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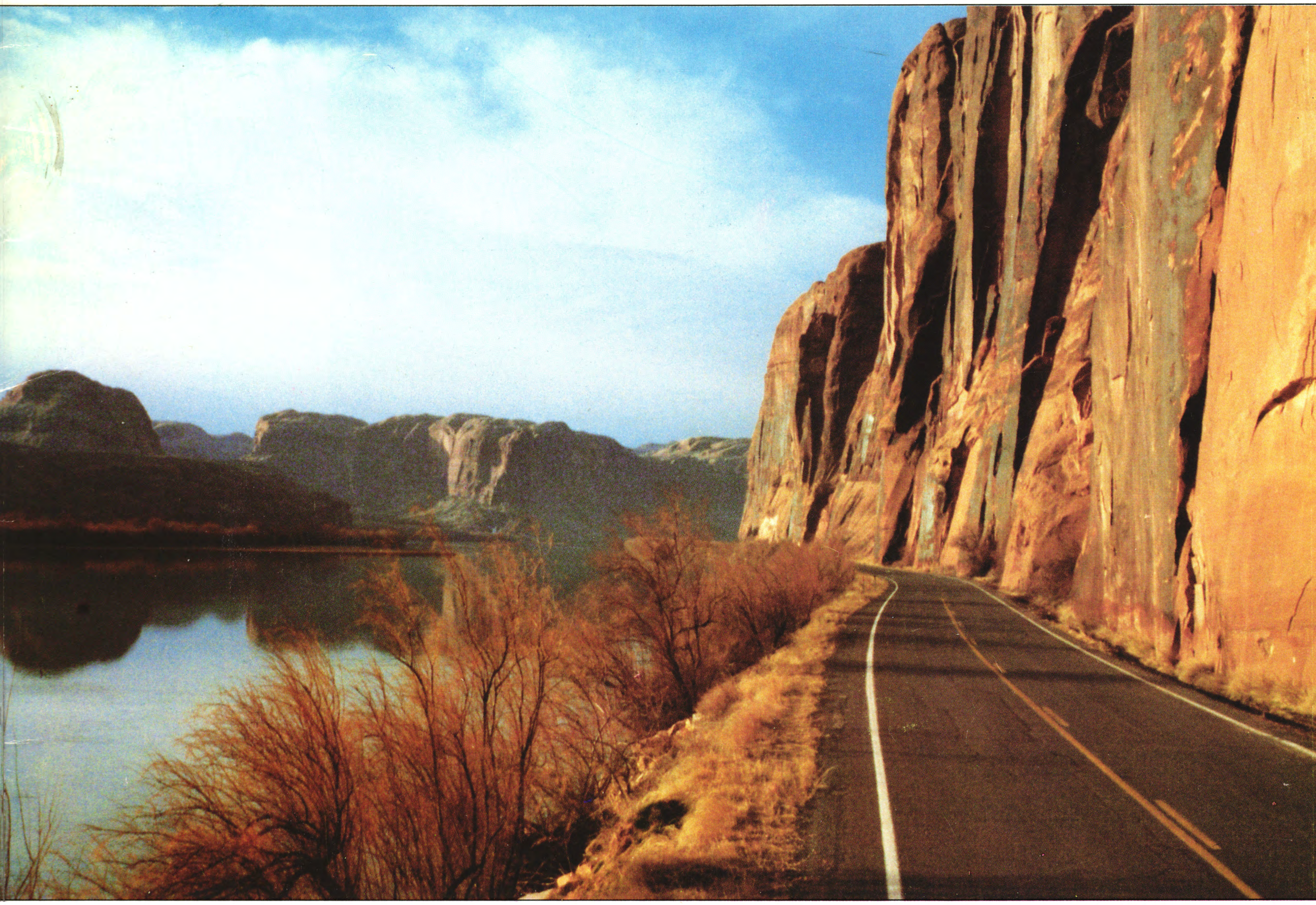

Grand County

STATE OF UTAH
DEPARTMENT OF NATURAL RESOURCES
UTAH GEOLOGICAL AND MINERAL SURVEY

in cooperation with

DEPARTMENT OF COMMUNITY AND ECONOMIC DEVELOPMENT

Information

GRAND COUNTY is located in the heart of the Colorado Plateaus physiographic province, ranks 9th in land area with 3692 square miles with a population of only 8241, 20th out of 29 Utah counties (1980 census). Perhaps more than in any county in Utah, the financial base is linked to the geology. Mining (extracting minerals), tourism (seeing the geologic wonders), and land management and exploration provide many jobs for its people.

Limestone, salt, and shale were deposited in an ocean basin that covered Grand County in Pennsylvanian time. From then until Upper Triassic time, the ancestral Rocky Mountains (Uncompahgre Uplift) rose near the present Colorado line as a mountainous peninsula or island. The erosional products of the mountain range were deposited in huge coalescing alluvial fans that extended across Grand County as a coastal plain. The salt anticlines formed during this time.

During the remainder of Triassic time and extending well into the Tertiary Period, the area subsided and received sediments. Savannah-type landscapes, floodplains, tidal flats, and sandy deserts prevailed into which the dinosaurs and other primitive life forms wandered. During the Cretaceous Period the area was again inundated by an ocean at the bottom of which the drab gray Mancos shales were deposited. Sharks, oysters, and cephalopods inhabited this sea. As the seas withdrew, sandy beaches, marshy backswamps and lagoons appeared. The swamp vegetation was preserved and coalified to form the coal beds of the Book Cliffs.

In mid-Tertiary time Grand County experienced crustal deformation and igneous activity. The rock formations were folded and faulted. Deep rocks were melted and forcefully intruded into overlying strata in the La Sal Mountain area. About 10 million years ago Grand County was elevated and subjected to erosion. Since then, the Colorado River and its tributaries have cut magnificent canyons, exposed the granitic rocks of the La Sal Mountains, exhumed the salt anticlines, and formed the beautiful landscapes we enjoy today.

STATE OF UTAH, Norman H. Bangerter, Governor. GEOLOGY AND GRAND COUNTY is published by the UTAH GEOLOGICAL AND MINERAL SURVEY, 606 Black Hawk Way, Salt Lake City, Utah 84108, (801) 581-6831. The Utah Geological and Mineral Survey, Genevieve Atwood, Director, is a division of the UTAH STATE DEPARTMENT OF NATURAL RESOURCES, Dee C. Hansen, Executive Director. This pamphlet was published in cooperation with the DEPARTMENT OF COMMUNITY AND ECONOMIC DEVELOPMENT, David Adams, Executive Director.

