence of fresh-water gastropods and other mollusks. The Wasatch consists of varicolored mudstones and shales, brown to gray, poorly-sorted lenticular to massive sandstones, and local conglomerates. Some oolitic and ostracodal limestones, particularly in the southwest part of the Uinta Basin, differ from those of the overlying Green River in that they contain less clastic material (Picard, 1957, p. 118) and were probably deposited in clear, fresh-water lakes. The Wasatch thins rapidly to the east, from more than 4,000 feet in Duchesne County (Carter Oil Company's Ute Tribal No. 2 well), to 850 feet in eastern Uintah County near the Utah-Colorado line. In the latter area the upper part of the formation is well exposed in the Snake John valley south of Highway No. 40, the Wasatch formation is progressively overlapped by Green River and Uinta (Eocene), and Duchesne River (Eocene (?) - Oligocene). On the north side of Asphalt Ridge west of Green River, what frequently has been mistaken for Wasatch is, in reality, Duchesne River. In the southern part of Uintah County, Wasatch is exposed in deeper canyons as in upper Bitter Creek and in Desolation Canyon along Green River.

Fossils: Fragmental vertebrate fossils found in the Wasatch of this area (correlative with the early Eocene Gray Bull of Wyoming) consist of the following genera: Phenocodus (a large primitive hoofed mammal), Coryphodon (a large elephant-like animal), Hyracotherium (Eohippus horse), and Paramys (a primitive rodent) (J. L. Kay, 1957, p. 110). Some fresh-water invertebrates have also been found in the formation.

Green River Formation

Black Shale Facies: In 1955 Picard (p. 83) described from subsurface drilling a black shale unit. It occurs at the base of the Green River at the first occurrence of red beds, and grades downward into the Wasatch formation. It does not outcrop in Uinta County, except along the southern edge of the Uinta Basin. In the Carter Oil Company's well, Ute Tribal No. 2, near the town of Duchesne, in Duchesne County, the black shale unit is 1,080 feet thick. It thins eastward and southward to less than 200 feet thick near the Utah-Colorado line. This black shale facies consists of thin-bedded dark gray to black carbonaceous and calcareous shales, often pyritic, and some grayish-green shale which grade northward into the overlying Green River beds. Some brown argillaceous to carbonaceous limestone and light-gray sandstone and occasionally oil shale are present. The black shale is a lacustrine facies containing abundant ostracods. Ostracodal zones were recognized (Swain, 1956) and used in the stratigraphic study of some of the wells of this area. Instead of "Black Shale Facies" Swain named these the "Colton-Green River transition beds." The black shale is the lacustrine time equivalent of the upper Wasatch which is largely fluviatile and with

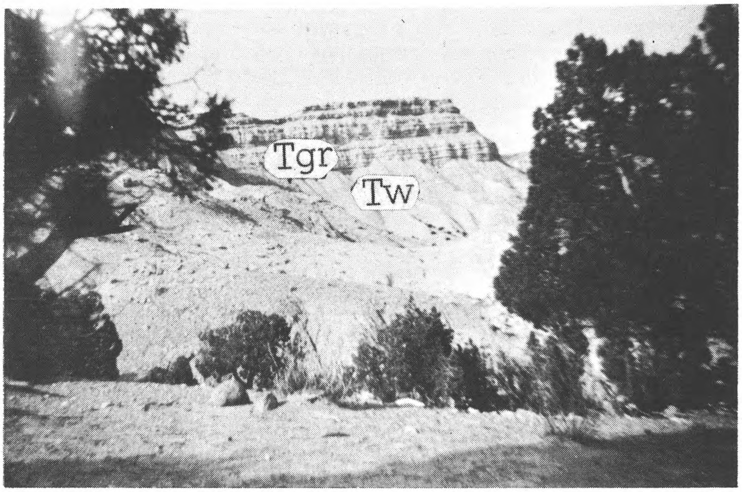

Figure 24. Wasatch-Green River (Eocene) contact. Snake John area, east of Jensen, Utah, south of Highway No. 40.

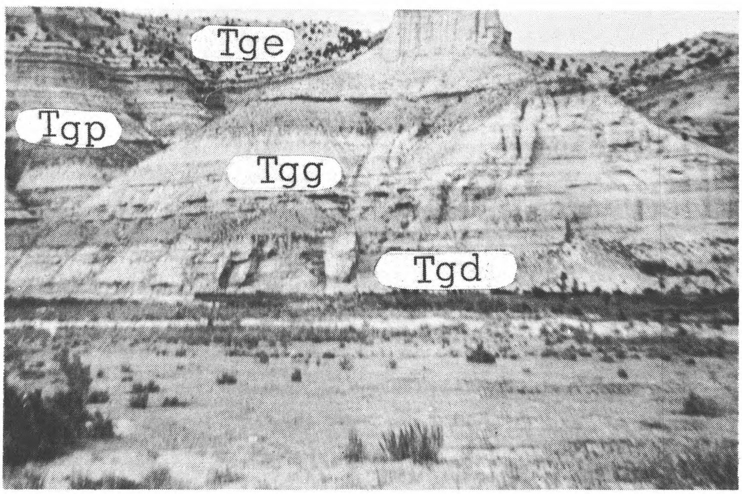

Figure 25. Green River formation: Evacuation Creek (top), Parachute with Mahogany ledge oil-shale bed, Garden Gulch (lower half of picture) members. Hells Hole Canyon, southeast of Bonanza.

which, in some places, particularly to the west, it complexly interfingers. Between the Duchesne area, Duchesne County, and the Red Wash field, Uintah County, 1,700 feet of transgression occurs (Picard, 1957, p. 118).

Fossils--_Vivaparus_, _Unio_, and _Goniobasis_ are common molluscan genera in the lower part of the Green River series.

Douglas Creek Member (Delta Facies): The Black Shale facies and, in places, the Wasatch grade upward into the Douglas Creek member of the Green River formation. The Douglas Creek is correlated with the lower part of the delta facies into which it grades laterally a few miles west of the Red Wash field (Picard, 1957, p. 124). In eastern Uintah County it consists chiefly of thick brown lenticular sandstones, black, gray, green, and brown shales, and oolitic and algal limestones. In Hells Hole Canyon, four miles northeast of Watson, it is 360 feet thick and thickens to 830 feet farther south (Cashion and Brown, 1956). Algal reefs are abundant in this area. The member thickens to 1,480 feet to the south near the Uintah-Grand County line. In the latter area it contains more sandstone and fewer algal limestones. The sandstones contain pebble conglomerates and fore-set and bottom-set bedding can be distinguished (Abbott, 1957, p. 104). Gray, green, mottled green, and red shales are also present. The Delta Facies is similar in lithology to the Douglas Creek member, but contains fewer algal limestones and more abundant green and purple shales which are interbedded with grayish-brown sandstones. In the Red Wash area where the thickness ranges from 350 feet to 500 feet, sandstones and siltstones are abundant and contain commercial quantities of oil and gas.

Fossils--Fossils include algal reefs and ostracodal zones.

Garden Gulch Member (Delta Facies in part): The Garden Gulch is gradational into the overlying and underlying beds. It is less coarsely clastic than the underlying Douglas Creek member. It is a slope forming unit composed of gray- to buff-weathering gray, green, and brown paper-thin and thicker shales, interbedded thin sandstones, siltstones, light-gray limestones, occasional dolomites, and some thin low-grade oil shale. Locally, oolitic and algal limestones are present. The thickness of this member ranges from 200 to 700 feet. At Hells Hole Canyon, it is 200 feet; at Red Wash field, 550 feet. It thins to the west and south as it grades laterally into the algal limestones and sandstones of the Douglas Creek member (Abbott, 1957, p. 108). The Garden Gulch is tentatively correlated with the middle part of the Delta facies, from which, like the Douglas Creek member, it cannot be distinguished a short distance west of the Red Wash oil field.

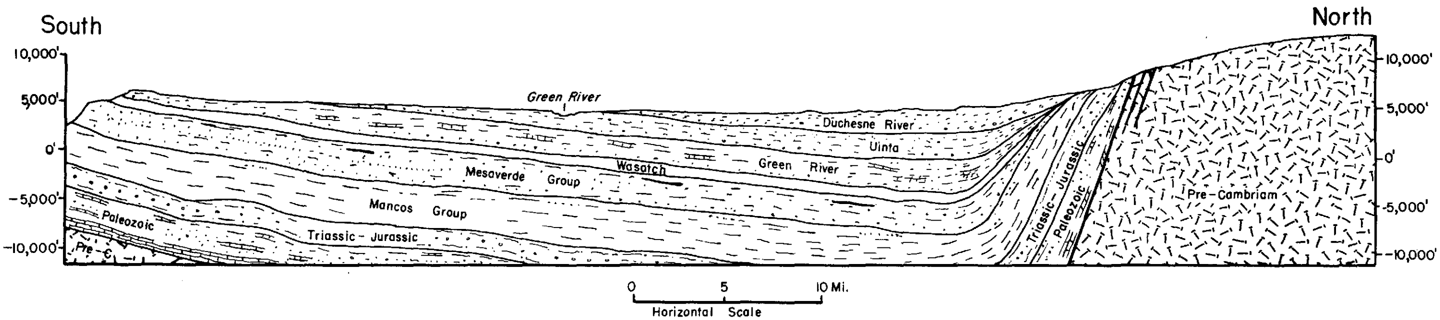

Figure 26. Generalized cross section of the Uinta Basin showing Tertiary overlap.

Fossils--"Fossil reptiles, birds, and mammals now known from the Green River formation are practically all from one small area. They are found in a sandy deltaic facies along the basin side of Raven Ridge in the eastern end of the Uinta Basin. This sandstone is composed largely of well-rounded grains of quartz and quartzite. The stratum passes into shale along the outcrop in both directions. The collection is still under study, but already four genera of lizards, two of birds, one marsupial, two insectivores, three carnivores, one condylarth, three rodents, and three primates have been identified. Additional genera and quite a number of species will probably be found upon further study." (J. L. Kay, 1957, p. 110-111). Dr. Kay further states that this fossil material is from small sized animals, but that one fairly large carnivore came from a lower horizon about 1 mile to the north. Three species of birds from the latter area were described by Dr. Alexander Wetmore as being shore birds similar to the Auks and Avocets. This Raven Ridge fauna, according to Doctor Kay, is very similar to the Bridger fauna from the north side of the Uinta Range, and "at the present time, it appears that the Green River formation of the Uinta Basin is somewhat younger than the Green River formation of Wyoming."

Parachute Creek Member: The Parachute member, predominantly oil shale, overlies the Garden Gulch and Douglas Creek in eastern Uintah County. West of Red Wash it overlies the Delta facies. It is perhaps the most distinctive and widespread member of the Green River formation and contains the principal oil rich shales. In the vicinity of Watson, Uintah County, the Parachute is about 175 feet thick, and thickens to 1,450 feet in the Red Wash field. In addition to the bluish gray-weathering dark gray to brown and black oil shales, the Parachute member is composed of interbedded greenish and brownish shales and thin tuff beds, frequently analcitized gray limestones and dolomite, and gray- to buff-weathering siltstones and sandstones. The unit is typically cliff forming.

The Mahogany Ledge oil-shale bed, 2 to 8 feet thick in the upper part of the formation, contains the richest and most persistent oil-bearing shales in the Green River formation. It is an excellent key bed and time horizon in which delicate light-colored carbonate laminae alternate with dark-colored laminae rich in organic material. These represent seasonal accumulations and are useful in indicating time and duration of Lake Uinta. The oil shale is "a magnesian marlstone rich in organic matter that was derived chiefly from aquatic organisms and waxy spores and pollen grains. This organic matter is only slightly soluble in petroleum solvents, but most of it is distillable into petroleum. The amount of organic matter in the marlstone ranges from zero to about 50 per cent. The main inorganic constituents of the marlstone are dolomite, calcite, analcite, and clay minerals." (Cashion 1957, p. 132). Average potential yield is 30 gallons of oil per ton (see mineral section of this paper). "In general, the oil content of the principal oil shale zone is greatest near the axis of the depositional basin and decreases toward the margins of the basin." "The richest exposed oil shale in the eastern Uinta Basin is located along the White River near its confluence with Evacuation Creek." This bed thins toward the southern edge of the Basin.

Fossils--Locally the low grade oil-shales contain abundant scales and partial skeletons of garpike (Lepidosteus sp.) Bradley (1931, p. 12). Mature insects, leaf and stem imprints occur. Along White River, Bradley noted that about 49 per cent of the lower part of the oil-shale group consists of larvae bearing beds, sufficiently abundant on some of the bedding planes to make a thin glossy dark-brown layer. The larvae are from one-eighth inch to two inches in length and represent the following fly-larvae families: Chironomidae, Stratiomyidae, Tabanidae, Syrphidae, and Oestridae, forms whose larval life was, at least in part, aquatic. Some of these larvae-bearing shales yield 8 to 15 gallons of oil per ton. Filiments and spores of fungi, algae, chiefly the blue-green variety, pollen, protozoa, and bacteria were studied by Bradley. Ostracods are numerous in some of the limestones.

Figure 27. Evacuation Creek member (saline facies) of the Green River formation showing solution cavities where minerals have been leached out, south of Bonanza, Utah.

