The Geology of Quail Creek State Park

by Robert F. Biek

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INTRODUCTION

The first thing most visitors to Quail Creek State Park notice, apart from the improbably blue and refreshing waters of the reservoir itself, are the brightly colored, layered rocks of the surrounding cliffs. In fact, Quail Creek State Park lies astride one of the most remarkable geologic features in southwestern Utah. The park lies cradled in the eroded core of the Virgin anticline, a long upwarp of folded rock that trends northeast through south-central Washington County. The fold is breached by erosion along its crest, creating a window into the geologic past.

Quail Creek State Park, looking south across the reservoir.

Through this "window" we can see not only colorful rock layers, but also the geologic history that these layers hold. Clues in the rock tell us of ancient landscapes, including a gently sloping coastal plain and tidal flats vastly different from the high deserts that characterize southwestern Utah today. Other clues point to the enormous compressional forces that folded and faulted the rocks during a mountain-building episode known as the Sevier orogeny, about 70 million years ago. Still other clues record a much more recent history, including the catastrophic failure of the Quail Creek south dike on January 1, 1989.

The old Harrisburg town site circa 1861, an early Mormon settlement, immediately west of Quail Creek State Park. The Pine Valley Mountains are in the distance.

While this booklet focuses specifically on the geology of Quail Creek State Park itself, the park is surrounded by a landscape of enormous geological and human interest. Long before Mormon pioneers settled this region, an Anasazi farming community occupied the area intermittently from about A.D. 600 to A.D. 1050. The remains of stone- and clay-lined rooms for storage of corn and other crops can be seen at the Red Cliffs Recreation Area, just west of Quail Creek State Park. Southern Paiute Indians lived in this area for hundreds of years before the first European explorers arrived in the 1700s, and the junction of Quail Creek and the Virgin River was an important crossroads for these Native Americans. In 1859, Mormon pioneers spent their first winter in this immediate area at a site called Harrisville, near the confluence of Quail Creek and the Virgin River. In 1861, they moved about two miles upstream on Quail Creek and established Harrisburg, where remains of early dwellings can still be seen. Due to insufficient water and arable land, most Harrisburg settlers moved about three miles north to establish Leeds in 1867.

In 1866, while traveling through the Harrisburg area, an itinerant prospector discovered high-grade silver ore in sandstone. The mineral occurrence - ore-grade silver in sandstone - was so unusual that he doubted his own findings and moved on to the silver boom town of White Pine, Nevada. Still, the Harrisburg area attracted him, and he returned and eventually established the first claim in 1871 in what was to become the Silver Reef mining district. In *Silver, Sinners, and Saints: A History of Old Silver Reef, Utah*, Paul Proctor and Morris Shirts provide a fascinating account of the discovery, disbelief, re-discovery, and development of this unusual mineral occurrence. The mining district, located immediately northwest and east of Quail Creek State Park, produced about 8 million ounces of silver prior to 1910, and sporadic production of silver, copper, gold, and uranium through the 1960s.

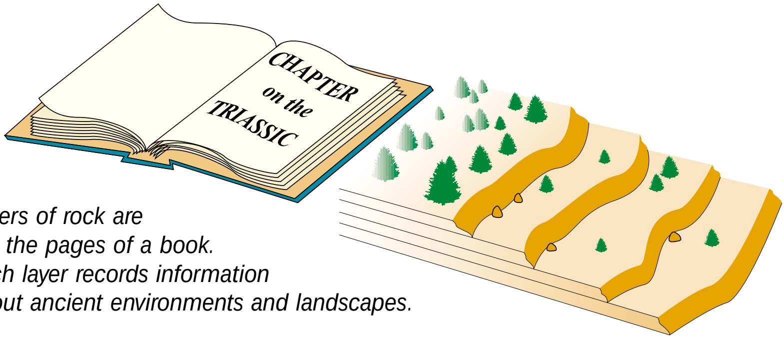
Although Quail Creek State Park is located in the middle of a truly exceptional geologic setting, the park may be best known for its fishing and boating. Trout, bass, crappie, bullhead catfish, and bluegill attract anglers from throughout the west, and its warm waters make for a swimmer's paradise. The reservoir itself is operated by the Washington County Water Conservancy District for storage of Virgin River water. At its maximum pool elevation of 2,985 feet, the lake covers 640 acres (one square mile) and stores 40,325 acre-feet of water. Most of the water is diverted from the Virgin River east of Hurricane and is piped to the reservoir; this is done in order to avoid the salty water discharge at Pah Tempe Hot Springs between Hurricane and La Verkin. The annual yield of the reservoir is about 20,000 acre-feet, an important part of the St. George basin water supply.

LAYERS OF ROCK

Regional Overview

Geologists often view the crust of the earth as a book. The story is not told in words and sentences, however, but in layers of rock that record geologic history. Each layer is like a page in a book. In southwestern Utah, one layer, or page, of the geologic book might tell us that several hundred thousand years ago, and perhaps as recently as 10,000 to 20,000 years ago, volcanoes erupted in the St. George area, producing lavas that cascaded over cliffs and flowed down valleys for miles; cinder cones can still be seen at these old volcanic vents. A much older, 200-million-year-old layer, which now forms the sheer walls of Zion National Park, shows that much of what is now Utah, including the St. George area, was once covered by Sahara-like sand dunes. Still another deeper layer, a 280-million-year-old limestone with fossil corals, clam-like brachiopods, and sea lilies, bespeaks of a long-vanished, warm, shallow, Caribbean-like sea.