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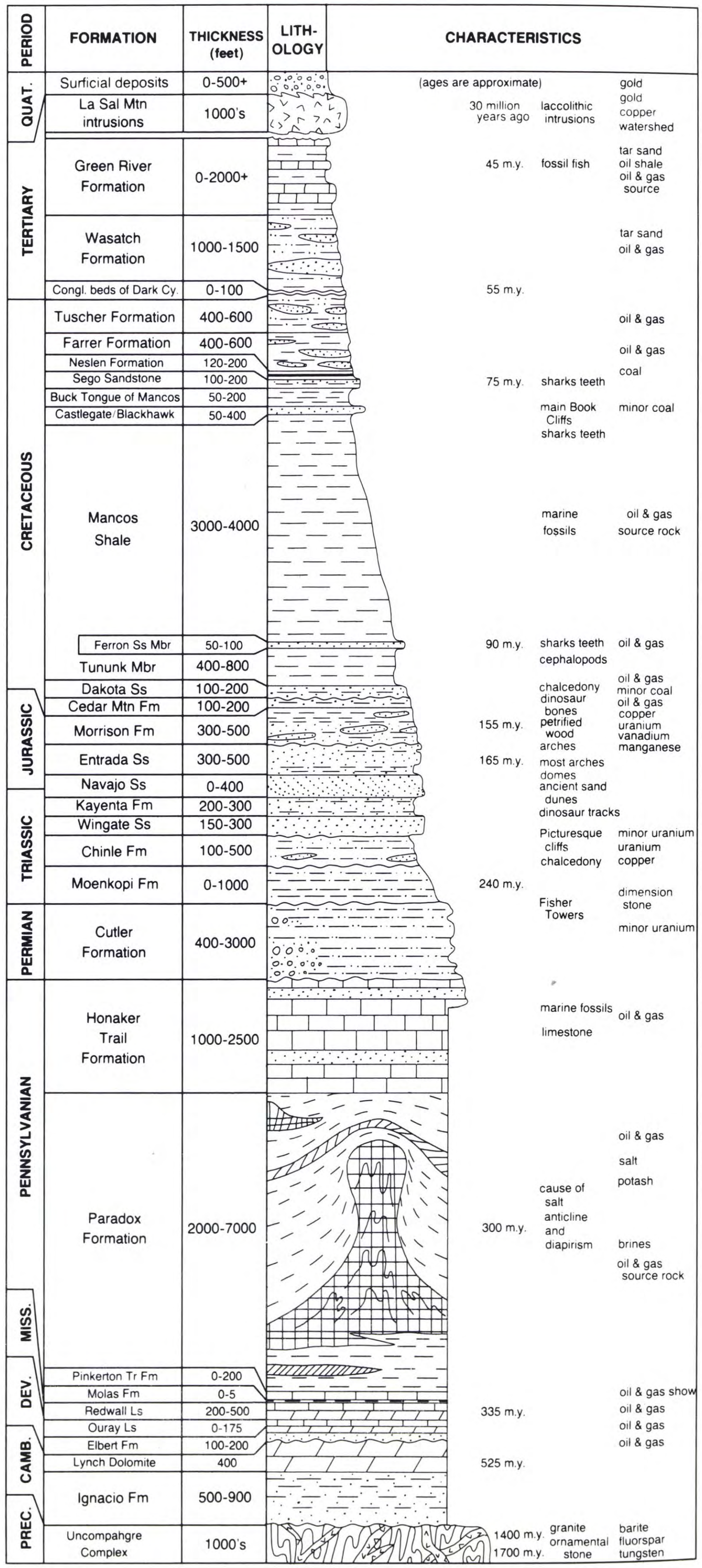


Lithologic column of the rock formations of Grand County.

View looking north in canyon cut by the Green River, along the western edge of Grand County.

The canyons of Grand County are spectacular erosion features. Their formation began about 10 million years ago as the Colorado Plateau was uplifted several thousand feet by tectonic forces, and the Colorado River and its tributaries began downcutting. As the rivers and streams cut through, softer rocks eroded to form slopes and harder, more resistant rock units, such as the Wingate Sandstone, formed benches and cliffs. When the river bed was topographically higher than it is today, the river formed meander bends as it flowed across wide, flat areas. Then, as the river cut into the hard, cliff-forming rocks, these meanders became entrenched. Entrenched meanders can be found along both the Colorado and Green rivers in Grand County.

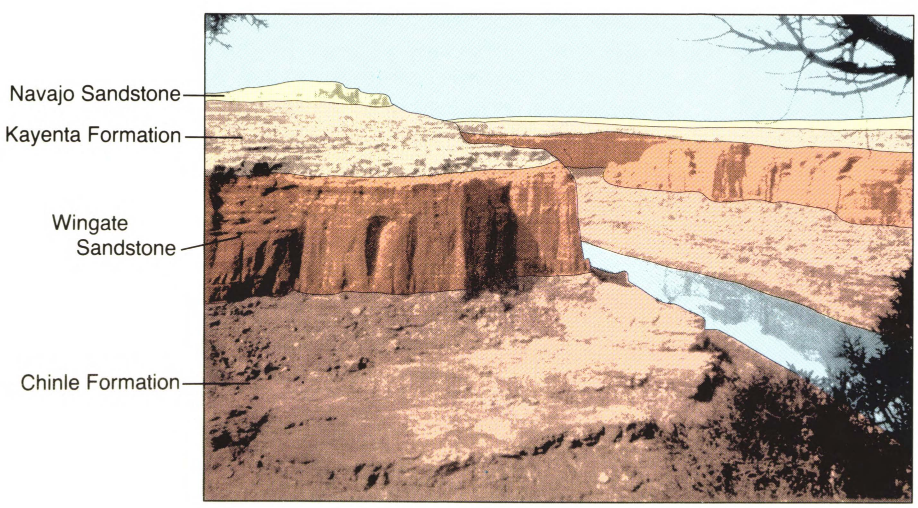
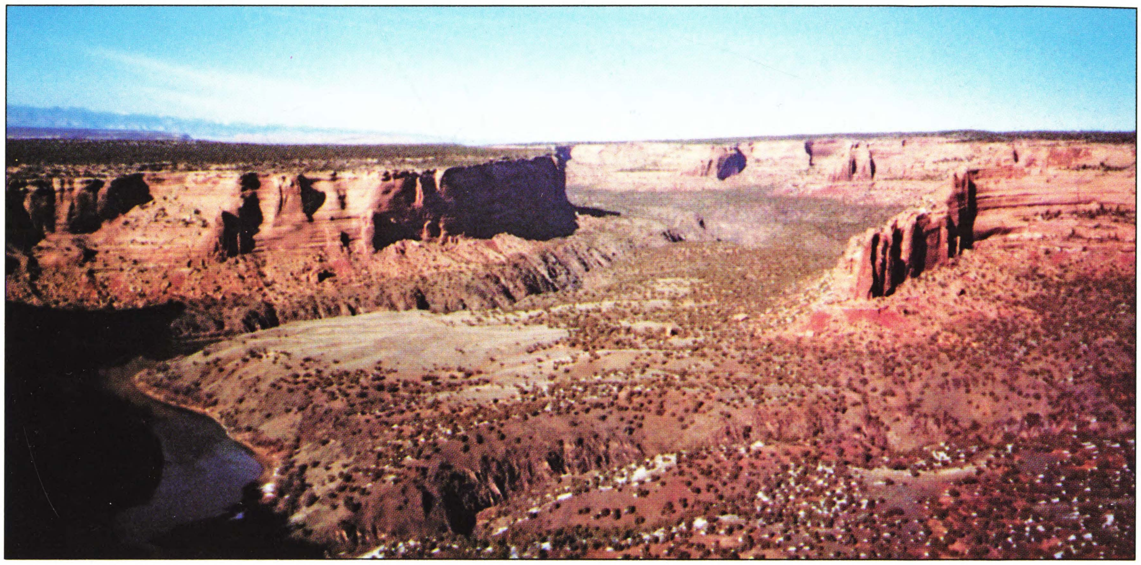


Photo illustration of above photograph showing cliffs, benches and slopes formed by erosion of relatively hard (Navajo and Wingate Sandstones) and soft (Kayenta and Chinle Formations) by the Green River.

Uncompahgre Uplift



Easterly view of Westwater Canyon, showing erosion by the Colorado River and a prominent bench formed on top of the Uncompahgre metamorphic and intrusive rocks.

The oldest exposed rocks of Grand County are found in the east-central part in a highland area known as the Uncompahgre Uplift (see map on back). These are metamorphic rocks (formed by intense heat and pressure) that were later intruded by molten materials which crystallized to form granitic rocks. Radiometric dates show these rocks to be between 1.8 and 1.4 billion years old. Younger rocks were deposited on them during early Paleozoic time, and during Pennsylvanian and Permian time (320-245 million years ago) the area was uplifted as part of the ancestral Rocky Mountains. The uplift was stripped of all overlying sediments and the old rocks were deeply eroded. After this period of erosion, stream deposits of the Triassic Chinle Formation (about 220 million years old) were the first sediments to again cover the exposed metamorphic and intrusive rocks. After Chinle time a normal succession of formations buried the remnants of the old mountain range. With the uplift of the Colorado Plateau commencing about 10 million years ago, the Colorado River and its tributaries have reexposed the roots of the old mountains.