Evacuation Creek Member: In the eastern part of the Uinta Basin and Uintah County, the Evacuation Creek, as well as the Parachute, is distinguished as a separate member. A series of gray-weathering, thin-bedded to platy grayish brown shales, limestones, mudstones, siltstones, sandstones, tuffs, and minor oil-shale beds, it includes the Horse Bench sandstone and a saline facies as distinctive markers (Abbott, 1957, p. 108). In western Uintah County, the Horse Bench, a brown resistant sandstone and siltstone, is approximately 50 feet thick and lies some 350 feet below the Uinta-Green River contact. It forms prominent mesas, making an excellent marker bed, but wedging out to the east. Twenty-five to 150 feet below the Uinta contact, a saline phase occurs which contains abundant cavities which may have been formed by leaching of Nahcolite ($NaHCO_3$) from thin calcareous shales (Cashion and Brown, 1956). In the Red Wash field the Evacuation Creek member is 500 feet thick. To the west, where the Evacuation Creek is 1,700 feet thick, it grades into the saline facies of the Green River-Uinta series and can no longer be separated from the Parachute. Lake Uinta had apparently attained its maximum development and stability during deposition of the Parachute and Evacuation Creek sediments (Picard, 1957, p. 125).

Fossils--Fossils are preserved in abundance in some of these shales. Most common are insects (mosquitoes, beetles, ants, flies, bees), especially well preserved in the lower part of the Evacuation Creek member, as are also aquatic larvae of many of these forms. Fish, occasional bird feathers, imprints of many kinds of leaves, flowers, and seeds occur. A few algal reefs, ostracodal limestones, gastropod shells, fragmentary remains of turtles, crocodiles, and garpike fish (Bradley, 1931, p. 14) are also represented.

Minerals--In an excellent article on the unusual minerals of the Green River formation, Milton (1957, p. 136-143) stated that 31 authigenic species have been found in this formation, most of them in the Uinta Basin of Utah. In contrast to their characteristic association with intrusive igneous rocks, none of which has been found in the Basin, some of these minerals, like the zeolites (acmite, analcite), are probably alteration products of volcanic ash commonly found in the Evacuation Creek member. Other minerals are evaporites and precipitates of unusual occurrence, many having been described recently for the first time. Quantities of calcium, sodium, magnesium, and other substances derived from stream inflow, accumulated in the fluctuating lake waters which at times were reduced to concentrated brines. It was in this environment that the rare assortment of minerals of the Green River formation originated. A partial list of these minerals from the Uinta Basin follows:

Nahcolite	$NaHCO_3$
Thermonatrite	$Na_2CO_3 \cdot H_2O$
Shortite	$Na_2Ca_2(CO_3)_3$
Eitelite	$Na_2CO_3 \cdot MgCO_3$
Burbankite	A rare earth carbonate approximated by $Na_2R_4(CO_3)_5$, where R is Ca,Sr, Ba and an amount of Na equal to the amount of rare earths.
Northupite	$Na_2CO_3 \cdot MgCO_3 \cdot NaCl$
Analcite	$NaAl\ (Si_2O_6) \cdot H_2O$
Riebeckite-crocidolite	$Na_2Fe^{++}_3Fe^{+++}_2Si_8O_{22}(OH)_2$
Acmite	$NaFe^{+++}Si_2O_6$
Reedmergnerite	$NaBSi_3O_8$
Searlesite	$NaBSi_2O_6 \cdot H_2O$
Garrelsite	$(Ba, Ca, Mg)H_3B_3SiO_9$
Leucosphenite	$(Na_2, Ba, Ca)_{10}B_2Ti_5Si_{19}O_{51}$
Collophane	$Ca_9Na\ (OH,F)_2\ (PO_4)_2\ (CO_3) \cdot H_2O$
Anhydrite	$CaSO_4$
Bassanite	$CaSO_4 \cdot 1/2\ H_2O$

(These are taken from Milton's Table I, p. 138, Eighth Annual Conference.) Many of these unusual Green River minerals occur in the Evacuation Creek member in Uintah County. Other mineral types occur in the Green River formation of Colorado and Wyoming which have not as yet been found in the Uinta Basin of Utah.

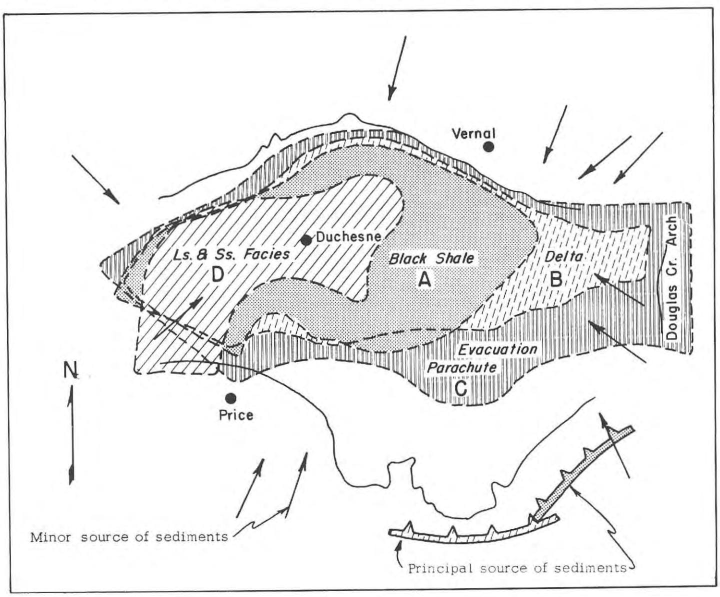

Figure 28. Fluctuation of Lake Uinta shoreline during deposition of members of the Green River formation. (Modified from M. D. Picard.)

In late Green River time Lake Uinta began to shrink rapidly and was confined largely to the western part of the Uinta Basin where, extending into Uinta time, it continued to increase in salinity. The Uinta formation, as a result, is composed of both fluviatile and lacustrine sediments, the former predominating. It grades westward into lacustrine oil-shales which consist in part of cavernous cherty bituminous carbonates, whose cavities were once filled with soluble salts.

In eastern Uintah County, the Uinta formation consists of a sequence of interbedded gray, buff, brown, and reddish brown sandstones and gray, white, purple and red mudstones, siltstones and clay-shales of fluviatile origin. The sandstones are medium- to coarse-grained, poorly sorted, crossbedded and irregularly bedded, frequently representing channel fill. These sandstone lenses directly overlie the Evacuation Creek member of the Green River formation where the latter is distinguishable from the Parachute, and the weight of these overlying lenses has produced in many places a differential compaction and contortion of the underlying shales to conform to the shape of the sandstone beds, giving the false appearance of an erosional unconformity (Bradley, 1931, p. 20). In the eastern part of Uintah County and the Uinta Basin, the Uinta formation was divided by Peterson (1895) into horizons A, B, and C which were later called by Wood (1934) Wagon Hound (A and B) and Myton (C) members. The upper part of C was named by Scott (Kay, 1934, p. 358-360; 1957, p. 111) the Duchesne River. The Wagon Hound member, 685 feet thick in Wagon Hound Canyon south of Bonanza, includes the heavy-bedded channel sandstones whose source was from the east and not from the Uinta Mountain area. Horizon B (420 feet thick), upper Wagon Hound, which includes the Amynodon sandstone, contains more shale and mudstone than does A. The Myton member (C) is composed of varicolored clay-shales, mudstones, siltstones, and sandstones, the latter more common in the lower part. It attains a thickness of about 700 feet. A sharp lithologic break was noted between the Myton and the overlying Duchesne River in the central part of the Uinta Basin, while in the eastern and western parts of this area there is a gradual transition, making their separation more difficult (Kay, 1934, p. 361).

In the western part of Uintah County where the Parachute and Evacuation Creek members of the Green River formation pass westward into saline facies, the lower Uinta also grades into beds that resemble the lacustrine lithographic shales of the Green River. The Uinta-Green River contact in the central part of the Uinta Basin is placed near the middle of the Saline facies, which consists of thin gray to brown shales in part calcareous, dolomitic, cherty, and with salt crystal molds. Thin sandstones occur in the upper part. The basal

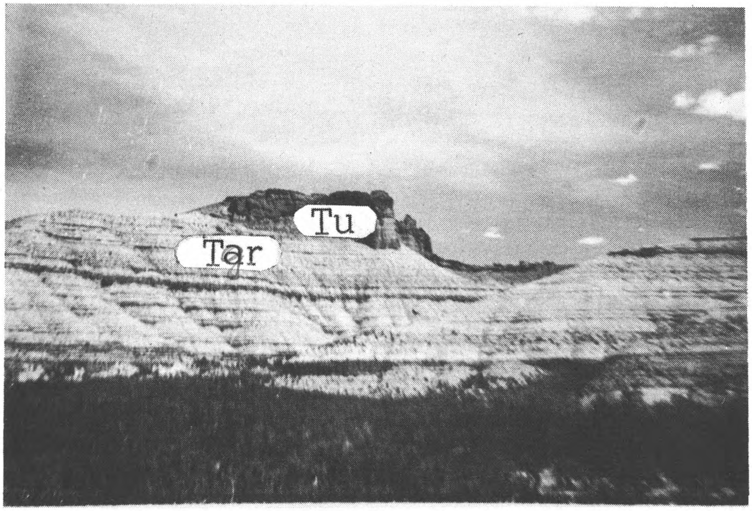

Figure 29. Green River, Evacuation Creek member — Basal Uinta ("A") contact.

Figure 30. Uinta "B" (Eocene), northeast of Ouray, Utah.

Uinta saline beds resemble the Evacuation Creek member farther east (Abbott, 1957, p. 108). Thickness of this unit is 950 feet (Picard, (1955). Above the Saline facies is a regular-bedded westward lensing unit named the "Sand and Limestone facies" (Dane, 1955) which consists of "gray to brown, fine-grained sandstones, shales, and white-weathering silty limestone," at the base. These beds are believed to represent the closing phase of lacustrine deposition. A series of red, gray, purple, and reddish-brown shales, siltstones, and lenticular sandstones of chiefly fluviatile origin overlie the Sand and Limestone facies in western Uintah County and the western part of the Uinta Basin. Southwest of Roosevelt (Abbott, 1957) minor algal reefs occur 150-200 feet below the Uinta-Duchesne River contact. Dane (1955) considers the age of the Uinta to be middle to upper Eocene. Total thickness of the Uinta formation in western Uintah County, measured by Kay north of Ouray, is 1,650 feet. At the Red Wash field it is 2,600 feet (Picard, 1957, p. 182). The Uinta is generally conformable with both the overlying Duchesne River and the underlying Green River formations.

Fossils--The Uinta formation contains an abundance of fossil vertebrates, more than 100 species of which have been collected in Uintah and eastern Duchesne counties. A greater number of both individuals and species have been recorded from this area than from the Uintah of any other region (Kay, 1957, p. 111-114). They include fish (garpike) and scales of the ganoid type, crocodiles, turtles, both fresh-water terrapins and terrestrial tortoises, a lizard, insectivores, carnivores, herbivores (amblypods, perissodactyls, artiodactyls), rodents, and others. For a complete list of genera and species, see Kay (1957, p. 113-114). Numerous individual beds are known for their characteristic faunal species.

Minerals--The principal production of gilsonite, a solid, very pure hydrocarbon, occurs in vertical veins in the Uinta formation (see mineral section of this paper).

Oligocene Series

Duchesne River Formation

The Duchesne River resembles the fluviatile beds of the upper Uinta, but has a higher percentage of sandstone and conglomerate of a darker, more uniform red color, while the upper Uinta lake beds are lighter and more variegated. To the west, however, where both formations are derived from the Uinta Mountains, they are more difficult to distinguish (Kay, 1949, p. 107). The Duchesne River consists of interbedded red, brown, and varicolored clay-shales, gray to buff red-weathering sandstones and some conglomerates of fluviatile origin, derived chiefly from the Uinta Mountain area. It has a maximum thickness of 1,500 feet and is conformable with the underlying beds except along the northern boundary where it lies with angular discordance on older Tertiary, Mesozoic, and Paleozoic formations. The progressive overlap of younger over older Tertiary is pronounced along the Rim Rock-Asphalt Ridge area from a few miles southeast of the Green River to near Vernal.

The Duchesne River was divided (Kay, 1934, p. 359) from base upward into three members: Randlett, Halfway, and Lapoint, which represent localities in the western part of Uintah County. The Randlett is best exposed north and east of the town of Randlett and consists of approximately 478 feet of red, brown, bluish gray and variegated clay shales and interbedded brown to gray sandstones, overlain by a bed of conglomerate 10 feet thick. The Halfway member, exposed along the Halfway Hollow drainage west of Vernal, comprises 557 feet of interbedded shales, sandstones which for the most part are coarser than those of the Randlett, and conglomerates. The basal bed of the Lapoint member, which is exposed north of the Vernal-Lapoint highway, consists of 22 feet of bluish white clay shale that is quite persistent in the area. Clay-shales, sandy shales, conglomeratic sandstones, and conglomerates comprise the 336 feet of the Lapoint member, being well exposed east and north of the town of Lapoint along the head of the Halfway Hollow.

Fossils--Known fossil vertebrates are sparse in the Duchesne River, but represent 6 orders, 22 families, and 26 genera (Kay, 1957, p. 112). These forms include turtle, crocodile, insectivore, carnivore, herbivore (perissodactyl, and artiodactyl), and rodent types. Almost every specimen represents a different species of a different genus or family. A few of the genera are found in both the Uinta and Duchesne River formations, but the assemblages are mostly quite distinct (Kay, 1957). On a basis of fossil vertebrates, the Duchesne River formation is considered by most palentologists to be of lower Oligocene age.

Minerals--At Asphalt Ridge, southwest of Vernal, bituminous material has saturated parts of the lower Duchesne River and in it a few gilsonite veins have also been found at Gusher and at Ft. Duchesne in western Uintah County (see mineral section of this paper).

Miocene (?) Series

Bishop Conglomerate — Browns Park Formation

The higher slopes of the Uinta Range are covered in many places by an unconformable capping of poorly-sorted, often well-cemented conglomerate consisting chiefly of red Uinta Mountain quartzite and sandstone derived from the core of the Range, with minor amounts of Paleozoic limestone, chert, and other materials. The constituents vary in size from small pebbles to boulders several feet across, cemented with a calcareous sandy matrix. Calcareous gray, white, or pink sandstone, tuffaceous sandstone, tuff, and bentonitic beds, tough to soft and friable, are often interbedded with the conglomerates.