The difference between a real book and the book of geology, however, is that in the latter many pages and even whole chapters are missing. The



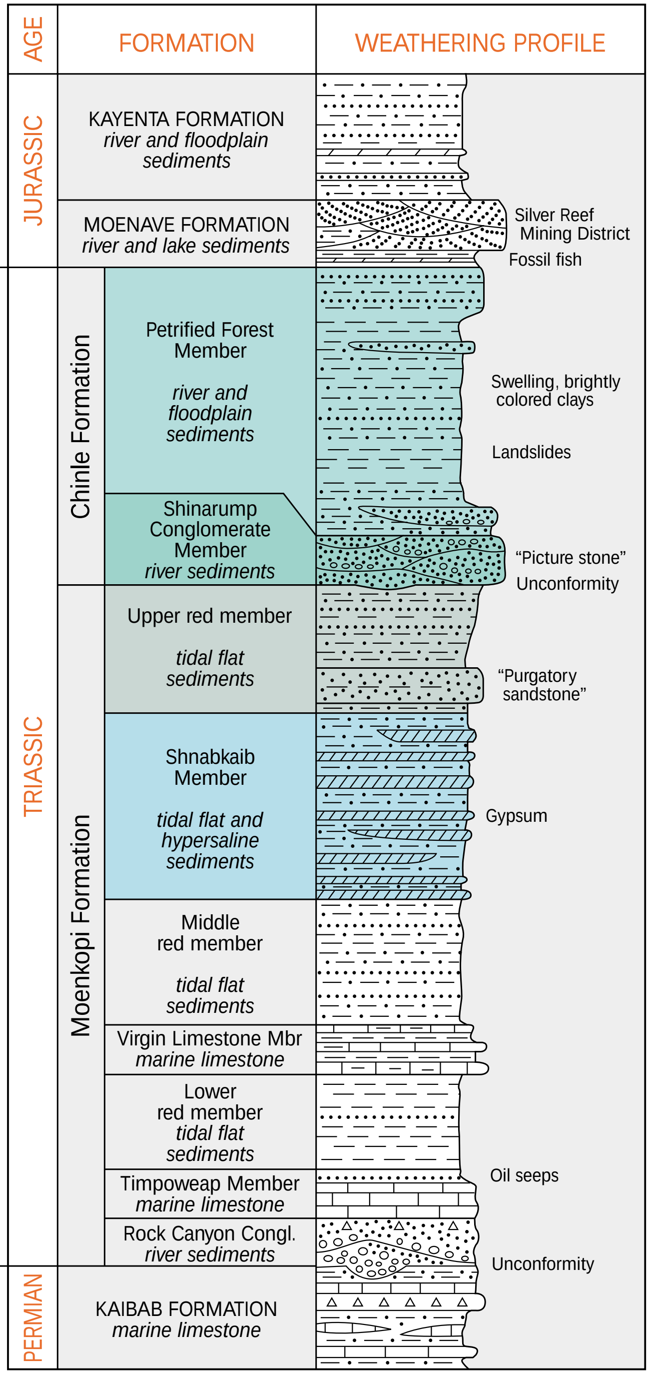
Layers of rock are like the pages of a book. Each layer records information about ancient environments and landscapes.

book of geology is perhaps better visualized as an incomplete diary, with many gaps in the record of continuous time. Sometimes sediments are not deposited, and sometimes existing layers are removed by erosion; either condition creates a surface denoting a gap in the rock record that geologists call an unconformity. The pages that remain can themselves be crinkled (folded) or torn (faulted); torn pages can be pushed together out of order (thrust faulted), in essence mixing up the page numbering sequence in our book. The book of geology has, by any librarian's standards, been horribly abused! Even so, it is a record that with careful observation can be pieced back together.

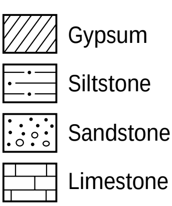
Geologists summarize the book of geology by using a stratigraphic chart, what you might call a table of contents. The pages, or rock layers, are grouped into chapters based on geologic time. One chapter, for example, is titled the Triassic Period (named after a three-fold division of rocks first studied in Germany), which marks the beginning of the era of dinosaurs. In southwestern Utah, the Triassic chapter contains a section called the Moenkopi Formation, which itself is divided into seven members, or subheadings, whose rock layers reveal a complicated series of sea-level rises and falls along a gently sloping continental margin. The numbers at the side of the chart tell us how long ago in millions of years each chapter began. The rock layers at Quail Creek State Park tell of a time when southwestern Utah resided near the western edge of North America, with a shallow sea to the west.