The surface between the older metamorphic and intrusive rocks and the younger sedimentary rocks is an unconformity. This unconformity represents the period of erosion during which thousands of feet of overlying rock were removed before stream sediments of the Chinle Formation were deposited directly over the older rocks. Areas of metamorphic and igneous activity are favorable for mineralization. Tungsten, barite, and fluorspar occur in veins adjacent to and within Precambrian rocks of the Uncompahgre Uplift.

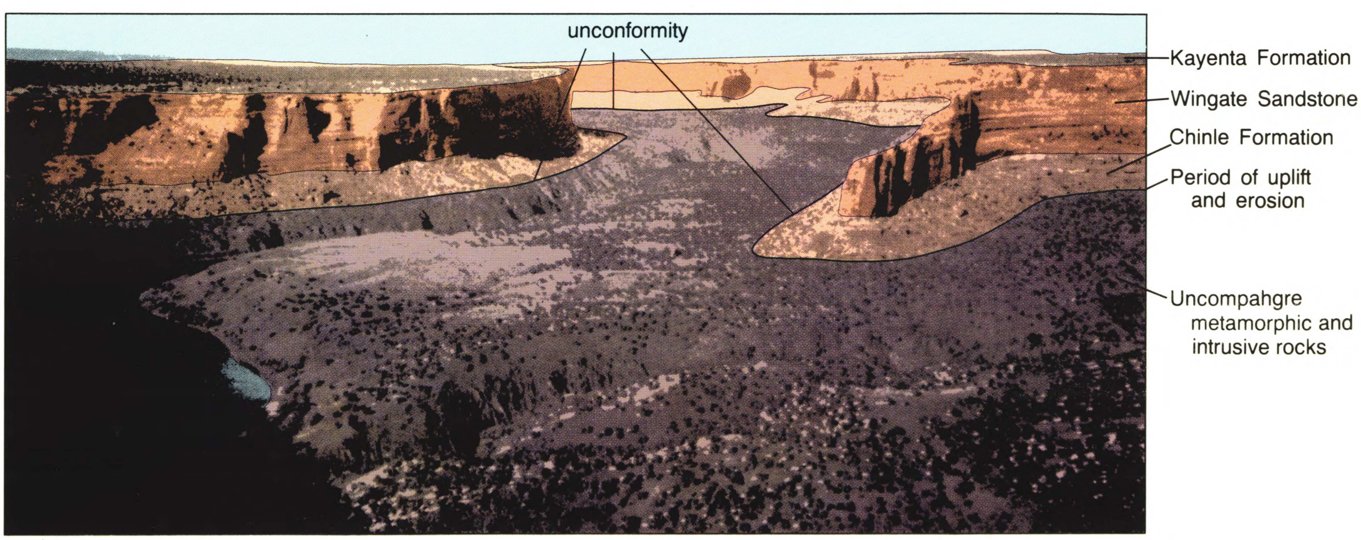


Diagram of upper photograph indicating geologic contacts and the unconformities between Precambrian and younger rock units.

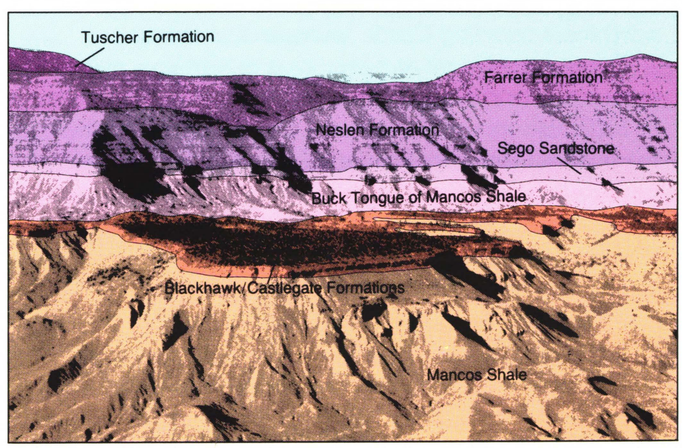
The Book Cliffs are a prominent east-west escarpment in the northern part of Grand County. The lowest ledge forms a conspicuous series of flat-topped mesas easily seen to the north of Interstate Highway 70.

The Wasatch Formation is exposed in a high plateau along the southern margin of the Uinta Basin and "above" the Book Cliffs throughout the county. View is about 10 miles north of Thompson.

The Book Cliffs, which form a great wall across the county that extends into Colorado to the east and into central Utah to the northwest, may be the most prominent topographic feature in Grand County. They have effectively isolated the north third of the county and have blocked transportation throughout human history. The early explorers, trappers,and other newcomers were impressed by their grandeur even as they painfully detoured around or crossed over them. Even today only a few rough, winding roads manage to cross the cliffs. They are cut by only one major drainage, the Green River, which has cut a deep, narrow gorge that is mainly the habitat of wildlife and whitewater river runners.

The cliffs are no accident of nature but rather are the result of several geologic phenomena working together. During the Late Cretaceous, about 65 to 100 million years ago, eastern Utah was covered by a shallow sea in which thousands of feet of material were deposited to form shale and mudstone. As the seas regressed toward the east, thick shoreline sandstone layers were deposited directly over the shale. They were in turn generally overlain by extensive coal-forming swamps. Later sediments included interbedded fluvial sandstone channels, and back-levee and lacustrine mudstone. During the last ten million years the Colorado Plateau was uplifted and tilted toward the Uinta Basin. Joints or fractures associated with the uplift fractured the sandstone beds, giving them a blocky fabric. The sandstones resist weathering and erosion, but once they are breached the underlying marine shales are easily eroded away. The resulting cliffs are eroded back not by erosion from above but primarily by removal of the softer, underlying shale, causing blocks of fractured sandstone to break off. The result is a broad "badlands" plain rimmed by a high, sandstone-capped cliff. The badlands, which are up to 20 miles wide, were carved from the easily eroded Mancos Shale. High salt and alkali content of the Mancos limits vegetation to a few particularly hardy species. Remnant benches at various elevations, capped with gravel and rubble lag deposits, are a reminder of the erosion that continues to carve the badlands.

The Book Cliffs dip gently northward toward the Uinta Basin, which covers the northern third of Grand County. Tertiary rocks, including the Wasatch Formation and the Green River Formation, are exposed in the Basin.



The Book Cliffs area of Grand County marks the southern edge of the Uinta Basin. Its rocks contain coal beds, tar sands, and oil shale. The formations visible from the highway are indicated in the diagram.

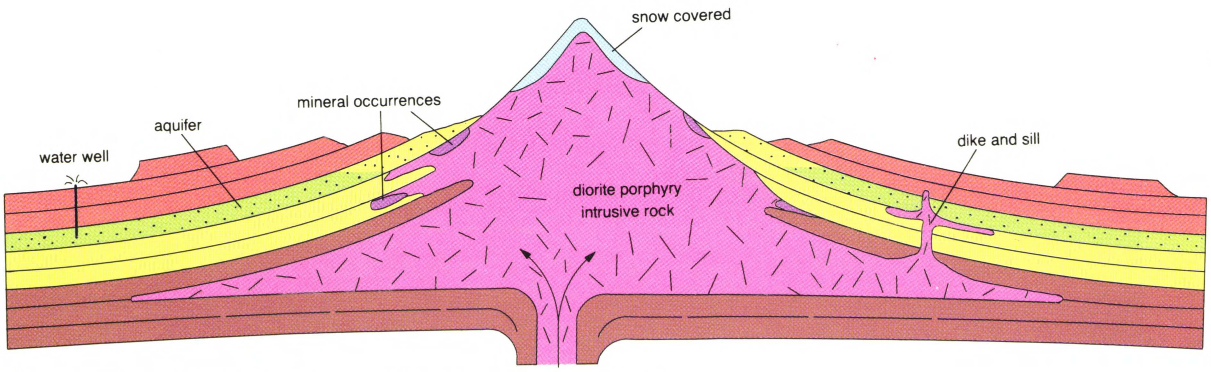
Book Cliffs · Uinta Basin

La Sal Mountains

The La Sal Mountains as viewed from the northwest. The winter snow that collects on the peaks is vital to the region for replenishing creeks, recharging ground-water aquifers and filling municipal reservoirs.