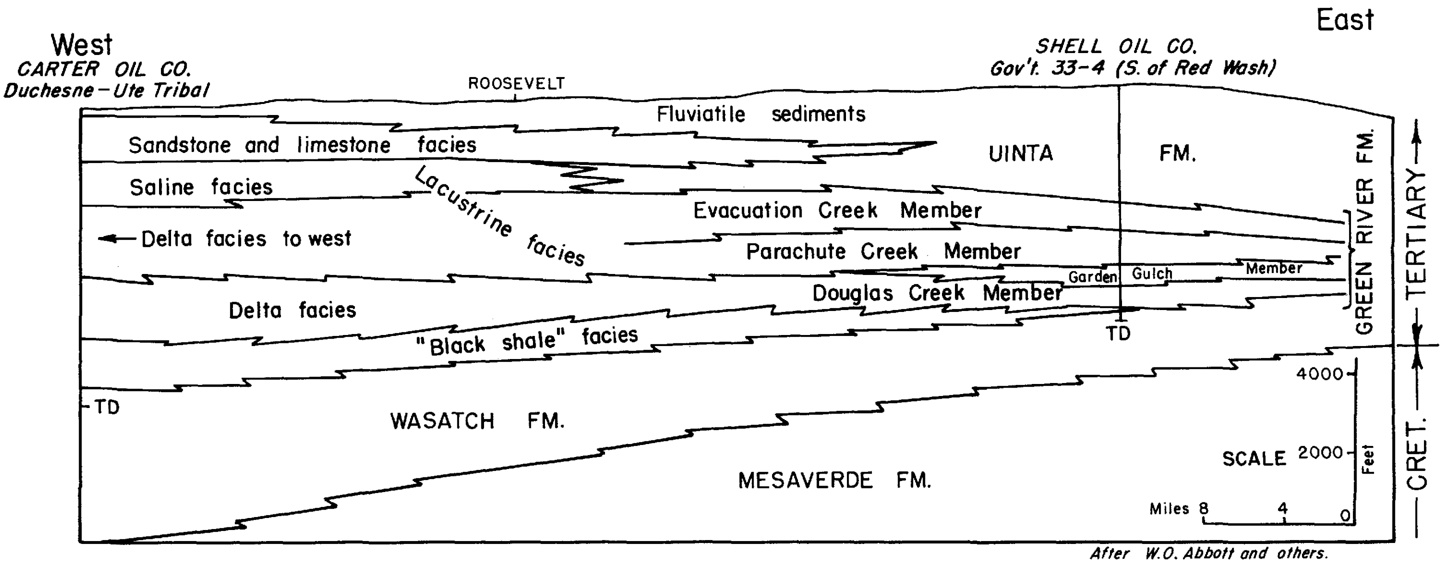

Figure 31. Diagrammatic cross-section showing distribution and intertonguing relationships of Eocene beds.

Figure 32. Browns Park formation, conglomerate. Interbedded with tuffaceous sandstones exposed at edge of plateau rim, head of Diamond Mountain road.

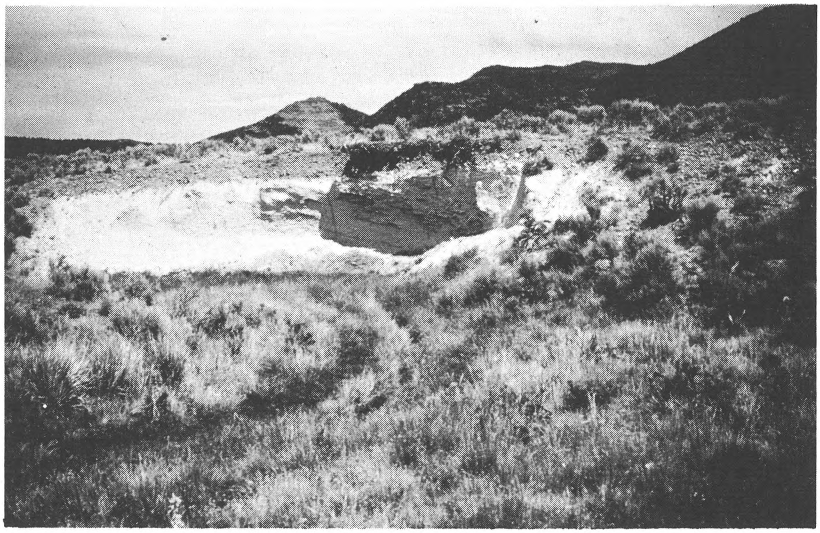

Figure 33. Browns Park white tuffaceous sandstone. Crouse Canyon, north of Pot Creek.

The formation was named by Powell (1876, p. 44) "Bishop Mountain Conglomerate" for its occurrence on Bishop Mountain (now Pine Mountain) of southwestern Wyoming, where he observed that it unconformably overlies Tertiary and older formations. In his stratigraphic table (p. 40) Powell placed the Bishop above the Browns Park, no doubt as a result of the occurrence of conglomerates (assumed to be Bishop Mountain in age) capping some of the Browns Park terraces. Sears (1924, p. 289-298, 1924, p. 1296) believed the Bishop to be the basal conglomerate of the Browns Park formation and gave ample reasons for correlating the two formations. He also postulated that the present difference in elevation in some areas between the Bishop and Browns Park, a feature which apparently led to the dual terminology, is due to crustal movement following their deposition, disrupting the once continuous layer, and elevating part of the formation so that upon erosion the conglomerate stood higher than the overlying beds. Later, Sears accepted Bradley's view (1936, p. 182) that the Bishop was possibly laid down on an older erosion surface (Gilbert Peak) that was the Browns Park (Bear Mt.), instead of the two surfaces (and the two formations) being equivalent but separated vertically by crustal movement. The latter view is again being considered as possibly the correct interpretation. In 1936, Bradley (map, plate 34) considered the Bishop Conglomerate to be Miocene (?) and the Browns Park to be late Miocene or early Pliocene in age.

While the conglomerate often mantles the upper slopes and valleys along the south side of the Uinta Range, it probably represents lenses within and at the base of the Browns Park formation, and it is this relationship that has recently led the writers and other geologists (Hansen, et al., 1958, p. B258) to conclude that the beds designated "Bishop Conglomerate" are, in reality, Browns Park (see section on geomorphology). The writers have noted the large quantity of tuffaceous material in clastic sediments that mantle the slopes and valleys of the Diamond Mountain-Pot Creek area, and the similarity in lithology of this material and the sediments in the Browns Park Valley on the east side of the Range, type locality for the formation. In 1958, the writers began mapping outcrops of tuffs and tuffaceous sandstone as Tbp (?). Subsequently, it was noted that much of the conglomerate in adjoining areas, which had been mapped as Bishop, was found to overlie these tuffaceous beds. It was realized that if the latter were Browns Park in age, the overlying gravels could not belong to the Bishop Conglomerate, which, in more recent years, has been regarded as of pre-Browns Park age.

Further study by Hansen, et al., as well as by the writers, disclosed the interbedded character of the gravels and tuffaceous beds along the south slopes of the Uinta Range, revealing the close resemblance to the typical Browns Park. While no fossils have as yet been found in these sediments, it seems pertinent on a basis of lithology to correlate them with those of the type Browns Park. Kinney (1955, p. 114-115) traced similar beds (also mapped as Bishop) along the south side of the Range in eastern Duchesne and western Uintah counties, noting their outcrops at Jefferson Park, Pole Mountain, Mosby Mountain, Lake Mountain, Dry Fork Mountain, Little Mountain, and the higher plateau area between Ashley Creek and Diamond Mountain. He observed that the conglomerate beds are less prominent in the latter area than farther west, passing into thinner lenses with medium-grained, partly tuffaceous light-colored sandstones predominating. The formation thins eastward from about 800 feet at Jefferson Park in Duchesne County to approximately 300 feet on Diamond Mountain in eastern Uintah County. Similar beds continue to the east along the plateaus and valleys of Blue Mountain in Dinosaur National Monument area. They were also observed by the writers on Iron Springs Bench and along the Mantle road in the Pats Hole area, just east of the Utah-Colorado line, where they appear to have been faulted down by the Uinta Mountain graben.

Medium to coarse light-colored sandstones are frequently tuffaceous, friable, and chalky, and generally conglomeratic. Thinly bedded rhyolitic tuffs are pink, white or gray in color. Some of these tuff beds on Diamond Mountain and elsewhere are "peppered" with flakes of biotite mica. Other types contain magnetite grains, small crystals of augite, and hornblende.

Browns Park of the type locality is composed of friable chalk-white gray, pink, or buff, quartz-sandstones, commonly tuffaceous and occasionally cherty. It appears to be chiefly stream laid. Minor amounts may be eolian, lake, and spring deposited. Conglomerate lenses, thin-bedded glass tuffs, finely crystalline tuffs, bentonite, chert beds, and concretions are locally prominent.

QUATERNARY SYSTEM

Denudation that greatly beveled the Uinta Mountains during the Tertiary continued into the Quaternary. Movements along faults have resulted in successive periods of elevation or subsidence with consequent renewal of stream activity. Elevation of portions of the Range is still taking place. Many current relief features began to develop during late Tertiary time. Although much modified, their early stages are still discernable. Arid climates and flash floods produced fanglomerates and mud flows carried 5-foot Precambrian quartzite boulders more than 10 miles from the original source.

Glacial debris, as well as late Tertiary and early Quaternary stream deposits, much of it derived from the Browns Park (Miocene?) conglomerate (Bishop), were redistributed farther down the slopes forming the terrace gravels of successively younger stages of erosion. Along the foothills, 5- to 10-foot-thick caliche-cemented boulder-alluvium (mostly from Red Uinta Mountain quartzite, but in places containing much white to blue Red Creek older Precambrian from the northeast corner of Utah, or minor amounts of Carboniferous cherty limestone and sandstone, Permian limestone and chert, Triassic sandstones, etc.) now caps well-developed pedimented slopes, mesas, and terraces some distance from the main stream. Two or more terrace levels (the older nearly obliterated) in places can be seen in addition to the present flood plain. The older alluvium consists chiefly of sands that filled the intermittent channels possibly to a depth of 30 to 40 feet during late Pleistocene and Recent times.

In park areas along major streams where broad flood plains have been formed on less resistant formations, well-developed meanders indicate a high degree of maturity. Island Park and the large meanders on the Green River in Dinosaur National Monument are excellent examples. The Island Park area has mesa-like terraces and long gentle southward-dipping slopes, generally capped by gravel beds. Near the mouth of Split Mountain Canyon, the occurrence of a broad syncline in which the Mancos shale forms the center, has made possible the development of a fairly large flood plain over which the Green River now meanders. Older bench levels carved in Mancos shale may in part be comparable to the Tipperary (early Pleistocene) and Lyman (later Pleistocene) erosion surfaces on the north side of the Uinta Range (Bradley, 1936, p. 190-191). The older and higher of these terraces were named the Jensen surfaces (J_1 and J_2, 50-75 feet apart) for their excellent development between Ashley Creek and the community of Jensen, east of Vernal (Kinney, 1955, p. 129). They are 250 feet above the present stream level. The name "Vernal strath terrace" (Qtv_1 and Qtv_2 slightly lower) was given to a second surface, 150 to 180 feet below the Jensen. Lowest and youngest surface noted by Kinney is the "Thornburg strath terrace," which is 50 feet below the Vernal surface or 55 feet above the present low water level of Ashley Creek, and was named for Ft. Thornburg, an early army post located northwest of Vernal.

Buff or reddish dune sand derived chiefly from easily eroded Navajo is accumulating on the lower benches and slopes. Much of this wind transported material was deposited when the lower Vernal surface was being cut (Kinney, 1955, p. 130). Thus, Pleistocene and Recent deposits, usually very difficult to differentiate, consist chiefly of stream gravels, sands and clays, alluvial fans, glacial till in higher regions, talus slopes, rock slides, and sand dunes.

Figure 34. Terrace levels (Jensen, Vernal, and Thornburg) developed in Mancos shale near Ashley Creek, east of Vernal.

Figure 35. Late Terrace levels along Cliff Creek, east of Jensen, developed on channel fill alluvium.

Fossils--Fossils are rare, but on display at the Utah Field House of Natural History at Vernal are two bison skulls believed to be _Bison_ cf. _B. antiquus_, which is a species considered to have become extinct between 10,000 and 20,000 years ago. They were found in the alluvium along stream channels.

Glacial Till: Pleistocene glaciation of the higher portions of the Uinta Mountains occurred principally west of longitude 109° 40' (Ashley Canyon, northwest of Vernal). Most of the catchment basins were located at an elevation of 10,000 feet (Atwood, 1909, p. 67). Moraines and other glacial deposits accumulated and much secondary sculpturing took place in the higher canyon areas; but practically none in the lower part of the Uinta Range north and east of Vernal (see Geomorphology section). Three stages of glaciation have been tentatively established for the Uintas (Kinney, 1955, p. 131-134). The earliest stage is represented by moraines that lie on a remnant of the earliest (Jensen) erosion surface, located west of the Uinta River in eastern Duchesne County. Kinney tentatively correlates the main Vernal surface with the glacial outwash formed during the interglacial stage that followed maximum glaciation. The Thornburg level dates from near the close of the latest ice advance.

METAMORPHIC ROCKS

Grading upward into the sedimentary rocks is a great thickness of late Precambrian quartzites known as the Uinta Mountain group. These are little disturbed, except for the flank folding along the Uinta arch.

