



Green River Overlook, Island In The Sky District, Canyonlands National Park, Southeastern Utah

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Cover Image: View to the southwest from the Green River Overlook.

INTRODUCTION

The stream is still quiet, and we guide along through a strange, weird, grand region. The landscape everywhere, away from the river, is of rock—cliffs of rock, tables of rock, plateaus of rock, terraces of rock, crags of rock—ten thousand strangely carved forms; rocks everywhere, and no vegetation, no soil, no sand. In long, gentle curves the river winds about these rocks.

These are the words Major John Wesley Powell (figure 1) used to describe what is called Stillwater Canyon along the Green River on July 17, 1869, on his way to the Grand Canyon during his famous journey exploring the canyons of the Colorado River and its tributaries (Powell, 1895). This same region is spectacularly displayed from the Green River Overlook in the Island in the Sky District of Canyonlands National Park (figure 2). The exposed rocks consist of Early Permian- (299 million years ago [Ma]) through Early Jurassic-age (176 Ma) rock layers that were uplifted and subjected to massive erosion. Changes in the color, thickness, and composition of the rock layers and erosive work of running water and gravity (i.e., mass wasting) created the magnificent landscape seen at the overlook today.



Figure 1. Major John Wesley Powell with Tau-gu, a Southern Paiute guide; circa 1873. Photo courtesy of the National Park Service.

The primitive and remote Maze District of Canyonlands National Park is the area west of the Green River. Prominent features viewed in the Maze District from the Green River Overlook include Ekker Butte, Turks Head, Elaterite Butte, and the Orange Cliffs (figure 2). On a clear day, the 11,000-foot (3350 m), Henry

Mountains, which are cored by volcanic remnants (laccoliths) can be seen to the southwest. The Green River Overlook is one of Utah's most iconic views, often appearing on book covers, scenic calendars, and postcards, and therefore it is fitting as a geosite for its beauty and the exposures of rocks that so much impressed John Wesley Powell over 150 years ago.

HOW TO GET THERE

The Island in the Sky District of Canyonlands National Park is about 250 miles (400 km) or a little less than 4-hour drive from Salt Lake City, Utah, via Interstate 15 (I-15), U.S. Highway 6, I-70, and U.S. Highway 191; 30 miles (48 km) or about 45 minutes if coming from the town of Moab, Utah. Turn west onto State Highway 313 and continue to Canyonlands National Park (figure 3), at which point the road becomes Grand View Point Road, proceeding through the entrance station (fee required) to the junction with Upheaval Dome Road, a total of 28 miles (45 km). Turn right onto Upheaval Dome Road and then left after 0.3 miles (0.5 km) onto Green River Overlook Road proceeding 1.4 miles (2.3 km) to the parking lot for the overlook (restroom facilities, camping, and picnic grounds are available). A short walk along a flat, paved sidewalk leads to the overlook, 38°22'38" N., 109°53'19" W., elevation 6000 feet (1829 m). A wooden guard fence separates the view area from dangerous sheer cliffs.

STRATIGRAPHY AND DEPOSITIONAL HISTORY

Consolidated sedimentary rocks seen in the vistas from the Green River Overlook include strata of Early Permian to Early Jurassic age (299–176 Ma) (figures 2, 4, 5, and 6). These strata have a cumulative thickness of 3000 feet (900 m) (Hintze and Kowallis, 2009).

Permian Rocks

The Permian section viewed from the Green River Overlook is part of the Cutler Group (figure 5). Northeast of the Island in the Sky District of Canyonlands National Park, equivalent rocks represent a thick sequence of conglomeratic, arkosic alluvial-fan sediments deposited in front of the Pennsylvanian-Permian-age Uncompahgre Highland to the northeast. These strata grade southwest into the fluvial, coastal dune, and tidal flat deposits exposed in Canyonlands. Two units are viewed from the Green River Overlook—the Lower Permian (299–271 Ma) Organ Rock Formation and White Rim Sandstone.

Organ Rock Formation

The Organ Rock Formation consists of reddish-brown fine-grained to silty sandstone, sandy shale, and minor siltstone (figure 2). It is medium to thick bedded and forms steep slopes to ledgy cliffs. The Organ Rock represents a floodplain depositional environment that was near the edge of a large dune field (figure 7A).