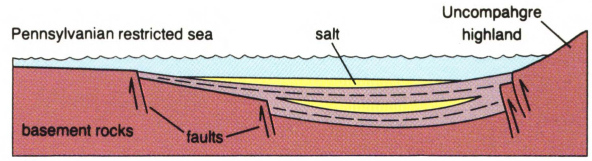
The La Sal Mountains consist of three distinct topographic and geologic masses located in southeastern Grand County and northeastern San Juan County. About 30 million years ago, molten rock (magma) was intruded into the sandstone and shale formations as laccoliths, dikes, sills, and bysmaliths far below the levels now exposed by erosion. This magma slowly cooled in the subsurface and congealed into a rock known as diorite porphyry. North Mountain, the largest of the La Sal Mountain masses, is mostly in Grand County and has at least three named peaks rising above 12,000 feet. Mesas and canyons, typical of the Colorado Plateaus, surround the foot of the mountains. North Mountain is curiously aligned along, and south of, the northwest-trending Castle Valley salt anticline.

These magnificent and imposing mountains, glaciated during the Ice Age, are important to Grand County for a number of reasons. In arid climates, fresh water is vital. The high mountains collect copious quantities of snow during the winter months to replenish mountain streams and recharge the bedrock aquifers. In the summer, cool, high places afford recreation and magnificent vistas for tourists; the La Sal Mountain peaks, with an 11,500-foot tree line, can be seen for a hundred miles. The La Sals have small deposits of copper, lead, zinc, and gold ore emplaced in and adjacent to the magma intrusions.

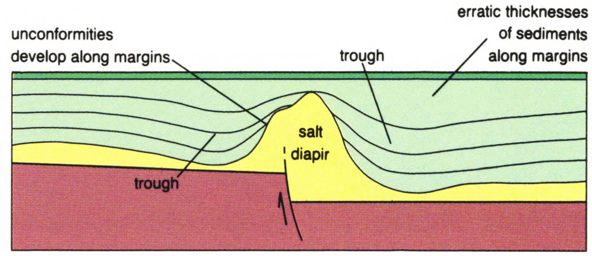


Diagrammatic section of a laccolithic mountain intruded into sediments.

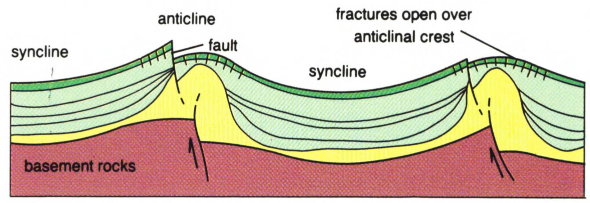
Moab salt anticline as viewed from the south. Much of the valley floor is covered with alluvium. Note the high cliffs to the left as elevated along the Moab fault, and the gentle downfold of the Courthouse Syncline in the upper left.



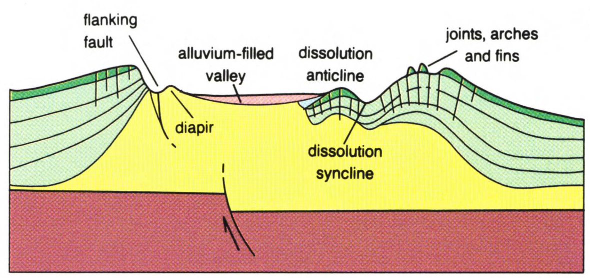
MIDDLE PENNSYLVANIAN TIME (300-290 million years ago). Faulting and salt deposition.



LATE PENNSYLVANIAN TO CRETACEOUS TIME (290-70 million years ago). Continued fault movement, development of salt anticline and deposition of younger sediments.



EARLY TO MID-TERTIARY TIME (40-20 million years ago). Folding and renewed faulting.



LATE TERTIARY TO PRESENT TIME (10 million years ago to present). Uplift, erosion, and dissolution.

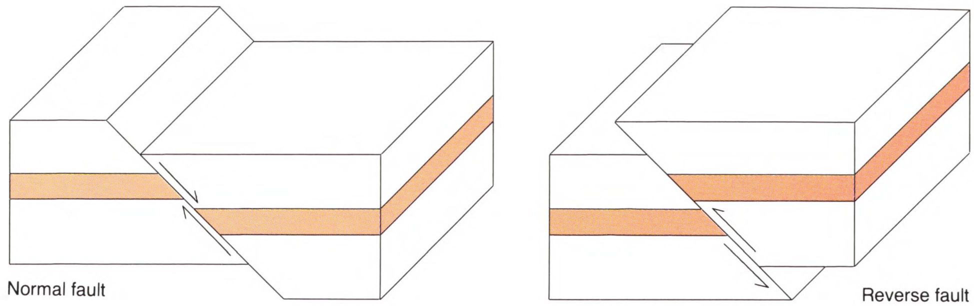
Episodes of the history of Grand County salt anticlines (diagrams not to same scale).

Salt anticlines are unusual geologic features and their display in Grand County is unsurpassed anywhere in the world. Four episodes in the geologic history shaped their development. The Paradox Basin (episode I) formed in Pennsylvanian time under arid conditions along northwest-trending faults which ruptured the older (basement) rocks. The basin was submerged by an arm of an ocean that periodically evaporated, leaving mostly thick salt and gypsum deposits at the bottom. Salt, which is plastic and can be slowly squeezed like toothpaste in conditions of unequal confining pressure, thickened over the still-active basement faults as additional sediments were deposited across the region (episode II). Most of the salt was squeezed from troughs that developed along the flanks of the rising mass. Some rock formations were deposited more thinly over and adjacent to the salt anticlines. Others were uplifted with the salt and eroded, only to be unconformably overlain by the next formation. Eventually the salt anticlines were completely covered by younger rock units. In some places, however, the salt thickened to more than 10,000 feet.

After a "quiet" interval, compressional tectonic activity disturbed the region, downfolding the rocks between the salt anticlines into broad synclines to mark episode III. The basement faults moved again, but the displacements were probably absorbed by the thick salt. The stresses created by the fault movement were relieved by new faults that ruptured rocks marginal to the salt, where the rocks are the weakest. Sets of joints developed parallel to the anticlines and faults, especially over the crestal parts of the salt anticlines. The final episode (IV) was marked by regional uplift, and by erosion by the Colorado River and its tributaries. The erosion removed overlying rock and soon reached the top of the salt. Subsequent streams developed along the weak fault and joint zones, the water eventually leaking down to the salt and dissolving it. V-shaped collapse of rock formations mark areas where dissolution has occurred. Surface and ground water have successfully dissolved all salt above the zone of water saturation, so that none can be observed at the surface. Bulges of contorted gypsum and shale are found at the flanks and crests of some anticlines and are called "diapirs." Some may be the exhumed tops (cupolas) of the ancient salt diapir, others may be eroded remnant ridges (dissolution anticlines) paralleling v-shaped collapse zones (dissolution synclines), and others may be true diapirs, squeezed upward from under the weight of flanking erosional cliffs. Some of the salt anticlines have been eroded into valleys now filled with rather recent alluvium. Recent dissolution is evident because the alluvium is locally deformed.