Beneath these, though not in Uintah County, is the Red Creek series, the source of much enigmatic material in the conglomerates within the Browns Park formation. It occurs in Daggett County, north of Browns Park and westward from the Colorado State line nearly to the Green River. Described by Powell (1876, p. 42, 62, 72, 137) as metaquartzites, amphibolites, garnet-staurolite-quartz-mica schists, and descriptions by Ferdinand Zirkel (1876, p. 28) were incorporated in the publications of the U.S. Geological Survey of the Fortieth Parallel, and later discussions may be found by Untermann (1954, p. 22), Hansen (1957, Map GQ 101), Ritzma (1959, p. 17), and Blackwelder, Granger, and Cohenour (1963, p. 41).

Figure 36. Glacial lake, Lake Shore area, southwest side of Leidy Peak. Looking toward north slope of Marsh Peak area.

Figure 37. Morainal debris, west shoulder of Leidy Peak. Quartzite from the Uinta Mountain Group (Precambrian) plucked loose by movement of glacial ice.

IGNEOUS ROCKS

Though pegmatites occur in the Red Creek series of Daggett County to the north, and abundant lavas flank the west end of the Uinta Range, the only igneous rock in Uintah County is a 60-foot thick vertical gabbroid dike along the crest of the Uinta Mountains. It strikes N 65° W from the southwest side of Leidy Peak to the head of the Uinta River. No petrographic study of this dike has yet been made.

STRUCTURAL GEOLOGY

Folds

The Uinta anticlinorium, which forms the Uinta Mountains, and its complimentary Uinta Basin synclinorium on the south are asymmetrical. Their steeper flanks are to the north. The anticlinorium, narrowing at both extremities, merges westerly into the Wasatch Range and easterly into the Axial Basin anticline in Colorado. It pitches downward at both ends and near the Colorado state line, where its convexity is greatest, the axis turns southeastward and there is a concentration of minor folds along the south slopes, suggesting that the compressive stresses were probably intensified from the south.

Split Mountain anticline (flanked on the north by the Island Park syncline) and Section Ridge of Blue Mountain (separated from Split Mountain by Jensen or Daniels Draw syncline, Untermann, 1954, p. 73-76) are prominent minor folds. Section Ridge has its steep scarp on the south facing U.S. Highway 40. Split Mountain with its steep scarp on the north pitches westerly at moderate angles. These subsidiary anticlines, duplicating the general structure of the Uinta Range, exhibit relatively flat-lying formations on their crests and very sharp flexings on their flanks, in many places steepened by drag-folding along fault zones. In the western half of the county are the Little Mountain, Coal Mine, and Mosby Mountain synclines, and the Neal dome, Brush Creek, Barker Spring, Davis, Ashley Creek, Dry Fork, and Whiterocks anticlinal noses (Kinney, 1955, p. 120-124).

Age of Deformation

Three periods of deformation, dated as pre-Mississippian, post-Moenkopian, and post-Cretaceous were recognized by Kinney (1955, p. 126-127) in the western part of Uintah County. The first of these involved the faulting of Precambrian rocks prior to Mississippian time. The second, following deposition of the

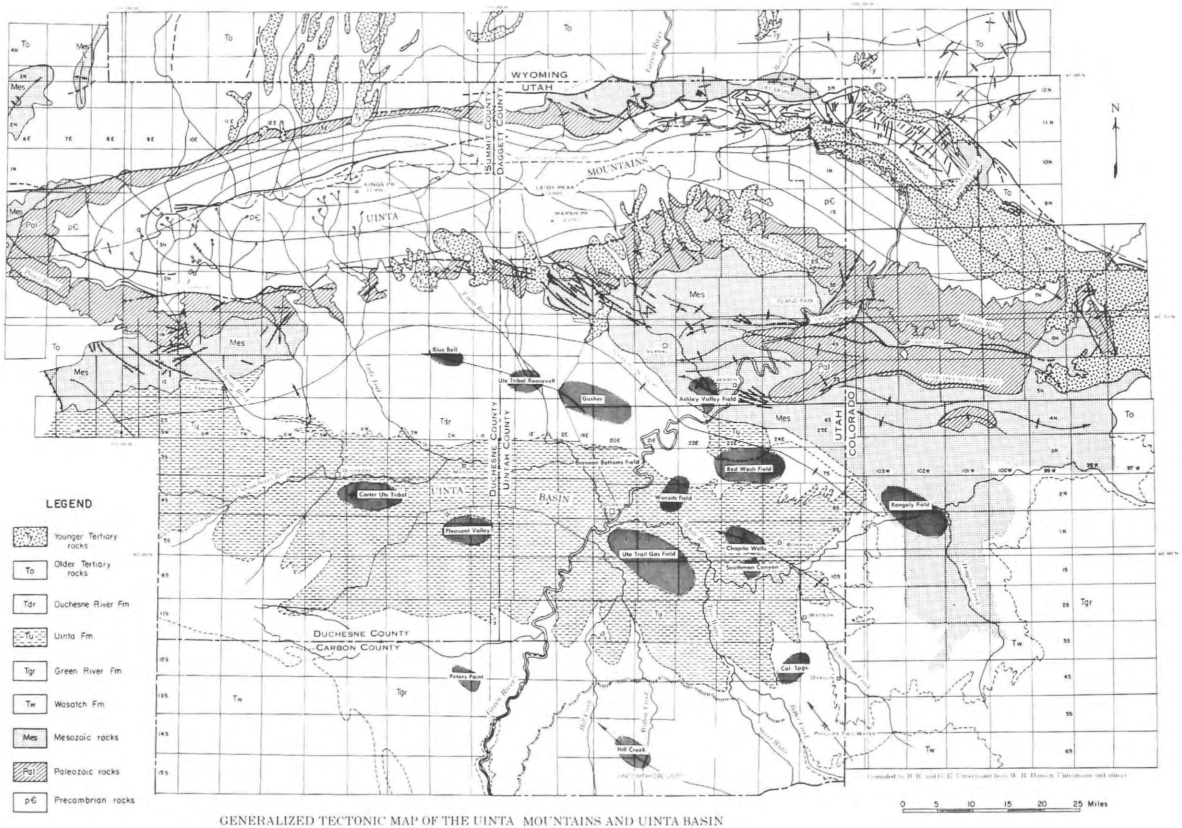

Figure 38. Structural Geology.

Moenkopi formation, gently tilted the area to the west before the Shinarump conglomerate was laid down. The third and most important deformation followed deposition of youngest Cretaceous beds, the Mesaverde. First indications of uplifting and folding in this period are believed to be represented by the Upper Cretaceous coarse clastics which outcrop between the Current Creek and Duchesne River formations (Walton, 1944, p. 126-127). The Current Creek lies on an eroded surface of the Mesaverde group (Niobrara) without discordance and is unconformably overlapped by Eocene (Uinta). It thins toward the mountain slopes. Forrester (1937, p. 655, 659) estimates that the initial uplift must have elevated the range 10,000 to 12,000 feet to furnish the amount of material eroded during the early Tertiary that followed.

The major uplift of the range and maximum warping of the adjacent synclinal basins may have occurred near the close of the Eocene, at which time the Bridger and Green River formations were faulted into contact with Paleozoic sediments along portions of the North Flank and Crest (Uinta) faults. Some of these Eocene faults are covered by Browns Park (Miocene?) sediments without disturbance. Warping of the Uinta formation as much as 36° has occurred in the Whiterocks-Deep Creek area. Forrester (1937, p. 657, 660) believes the elevation to have amounted to some 25,000 feet in the center of the range, and that this uplift was caused primarily by the intrusion of a batholithic core.

Downwarping of the Basin area and elevation of the range recurred sufficiently late to have involved the lower Oligocene Duchesne River formation. Greatest warping of the Uinta Basin appears to have been adjacent to the south flank of the mountain and to have caused a northward migration of the synclinal axis 5 to 10 miles beyond the present topographic low of the basin, which coincides approximately with the Duchesne and Strawberry river drainage system.

Finally, continental uplift in Pliocene time amounted to 8,000 to 10,000 feet (Forrester, 1937, p. 663), the amount of early Laramide and subsequent uplift totaling some 45,000 feet in the center of the range. This uplift, minus erosion, has left the range with an average elevation of 8,000 to 9,000 feet, with a maximum in Kings Peak of 13,498 feet. Downfaulting, possibly in late Miocene-early Pliocene time, occurred on the east end of the arch after deposition of the Browns Park (Miocene?) formation, and tilted the Dinosaur National Mounument area westward.

FAULTS

Major faults, uniformly high angle, parallel the Uinta Range. Their maximum displacement occurs outside the county and varies from 4,000 feet along the Yampa Fault in the eastern part of the Uinta Mountain Graben (Untermann, 1954, p. 152) to 40,000 feet along the reverse Uinta or Crest Fault (Ritzma, 1959, p. 73). The latter, in spite of its steep southward dip (75°) is sinuous in places. In the eastern part of the county the Yampa and Miners Draw-Wolf Creek faults bound Blue Mountain on the north and south, respectively, greatly rupture the eastern end of the Uinta arch and produce the Uinta Mountain Graben of the Browns Park and Yampa Canyon areas.

South Flank Fault Zone

In the area between Dry Gulch in Duchesne County and Ashley Creek in the western half of Uintah County occur a series of nearly vertical pre-Mississippian echelon faults (Kinney, 1955, p. 124) with downthrow on the south. They form what appeared to Forrester (1937, p. 644) to be a more or less continuous fracture that bounds the core of the Uinta Range on the south and to which he gave the name South Flank Fault. These trend northwest-southeast to west-east, approximate the strike of the Deep Creek fault zone to the south with which they may merge in the area between Whiterocks River and Dry Fork Canyon, and may represent a westward extension of the Yampa and Miners Draw-Wolf Creek fault zones.

Deep Creek Fault Zone

The Deep Creek fault zone trends southeastward from Mosby Mountain through Little Mountain, extends beneath the alluvium of Ashley Valley, and may connect with faults that occur along the south flank of Section Ridge. Displacements range from a few feet to several hundred feet, but total vertical displacement is not believed to be great (Kinney, 1955, p. 125), inasmuch as downthrows on the north sides of some faults more or less balance those on the south sides of others. Rejuvenation along old lines may have continued until late Cretaceous (Kinney, 1955).

Island Park Fault

In the eastern part of Uintah County is the Island Park Fault zone (Untermann, 1954, p. 109-110). Westward, it splits and is terminated in Mancos shale in the "summit" area of the Island Park road, on the north side of Split Mountain, a few miles east of Brush Creek. To the southeast it intersects Jurassic and Triassic formations, then turns east along the north side of Split Mountain anticline where its

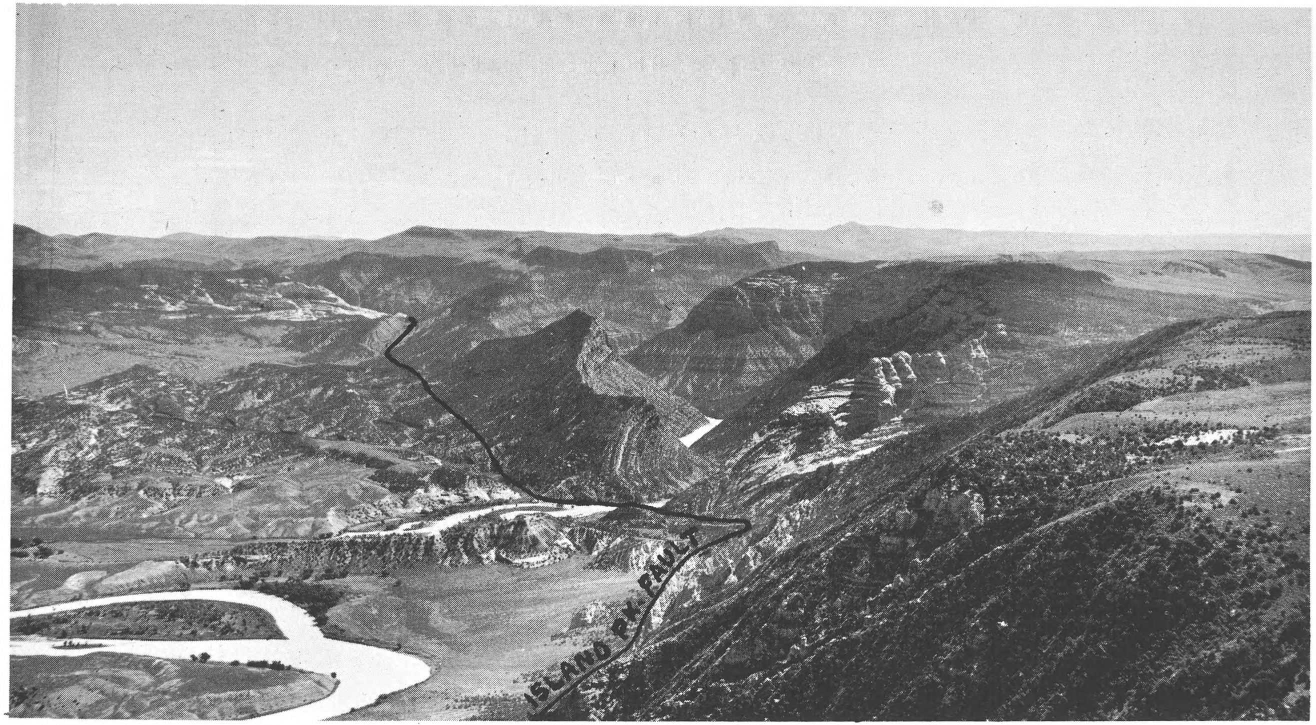

Figure 39. Island Park fault. Whirlpool Canyon, center, between Harpers Plateau, right, and Little Split Mountain (left).

trace is confined to the Moenkopi, which, in places, appears to be much thinned. Near Green River, at Little Rainbow Park, the fault again offsets Triassic and Jurassic beds and is joined by a fault from the McKee Spring area where Mancos shale, Frontier, Mowry, and Dakota formations are affected. The McKee Spring Fault is roughly parallel to the echelon branches that enter the Mancos shale at the west end of the Island Park fault in the Summit area. The writers believe that these faults merge at or just east of the Green River to form the main Island Park fault. Here the formations are obscured for some distance by slides, but the fault continues along the foot of Blue Mountain, north slope, around the east end of Island Park, through Jones Hole and beyond to the Pot Creek country. Near the mouth of Whirlpool Canyon, at the eastern end of the Island Park syncline, where Navajo sandstone (Jurassic) rests against Morgan (Pennsylvanian), the fault reaches its maximum vertical displacement of approximately 1,500 feet. Within a 2- or 3-mile section along the strike of this fault, part of the following beds have been cut out: Weber, Park City, Moenkopi, Shinarump, and Chinle. The fault zone has a maximum width of about 400 feet and small silver blocks of the above formations are left here and there in the disturbed zone. Some of these wedges are capped by 10 to 15 feet of well-cemented conglomerate containing 2-foot boulders derived from the older formations of the Uinta Range. In some places the conglomerate lies horizontally on the prefaulting eroded surfaces of these upturned beds and may represent some of the Browns Park Miocene (?).