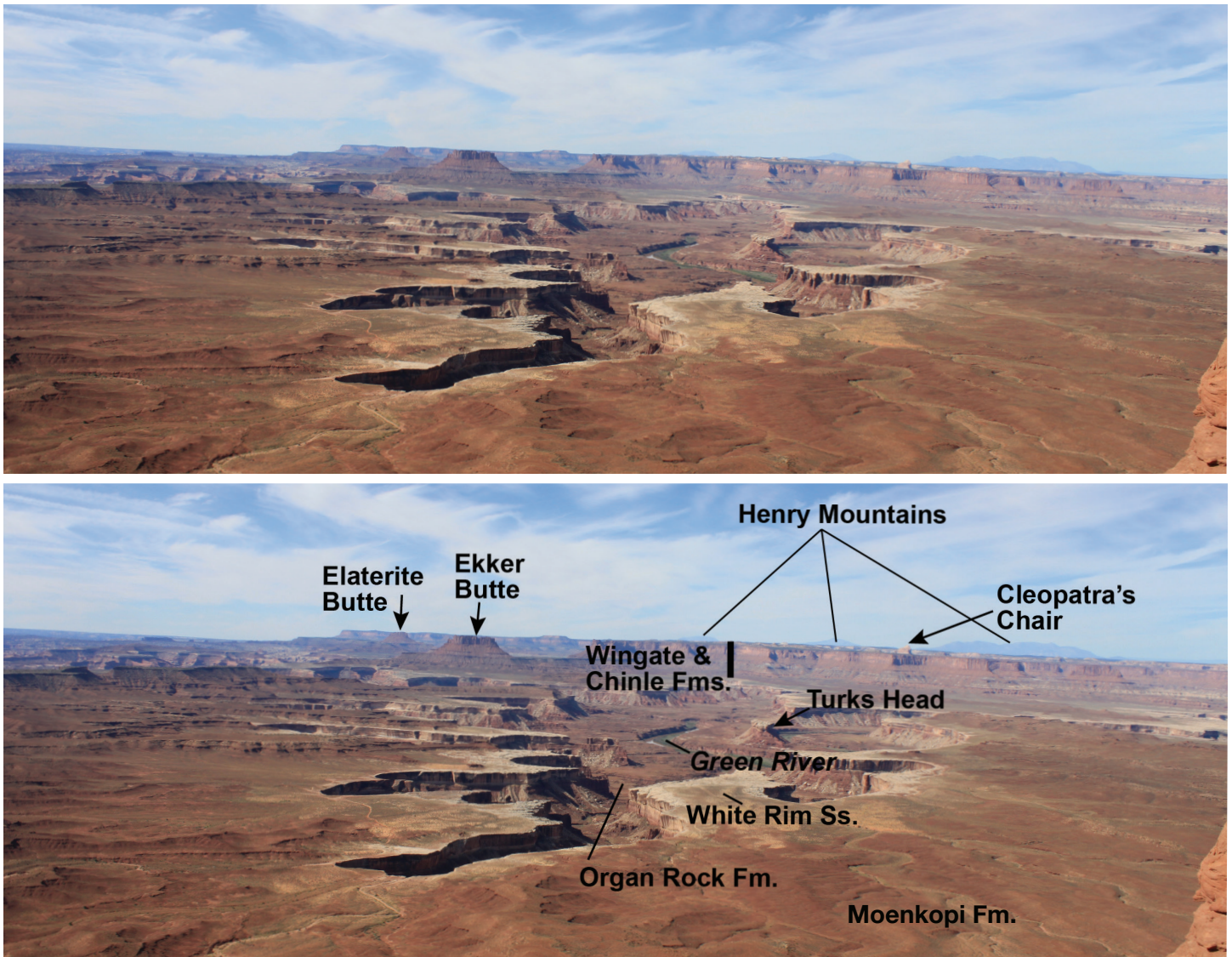


Figure 2. View to the southwest from the Green River Overlook; unannotated (A) and annotated (B). The Green River can be seen in the center distance flowing through Stillwater Canyon with the Permian Organ Rock Formation at river level. The deeper canyon is rimmed by the prominent Permian White Rim Sandstone, whose name best describes the formation in outcrop. The highly eroded red-brown Triassic Moenkopi Formation is extensively exposed in the foreground whereas the far distant cliffs display outcrops of the Triassic-Jurassic Wingate Sandstone. The faint outlines of the laccolithic Henry Mountains can be seen in the very far distance on clear days. Photo courtesy of Richard Emerson.

The upper contact of the Organ Rock strata with the overlying White Rim Sandstone is sharp and conformable. The Organ Rock ranges in thickness from 200 to 400 feet (60–120 m) in the Island in the Sky District (Hintze and Kowallis, 2009).

From the Green River Overlook, the Green River cuts through the Organ Rock formation in Stillwater Canyon (figures 2 and 3). The softer units within the Organ Rock cause the canyon to widen as the Green River meanders through it.

White Rim Sandstone

The White Rim Sandstone forms the prominent white rim cliff around the Island in the Sky District and is the surface of the popular biking trail by the same name (figure 2). The White Rim is a fine- to medium-grained quartzose sandstone exhibiting both

planar and cross-stratified beds. The upper section is a reworked marine unit whereas the lower unit is eolian dominated large-scale cross-stratification. The White Rim formed as a near-shore, beach, back-beach deposit, and as coastal dunes (figure 7B). The White Rim Sandstone is up to 250 feet (76 m) thick, thinning to the northeast and pinching out below Dead Horse Point (see figure 4 in the Dead Horse Point geosite, this volume).

The upper contact of the White Rim Sandstone strata with the overlying Triassic beds is sharp, marked by local scouring and channeling and is unconformable. In most cases the plane of unconformity appears flat. The unconformity is regional and indicates a period of non-deposition lasting at least 30 to 35 million years (Doelling and others, 2010).