Moenkopi Formation

The oldest formation exposed at Quail Creek State Park, the Moenkopi Formation, is about 1,700 feet thick in this area, but only the upper two members - the Shnabkaib and upper red members - crop out in the park. The Moenkopi Formation is a thick sequence of mostly bright red layered

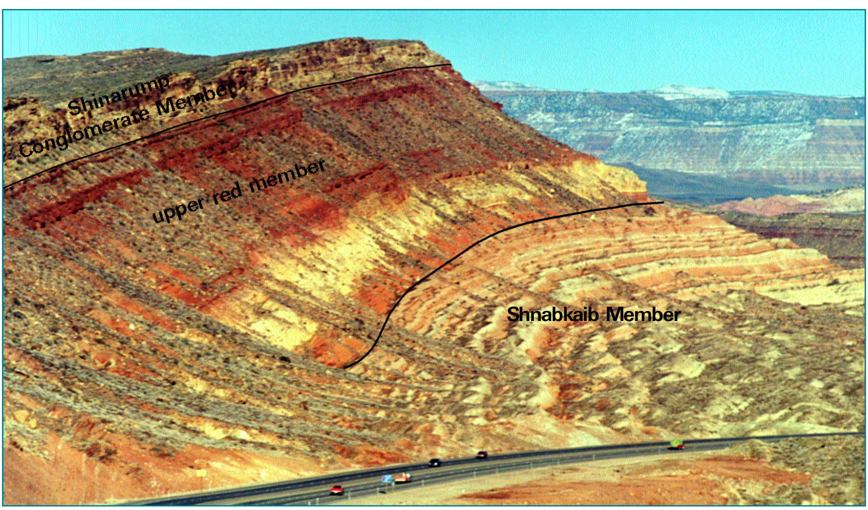


Rocks present in Quail Creek State Park and surrounding area. Only those intervals highlighted in color are present in the park; enclosing rock units are found in nearby areas. The oldest rocks exposed in the park belong to the Shnabkaib and upper red members of the Moenkopi Formation, which is overlain by the Shinarump Conglomerate and Petrified Forest Members of the Chinle Formation.



rocks that were deposited in the Early Triassic, about 240 million years ago. These rocks reveal a time when the area we now call Utah lay near the equator, straddling the eastern shore of a shallow ocean and a very gently sloping coastal lowland. Rising seas occasionally flooded the warm, arid, coastal lowlands, creating eastward-thinning wedges of marine limestone and other sediments known to geologists as the Timpoweap, Virgin, and Shnabkaib Members of the Moenkopi Formation. As the seas retreated, these marine deposits were overlain by westward-thinning wedges of mostly non-marine red-bed sediments - known appropriately as the lower, middle, and upper red members - deposited on broad tidal flats. These six members locally overlie the Rock Canyon Conglomerate, the oldest member of the Moenkopi Formation. The Moenkopi Formation is thus divided into seven members, or distinct rock units, that record a complicated series of sea level rises and falls from about 245 to 240 million years ago.

Shnabkaib Member - The Shnabkaib (pronounced “shnab-kibe”) Member forms striking red- and white-banded slopes and ledges around Quail Creek Reservoir. These rock layers are best seen above the west abutment of the Quail Creek south dam, and along the north shore of the reservoir. The banding is due to alternating layers of reddish-brown mudstone that weather to slopes, and more resistant white gypsum and dolomite that weather to



Looking north at a brightly colored hillside of Shnabkaib, upper red, and Shinarump strata just north of Highway 9, immediately south of Quail Creek State Park. These are the bedrock units seen surrounding Quail Creek Reservoir. Note the “bacon-striped” appearance of the Shnabkaib Member; the yellowish-brown sandstone, locally known as the “Purgatory Sandstone,” near the base of the upper red member; and the cliff-forming Shinarump Conglomerate. Note also the veneer of talus that locally conceals bedrock.

ridges and low ledges. The member is named for exposures at Shinob Kibe butte, just southeast of Washington, which derives its name from the Piute words *Shinob* (Great Spirit) and *Kaib* (Mountain).

The Shnabkaib Member contains about 30 percent gypsum as white nodules and layers up to several feet thick. The gypsum was deposited in a sabkha environment (broad evaporation pan) from evaporation of restricted marine waters and hypersaline, or very salty, ponds. Gypsum is also present as coarser grained varieties known as selenite and satin spar that occur in cross-cutting veins. The Shnabkaib Member is about 600 feet thick at Quail Creek State Park.

Upper red member - The upper red member forms steep, ledgy slopes above the Shnabkaib Member and below the cliff-forming Shinarump Conglomerate. The upper red member consists of reddish-brown mudstone, siltstone, and sandstone. The base of the upper red member is marked by a prominent, cliff-forming, 100-foot-thick yellowish-brown sandstone known as the "Purgatory Sandstone." The upper red member is about 400 feet thick and was deposited in arid tidal-flat and coastal-plain environments.

Chinle Formation

A pronounced gap in geologic time - about 10 million years - separates the upper red member of the Moenkopi Formation from the overlying, and therefore younger, Shinarump Conglomerate Member of the Chinle Formation. Geologists call this an unconformity, and here it marks an abrupt change from mostly shallow-marine to continental sedimentation; because no rocks from this 10-million-year time span remain, we are not sure what the climate or landscape were like during that time. Although the rock layers above and below the unconformity are essentially parallel, evidence of the unconformity is found as minor stream channels at the base of the Shinarump Conglomerate that are eroded into the upper red member. In southwestern Utah, the Chinle Formation consists of two distinct units, the lower Shinarump Conglomerate Member and the upper Petrified Forest Member.