In following the Island Park fault along the foot of Little Split Mountain, near the mouth of Whirlpool Canyon, to Sage Creek, Park City and Weber beds are successively omitted. At Sage Creek, Morgan (Lower Pennsylvanian, Round Valley) is in contact with Moenkopi (Lower Triassic). To the north the fault passes through Jones Hole affecting Pennsylvanian, Mississippian, and Cambrian strata and repeating Pennsylvanian and Mississippian beds along bifurcating branches which cross into Pot Creek.

Red Rock Fault

In the Island Park area on the north slope of Blue Mountain (Ruple Ridge), the Red Rock fault, which traverses Harpers Plateau from the east, joins the Island Park fault. East of Harpers Plateau, it offsets the Mitten Park fault which bounds the east side of Harpers Plateau and joins the main Yampa fault east of Pearl Park bench in the Pats Hole area, just beyond the Uintah County line in western Colorado. Harpers Plateau is a large horst block between the Island Park fault on the west and the Mitten Park fault on the east (Untermann, 1954, p. 149-150).

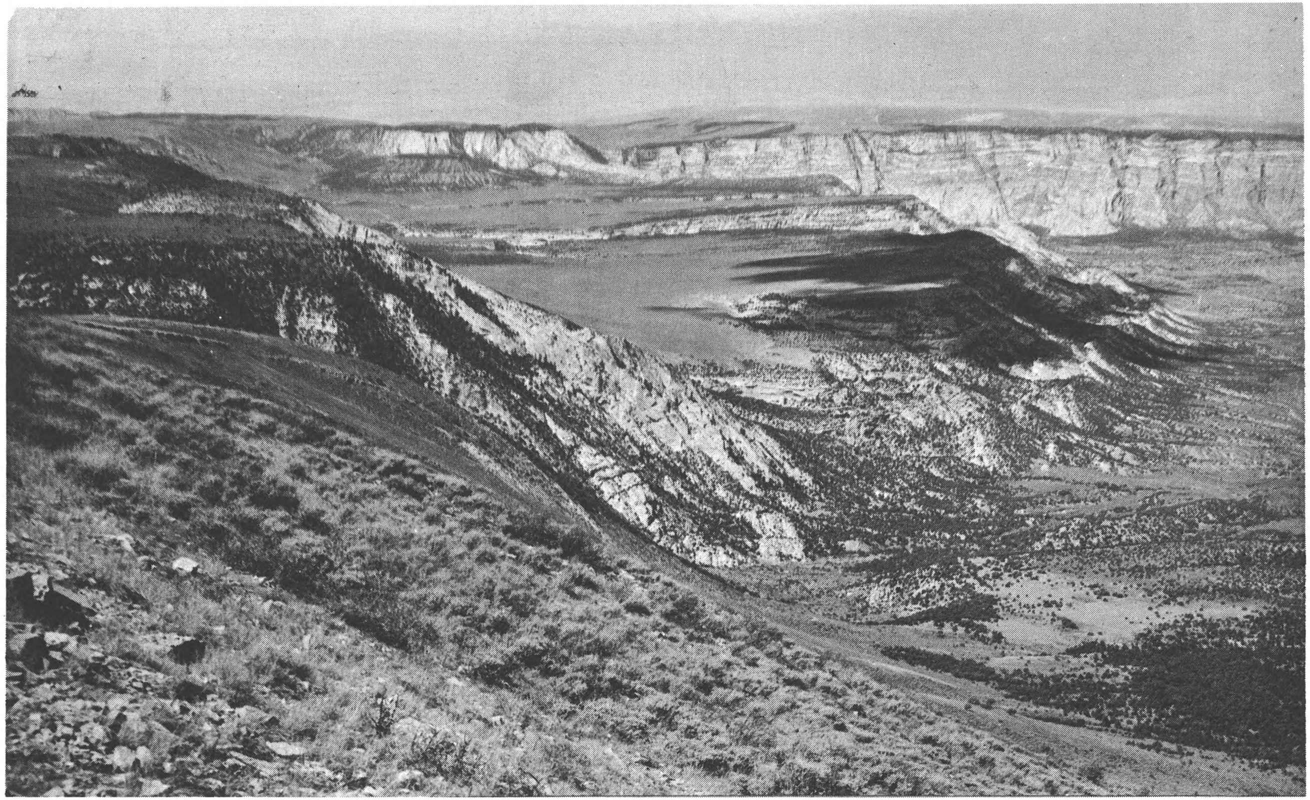

Figure 40. Looking west from Round Top toward Harpers Plateau (Blue Mountain). Red Rock fault on right, Mitten Park fault upper right corner. Yampa fault on left, diagonally across photo.

Yampa Fault

In the upper end of the east-west section of Split Mountain Canyon, the Split Mountain gorge continues along the trend of Yampa fault. Although the Yampa fault appears to die out westward as it approaches the Green River, it is possible that fracturing, with little displacement along the axis of the Split Mountain anticline, may have predetermined erosional position of Split Mountain gorge. Eastward the Yampa Fault follows Moonshine Draw and over the top of Blue Mountain where it enters the outer Yampa Canyon.

Miners Draw — Wolf Creek Fault

Along the south slope of Section Ridge anticlinal nose of Blue Mountain, the Miners Draw fault appears to pass into numerous branches in the Cliff Creek (Cocklebur)-Burdette Wash area. Downthrow on some is south, on others north. Chinle and Navajo are offset. Across Cliff Creek at the west end of Section Ridge, permanent-flowing warm sulphur springs are in line with these fractures which Kinney (1955, p. 125) believes may pass beneath the alluvium of Ashley Vallen and connect with faults in the Little Mountain-Whiterocks Canyon area. Swampy areas along the way seem to indicate seepage from fractures beneath the surface mantle. Along the Section Ridge front, north of Highway No. 40, the Miners Draw fault is difficult to follow. But eastward, at the head of Miners Draw, where the Blue Mountain road ascends the slope to the rim, Morrison has been let down against Navajo and Triassic beds. Near the Utah-Colorado line, nearly vertical Weber sandstone is in contact with Navajo sandstone. Here displacement may be more than 1,000 feet. The Miners Draw-Wolf Creek fault continues eastward across Blue Mountain and into the Wolf Creek area near Elk Springs, Colorado.

Trail Creek Fault Zone

This zone of faulting begins near the eastern edge of Uintah County, north of Highway No. 40, and in the southern edge of the downthrow of the Miners Draw fault. It forms several larger northeast-trending faults and smaller branching cross faults that are developed chiefly in beds of Jurassic age.

Faults Confined to Tertiary Beds

East-west to northwest-southeast faults of the Uinta Basin occur chiefly in the Green River and Uinta formations of Eocene age. They generally parallel gilsonite veins and joints of the basin, and probably were formed by the same tensional stresses.

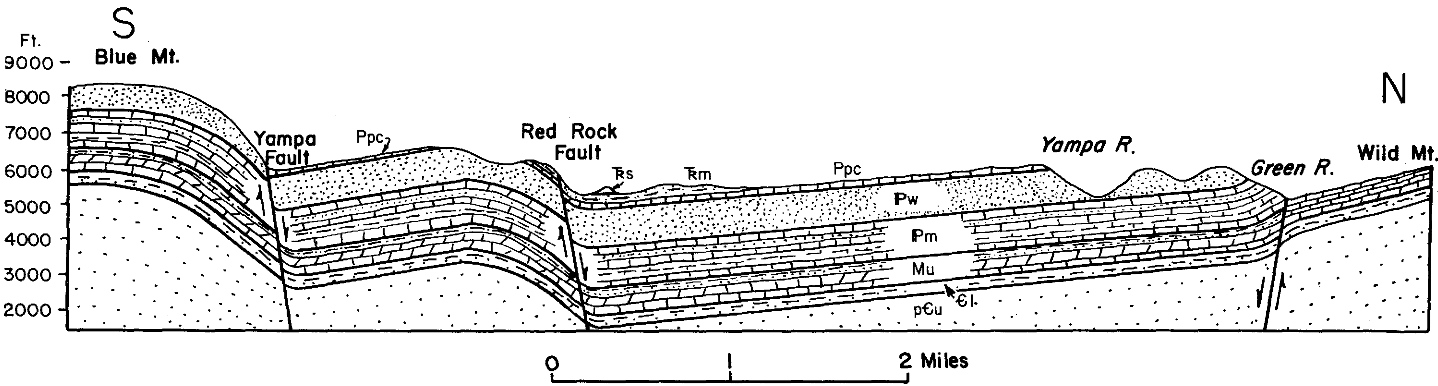

Figure 41. North-south cross section in Colorado near the Utah-Colorado line, facing westerly showing step-faulting with repetition of beds.

AGE OF FAULTING

Faulting probably occurred at many periods during the geologic history of the Uinta Mountain and Basin region, and each uplift of the Range undoubtedly rejuvenated old faults and initiated new ones. Pre-Mississippian faults, possibly correlated with the sharp diastrophism in the Stansbury area (in what is now the Great Basin) during Devonian time (Stokes and Arnold, 1958) are noted along the south flank west of the Uintah County line. Much faulting occurred at the close of the Tertiary, when beds of late Tertiary age (Browns Park, Miocene?) were involved.

JOINTS

Three systems of joints usually occur in the area: east-west and north-south systems, and a third set striking northwest-southeast at approximately 45 degrees to the others. The east-west system strikes more or less parallel to the folds, but may be inclined from the vertical 50 to 60 degrees toward the axis. The other two systems are almost vertical. Tensional stress is frequently indicated by small offsets along the joints. Often erosion has been greatly accelerated by the presence of these fractures. Parallel vertical-walled gorges have been incised at right angles to the south slopes of the Uinta Mountains and are particularly well developed east of the Green River near the mouth of Split Mountain Gorge.

A striking example of well-developed jointing may be observed in the "fence post" slabs formed in thin limestone beds of the Green River formation. Gilsonite and other hydrocarbon veins and some faults are usually closely associated with these joints.

GEOMORPHOLOGY

From the alpine heights of the Uinta Range to the semi-arid badlands in the basin, elevations vary from more than 12,000 to approximately 4,800 feet above sea level.

Green River, the master stream, lying in Colorado just beyond the Utah line, crosses the eastern part of the Range at right angles, then swings west into Uintah County which it traverses diagonally from northeast to southwest. Its two main tributaries, the Duchesne River, which enters from the west, and the White River, which enters from the east, follow the topographic low of the Uinta Basin and join the Green approximately in the center of the county.

Early Laramide uplift and folding of the Uinta Range was followed by erosion which more or less kept pace with continued elevation during Tertiary time. Abrasion of the rising mountain and transfer of sediments to the Basin gradually built up a thick series of overlapping Tertiary sediments which unconformably overlie the truncated edges of the older formations. Resultant mature mountain terrain can still be seen in the smooth rounded hilltops and benches along the higher slopes of the Uintas. Soft Mesozoic strata were removed (with possibly some incising of older formations) and redeposited as the earliest fresh-water Tertiary beds (Bradley, 1938). Downwarping of the basin continued and ponds and lakes received the Paleocene and Wasatch (Lower Eocene) sediments, the latter containing both Triassic and Carboniferous derivatives.

Small lakes finally coalesced into large fresh-water bodies. Lake Uinta flanked the south side and Lake Gosiute (Bradley, 1929, p. 88–90; Jones, 1957, p. 31) flanked the north side of the range and occupied the present Bridger, Green River and Washakie basins. These lakes were apparently connected by a small arm around the east end of the Uintas as evidenced by remnants of the Green River formation in southern Sweetwater County, Wyoming, the Sand Wash and Coyote basins of Moffat County, and the Piceance Basin of Rio Blanco County, Colorado (Owen, 1955, plate VII; Jones, 1957, p. 30, 32). These remnants line up north and south of the Yampa River between Cross Mountain and Maybell, Colorado, and buried remnants line up north and south of the Yampa River between Cross Mountain and Maybell, Colorado, and buried remnants may be covered by the Browns Park formation. In these vast lakes were deposited great quantities of sediments which contain the oil-shales and many unusual minerals (Milton, 1957, p. 136-143). Shrinking of the lakes accompanied by deposition of fluviatile sediment around their margins during late Bridgerian time (Jones, 1957, p. 32) is believed to have caused their separation into isolated depositional basins, Uinta Lake continuing longer than Gosiute Lake, and forming the lake facies of the Uinta formation in the Uinta Basin area. More than 9,000 feet of fresh-water Tertiary beds accumulated in this subsiding trough (Jones, 1937, p. 33, 34).