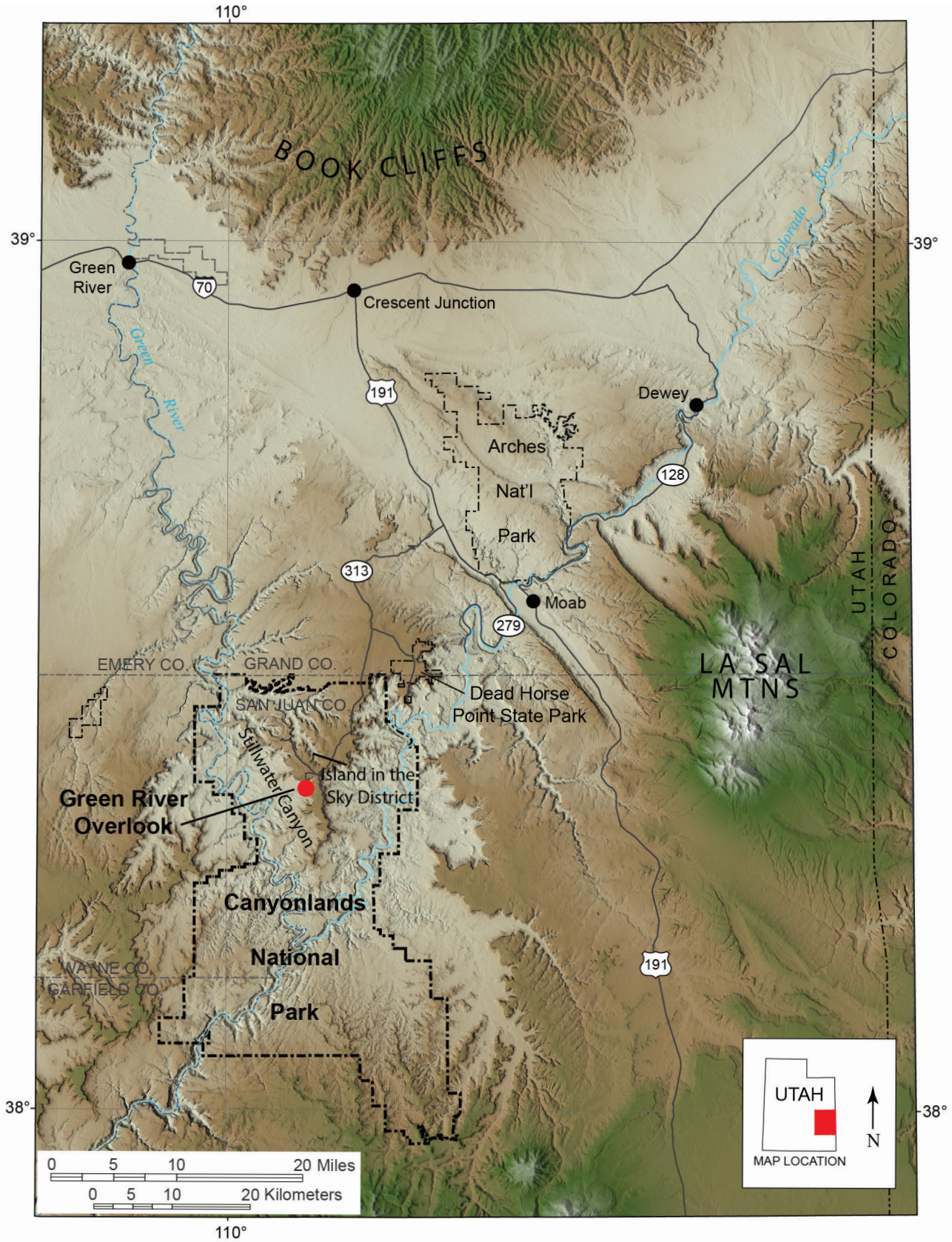


Figure 3. Canyonlands National Park and vicinity, southeastern Utah, showing the location of the Green River Overlook geosite and Stillwater Canyon as well as surrounding parks, towns, and highways.