Salt Anticlines

Joints and Faults



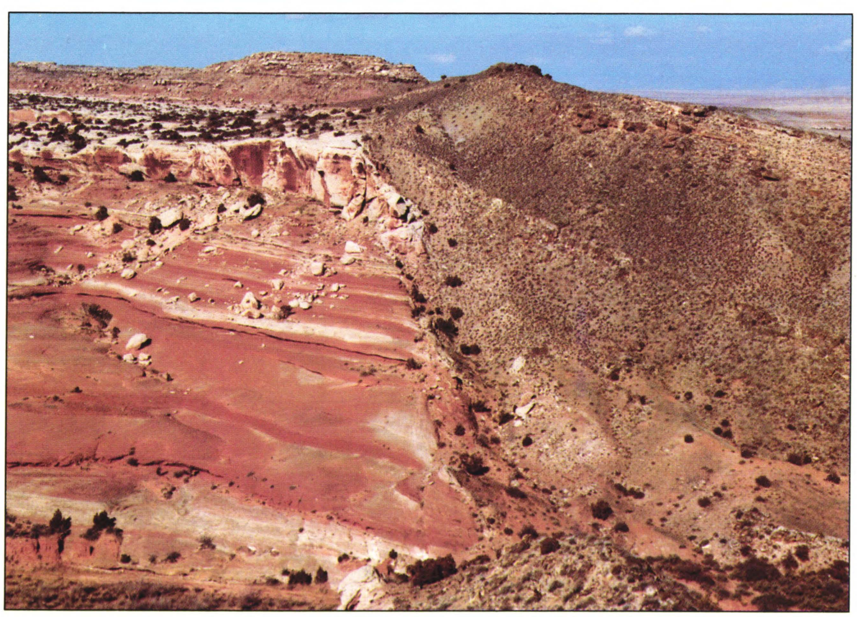
Joints and faults are spectacularly displayed in many areas of Grand County. Joints are fractures in rocks along which there has been no visible movement parallel to the fracture plane or surface. Joints may have any attitude; some are vertical, others are horizontal, some are inclined at various angles, and some are curved. Joints, ranging from a few inches to thousands of feet in length, never occur alone and the interval between them may be a fraction of an inch to hundreds of feet. Joints form in brittle rocks when the rock layers in the earth's crust are under stress. In Grand County the joints are chiefly extensional because of anticlinal folding. Due to the inherent nature of the sandstone, the joints are magnificently developed in the Slickrock Member and the overlying Moab Member of the Entrada Sandstone.

The most prominent joints and faults in Grand County trend northwest, which is also the orientation of the axes of the anticlines and synclines.

Faults are joints or fractures along which the opposite walls have moved past each other. Tectonic forces produce numerous types of fault movements; the more common ones are normal (or gravity) faults, reverse faults, and strike-slip faults.

Most faults in Grand County are normal faults. A prime example is the Moab fault that bounds the west side of Moab Valley and displaces rocks as much as 2600 feet. It can be traced northwest of the Colorado River for at least 16 miles where it branches. A major subsurface fault along the southwest side of the Uncompahgre Uplift is a low-angle reverse fault . This fault trends northwest, is covered by the Chinle Formation, and has a stratigraphic displacement of about 20,000 feet.

A southeast view of the spectacular joints in the Moab Member of the Entrada Sandstone. The La Sal Mountains are in the right background.



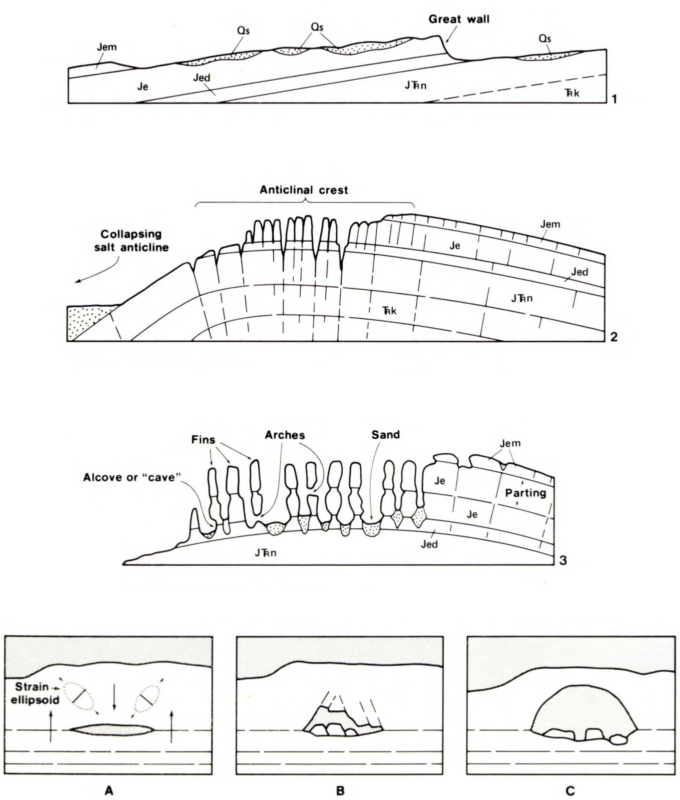
A view west at Bartlett Wash of a northern branch of the Moab fault. The Cretaceous Cedar Mountain Formation on the right abuts the Jurassic Entrada Sandstone on the left.

A northwest view of fins developed in the Slickrock Member of the Entrada Sandstone, northeast flank of the Salt Valley anticline.

An arch in a fin of the Slickrock Member of the Entrada Sandstone, Arches National Park.

Arches National Park has the greatest concentration of natural rock arches in the world. Most arches and fins in the park have formed wherever the Entrada Sandstone is arched over an anticline on which closely spaced parallel joints have developed. After joints form, the development of fins begins as chemical weathering, mechanical weathering, and differential erosion attack the jointed rocks. The Slickrock Member of the Entrada Sandstone is mostly quartz grains cemented by calcium carbonate ($CaCO_3$). Rain water, charged with atmospheric carbon dioxide (CO_2), forms weak carbonic acid which eventually dissolves the cement. Thus, much sand is loosened and accumulates on the rock surfaces and in the joints. The slightly acidic rain water passes through the sand veneer and attacks the top and sides of the unweathered rock beneath, forming more sand. The sand accumulation protects the acidic ground water from quick evaporation by the hot sun or wind (Doelling, 1985). The joints gradually widen as weathering and erosion differentially affect the tops and sides of the fins.

Some of the horizontal partings in the Slickrock Member, being soft and not well cemented, are especially vulnerable to the lateral attack of the ground water. The water seeps into the partings and dissolves the cement, freeing the sand grains at a faster rate than in the sandstone above or below. Eventually a thin horizontal opening is produced (diagram A). Gravity stresses then appear in the overlying rock and tensional fractures propagate upward (diagram B). The roof of the opening collapses until a stable arch is formed (diagram C). Delicate Arch has formed along the parting made by the contact of the Moab and Slickrock Members of the Entrada Sandstone. Skyline Arch is formed along a parting entirely within the Slickrock Member. The "windows" arches occur along the Dewey Bridge and Slickrock Member contact. Thick-walled fins are not as favorable for arch development as the thin ones, but alcoves and "caves" can form on their sides.



Diagrams illustrating the development of the fins and arches in Grand County (from Doelling, 1985). Ps, *surficial sand deposits;* Jem, *Moab Member of Entrada Sandstone;* Je, *Slickrock Member of Entrada Sandstone;* Jed, *Dewey Bridge Member of Entrada Sandstone;* JTRn, *Navajo Sandstone; and* TRk *Kayenta Formation.*

REFERENCE

Doelling, H. H., 1985, Geology of Arches National Park: Utah Geological and Mineral Survey Map 74, 15 p.