As the region became more stable, streams gradually filled the lake basins forming extensive flood plains as revealed in the sandstones and conglomerates of the later Eocene and Oligocene formations. They formed the sediments of the Uinta formation which, in the western part of the Uinta Basin, were derived chiefly from mountainous areas to the east (Stagner, 1945, p. 284-285). Extensive elevation and faulting are believed to have occurred during Uinta time near the close of the Eocene (Late Laramide) as evidenced by the Duchesne River beds which appear to have originated from the exposed Precambrian quartzites of the Uinta Range.

The topographic axis of the Uinta Basin coincides with the east-west drainages of the Strawberry and Duchesne rivers, west of Green River, and by the White River to the east. As downwarping of the basin progressed, estimated by Crowley (1957, p. 29) to have been 3,000-4,000 feet, the synclinal axis, which originally must have coincided with the topographic axis, migrated northward toward the south flank of the Range, so that its present position lies some 5 to 10 miles north of the topographic low of the Basin, thus increasing the asymmetrical attitude of the syncline. During this period, downwarping, aided by the rising Uncompahgre and San Rafael highlands, produced in the Uinta Basin numerous tension fractures into which gilsonite was injected.

Erosion Surface

Gilbert Peak-Bear Mountain: After deposition of the Duchesne River formation, elevation of the region in late Eocene (?) - early Oligocene was followed by late Oligocene or early Miocene erosion which formed the Gilbert Peak (Bradley, 1936, p. 181-182) and the Bear Mountain erosion surfaces. Although the latter is some 500 feet lower than the former, they are now generally believed, as formerly postulated by J. D. Sears (Bradley, 1936, p. 182), to be equivalent, and that remnants of the Gilbert Peak surface (Goslin, Mt. Home, O-wi-yu-kuts, Cold Spring and other mountains, near the northeast end of the Uinta Range, merge with the Bear Mountain surface, and that discordances in altitude between the two surfaces (Hansen, et al., 1959, p. B257) seem due to faulting and deformation that occurred before, during, and after the deposition of the Browns Park formation. This (Bear Mountain) period of erosion denuded and rounded off the crest of the range greatly reducing its relief and created the Bear Mountain surface on which the Browns Park sediments have been deposited. In the western half of Uintah County, this terrain is represented by the upper surface of Mosby, Lake, Dry Fork, and Little mountains. In the eastern half of the county, it is represented by Brush Creek, Diamond, Split, and Blue mountains.

Consequent streams flowing southward, southeastward, and northward from the crest of the Uintas have deeply incised the Precambrian quartzites, and have broadened parts of their valleys. In the Pot Creek area minor short box canyons, cutting through hard patches of Uinta Mountain quartzitic sandstone instead of taking what otherwise would have been an easier course around them, appear to have followed joint planes. These vertical joints in the Uinta Mountain formation probably account for the parallelism in the northern portions of such canyons as Ashley, Big and Little Brush Creeks, Lambson, Jackson, Warren, Sears, Crouse, and others along the south slopes

Figure 42. Lodore Canyon, Green River, showing Uinta Mountain Group, Precambian (PCU). ~~(PEU).~~

of the range (Untermann, 1954, p. 15-16). Resistant high ridges and lower isolated monadnocks of the Uinta Mountain quartzite separate these channels and rise above the valley fill.

In the northeastern part of Uintah County, two of the largest southeastward trending valleys are Summit and Diamond Gulch. Their eastern portions roughly parallel the Browns Park basin on the northeast side of the Uinta Range, and like the latter may have been somewhat affected by faulting, although faults are difficult to find.

Poorly-sorted clastics, believed to correlate with the Browns Park formation of the type locality, fill the above-mentioned valleys and partially cover the mountain slopes. This change from an actively degrading to an agrading environment has been postulated by Bradley (1936, p. 178) as due to increasing aridity. Recent investigation (Hansen, et al., 1959, p. B258) discloses the possibility that the change in such a cycle may have been caused by tectonic adjustments in the region instead of climatic change. Both conditions may have played a part.

Some faulting in the Browns Park valley and other parts of the region may have taken place prior to and during deposition of the Browns Park formation, but the major displacement has occurred subsequently, during the collapse of the eastern end of the Uinta Range. This collapse formed the Uinta Mountain Graben, downwarped the Browns Park sediments and accentuated their marginal dips.

During 1958 the writers mapped the Browns Park sediments in the Diamond Mountain-Pot Creek area and as discussed under "Bishop Conglomerate" became convinced that the Miocene (?) "Bishop" is a part of the "Browns Park." Further evidence was obtained in June 1959 when the area was revisited by Hansen, Kinney, Sears, and Good.

The subsidence of the eastern end of the Uinta Mountains between the Yampa Fault system on the south and the Uinta Fault system on the north which formed the Uinta Mountain Graben was postulated by Powell, and further expanded by Sears (1924, p. 291-298). During this subsidence, the Browns Park Valley, which had been formed along the crest of the range, and later filled with Browns Park sediments, was downdropped, isolating Cold Spring Mountain on the north from the rest of the range. Diversion of the Green River drainage from an easterly course farther north to a position southward through the Browns Park Valley and eastward around the east end of the Uintas, resulted in erosion and trenching of the Browns Park sediments in that area. Many of the prominent faults were formed at this time (Pliocene?), with some elevation and tilting toward the west beyond the eastern end of the range. Faulting in the region no doubt greatly influenced the direction and effectiveness of the

Figure 43. Split Mountain Canyon, Green River, looking southwest toward mouth of Canyon. Weber at top, Morgan forming most of canyon walls. Mississippian in floor of canyon at center.

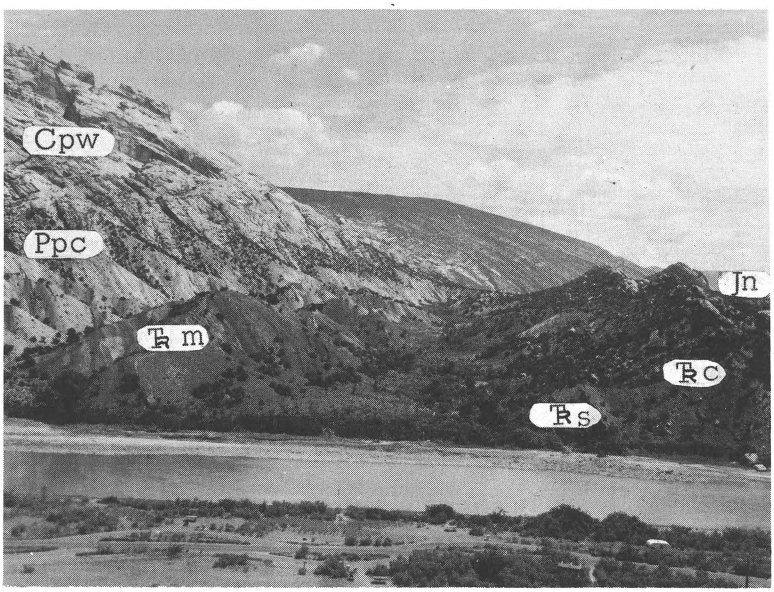

Figure 44. Mouth of Split Mountain Canyon at the "George" Weber (Pennsylvanian), Park City (Permian), Moenkopi, Shinarump, Chinle (Triassic).

drainage. New streams and some occupying old channels, began rapidly cutting through the soft Browns Park fill and working headward along their channels. Only short sections of these north-south canyons, such as Crouse, Sears, and others, are cut through the Browns Park and the underlying Uinta Mountain quartzite, at or near the present topographic axis of the range. Here outcrops of Browns Park on the south slope are separated from those on the north. The Crouse Canyon area well illustrates the former more or less complete blanketing of the crest by the Browns Park sediments. Present drainage* has not cut through the blanket except on the north slope in the canyon narrows where the stream is working its way headward.

The pattern of the Browns Park on the south slope of the range suggests that the valleys in which the formation was deposited began flowing south or southeast from a topographic axis that was farther north than the present crest which swings considerably southeastward in this area. Subsidence of Browns Park Valley accelerated northward flowing streams and reversed the drainage. Headward erosion became increasingly important, and the topographic axis migrated farther south as headward erosion progressed.

Occurrence of the Browns Park formation over most of the crest of the Uintas clearly shows that the present streams have been superimposed upon this cover. Later, it is believed, that Lodore Branch of Summit Valley, now Pot Creek, which had been filled with Browns Park sediments, began establishing its channel and finally cut deeply enough into the underlying Uinta Mountain quartzite to capture the Green River and divert it southward across the axis of the range. The Green River had been superimposed on the Browns Park formation in the Browns Park Valley. When the course of the Green River was changed from around the end of the Uintas to a position to the south across the axis of the Range, its channel would have had to be sufficiently high for such superposition to have taken place. But the valley began to subside even before the Browns Park was entirely deposited and continued after deposition when maximum displacement occurred. Whirlpool and Split Mountain canyons were probably established in much the same way. Lodore Branch must have established its course across the Wild Mountain-Douglas Mountain area and swung around between the south end of Wild Mountain and the north end of Harpers Corner, forming Whirlpool Canyon, then west across the Island Park synclinal area which was subsiding along the Island Park Fault. Headward

*Since this paper was written, a detailed discussion of much interest on the origin of the Yampa River drainage and its meander patterns in Dinosaur National Monument by Julian D. Sears, "Yampa Canyon in the Uinta Mountains, Colorado", U.S. Geological Survey Prof. Paper 374-I, 1962, has appeared.

erosion from the south through Split Mountain anticline, following the weakened zone at the west end of the Yampa Fault, captured this drainage thus forming Split Mountain Canyon.

With continued general uplift during Pleistocene time, entrenching of meanders of the Green and Yampa rivers was accelerated. Deep incising and headward erosion along Diamond Gorge, Big and Little Brush Creeks, Ashley, Dry Fork, Whiterocks, Uinta and other canyons progressed. But the latter four, in particular, owe their spectacular upper canyon development to the erosive action of mountain glaciation.

Jensen Surface: This erosion surface is represented by two or more gravel-capped terraces, named by Kinney (1955, p. 129) the Jensen surface. It is formed on Mancos shale between Ashley and Brush creeks. It is preserved on the east and south side of Little Mountain and on Diamond Mountain where it has probably truncated Frontier sandstone. The higher of these terraces is 50 to 75 feet above the lower, the lower one being 250-300 feet above the present stream level. The gravel capping this surface is 5-10 feet thick and contains well-rounded caliche-coated boulders derived from the older fanglomerates at higher elevations. The surface slopes away from the higher regions at 100-200 feet per mile. Kinney (1955) believes that these terraces were formed during a period of crustal stability and uniform climate, while the master stream of the area was at constant base level, and lateral planation and slope wash were dominant.

Vernal Surface: A younger terrace level, which Kinney (1955) named the "Vernal Strath Terrace," and which includes two slightly separated levels, was observed 150-180 feet below the Jensen surface. The lower member of the Vernal Strath Terrace may be seen along the west side of Ashley Creek, east of Vernal, and along the Green River northeast of Brush Creek. The main Vernal terrace is cut on Mancos shale and is covered with 5 to 10 feet of gravel, chiefly of red Uinta Mountain quartzite. Springs and seeps occur at the base of this cover on the west side of Ashley Creek. This surface is believed by Kinney (1955, p. 130) to have been formed by the lateral corrasion of Ashley Creek during the interglacial stage that followed maximum glaciation of the Uinta Mountains, and tentatively correlates it with the glacial outwash from that glaciation.

Thornburg Surface: Kinney (1955) also recognized a third surface which he terms the "Thornburg Strath Terrace," located 50 feet below and younger than the Vernal surface, and 55 feet above the present low-water level of Ashley Creek. The Thornburg surface is also cut in Mancos shale and capped with 5 to 10 feet of red quartzite boulder beds. It has been largely destroyed by the present flood plane of Ashley Creek, and is believed by Kinney to date from the close of the latest glaciation of the Uintas.

GLACIATION

Glaciation of the Uinta Mountains was chiefly confined to the higher parts of the Uinta Range in Duchesne and Wasatch counties where the longest glaciers, some of which attained a length of 27 miles (Atwood, 1909, p. 12, and plate IV) occurred in valleys that were fed by ice from the Kings Peak area. Outward from this central area, glaciation on both the north and south slopes of the range diminished rapidly. Little if any glaciation occurred east of Ashley Creek in Uintah County. Cirques and névé fields occur at the headwaters of Ashley Creek, in the vicinity of Leidy and Marsh Peaks.

West of Marsh Peak, in the headwaters of Dry Fork, glacial moraines are found 10 or more miles down the canyon at an elevation of 8,000 feet or more north of Lake Mountain. Whiterocks Canyon contains the longest of the glacial moraines in Uintah County, and its terminal moraine, altitude 7,200 feet like the Ashley Creek glaciation, is believed by Kinney (1955, p. 133) to correlate with the maximum glaciation in Uinta Canyon to the west.

Three stages of glaciation have been recognized by Kinney (1955, p. 131-134) in the Uinta Mountains. The earliest stage is represented by moraines that lie west of the Uinta River on a remnant of the Jensen erosion surface. During the stage of maximum advance, the massive moraines extended down to 7,000 feet in their descent in Uinta Canyon where all three stages are recognized. During the latest glaciation, the ice lacked more than a mile of advancing to the southern limit of the maximum advance, the massive moraines extended down to 7,000 feet in their descent in Uinta Canyon where all three stages are recognized. During the latest glaciation the ice lacked more than a mile of advancing to the southern limit of the maximum stage. In Whiterocks Canyon, the latest stage extended to an elevation of 7,300 feet. Most of the residual moraine is on the east side of the canyon. Ice correlating with this latest stage probably occupied the headwater areas of Ashley and Dry Fork canyons, but it is not possible to differentiate the late glacial deposits from those of the maximum stage (Kinney, 1955, p. 135).