Shinarump Conglomerate Member - Because of its resistance to erosion, the Shinarump Conglomerate forms cliffs along the central portion of the Virgin anticline. The cliffs form the skyline around the west, north, and east sides of Quail Creek State Park. The Shinarump Conglomerate consists of yellowish-brown sandstone and pebbly sandstone deposited by generally north-flowing braided streams. The streams were probably similar to the modern Platte River and other rivers that drain eastward from the Rocky

Looking west at a small channel (in Highway 9 road cut just above the car) at the base of the Shinarump Conglomerate. Channels such as these are evidence of an unconformity - a surface denoting a gap in geologic time - between the upper red member of the Moenkopi Formation and overlying Shinarump Conglomerate Member of the Chinle Formation. The channel shows that the area was exposed and erosion stripped off layers of sediment. This unconformity marks a pronounced change in depositional environments of these two rock units. Upper red strata were deposited principally in tidal flats whereas Shinarump strata were deposited by braid - ed streams.

Mountains and that consist of shallow, interconnected or braided channels and intervening gravel bars. When Shinarump sediments were deposited in the Late Triassic, about 220 million years ago, this area was a gently sloping basin with mountains to the east and west.

The small pebbles found in the Shinarump Conglomerate are mostly chert, quartzite, and quartz. Petrified wood is locally common in coarser, pebbly beds; the logs and limbs are remnants of trees deposited by floods. Much of the Shinarump, however, lacks pebbles and instead consists of sandstone. These sandstones are commonly stained dark brown or black by iron-manganese oxides and locally form “picture stone” or “landscape stone” as described later. Shinarump strata are about 100 feet thick at Quail Creek State Park.

Petrified Forest Member - Petrified Forest strata are widely exposed along the flanks of the Virgin anticline just outside the park boundaries. Small outcrops of Petrified Forest strata can be seen, however, at the northwest entrance to the park near Interstate 15. As might be surmised from its name, the member contains petrified wood; it also contains brightly colored clays - locally known as "blue clay" - that swell when wet and shrink when dry. These swelling clays are responsible for numerous building and road foundation problems in the area.

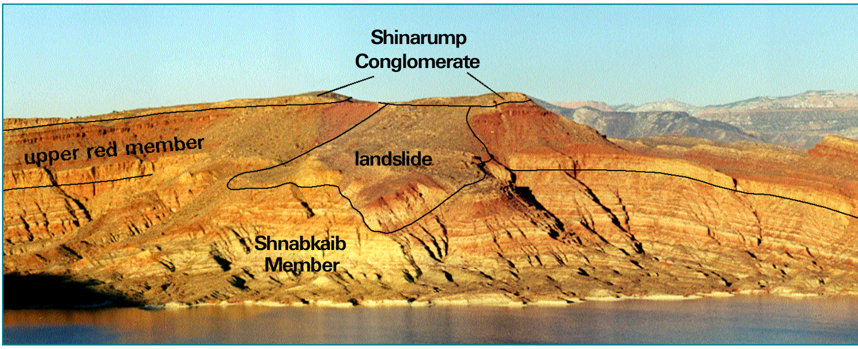
Surficial Deposits

The ancient Shnabkaib, upper red, Shinarump, and Petrified Forest bedrock of Quail Creek State Park are locally covered by much younger, unconsolidated deposits including talus, sand and gravel, and landslides. Just outside the park, on the eroded flanks of the Virgin anticline, a variety of river-channel, floodplain, and other unconsolidated deposits are found. Sand and gravel are naturally found along the modern channels of the Virgin River, Cottonwood Creek, and Quail Creek, but it is interesting to note that sand and gravel are also found in isolated deposits high above these streams. The streams are actively eroding the landscape, migrating side to side and carving ever deeper into the bedrock. As they do so, they leave behind isolated remnants of the older river channel. Such deposits point to the complex, episodic nature of erosional downcutting along the Virgin River and tributary streams.

Talus deposits - At Quail Creek State Park, talus deposits are characterized by angular blocks of Shinarump and upper red strata that form a veneer of unconsolidated, poorly sorted debris on steep slopes. These deposits form as rocks break away from the surrounding cliffs and ledges and tumble downslope. The talus grades downslope into colluvium, a poorly sorted mixture of clay- to boulder-size sediment deposited by slopewash, soil creep, and debris flows. Talus deposits are especially prominent along the west shore of Quail Creek Reservoir.

Mixed river and slopewash deposits - As its name implies, mixed river and slopewash deposits are characterized by both sand and gravel deposited by streams, clay- to boulder-size sediments deposited by debris flows, and angular pebbles to boulders deposited by rock-fall and slopewash processes. The deposits are found at the north end of Quail Creek Reservoir and include large boulders from the Pine Valley Mountains, described below.

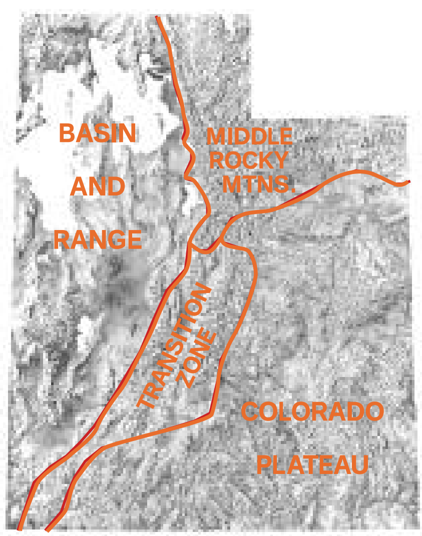
Landslides - A large landslide at the north end of Quail Creek Reservoir is deeply eroded, suggesting it is relatively old and may have formed during the Ice Age, perhaps 15,000 to 25,000 years ago when the climate was wetter than present. The landslide is characterized by chaotically oriented Shnabkaib, upper red, and Shinarump blocks that slumped down the hillside.



