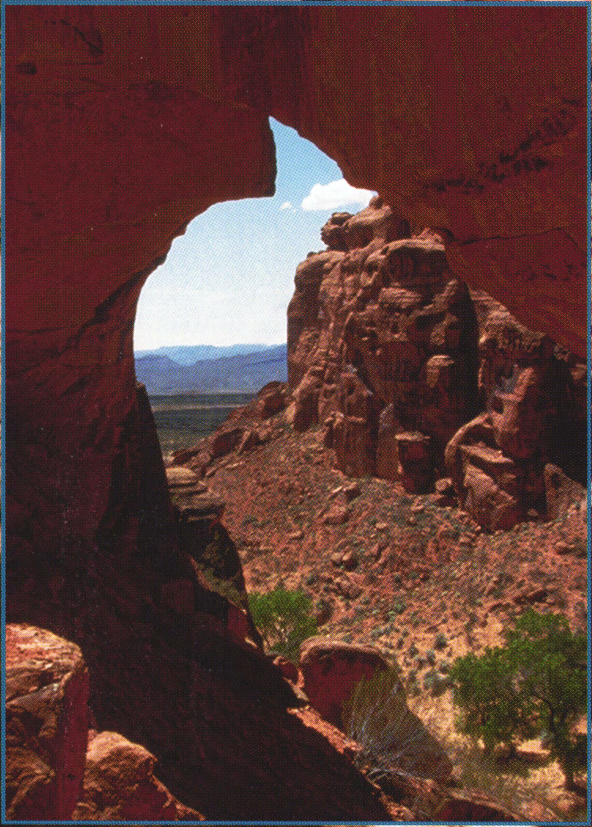
THE GEOLOGY OF

Snow Canyon
STATE PARK

Washington County, Utah



BOOK DESIGN / PATTI [illegible] McGANN

The Geology of Snow Canyon

by Miriam Bugden

The stark intensity of Snow Canyon State Park's colors, terrain, and vegetation create a surrealistic flair to one of southern Utah's most striking recreation areas. Snow Canyon's scenery reminds us of the earth's past when extensive river systems meandered through Utah, desert sands enveloped the lands, and volcanic eruptions scorched the earth with hot molten rock. Remnants from these spectacular events in Utah's history are preserved in the park's landscape. With a little imagination, this brochure will help you see how elements of those ancient climates and lands are recorded in the rock walls and how slow, constant natural processes continue to alter the park's facade.

GEOLOGIC TIME

Geology, or the study of the growth and development of the earth, can be as confusing as physics, astronomy, chemistry, or any other science with language and concepts of its own. One of the most bewildering aspects of the earth's history is understanding and thinking in terms of geologic time. Geologists seldom think in terms of years, decades, or even centuries. Instead, they contemplate events that occurred millennia and aeons ago.

Like growth rings revealing a tree's age, different layers of the earth's crust represent lapsed time, past climates, and ancient environments. Although rocks are "dated" through various methods, they are often assigned relative ages by their position in relation to surrounding rocks.

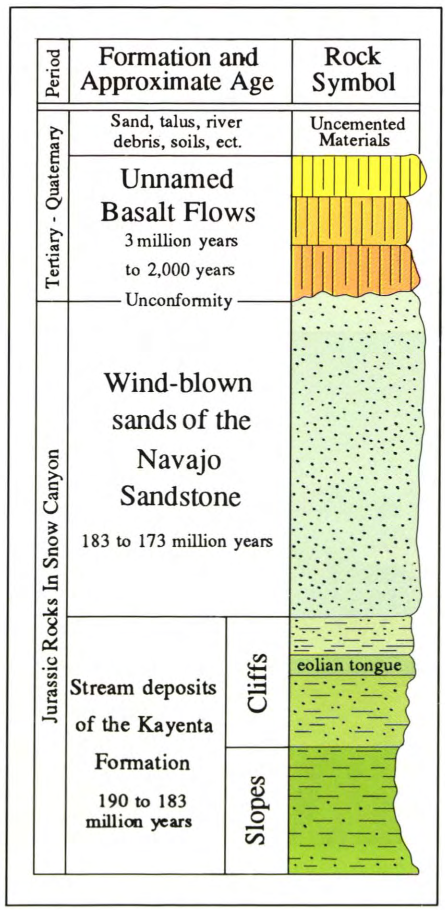


Figure 2. Not drawn to scale, this figure shows the rocks found in the vicinity of Snow Canyon State Park. Only the upper and upper-middle parts of the Kayenta Formation can be seen in the park. Therefore, this is not a complete representation of the Kayenta Formation.

Figure 3. Sedimentary rocks are deposited in flat or nearly flat layers. If the rocks have not been deformed or overturned, each successive layer is younger in age than the rocks on which they rest.

In Snow Canyon, for example, we know that the black rocks (basalts) are younger than the red and white sedimentary rocks because the basalts are always found on top of the sedimentary rocks. From the highest elevation in the canyon to the lowest, the rock walls steadily increase in age. The oldest rocks in the park are in the southern section where erosion has cut deeply into the earth, exposing rock layers of the Kayenta Formation.