Glacial lakes, both morainal and tarns, are abundant in the glaciated areas.

Kinney is of the opinion that the earliest glacial stage here mentioned may correlate with Bradley's Little Dry stage (1936, p. 194-195) on the north slope of the Uinta Mountains, and in the Wind River Range with the Buffalo stage which, in turn, has been tentatively correlated with the standard Kansan stage. The maximum glaciation of the Uintas may correspond to Bradley's Black Fork, and the latest to his Smith Fork (Wisconsin) stage.

Age Relations Between Stream and Glacial Erosion

After formation of the Bear Mountain surface, great quantities of Brown's Park (Miocene ?) coarse clastic debris were spread out far down the slopes of the Range and out across extensive pediments, covering Blue, Split, Diamond, Brush Creek, Little, Dry Fork, Mosby, and Lake mountains, and other areas, at elevations possibly as low as 6,500 to 7,000 feet. There must have been fairly steep slopes from the crest of the range to the lower pediments, or exceptional mud flows, for 5-foot Uinta Mountain Quartzite boulders to have been carried such distances. Deep canyons dividing gravel-capped areas show that the erosion which formed these canyons post-dated the deposition of the Browns Park clastics.

The following chronological order seems to be indicated: (1) Formation of the Bear Mountain erosion surface (Late Oligocene or early Miocene), extending some distance south of the crest of the Uinta Range; (2) Deposition of the interbedded fanglomerate, tuffaceous sandstone and tuff forming the southern extension of the Browns Park formation (Miocene ?); (3) Faulting which formed the Uinta Mountain Graben on the eastern end of the Uintas greatly affecting the Browns Park formation in many areas; (4) Development (late Pliocene or early Pleistocene) of the deep canyons of the Green River drainage and other streams isolating the boulder-capped pediments; (5) Reworking of the Browns Park mantle has furnished material that caps successively lower and lower terraces which correspond to more recent erosion surfaces, Jensen, Vernal, and Thornburg, etc.; (6) the morainal deposits of the earliest glaciation (Kansan) rests on remnants of the Jensen erosion surface. The third and latest glacial ice advance probably correlates with the Wisconsin of the standard classification.

ECONOMIC GEOLOGY*

General Statement

Economic minerals in Uintah County are confined mainly to the non-metallics. While metallic ores are of little importance, hydrocarbons occur in vast quantities, as do phosphate rocks.

Hydrocarbons

The hydrocarbons of the Uinta Basin occur primarily as fissure veins closely associated with oil-shales; as oil shales; and as saturated sands. Hunt (et al., 1957, p. 1690) is of the opinion that hydrocarbon varieties were produced, not by evolutionary changes as in coal, but by original differences in mineral and fossil content and by differences in the depositional environment of Eocene Lake Uinta. and that the increasing salinity of the lake waters during Green River time was the chief factor that controlled composition of the hydrocarbons. Source beds and their resultant hydrocarbon varieties seem to have closely similar compositions. Gilsonite seems to have been derived chiefly from the kerogen shales of the Green River formation. Other hydrocarbons seem likewise to have had their source in the kerogen of their enclosing beds. In each case the kerogen was derived from the abundant and varied flora and fauna which inhabited Lake Uinta, when the respective lake sediments were laid down. Also the rich organic matter of Lake Uinta gave rise to the oil and gas deposits of the Green River and other Tertiary formations of this area. Hydrocarbons resulting from this source, in addition to the oil shales and bituminous sandstones, are gilsonite, ozocerite, elaterite, wurtzilite, and others. Gilsonite has been the major hydrocarbon of economic importance in Uintah County.

Oil and Gas

Beginning with the first commercial well in Utah, 300 barrels per day in 1948, Ashley Valley Field oil production in Uintah County has risen to an annual output of 5,739,672 barrels, and gas to 22,351,935 MCF for the year 1962. The major portion of the oil has come from the Red Wash, Walker Hollow, Ashley Valley, and Wonsits oil fields. Red Wash oil field and the Ute Trail and Chapita gas fields have been the three highest producers of gas.

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*Only a brief summary of this subject is given here in view of the recently issued detailed companion volume THE MINERAL RESOURCES OF UINTAH COUNTY, Utah Geological Survey Bulletin 71 (1961) by Robert G. Pruitt. See also Bulletin 54, OIL AND GAS POSSIBILITIES OF UTAH, RE-EVALUATED (1963) for a discussion of hydrocarbons.

In the Red Wash-Walker Hollow area, production began in 1951 and from stratigraphic traps developed in a lenticular sandstone network in basal Green River, Eocene (Douglas Creek member), on a fairly large northwest to westerly pitching anticlinal nose. Well depth varies from 5,000 to 5,500 plus feet. The oil has a pour point of 85 degrees and a gravity of 29 to 30 degrees. Wax content is high. The field is located approximately 35 miles southeast of Vernal.

Ashley Valley Field production comes from the "top" of the Weber sandstone (Pennsylvanian). Well depth is 4,100 feet plus. Gravity is 32 degrees. The field represents a closed and faulted dome located on a northwest-southeast anticline situated on the westward pitching nose of Blue Mountain (Section Ridge). The oil has an asphaltic base.

The Brennan Bottom and Ute Tribal pools have contributed small quantities of oil to the total county production. The Brennan Bottom field, located on Green River, 17 miles south of Vernal, produces from lenticular sandstone and silty ostracodal limestones and shales of the lower Green River and upper Wasatch formations. Well production is less than 100 barrels per day. The Roosevelt field (Ute Tribal) of western Uintah County produces from a fracture zone in basal Green River shales at a depth of about 9,300 feet. Structure and stratigraphic conditions probably also play a part in its production. This oil has a high pour point of 90 degrees Fahrenheit and a gravity of 30 degrees A.P.I. Brennan Bottom pour point is 105 degrees and gravity is 32 degrees, Average production from the Roosevelt field has been 400 barrels per day.

Oil Shale

By far the most abundant single mineral resource in Uintah County is oil shale which occurs in the Green River formation (Eocene). The Parachute Creek member, with its mahogany beds, is the richest section. East-central Uintah County contains the highest grade oil shale in the State of Utah. There is no present production, but the potential is great. On a basis of 15 gallons per ton recovery of shale oil (much of it runs considerably higher), it is estimated that Uintah County alone could produce in the neighborhood of 100 billion barrels of shale oil once competitive processes have been perfected.

Gilsonite

The unique, 99 per cent pure hydrocarbon, gilsonite (uintaite) has long been a principal source of revenue for Uintah County. Production is approximately 450,000 tons annually, mainly by the American Gilsonite Company at Bonanza. Gilsonite reserves are estimated to be less than 20,000,000 tons. The world's only commercial production comes from this area. Deposits occur in the Green River, Uinta and Duchesne River formations. However, the production is principally from the upper Green River, lower and middle Uinta.

Mining is conducted through the use of high pressure water cutting of the ore. Veins are vertical and vary from a few inches to nearly 18 feet in width and have been worked to a depth of 1,500 feet. They strike northwest-southeast and cover an area roughly 20 miles wide by 60 miles long.

A 6-inch, 72-mile long pipeline extends from the mines to Gilsonite, Colorado, on the Denver and Rio Grande Railroad (near Grand Junction) through which the ore is pumped in a water slurry to the refinery. Here it is converted into electrode coke and gasoline. Gilsonite produces 4 1/2 barrels of crude oil per ton. Melting point of the ore varies from approximately 230 to 400 degrees Fahrenheit. Several dozen products are made from gilsonite among which are paints and varnishes, lithographic inks, roofing materials, electrical and other insulations, battery boxes, phonograph records, floor coverings, brake linings, caulking material, gilsulate for underground pipe insulation, high test gasoline, and metallurgical coke.

Hunt, et al. (1957, p. 1690) were of the opinion that gilsonite and asphaltite originated in the bituminous material of the upper Green River calcareous and dolomitic shales rich in aromatic rings and nitrogen compounds. Several theories have been advanced to account for the occurrence of the gilsonite veins. The most generally accepted one, with slight variations, postulates the formation of tension cracks as a result of compaction of the Green River bituminous calcareous shales and the downwarping of the Uinta Basin syncline which was taking place between the rising Uinta Mountains on the north and the renewed uplift of the Uncompahgre Highlands on the south. These tensional stresses produced a general widening of the fissures in depth releasing the viscous bitumen and permitting its upward injection into the fissures forming the gilsonite (Crawford, 1949, p. 238). The filling of the gilsonite veins is believed to have occurred during Eocene and Oligocene time (Crawford, 1949, p. 248-252; Davis, 1957, p. 144-146; Hunt, et al., 1954, p. 1690-1682).

Asphalt

The bituminous sandstones along Asphalt Ridge, 4 miles west of Vernal, are estimated by the U.S. Bureau of Mines to contain between 2 and 3 billion barrels of bitumen. Feasibility studies have been made by various groups seeking recovery of this material by combination open pit and underground mining methods. Up to the present time the asphalt has only been used as a paving material. It is "cold-rolled" on the highway after mixing with sand to give it the desired rigidity. Like the oil shale of Uintah County, the bituminous sandstones represent a tremendous potential for the future. They occur in the Rim Rock member of the Mesaverde formation and at the base of the overlapping Duchesne River formation. Sulphur content is low, being only 0.09 per cent. The Green River formation, 27 miles east of Vernal, also contains numerous beds of bituminous sandstone. Most of the bitumen contained in all these beds is believed to have originated from the bituminous limestones and shales of the Green River formation. At Asphalt Ridge near Vernal the asphalt is closely associated with and apparently migrated upward along the Cretaceous Tertiary unconformity where the richest saturation of beds occurs. Covington (1957, p. 174) observed that saturation is definitely related to the porosity and permeability, and that structure has played a secondary role. This migration is believed to have taken place in late or post-Oligocene time and upward movement may in fact be continuing at the present time inasmuch as late Quaternary or Recent gravels have been cemented by the tarry material. Minor faulting at Asphalt Ridge in the County Pit area has helped control the saturation, restricting it to the southwest side of a post-Cretaceous and pre-Duchesne River fault (Covington, 1957).

Coal

Coal deposits of Uintah County are of minor significance and are of little economic importance. They occur in the Frontier formation and at present only one mine is in seasonal operation. The coal is bituminous and is rated at 13,060 BTU.

OTHER MINERALS

Phosphate

Thirteen miles north of Vernal, the San Francisco Chemical Company is mining and concentrating phosphate rock which occurs at the base of the Park City Phosphoria formation (Permian) and is estimated to have a reserve of 700,000,000 tons. Much of the deposit (which averages about 20 feet in thickness) is amenable to stripping. Raw ore averages 20 per cent P_2O_5, and flotation processes at the mine concentrate this to an average of 30 per cent. At this writing, production is at a rate approximating 200,000 tons per year. Plans call for an ultimate production of 1,000,000 tons annually. Expanded development may result in building of the first standard guage railroad into Uintah County, but a pipeline is also being considered for transportation of the concentrates and may prove to be more economical.

Sand and Gravel

Deposits of sand and gravel are abundant. A number of pits are operated, chiefly for road construction and maintenance with a small outlet to the building trades. Some building stone has been obtained from the Frontier sandstone. A red to green shellstone (limestone) in the Carmel formation has slight potential as a facing stone. It is known locally as Vernal "marble."

Bentonite

Deposits of bentonite occur in the Morrison (Jurassic) and Uinta (Eocene) formations but no development of these beds has taken place to date.

METALLIC MINERALS

Metallic ores are poorly represented in Uintah County. Intrusives frequently associated with mineralized zones are almost totally absent in the sedimentary formations of this region.

Copper

Uintah County copper deposits should be spoken of in the past tense. There are small scattered deposits which were worked near the close of the last century. Chief among these, the old Dryer mine on Brush Creek Mountain 25 miles north of Vernal, worked out its "Glory Hole" and ceased operation. Its malachite represented limestone replacement in the Madison (Mississippian). Minor associated minerals were chalcocite, gold, and silver.

A small copper pocket occurred in the Manning Canyon shale (Mississippian) at the mouth of Sage Creek where it empties into Whirlpool Canyon of the Green River. In 1899, five tons of concentrate running about 55 per cent copper and 69 ounces of silver per ton were recovered in this locality (F. L. Hess, 1920, p. 606).

Sandstones of the Uinta (Eocene) a few miles below Ouray, on the west side of the Green River, produced a small amount of malachite at the Uteland Mine.

There is no copper production in Uintah County at this time.

Iron

The Mississippian limestones 20 miles north of Vernal carry fairly large deposits of a good grade of hematite iron ore. There is no production at present.

The Jurassic-Triassic formations which have been so profitable in uranium in southeastern Utah-southwestern Colorado have produced little of interest in Uintah County.

WATER RESOURCES

As previously noted, Uintah County is bisected diagonally from northeast to southwest by Green River. Annual precipitation about 12,000 feet varies from 25 to 30 inches. Below 5,000 feet the annual rainfall averages less than 10 inches. Major drainages in the county (all tributaries to the Green) from east to west are Jones Hole Creek, Brush Creek, Ashley Creek, Whiterocks, Uinta, Duchesne, and White rivers. Drainage south of the White River is negligible.

The traversing of the great expanse of badland country of the Uinta Basin by the Green, White, and Duchesne rivers and other smaller tributaries, invites exceedingly rapid evaporation and transpiration by vegetation along the stream banks, especially during hot summer months. This, added to the extreme drought of some years (such as the late 1950's and early 1960's) greatly diminishes stream flow, dries up many of the springs and reservoirs, and creates water shortages for irrigation and livestock use.