Old, deeply eroded landslide just north of Quail Creek Reservoir. The base of the landslide is in Shnabkaib strata, which are comparatively weak and unstable. Undisturbed Shnabkaib and upper red members of the Moenkopi Formation and the Shinarump Conglomerate Member of the Chinle Formation are also visible.

THE BIG PICTURE

If rock layers and all the information they contain constitute our book of geology, then the glue that binds these pages together is both geologic structure and geomorphology.
The study of land forms - geomorphology - helps geologists to decipher the complex geologic history of a region. At its simplest, for example, Utah is divided into three major physiographic regions, each defined by characteristic land forms or geomorphic features that differentiate it from its neighbors.

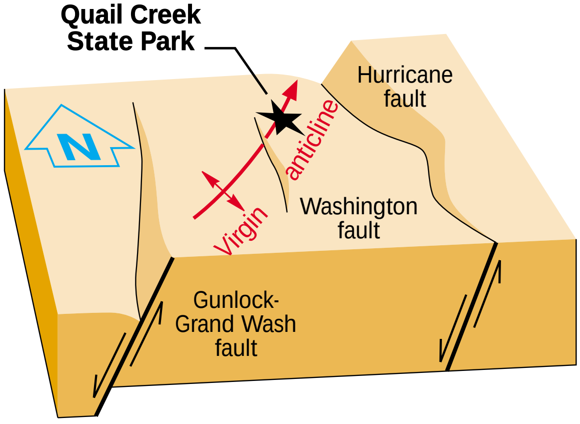


Shaded-relief map of Utah showing major physiographic provinces of the state.

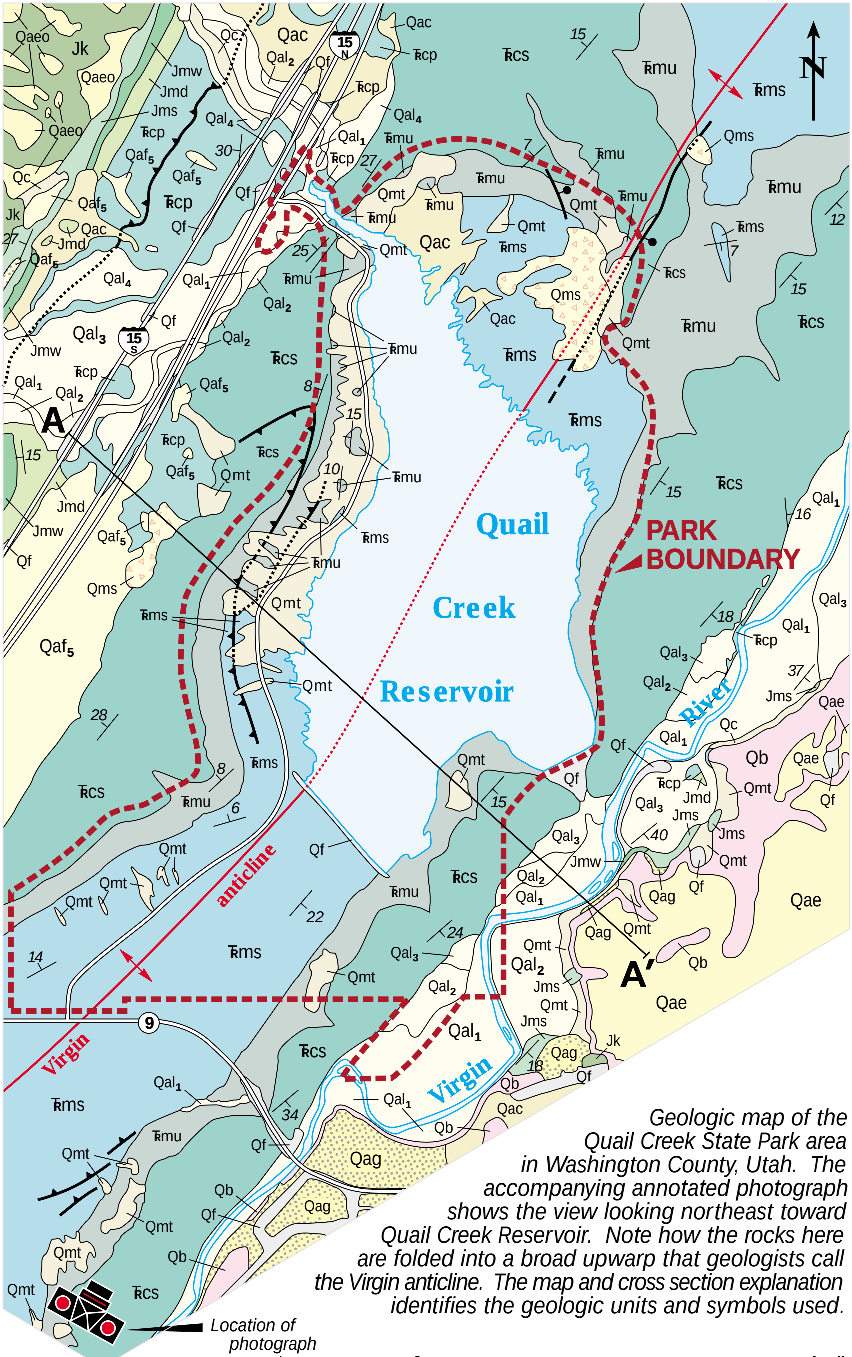
The boundaries and names of these physiographic regions are not arbitrary, not capriciously drawn like the misleading names hung on some suburban streets. Each line reflects an important underlying geologic feature. The boundary between the Middle