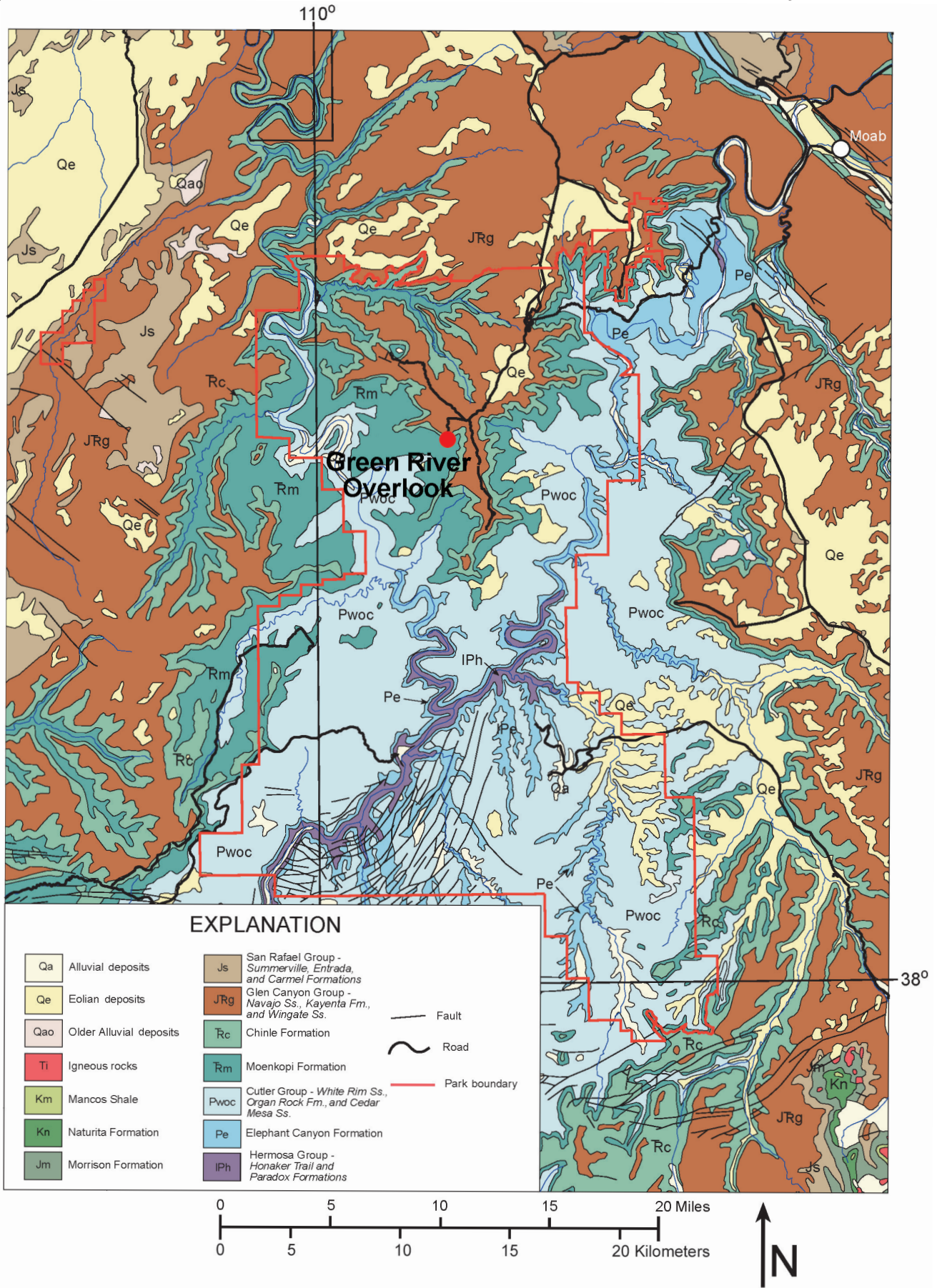


Figure 4. Geologic map of Canyonlands National Park and surrounding areas. Modified from Hintze (1980), Hintze and others (2000), and Baars (2010).

		Age	Formation	Map Symbol	Thickness in feet	Lithology	Environment
Rocks viewed from the Green River Overlook		Quaternary	alluvium	Qa, Qe, Qao	0–100	River gravels; dune sand	
		Oligocene	Henry/Abajo Mountains laccoliths	Ti	not bedded	28–24 million-year-old intrusions of diorite	
	Jurassic	Glen Canyon Group	Navajo Sandstone	JNg	300–700	Petrified sand dunes; cross-bedded, jointed, forms domal beehive landforms	Eolian erg
			Kayenta Formation		100–300	Interbedded sandstone and shale; forms tree-covered bench above Wingate sandstone cliff	River and floodplain
			Wingate Sandstone		250–400	Red sandstone; forms vertical cliffs	Eolian
	Triassic	Chinle Formation	Tc	360–800	Red and varicolored shale; locally contains uranium	River floodplain and lakes	
		Moenkopi Formation	Tm	140–400	Red sandstone, siltstone, and shale; bedding planes show ripple marks	Tidal flat	
	Permian	Cutler Group	White Rim Sandstone	Pwoc	0–250	Thin, white sandstone; forms a rimrock west of Dead Horse Point	Coastal dune
			Organ Rock Shale		200–400	Reddish-brown shale found in the southern part of Canyonlands but not present in the northern part	Floodplain
			Cedar Mesa Sandstone		300–1000	White to pale-red, cross-bedded sandstone; forms rugged cliffs and canyons in the southern half of Canyonlands; equivalent beds in the north are red Cutler rocks	Eolian
		Elephant Canyon Formation	Pe	400–1200	Gray, cherty limestone and dolomite interbedded with sandstone, siltstone and gypsum. Named from Elephant Canyon near the Colorado/Green River confluence	Interfingering back beach, marine, and alluvial fans	
	Pennsylvanian	Hermosa Group	Honaker Trail Formation	Iph	500–1500	Dark-gray, cherty limestone with interbeds of shale and sandstone; forms ledges and slopes; contains fossil seashells	Shallow marine
Paradox Formation			up to 14,000		Salt, gypsum, and anhydrite interbedded with black shale and limestone; exposed at Cataract Canyon where dissolution of the salt has induced subsidence and riverward slumping, creating The Grabens fault blocks	Shallow restricted marine	

Figure 5. Stratigraphic column of exposed rocks in Canyonlands National Park and surrounding areas. Note the section viewed from the Green River Overlook. Modified from Hintze (2005).