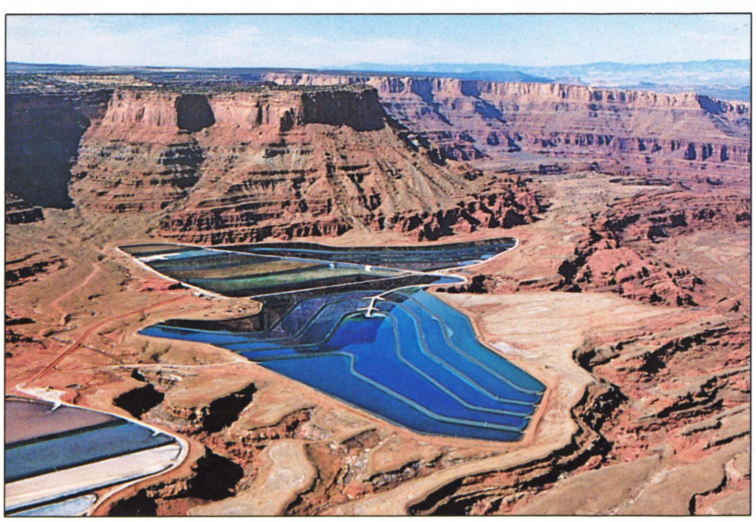
Evaporites
Potash · Gypsum · Brine

Texasgulf potash plant adjacent to the Colorado River. Triassic rocks form the cliffs behind the plant.

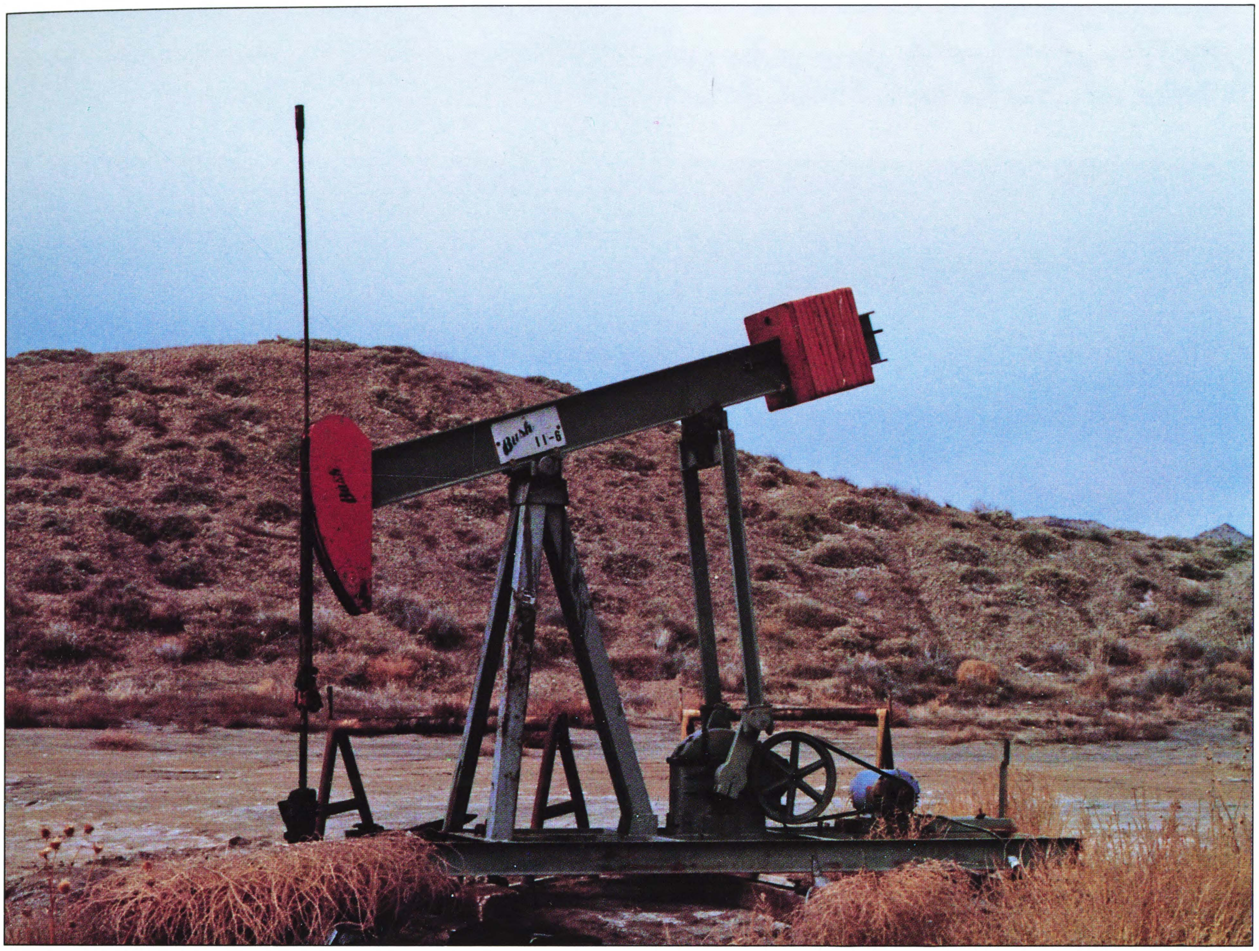
Potash produced in Grand County is extracted from the Paradox Formation, the principal minerals are sylvite (KCl) and carnallite ($K,MgCl_3 \cdot 6H_2O$). During Pennsylvanian time (about 300 million years ago) southern Grand County was part of the ancient Paradox Basin in which these minerals, plus halite (salt), gypsum, anhydrite, and other evaporite minerals, were deposited. As water evaporated, the minerals precipitated and were deposited as extensive beds on the basin floor. Geologists recognize 29 cycles of widespread evaporation in the Paradox Basin sediments, and 18 of these contain potash minerals. These evaporite beds have been thickened in salt anticlines due to salt flowage, and the potash reserves are considered huge.

At the Texasgulf Inc. Cane Creek mine, about 7 miles southwest of Moab, solution mining is utilized to extract the potash minerals. Fresh water is pumped from the Colorado River to the potash horizon about 2500 feet below the surface, flows through old underground mine workings and dissolves the potash minerals. The solution is then pumped to solar evaporation ponds on the surface, where controlled evaporation yields the brines that are fed to the processing plant.

Potash is used in fertilizer, chemicals, pharmaceutical products, and it has many other uses. Brine, produced by dissolving salt from the Paradox Formation, has been used as drilling fluid for petroleum wells. Small amounts of salt have been produced and used for de-icing roads. Experimental work continues which may eventually allow magnesium metal to be extracted from the brines.



Solar evaporation ponds at the Texasgulf Cane Creek potash mine.



Producing oil well in the Greater Cisco oil and gas field.

Grand County is rich in petroleum resources which occur as oil, natural gas, tar sand, and oil shale. The map on the back cover shows the locations of major fields and deposits. Grand County, which has produced more than 4,310,000 barrels of oil (a barrel is equivalent to 42 gallons), is the sixth largest producer in Utah. The county has yielded more than 201,000,000 cubic feet of natural gas, giving it a solid fifth place. In addition, carbon dioxide has been commercially produced in conjunction with gas production. Tar sand and oil shale deposits have not been developed but vast reserves have been documented. There are 23 identified oil and gas fields and 461 producing wells (as of November, 1986) in the county.[1] Of these, two fields, the Salt Wash and the Greater Cisco, account for 57% of the total cumulative yield. The San Arroyo and the Westwater fields have produced 61% of all natural gas. Although producing fields occur in most areas of the county, most of the production comes form the northeastern part.

The petroleum resources originated primarily in three important formations, the Pennsylvanian Paradox Formation, the Cretaceous Mancos Shale, and the Green River Formation of Eocene age, horizons of which contain in excess of 10% organic material by volume. The oil and gas is generated through a complex process involving heat, pressure, and time, after which it migrates through permeable rock until it either escapes to the surface or is trapped and concentrated in "reservoir rock." Most commonly, the reservoir is porous rock such as sandstone or fractured limestone which is overlain by an impervious seal such as shale. Folds and faults, most created by movement of underlying salt, form most traps in Grand County. The Green River Formation contains all the oil shale in the county. Oil shale is a unique type of source rock in which the organic materials have not yet been converted to petroleum. The stratigraphic chart on the inside front cover indicates important reservoir and source rocks.