Rocky Mountains and the Basin and Range Province, for example, is marked in part by a major, active earthquake fault that drops rocks down to the west relative to rocks to the east. The Basin and Range Province itself is characterized by mostly north-trending, fault-bounded, isolated mountain ranges separated by deep, sediment-filled basins; it is literally being pulled apart by deep extensional forces. The Colorado Plateau is a relatively coherent and tectonically stable region underlain by generally horizontal sedimentary strata only locally disrupted by faults and uplifts, igneous intrusions, and lava flows. Understanding the state's physiography is very much understanding an outline of the state's geologic history.

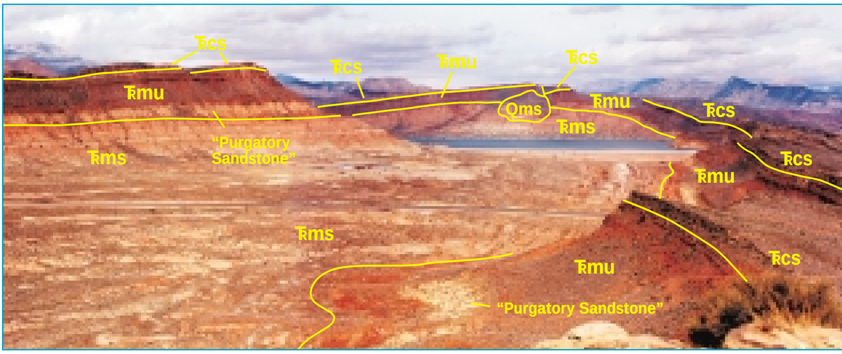
The greater St. George area, including Quail Creek State Park, lies in what geologists call the transition zone between the Basin and Range and Colorado Plateau physiographic provinces. The transition zone is characterized by strata and structures common to both the Basin and Range Province and Colorado Plateau. The brightly colored layered rocks in the transition zone are characteristic of the generally flat-lying rocks of the Colorado Plateau, but they are locally deformed by both compressional forces associated with the Sevier orogeny (mountain-building episode) and more recent extensional forces associated with the formation of the Basin and Range Province. In southwestern Utah, the transition zone includes two major down-to-the-west fault zones that step down from the Colorado Plateau to the Basin and Range Province. The greater St. George area lies on the intermediate structural block thus created, bounded on the east by the Hurricane fault zone and on the west by the Gunlock-Grand Wash fault.

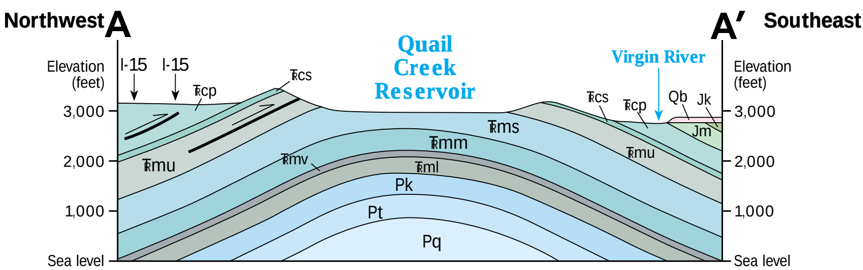


Schematic block diagram showing the relationship between the Gunlock-Grand Wash and Hurricane faults. Both faults are "normal" faults that formed during regional extension, allowing rocks on the west side of the faults to slip down relative to rocks on the east side.



Geologic map of the Quail Creek State Park area in Washington County, Utah. The accompanying annotated photograph shows the view looking northeast toward Quail Creek Reservoir. Note how the rocks here are folded into a broad upwarp that geologists call the Virgin anticline. The map and cross section explanation identifies the geologic units and symbols used.





Cross section not to scale. Thin surficial deposits not shown.

MAP AND CROSS SECTION EXPLANATION

Geologic Unit Descriptions

QUATERNARY

- Qf — Artificial fill
- Qal_{1-4} — River deposits
- Qaf_5 — Old alluvial-fan deposits
- Qmt — Talus deposits
- Qms — Landslide deposits
- Qac — Mixed river and slopewash deposits
- Qae — Mixed river and wind-blown deposits
- Qaeo — Old mixed river and wind-blown deposits
- Qb — Basalt lava flows
- Qag — Older river-channel deposits

JURASSIC

- Jk — Kayenta Formation

Moenave Formation:
- Jms — Springdale Sandstone Member
- Jmw — Whitmore Point Member
- Jmd — Dinosaur Canyon Member

TRIASSIC

Chinle Formation:
- Ꞧcp — Petrified Forest Member
- Ꞧcs — Shinarump Conglomerate Member