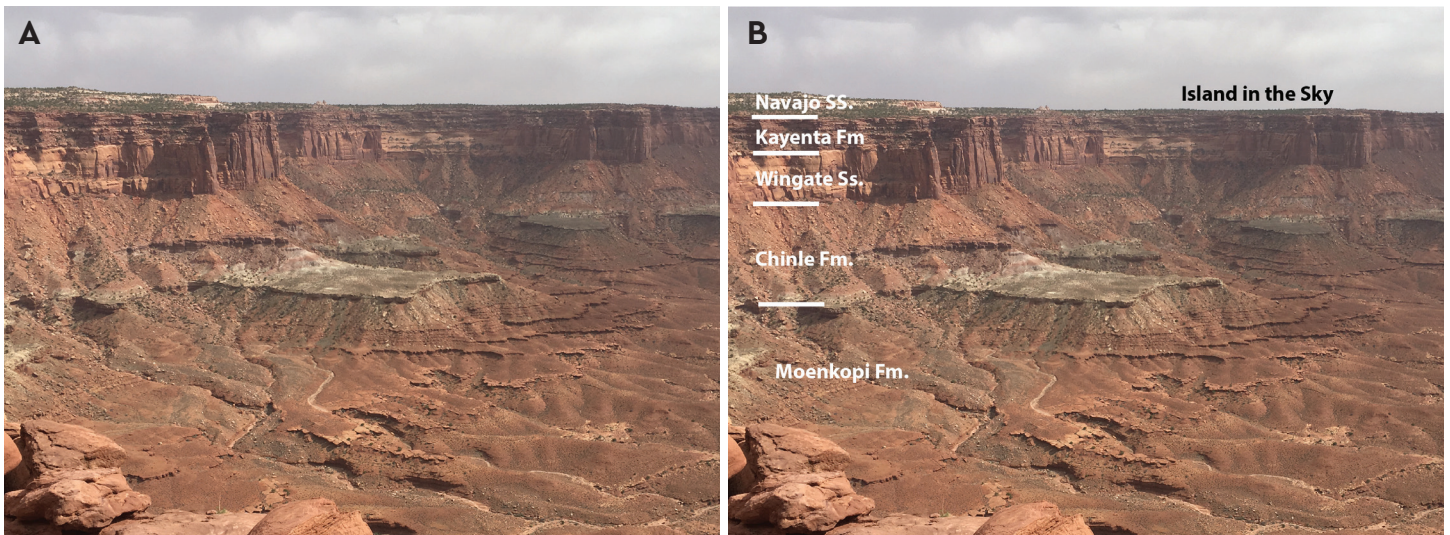


Figure 6. View to the southeast from the Green River Overlook; unannotated (A) and annotated (B). The fluvial Jurassic Kayenta Formation forms the ledgy rim of the overlook followed down section by the massive, vertical cliffs of the eolian Triassic-Jurassic Wingate Sandstone overlying the slope-forming Triassic Chinle and Moenkopi Formations representing fluvial/floodplain and tidal-flat deposition, respectively. A small section of the eolian Lower Jurassic Navajo Sandstone can be seen above the Kayenta in the far upper left of the photo.

Triassic Rocks

The Triassic Period in the Island in the Sky District is represented by the Moenkopi and Chinle Formations and the lower part of the Wingate Sandstone (figures 2, 4, 5, and 6). During Moenkopi time, the open sea or ocean retreated farther to the southwest and deposition was from sluggish streams migrating over broad tidal flats that were at or near sea level (figure 7C). During Chinle time, deposition was dominated by fluvial environments and the influence of the sea was gone (figure 7D). Moenkopi deposits were laid down approximately 245 Ma and again between 242 and 238 Ma and Chinle deposits were laid down from 220 to 215 Ma. Events occurring between Moenkopi and Chinle time are not recorded by rocks in this area. Sediments may have been deposited but later eroded during those 18 million years (Doelling and others, 2010). The top of the Triassic is within the Wingate Sandstone of the Glen Canyon Group and not at the base of the formation as once thought; the Triassic-Jurassic boundary is somewhere in the formation (see the Triassic-Jurassic section below).

Moenkopi Formation

The Moenkopi Formation represents a major change in environmental conditions from continental to marine and tidal flat. The basal section of the Moenkopi consists mostly of a chocolate-brown, fine-grained, poorly sorted, micaceous to sub-arkosic sandstone. It is poorly bedded and displays irregular to wavy laminae. The formation creates a steep slope in its lower part and a cliff in its upper part (figure 6). The middle section of the Moenkopi consists of chocolate-brown, thin- to medium-bedded siltstone slopes with numerous widely spaced, 1- to 10-foot-thick (0.3–3 m) sandstone ledges that display low-angle cross-stratification. Siltstone and shale beds display a plethora of ripple mark types. Ripple cross-stratification is particularly widespread. The uppermost section of the Moenkopi is a slope-forming unit consisting of homogeneous, gray-red to pale-red-brown siltstone, with widely spaced, thin (less than 3 feet [1 m] thick) sandstone ledges. The siltstone displays horizontal and ripple cross-lamination.