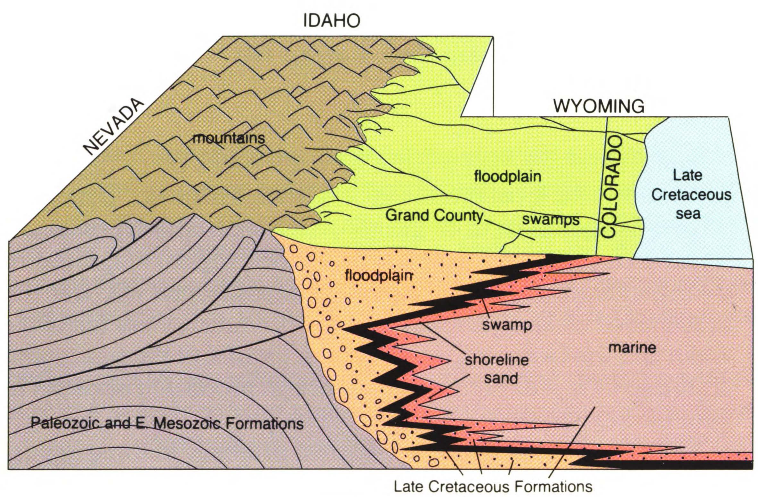
[1]Utah Department of Natural Resources, Division of Oil, Gas, and Mining Production Report, November 1986.

Petroleum Resources

Coal Resources

Chesterfield coal seam in Thompson Canyon.

Idealized diagram and cross section depicting Utah as it appeared during the Late Cretaceous about 65 to 100 million years ago when 5,000 to 10,000 feet of floodplain to marine sediments were shed from mountains to the west. The entire thickness on the right half of the diagram represents the Cretaceous formations shown on the lithologic column (inside front cover)..



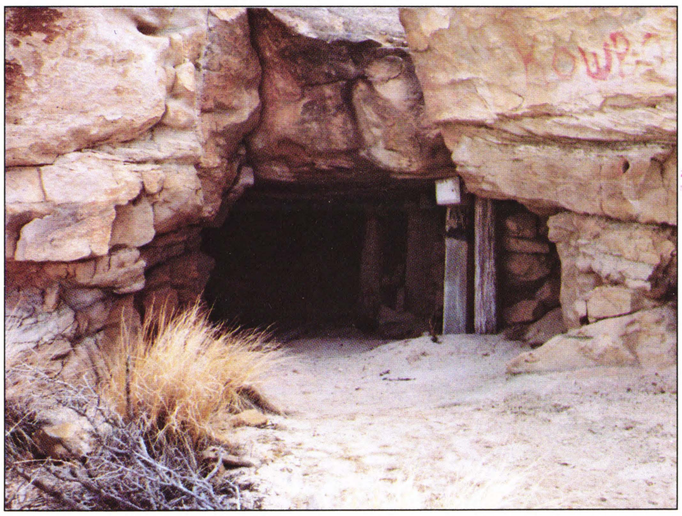
The Sego coal field, in the northern third of Grand County, is the seventh largest coal field in Utah. An identified resource of about 293 million tons occurs in beds greater than four feet thick and with less than 3000 feet of overburden[1]. The figure triples if overburden and seam thickness are not considered. The best coal occurs in the area north of Thompson where beds locally are more than seven feet thick. Several profitable mines have operated in that area since 1900, with most of the coal going to power the steam locomotives on the nearby railroad which passed through Thompson. From 1914 to 1930 production averaged about 100,000 tons a year. Mining continued until about 1954 when the conversion to diesel-powered engines marked the end of the need for railroad coal.

Most Sego coal seams are thin, usually less than 6 feet. The coal is high in heat value, low in sulfur content, but is high in ash. The coal beds are often split with sandstone or shale partings. The Sego coal field is presently inactive but it is likely that it will "boom" once again.

Coal seams occur in three major coal zones in the Cretaceous Neslen Formation. In addition, the Blackhawk, Castlegate and Dakota Formations have thin seams that reach thicknesses of about two feet. The Neslen coal originated in coastal and lower flood-plain swamps that bordered a shallow ocean which covered the area 75 to 85 million years ago. To the west were highlands from which numerous small to medium-sized rivers flowed. Lush vegetation collected in the stagnant swamp waters, building up thick peat beds. These were buried under thousands of feet of sediment for millions of years and were compressed into the coal beds we find today.

[1]Central Utah Coal Fields, Monograph Series No. 3, Utah Geological and Mineral Survey, 1972.

Uranium mill at north end of Moab Valley.

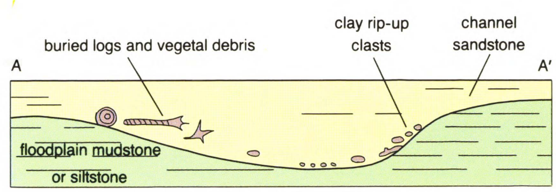


Typical uranium mine adit entering at base of mineralized sandstone channel.

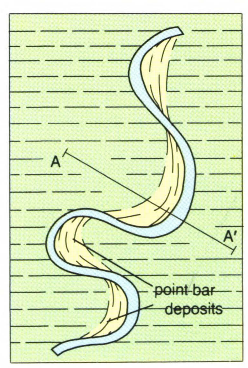
Gravel screening device and sluice box used for gold concentration along the Green River.

Uranium, vanadium, copper, manganese, and gold have been economically produced in Grand County, but uranium and vanadium have been the most important in terms of value. Grand County mines were active in 1912 for radium, in 1935 for vanadium, and after 1945 for both uranium and vanadium. During the uranium "boom" of the early 1950s, tens of thousands of uranium claims were staked each year. The prime districts were Gateway (Polar and Beaver Mesas), Seven-mile, and Thompsons (Yellow Cat). Uranium minerals replace, impregnate, or coat the sandstone host rocks in the Salt Wash Member of the Morrison Formation and in the basal sandstone of the Chinle Formation. The mineralization, brought in by ground water, was concentrated where logs, branches, and other vegetal debris were incorporated at the bottoms and sides of paleo stream sandstone channels. Grand County's past ore production has been significant, and generous minable reserves are still to be found and exploited.

Small quantites of copper and manganese have also been mined from the Morrison Formation of Grand County. Small nuggets and flour gold have been found in the gravels of the Colorado River and its principal tributaries. Gold has also been produced from small mines in the La Sal Mountains.



Cross-sectional view of paleo-channel deposit.



Plan view of ancient meandering stream. Logs and vegetal debris were more likely to be deposited in point bars.

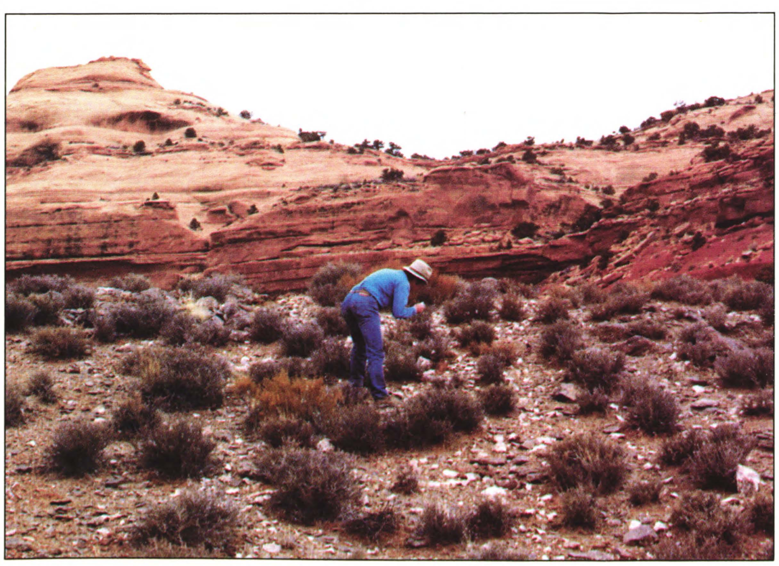
Minerals

Geologic Wonders

Distorted and convoluted beds adjacent to a major east-west normal fault near Crystal Geyser.