Moenkopi Formation:
- Ꞧmu — Upper red member
- Ꞧms — Shnabkaib member

Subsurface units- on cross section only:
- Ꞧmm — Middle red member, Moenkopi
- Ꞧmv — Virgin Limestone Member
- Ꞧml — Lower red member
- Pk — Kaibab Limestone *(Permian)*
- Pt — Toroweap Formation *(Permian)*
- Pq — Queantoweap Sandstone *(Permian)*

Geologic Symbols

- Contact
- High-angle normal fault: ball and bar on downthrown side; dashed where approximate, dotted where concealed
- Low-angle reverse fault: teeth on upper plate; dotted where concealed
- Anticline
- 15 Strike and dip of beds

GEOLOGICAL HIGHLIGHTS

Virgin anticline - Imagine a book that is folded into an arch. Cut away the top of the arch and you can see into the core of the fold at successively higher page numbers. Now imagine the Earth's upper layers of rock, similarly folded and eroded such that older rock layers are exposed in the interior of the fold. That, in a nutshell, is the Virgin anticline - a 30-mile-long, northeast-trending, symmetrical fold formed during the Sevier orogeny, about 70 million years ago.

The Sevier orogeny, or mountain-building episode, began about 130 million years ago as the North American and Pacific plates (two of the large crustal plates that make up the outer layer of the earth) collided. This collision resulted in complex deformation and broad uplift of western North America, including what is now southwestern Utah. Here, the deformation is expressed as a large fold - the Virgin anticline - that formed when the rocks slowly yielded like modeling clay to these great compressional forces.

Faults - The rocks exposed at Quail Creek State Park are offset by two types of faults, or breaks in the earth's crust where rocks once slid past one another. The high cliffs west of the reservoir are cut by small thrust faults that formed during the Sevier orogeny. The thrust faults formed during compression, allowing rock layers to slide eastward up and over the top of themselves during folding of the Virgin anticline. These west-tilted thrust faults are best seen where they displace the yellowish-brown "Purgatory Sandstone."

A second type of fault, called a normal fault, is found north of Quail Creek Reservoir, parallel to the axis of the Virgin anticline. This fault displaces rock layers down to the east so that Shinarump strata are juxtaposed against upper red strata. The fault probably formed during folding of the Virgin anticline. As the fold formed, the axis of the fold was an area of local extension, and movement on the fault helped to relieve those extensional forces.

Gypsum - Gypsum is a common evaporite mineral and an important component of the Shnabkaib Member of the Moenkopi Formation. Gypsum is soft and can be easily scratched with one's fingernail, and it is easily cleaved or parted in one direction. At Quail Creek State Park, gypsum is found in a variety of forms: as thick, massive beds; laminated, commonly silty or muddy beds; nodular horizons; and as large, transparent crystals

Looking north at a small, west-dipping thrust fault that places the "Purgatory Sandstone" on top of itself. The inset shows a small kink fold associated with the larger, west-dipping thrust fault. These beds were deformed about 70 million years ago during the Sevier orogeny (mountain-building episode).

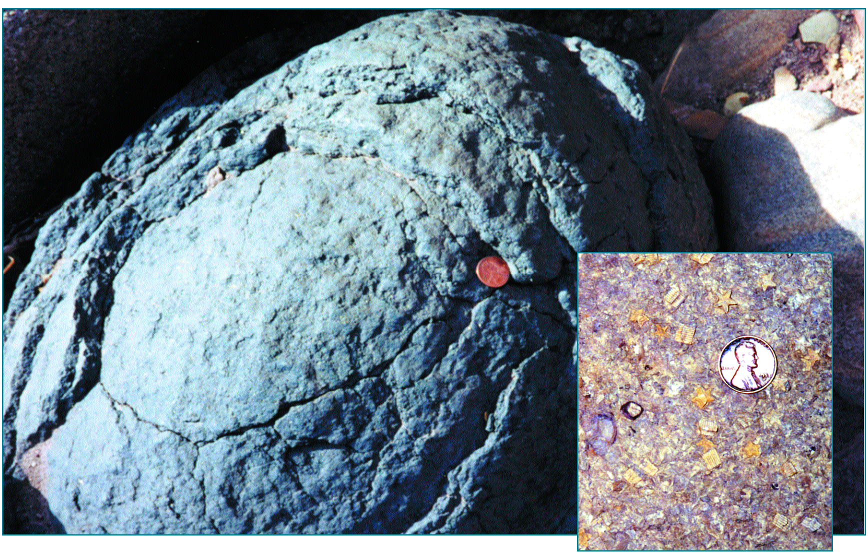
called selenite and satin spar in small vugs and cross-cutting veins. Gypsum weathers to a soft, powdery soil, commonly covered by a delicate cryptobiotic (microscopic life forms) crust. Gypsum is an important industrial mineral and is used to make plaster and gypsum board, as a filler in the paper and textile industries, to loosen clay-rich soils, and in the production of sulfuric acid.