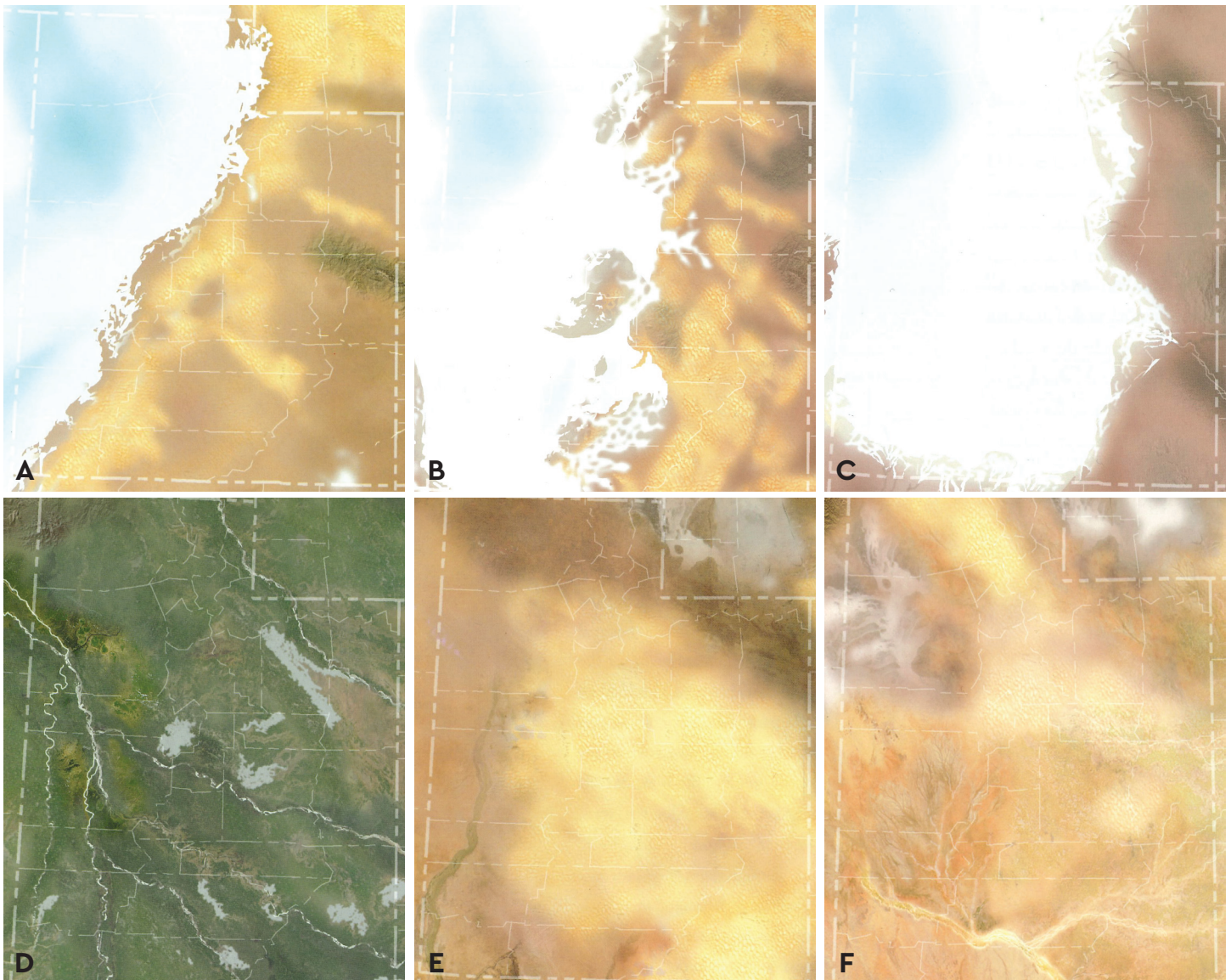


Figure 7. Paleogeographic maps of Utah during the: (A) Early Permian, Organ Rock Formation – 285 Ma; (B) late Early Permian, White Rim Sandstone – 272 Ma; (C) Early Triassic, Moenkopi Formation – 245 Ma; (D) Late Triassic, Chinle Formation – 215 Ma; (E) Late Triassic-Early Jurassic, Wingate Sandstone – 205 Ma; and (F) Early Jurassic, Kayenta Formation – 200 Ma. Modified from Blakey and Ranney (2008).

The contact with the overlying Chinle Formation is sharp and unconformable, but commonly poorly exposed. It is placed at the base of a distinctive white to mottled gritstone (figure 6), or between the gray-red or gray-green mudstone and siltstone of the lower part of the Chinle and the orange-red siltstones of the upper part of the Moenkopi.

Chinle Formation

The Chinle Formation is famous for its petrified wood, uranium in red-brown lenticular channel sandstone beds, and beautiful multicolored mudstone and shale derived from altered volcanic ash. The Chinle consists of complex interbedding and lensing arrangements of sandstone, pebble conglomerate, siltstone, mudstone, and rare limestone. The red-brown, tan, and gray-red sandstones are very fine to coarse grained, moderately to well sorted, quartzose, and slightly micaceous. Sedimentary structures include low-angle cross-stratification, horizontal stratification, asymmetric ripples, and channeling, all of which point to deposition in a floodplain having northwest-flowing river channels, adjacent oxbow lakes, ponds, and swamps (figure 7D). Pebble and intraformational conglomerates occur as lenses and in scour channels concentrated in the lower parts of sandstone beds. Siltstone is interbedded with the sandstones and conglomerates, and displays low-angle cross-stratification and ripple lamination. Mudstone is gray-red to gray-green, bentonitic, and poorly exposed.

White to variegated gritstone locally marks the base of the Chinle Formation (figure 6). The grit is poorly sorted and contains rounded to angular, coarse sand to pebble-size grains of quartz. Where variegated, the gritstone may represent a paleosol (ancient soil). Mudstones and siltstones dominate in the lower slope-forming section. Sandstones and conglomerate channels, when found in the lower slope-forming member, are locally mineralized with uranium, vanadium, and copper minerals. The lighter overall color of this lower section is caused by the reduced iron in this part of the formation (figure 6). This reduction of iron commonly extends as much as 3 feet (1 m) into the underlying Moenkopi Formation.

The middle section (Black Ledge Member) is dominated by red-brown sandstone and black, desert varnish-stained conglomerate (figure 6). The sandstones commonly contain scattered logs and branches of petrified wood. Lowermost lenses of sandstone are locally mineralized with uranium and copper minerals. The upper contact is gradational into the upper section (Church Rock Member).

The upper section is mostly a red-brown sandstone and siltstone (figure 6), but sandstone ledges are more common in the lower part. Some beds include distinctive ripple-laminated sandstone, but the bedding in much of this unit is indistinct. Blocky, red-brown, fine-grained, well-sorted, thick-bedded sandstone is common in the upper 10 to 30 feet (3–9 m) of the section.

The contact of the Chinle Formation with the overlying Wingate Sandstone of the Glen Canyon Group is sharp and conformable, commonly being placed below the massive cliff of well-sorted sandstone typical of the Wingate (figure 6). No regional channeling or angular unconformity is apparent, and the lowermost part of the Wingate does include thin, bedding-parallel sandstone and siltstone beds that suggest continuous deposition across the Chinle and Wingate contact. The Chinle and Wingate contact was once thought to represent an unconformity, named the J-0 unconformity, at the Triassic-Jurassic boundary (Pipiringos and O'Sullivan, 1978). However, the Wingate contains beds of both Triassic and Jurassic age (Molina-Garza and others, 2003; Lockley and others, 2004; Lucas and others, 2005). The J-0 unconformity, if it exists here, is within the Triassic and likely represents a short period of time (Doelling and others, 2010).