Grand County is widely known for its abundance of scenic and geologic wonders. They can be seen in all parts of the county and range from miniature erosional features and small mineral crystals to famous arches, deep canyons, precipitous cliffs, mountains, collapsed salt anticlines, entrenched river meanders, large faults, uplifts, synclines, geysers, and salt diapirs. Diverse processes have operated throughout geologic time to form these wonders. The rocks are textbooks used to learn of the past and how it has made Grand County what it is today.

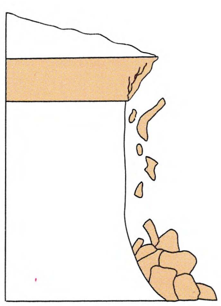
Rockhounding



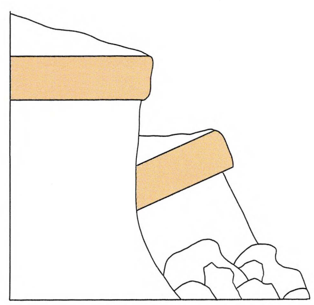
Many geologic processes have operated in Grand County to form the various minerals and rocks of the area. Several formations contain cryptocrystalline quartz (agate, jasper, and chert) which can be polished for bookends and other decorative items. Ornamental gypsum and anhydrite are often exposed in salt anticlines. Petrified wood is found in the Chinle Formation and Salt Wash Member of the Morrison Formation. Silicified dinosaur bones are found in the Brushy Basin Member of the Morrison Formation. Amethyst has been found in the La Sal Mountains of Grand County.

Cryptocrystalline quartz at the upper contact of the Uncompahgre complex. Overlying stratigraphic units are Chinle Formation and Wingate Sandstone.

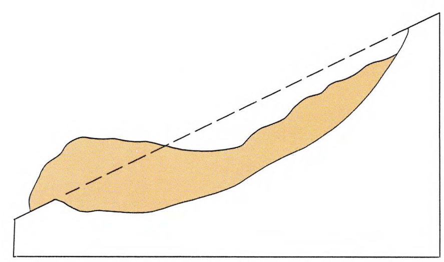
Rockfall is a geologic hazard. Large boulders may fall, slide, or roll hundreds of feet downslope.



Rockfall



Toreva block slide



Rotational slide

The main geologic hazards in the county are: (1) mass movements, including rockfalls and landslides of all types, (2) flooding and erosion, including flash floods, and (3) swelling and shrinking rocks and soils.

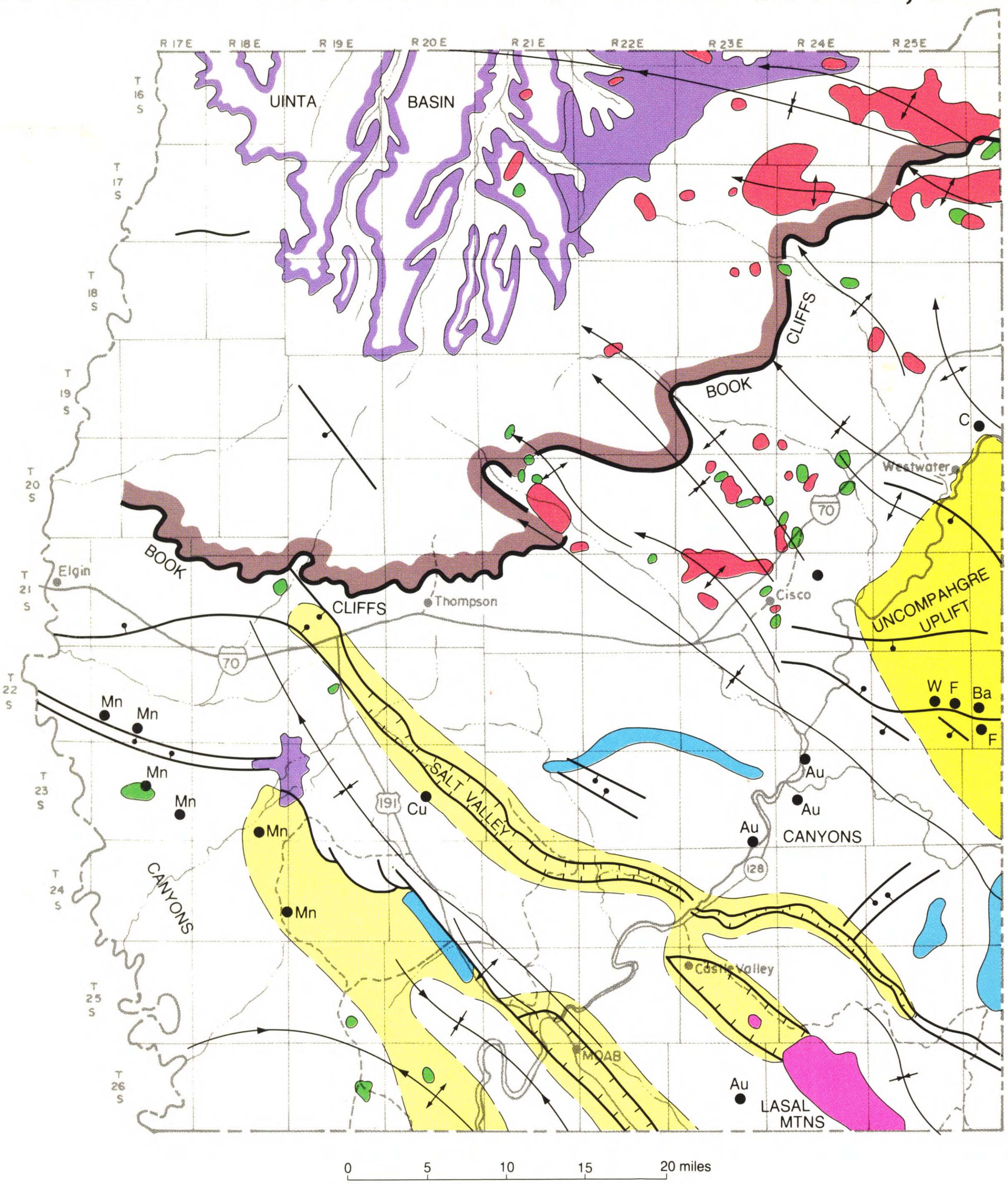
Many of the canyons and valleys in the county have steep bedrock and talus-covered sides. Weathering of the bedrock, precipitation, freeze and thaw, ground water, and other causes can trigger rockfall and landslides. Occasional flooding and erosion by rivers and streams during the spring snowmelt is a costly problem especially during unusually wet years.

Locally intense rainfall associated with summer thunderstorms produces damaging flash floods along dry washes, stream channels, and floodplains. Flash floods can arise in, or issue from, any canyon. Swelling or shrinking soils are found in the Mancos Shale, the Brushy Basin Member of the Morrison Formation, the Chinle Formation, parts of the Moenkopi Formation and derived soils. The expansive clayey shales and clayey mudstones in these units pose undesirable construction, foundation, and maintenance problems unless special engineering design features are incorporated into project plans and specifications.

Historically, only a few minor earthquakes have been felt in Grand County. The Utah State Building Code seismic zone map places the county in zone 1, the lowest earthquake risk zone in Utah.

Geologic Hazards

STRUCTURE AND RESOURCE MAP OF GRAND COUNTY, UTAH



STRUCTURAL FEATURES

- Fault, bar and ball on downthrown block
- Collapsed salt anticline
- Anticline showing plunge direction
- Syncline showing plunge direction
- Igneous intrusion
- Uncompahgre Uplift
- Coal outcrop, color on down-dip side
- Oil shale outcrop

RESOURCES

- Tar sands and oil shale
- Gas field
- Oil fields
- Area with important uranium-vanadium
- Potash, brines, Mg salts, gypsum (at reasonable depths)
- Minor commodity locations
  Mn=manganese, Cu=copper, Au=gold, W=Tungsten, F=Fluorspar, Ba=Barite, C=Chalcedony