"Picture stone" - The "picture stone" of southwestern Utah is a sandstone that is naturally stained by iron-manganese oxides. The staining can produce intricate patterns of twisted, swirling light and dark

Picture stone from the Shinarump Conglomerate Member of the Chinle Formation, the same unit that forms the high cliffs around Quail Creek Reservoir. The banding is due to naturally occurring iron-manganese oxides. This coaster is about 4 inches square.

bands and even images reminiscent of landscapes, thus giving rise to its other common name, "landscape stone." The sandstone comes from the Shinarump Conglomerate, the same rock unit that forms the high cliffs around Quail Creek State Park. Look closely at the Shinarump Conglomerate and you can see that the banding follows joints in the rock, so that large blocks become concentrically zoned in a variety of interesting patterns. The staining is caused by mineralized ground water that moves through the rock, locally precipitating iron-manganese oxides.

Boulders from the Pine Valley Mountains - Large, rounded boulders from the Pine Valley Mountains are found along the north shore of Quail Creek Reservoir in sediments mapped as mixed river and slopewash deposits. The boulders are quartz monzonite porphyry, a gray, coarse-grained, intrusive igneous rock similar to granite but with a slightly different mineral composition. These boulders provide a glimpse into the distant Pine Valley Mountains, which are capped by an igneous, mushroom-shaped intrusion called the Pine Valley laccolith. The Pine Valley laccolith was emplaced about 21 million years ago as molten rock from deep within the earth moved upward into shallow overlying sedimentary rocks. There it spread



Granite-like boulder eroded from the Pine Valley Mountains. This and other similar boulders were transported nearly 10 miles by ancient floods and debris flows to their present location at the north end of Quail Creek Reservoir. The boulder is now weathering into concentric layers, much like an onion. Limestone clasts with distinctive star-shaped fossils are also common in river deposits at the north end of the reservoir. The fossils are a type of crinoid, or sea lily, known as Pentacrinus *and come from Jurassic rocks that crop out on the flanks of the Pine Valley Mountains.*

Quail Creek south dike, shortly after its catastrophic failure on January 1, 1989. Note how floodwaters scoured the bedrock clean of loose, overlying sediments just below the dike. Photo by Ben Everitt, Utah Division of Water Resources.

out and crystallized into what is one of the largest such intrusions in the world; uplift and erosion have since uncovered this granite-like rock. The boulders are part of a large apron of sediment shed off the Pine Valley Mountains.

Catastrophic failure of the Quail Creek south dike - At 12:30 a.m. on January 1, 1989, the Quail Creek south dike broke and unleashed a torrent of water, causing millions of dollars of damage. Fortunately, the downstream area was evacuated in time to avoid fatalities. Approximately 25,000 acre-feet of water - more than half of the reservoir's capacity - flowed through a breach in the dike over a 12-hour period.

The original Quail Creek south dike was a 78-foot-high, 2,000-foot-long earthen dam constructed in 1984. The dam was poorly designed and seepage under the dam occurred immediately after filling the reservoir. This seepage eroded the dam and foundation materials over the years despite efforts to seal the leaks. Ultimately, seepage and erosion of the dam and foundation materials continued and accelerated until caving occurred on a developing opening in the dike. Frantic, last-minute efforts to stem the seepage were unsuccessful and the dike finally breached.

After the dike's collapse, investigators found that participation of an engineering geologist was limited during the exploration, design, construction, and operation of the dike. They further found that the dike's failure was principally due to poor foundation design and construction. Simply put, the dike was built mostly on the highly jointed, gypsum-bearing Shnabkaib Member of the Moenkopi Formation (except the southeast abutment which lies on the upper red member). The joints, or cracks, allowed water to rapidly infiltrate bedrock under the dike, bringing it in contact with gypsum, which readily dissolves in water.

The new dike, called the Quail Creek south dam, was completed in 1990 as a roller-compacted concrete gravity dam. The dimensions of the dam are basically the same as the dike, except that it now includes a new impermeable cutoff trench up to 75 feet deep, which is designed to prevent water from seeping under the dam. Evidence of the flood is still visible downstream from the new Quail Creek south dam, where the Shnabkaib Member was scoured clean of overlying loose bedrock and sediment.

Cutoff trench being excavated at the bottom of the new Quail Creek south dam in January 1990. Photo by Bill Lund, Utah Geological Survey.

ACKNOWLEDGMENTS

Many geologists have helped unravel the geologic story recorded in the rocks of Quail Creek State Park and southwestern Utah, and the story told here would be much abbreviated were it not for their curiosity and scholarship. Because of the technical nature of many of their reports, I include just a few of these in the references listed below. A comprehensive list of references accompanies the geologic maps and reports of the Harrisburg Junction and Hurricane quadrangles, which are listed below.

Sandy Eldredge and Grant Willis of the Utah Geological Survey (UGS), and Gary Pascoe, Superintendent of Quail Creek State Park, provided insightful reviews of the manuscript. Thanks also to Bill Lund (UGS) and Ben Everitt (Utah Division of Water Resources) who provided photos of the Quail Creek dike collapse and reconstruction, and to Bill Case (UGS) for providing the picture-stone coaster shown on page 15. Geologic mapping of the Harrisburg Junction and Hurricane quadrangles, in which Quail Creek State Park lies, was made possible in part by a U.S. Geological Survey STATEMAP grant. Book design by Vicky Clarke, cartography by Jim Parker.

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Looking east from Quail Creek State Park toward Zion National Park.

Quail Creek Reservoir - view to the north. Photo by Janice Higgins.

Public Information Series 63
Utah Geological Survey
a division of
Department of Natural Resources
1999

Utah Geological Survey

ISBN 1-55791-630-6