Upper Triassic-Lower Jurassic Rocks

The Upper Triassic-Lower Jurassic Wingate Sandstone is the prominent cliff below the Green River Overlook (figure 6). The Wingate forms red-brown, nearly vertical cliffs streaked and stained with desert varnish on weathered surfaces. The Chinle and Moenkopi slopes below the cliff are commonly littered with large blocks of the Wingate Sandstone (figure 6). The Wingate is ordinarily described as one massive unit because partings or bedding planes are rare except near the base of the formation. The Wingate consists mostly of light-orange-brown, moderate-orange-pink, or pale-red-brown, fine-grained, well-sorted, cross-stratified sandstone. The rock is usually well cemented and well indurated; weathered exposures are nearly smooth. Jointing and rockslides are common due to unstable swelling clays in the underlying Chinle Formation. The eolian Wingate was deposited in another great erg that extended from the Four Corners area to north-central Utah (figure 7E), as indicated by the high-angle cross-stratified sandstone. However, bedding-parallel sandstone beds near the base of the formation suggest that fluvial processes were still a large part of its early depositional history (Doelling and others, 2010).

The Wingate Sandstone ranges in thickness from 250 to 400 feet (60–120 m) in the Island in the Sky District (Hintze and Kowallis, 2009). The contact of the Wingate Sandstone with the overlying Lower Jurassic Kayenta Formation is generally sharp and conformable as seen from a distance, but difficult to place close-up. Generally, the line is placed at the horizon where the smooth cliff is replaced by thick cliffy ledges (figure 6).

Lower Jurassic Rocks

With the exception of the modern (Quaternary) unconsolidated sediments, Lower Jurassic strata form the top of the geologic column at the Green River Overlook (figures 5 and 6). These strata include the upper part of the Wingate Sandstone, Kayenta Forma-

tion, and Navajo Sandstone, and were deposited between 205 and 187 Ma. The Kayenta represents a floodplain environment (figure 7F) whereas the Navajo a sand-dune desert. A few sandstone beds in the upper Kayenta were also deposited by wind.

Kayenta Formation

The Kayenta Formation caps most of the upper benches at the Green River Overlook; the viewpoint is located on this unit (figures 4 through 6); it is rarely completely exposed. The Kayenta consists mostly of stream-deposited sandstone lenses, with lesser amounts of eolian sandstone, intraformational conglomerate, siltstone, and shale. The unit is primarily red-brown, but individual lenses and beds vary considerably in color; some are purple, lavender, tan, orange, or white. In outcrop, the Kayenta is ledgy and step-like (figure 6). Sandstone in the Kayenta exhibits both high-angle and low-angle cross-stratification. Some lenses display channeling, current ripple marks, and rare slump features. The grain size is more variable than in the Wingate and Navajo, ranging mostly from fine to medium. Siltstone, shale, and intraformational conglomerate appear as partings or are interlayered with the sandstone.

The Kayenta Formation was deposited in a sandy braided river system although the environment was arid. Perennial streams flowed west from the remaining Ancestral Rockies (figure 7F) and the Appalachians far to the east (Lynds and Hajek, 2006; Blakey and Ranney, 2008). Floodplains (overbank deposits) formed adjacent to active channels.

The Kayenta is 100 to 300 feet (30–90 m) thick in the Island in the Sky District (Hintze, 2005). The upper contact is mostly sharp, but intertonguing between the Kayenta and the overlying Navajo Sandstone is common. However, this contact is only observed in a few places in this area (Doelling and others, 2010).

Navajo Sandstone

The Navajo Sandstone is mostly seen as cliffy to rounded bare-rock exposures (figure 6). The Navajo is a mostly orange to light-gray, mostly fine grained, generally well-sorted, massive sandstone. High-angle, cross-stratified laminae lie as much as 30 degrees from the true attitude of the unit. Navajo cross-beds etch out in relief in contrast to the smooth-weathering habit of the Wingate Sandstone. The top of the Navajo is not exposed in the Island in the Sky District. The eolian Navajo is a classic example of a major Sahara-like erg environment.

STRUCTURAL AND GEOLOGIC HISTORY

Regional Setting

Canyonlands National Park is located in the Paradox Basin of southeastern Utah and southwestern Colorado. The basin is an elongate, northwest-southeast-trending evaporitic basin that

predominantly developed during Pennsylvanian (Desmoinesian) time about 330 to 310 Ma. During the Pennsylvanian, a pattern of basin and fault-bounded uplifts developed in the area of what is now Utah to Oklahoma. This pattern included the Uncompahgre Highland of eastern Utah and western Colorado and the adjacent Paradox Basin. Rapid basin subsidence, particularly during the Pennsylvanian and into the Permian, accommodated deposition of large volumes of deeper basin evaporite and marine sediments which intertongue with basin-margin, non-marine arkosic material shed from the mountain area to the northeast (Hintze and Kowallis, 2009). Later, the Uncompahgre Highland was eroded down during the Triassic and Jurassic. The area was uplifted again during the Late Cretaceous (about 70 Ma) and early Tertiary (about 40 Ma) Laramide orogeny (a regional mountain-building event) to form the Uncompahgre uplift observed today (Hintze and Kowallis, 2009 and references therein). The region continued to lie near sea level, but received continental deposition through Early Jurassic time. Because no bedrock units younger than the Early Jurassic Navajo Sandstone are present in the Island in the Sky District and surrounding area, no record exists here of the geologic events that happened in the interval from 187 to 1.5 Ma. The area likely received continental deposition during the remainder of the Jurassic and the Early Cretaceous and shallow-marine deposition during the Late Cretaceous, as attested in surrounding areas.