Oil wells of the Uinta Basin produce over 20,000,000 barrels of water annually in the course of field operations. Ashley Valley Field, 10 miles east of Vernal accounts for over 90 per cent of this. While somewhat saline, this water, originating principally from the Weber formation, is used locally for irrigation. Other oil field water in the basin for the most part is too saline for any use, and the fields are not near the arable lands (Goode, H. D., and Feltis, R. D., 1962).

Culinary water for the towns of the county comes largely from springs higher up on the mountain slopes and is piped down directly or stored in reservoirs. Water for industrial uses is obtained directly from streams, wells, or reservoirs.

Future water for agricultural and industrial uses is assured by completion of the first phase of the Central Utah Project. The Vernal unit as represented by the Steinaker Dam and the resulting 37,200 acre-feet reservoir, will supply supplemental water for Ashley Valley. Flood waters diverted from Ashley Creek are the source.

Flaming Gorge Dam and reservoir, accessible through Vernal, 45 miles to the south, lie in Daggett County and are adequately treated in Utah Geological Survey Bulletin 66, Geologic Atlas of Utah, Daggett County, by Howard R. Ritzma.

Data obtained by stream-gaging stations, hydrologic reconnaissance, and other means indicate amount of surface outflow, loss by evaporation, transpiration and surface-ground-water inflow, and relation of stream flow to regional geology and groundwater hydrology.

Principal aquifers of potable water in Uintah County are: Mississippian and Pennsylvanian limestones (Madison and Morgan) sources of springs and streams, Pennsylvanian sandstone (Weber), Permian limestone (Park City), Navajo and Entrada sandstones of the Jurassic.

Interesting occurrences of large warm springs are located on the Green River in Split Mountain Canyon in Mississippian limestone. Volume of springs is 5-6 second feet. Temperature is in the high 80's. Another series of warm springs occurs at the Park City-Weber contact on the west slope of Blue Mountain.

For the most part Tertiary water supplies are saline. However, exceptions occur in the sandstones of the Wasatch and Duchesne River formations.

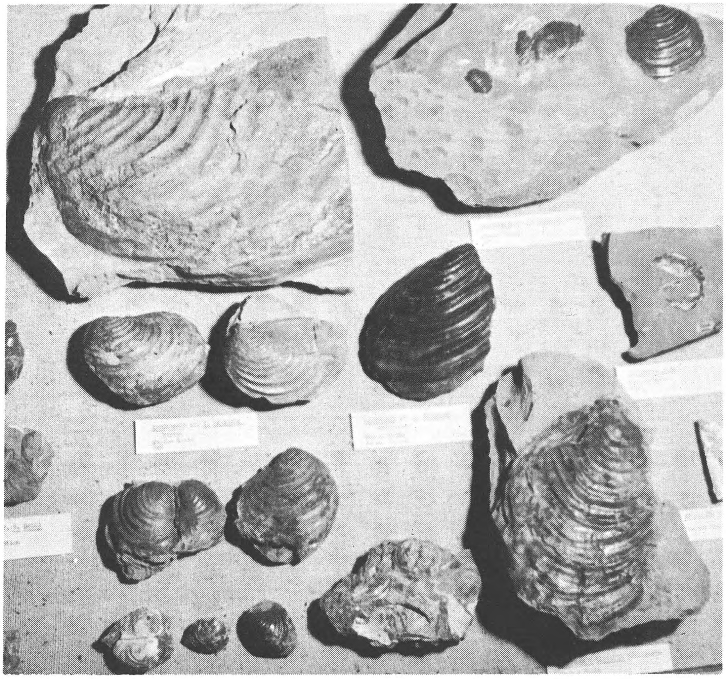
FOSSILS

Uintah County has been the source of a great wealth of fossil material, mainly vertebrate, representing a wide range of reptilian and mammalian types. Invertebrates (marine and fresh-water forms) are abundant in portions of some formations, but do not compare in interest to the spectacular terrestrial four-footed life that roamed the Uinta Mountain and Basin region and its ancestral terrain that existed prior to the deformation which formed these structural features.

The earliest fossils found in this area, which consist of a few trilobites that date the formation, and a few minute mollusks, go back more than 500 million years to upper Cambrian time. The remainder of the Paleozoic formations up to and including the Permian (Park City-Phosphoria) contain a rather wide range of marine types, most common of the Paleozoic formations up to the Permain (Park City-Phosphoria) contain a rather wide range of marine types, most common of which are brachiopods, crinoid stem plates, sponge spicules, sea urchin spines, horn and colonial coral, and foraminifera. Several species of clams, the horn-like dentalium scaphopod, the bellerophon gastropod and orbiculoidea are typical Park City Permian fossils.

Except for silicified wood, the Triassic beds are rather barren of fossil remains. In the oldest of this series, the Moenkopi, the only trace of life observed in this area is a group of reptilian tracks made on the muddy shores of an ancient lake or stream, probably belonging to the "hand" reptile or Chirotherium. Similar tracks were found in the sediments of the same age in Arizona and New Mexico. Their age

Figure 45. Reliefed partial skeletons in Dinosaur Quarry. (Vertebrae, pelvic bones, leg bones, and ribs.)



gure 46. Gastropods (left); Inoceramus pelecypods (clams) center; Crustacean claw, right. ancos formation — Upper Cretaceous. (Courtesy of Utah Field House of Natural History.)

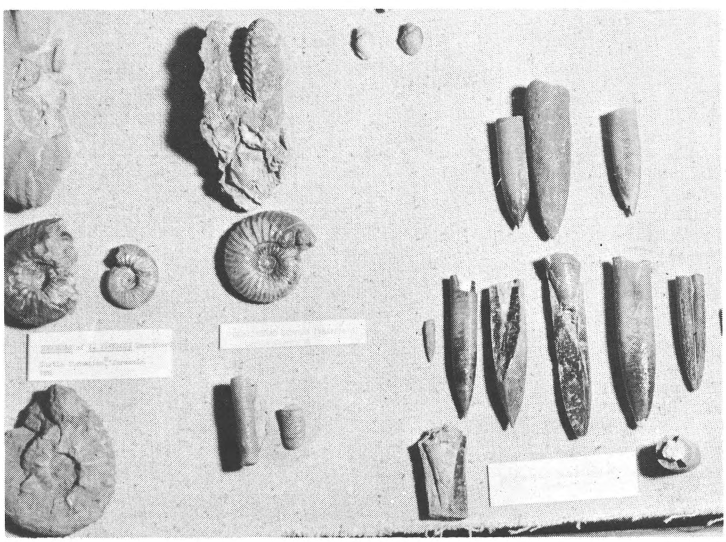


Figure 47. Curtis formation. Upper Jurassic. Cephalopods: ammonites (left) and Belemnites (right).

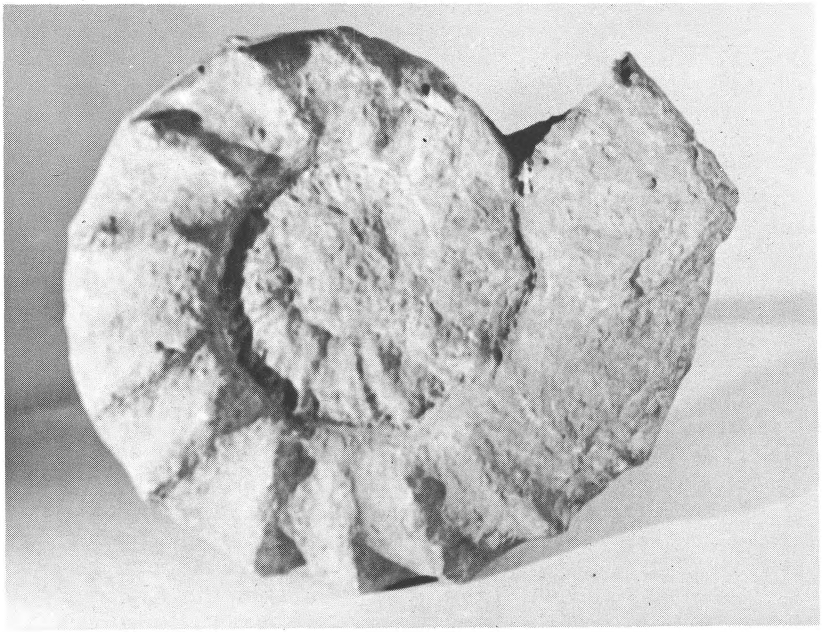


Figure 48. Cretaceous (Frontier) ammonite. *Mortoniceras cf. shoshonense* Niobrara. (Courtesy of Utah Field House of Natural History.)

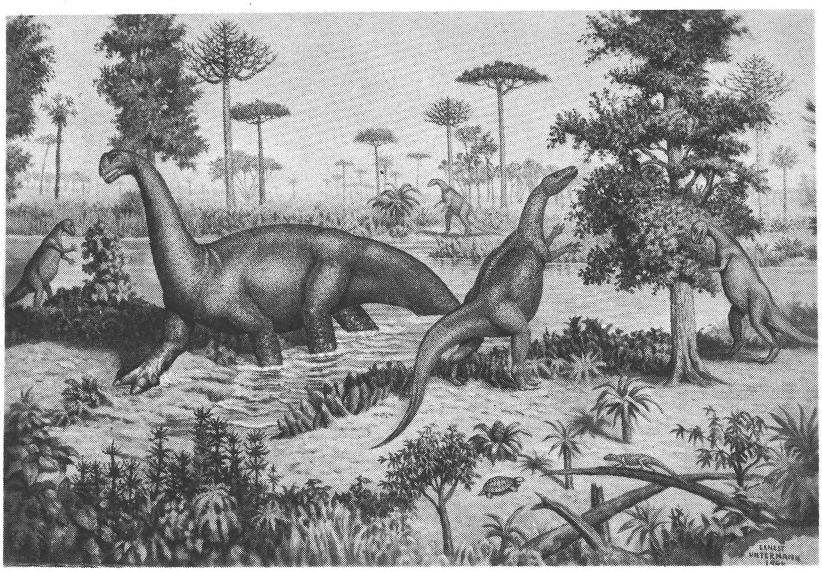


Figure 49. Dinosaurs from Dinosaur National Monument Quarry. Left to right: Laosaurus, Camarasaurus, Camptosaurus, Dryosaurus, Glyptops (turtle), Hoplosuchus kayi (small reptile lower ~~left~~ right).

is about 170 million years. Large sharp reptilian (phytosaur) teeth and fragments of amphibian bone (animals that attained a length of 15 to 25 feet) and locally, fossil wood, occur in the overlying Chinle formation. These two formations are separated by the Shinarump conglomerate which carries only silicified wood.

The middle Mesozoic or Jurassic formations have been more rewarding of fossils in this area. No fossils have been found here in the wind deposited Navajo, nor, for the most part, in the overlying marine Carmel, except north of Vernal. At this locality a 12-inch basal Carmel layer of red to green limestone carries an abundance of clam shells, with a few gastropods and rarely a colonial coral. It has some value as an attractive facing stone and is referred to as "Vernal marble."

The Curtis formation is rich in small types such as oysters, belemnites, clams, with occasional gastropods, brachiopods, ammonites, and icthyosaur vertebrae and other bones. This period of time brought to a close the marine Jurassic conditions in this area, and the rising shorelines eventually produced extensive floodplains, deltas and swamps during the Morrison upon which lived and foraged the great variety of dinosaur types that gradually migrated into the area. No doubt there were certain dinosauroid forms that had existed in the region from time to time since the Triassic, the period during which dinosaurs of North America first appeared. Tracks have been observed on occasion in both the upper Chinle and the Carmel. On page 39 of this paper a list is given of the more important fossils recovered from the world-famous Dinosaur Quarry in the Morrison formation, north of Jensen, Utah. At this writing, 13 species of Dinosauria, 2 species of Crocodilia, and 1 species of Chelonia (turtles) have been discovered. Of the 13 species of dinosaurs, 6 are amphibious sauropods (long necked, long tailed waders), 3 are carnivorous, 3 are duckbills, and 1 is armored. In places the formation carries Unio fresh-water clams and minute gastropods.

Seas transgressed this region again during Cretaceous time, except for the oldest formation, the Dakota, which carries petrified wood of varying degrees of silicification. Inoceramus clams, gastropods, ammonite, scaphite and baculite cephalopods are among the most common invertebrates.

During the Tertiary, Uintah County and the Uinta Basin region was a very favorable place for the development of mammal types that comprised a great variety of species, throughout Paleocene, Wasatch, Green River and Uinta; Eocene; and Duchesne River, Oligocene time. These animals ranged over floodplains and the shores of Lake Uinta. This lake, which covered much of central Utah, and particularly the Uinta Basin, migrated westward, remaining in that part of the region for a longer period of time and continuing in its deposition of sediments to within about 100 feet of the base of the Randlett horizon, lower part of the Duchesne River formation. These upper Eocene sediments are equivalent in age to the Manti beds and carry the same fossil species (Kay, J. L., personal communication). Remains of these animals were buried in the stream, delta, and shore deposits of the region, and consist of camels, 3-toed horses, rhinos, titanotheres (large rhino relatives), Uintahthere (a 6-horned elephant-like animal), tapirs, deer, primates, rodents, pigs, many mixed deer-camel-pig and other undifferentiated forms, carnivores of the cat and dog families, and many additional odd and interesting animals. In addition to these mammal types, more than 20 species of turtles have been found as well as several species of crocodiles and alligators, lizards, birds, fish, and a few land snails and in places an abundance of fresh-water gastropods. The region afforded many types of semi-modern plants and trees, especially of shore and stream types. Leaves and aquatic and other insects have been beautifully preserved in the fine shales of the Green River formation, the former representing a much greater variety of trees than is possible in our present arid climate.

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