Late Cretaceous–Early Tertiary Uplifts and Intrusions

Large uplifts and basins developed in the Colorado Plateau during the Laramide orogeny between the latest Cretaceous (Maastrichtian, about 70 Ma) and the Eocene (about 38 Ma). The Island in the Sky District is located on the northern end of the broad Laramide-age Monument uplift, which is responsible for exposing the impressive stratigraphic section and the incredible view at the Green River Overlook (figures 2 and 8). Other nearby Laramide features include the San Rafael Swell to the west, the Circle Cliffs uplift and Henry Mountains basin to the southwest, the Uinta Basin to the north, and a rejuvenated Uncompahgre uplift to the northeast (figure 8). The regional dip of strata in the Island in the Sky district is 2° to 4° northward.

The Henry Mountains (figure 2), on the horizon to the southwest, are the type locality for laccolithic intrusions as first described by the famous geologist G.K. Gilbert (1877). The Henry Mountains are a chain of five dome-shaped peaks that represent a complex of granitic (granodiorite porphyry) rocks intruded into the Jurassic Morrison Formation and overlying Cretaceous formations about 28 to 25 Ma during the Oligocene (Doelling, 1975; Hunt, 1980; Nelson, 1998). Each mountain consists of a laccolith with multiple sills (Nelson, 1998). These peaks range from 7930 to 11,522 feet (2417–3512 m) above sea level and were glaciated during the Pleistocene ice ages (Hunt, 1980).

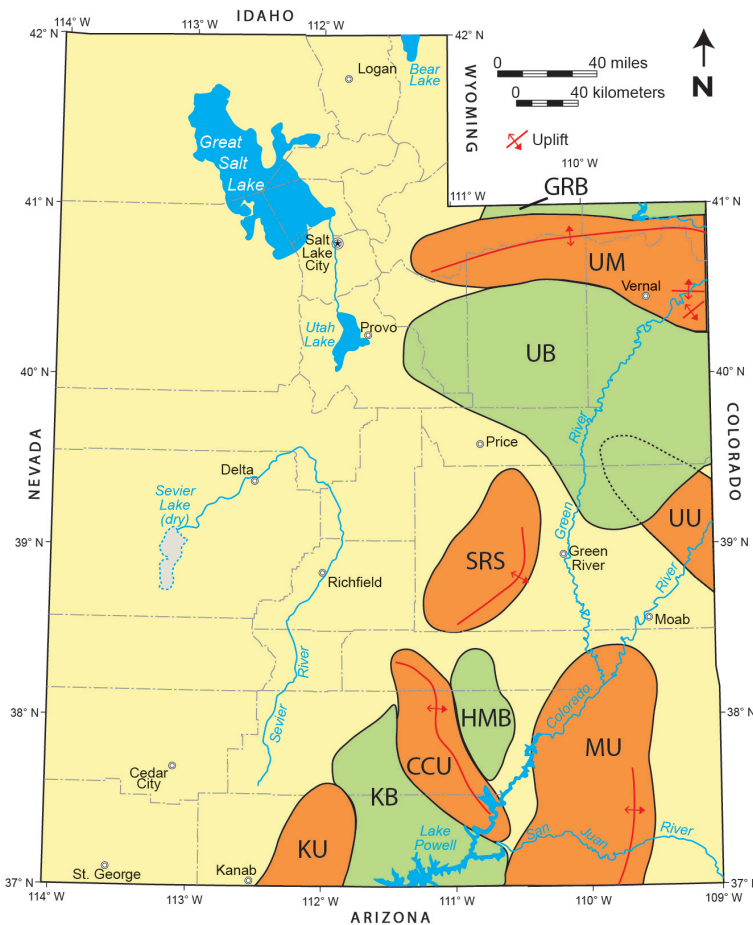


Figure 8. Major uplifts (orange) and basins (green) created during the Paleocene-Eocene Laramide orogeny. GRB = Green River Basin, UM = Uinta Mountains, UB = Uinta Basin, UU = Uncompahgre uplift, SRS = San Rafael Swell, KU = Kaibab uplift, KB = Kaiparowits basin, CCU = Circle Cliffs uplift, HMB = Henry Mountains basin, and MU = Monument uplift which, at the north end, includes the location of the Green River Overlook and the Island in the Sky District of Canyonlands National Park.

Late Tertiary–Quaternary Regional Uplift and Erosion

The Colorado Plateau began rising in late Cenozoic time during the Miocene epoch (23 Ma) (Hunt, 1956; Lucchitta, 1979; Hintze and Kowallis, 2009). This regional uplift changed the landscape from one of deposition to one of massive erosion. Several thousand feet of sedimentary rocks have been removed by the erosive processes of mass wasting, wind, and running water. Most of this material has been carried to the sea by the Colorado River system.

The Green and Colorado Rivers probably came into existence synchronously with the uplift of the Colorado Plateau. As the plateau rose, the rivers and their tributaries rapidly cut into the strata. The incision rate near the center of the Colorado Plateau (Lee's Ferry, Arizona) is calculated at about 35 centimeters per thousand years (14 in./k.y.) (Pederson and others, 2013). This incision produced Stillwater Canyon and the countless other smaller canyons visible from the Green River Overlook.

The Green River is classified as a superposed stream. It crosses structures formed long before it began to flow, such as Split Mountain to the north, east of the town of Vernal, Utah. When the Colorado Plateau rose, the ancestral Green River and its tributaries flowed through meandering channels in wide valleys on easily eroded rocks such as the now-removed Cretaceous Mancos Shale. Once these river channels were established, they later became superimposed and entrenched into resistant rocks such as the Wingate and Navajo Sandstones. When the Green River reached the softer sedimentary rocks of the Chinle and Moenkopi Formations, Stillwater Canyon widened until the river eroded down to the White Rim Sandstone. Again, the canyon likely narrowed before the river encountered the mudstone of the Organ Rock Formation near its current depth resulting in Stillwater Canyon widening, the process occurring today as observed from the overlook.

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