The Canyon Rocks - Oldest to Youngest

Geologists reconstruct the story of the earth's formation and evolution through careful examination of rocks and the "clues" fossilized within them. Each grain in a sedimentary rock, for example, has been altered by the environments through which it passed. If properly deciphered, clues like textures, minerals, grain sizes, degree of sorting, roundness of the grains, and horizontal and vertical changes in the rocks allow us to reconstruct ancient climates and environments that formed the rocks and shaped our modern scenery.

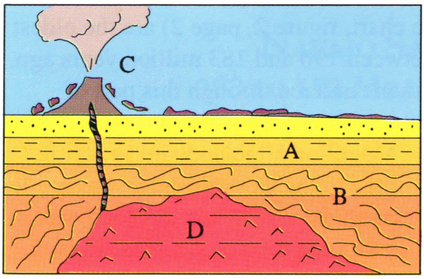


Figure 4. Three general classes of rock are: (A) sedimentary, (B) metamorphic, and (C and D) igneous. Igneous rocks are divided into (C) extrusive, and (D) intrusive. Extrusive rocks spew onto the earth's surface and are usually molten, or flow onto the ground before they cool and solidify. Volcanic lavas are extrusive. Intrusives are chemically the same as extrusives but they cool and solidify before reaching the surface. After cooling and solidifying, erosion of the overlying rocks, faulting, or other upward forces bring intrusive rocks to the surface. Sedimentary rocks form when particles accumulate in air or water and eventually cement together. Metamorphics are sedimentary or igneous rocks that have been changed by exposure to intense pressures and temperatures.

KAYENTA FORMATION
190 TO 183 MILLION YEAR OLD ROCKS

Figure 5. Looming like a sentinel over the town of Ivins is flame-colored Red Mountain. Gentle, reddish-orange slopes of the Kayenta Formation form the ramp that leads to the mountain's formidable cliffs. When hiking, look closely at these slopes and you will see textures and characteristics visible in sands and silts of modern rivers. As water flows over sediments on the floor of a river, currents align the sediments in long, sinuous ridges called ripple marks. Fossilized ripple marks can be found in Kayenta Formation slopes. Water action also forms small- to medium-sized cross beds. These can be seen throughout the Kayenta Formation. Channel scours, or areas where water has cut new paths, and mud cracks are also present but more difficult to find.

Sedimentary rocks of the Kayenta Formation (refer to lower Jurassic rocks in the generalized geologic time chart, figure 2, page 2) are the oldest rocks in Snow Canyon State Park. Between 190 and 183 million years ago, large silt, mud, and sand-bearing rivers meandered through this part of Utah. Surrounded by the eroding continental craton to the north, the Ancestral Rockies to the southeast, the Mogollon Highlands in the south, and the coastal highlands-volcanic complex to the west, this area was a natural trap where sediments slowly accumulated. The hot, dry land was not a deep basin, but an area with gentle, sloping topography that slowly filled with sediments as the rivers dropped their gritty loads. The even, reddish-orange slopes found in the southern part of the canyon are siltstones, mudstones, and fine-grained sandstones deposited millions of years ago by these slow-moving rivers.

Slightly younger and immediately above the slopes are the reddish-orange, cliff-forming Kayenta rocks. At first glance, these cliffs appear very different from the older slope-forming rocks immediately below them and are difficult to distinguish from younger Navajo Sandstone cliffs above them. More resistant to erosion than the slopes, the cliff-forming Kayenta rocks construct steep walls through the lower part of the canyon and almost imperceptibly merge upward into the Navajo Sandstone.

Upon close examination, these rocks are very different than those they are sandwiched between. They were deposited in an environment that vacillated between a slowly encroaching desert and an extensive system of braided and meandering streams. Drier climatic cycles caused ancient rivers to shrink. Deposition via rivers was exceeded by winds blowing sheets (flat-lying, thin veneers) and dunes (hummocky mounds) of sand over the land. Eventually, rivers ceased flowing as water became scarce and windy desert conditions prevailed.

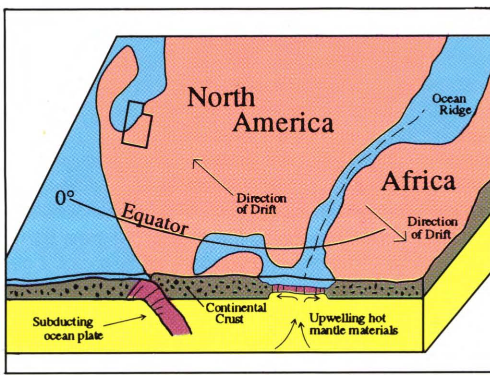


Figure 6. Through time, the earth's continents have changed their positions on the globe. During Jurassic time, North America was separating from Pangea (the name of an ancient landmass that consisted of most of the planet's continents). The area that we now call Utah was only about 15° north of the equator. This southerly position was probably a great contributor to the hot, dry conditions that prevailed as the Jurassic desert advanced into Utah.

Navajo Sandstone
183 to 173 Million Years Ago

Over hundreds of thousands and probably millions of years, the climate changed. The land, still surrounded by eroding highlands, began to assume the appearance of a wind-swept, sandy desert. Sands, most likely eroded from sources as far north as Canada, blanketed an area that stretched south into parts of Wyoming, Idaho, Utah, Colorado, Arizona, and New Mexico. This Sahara-like desert blasted and enveloped an extensive area of North America between 200 and 173 million years ago. This sand sea did not invade southwestern Utah however, until about 183 million years ago.

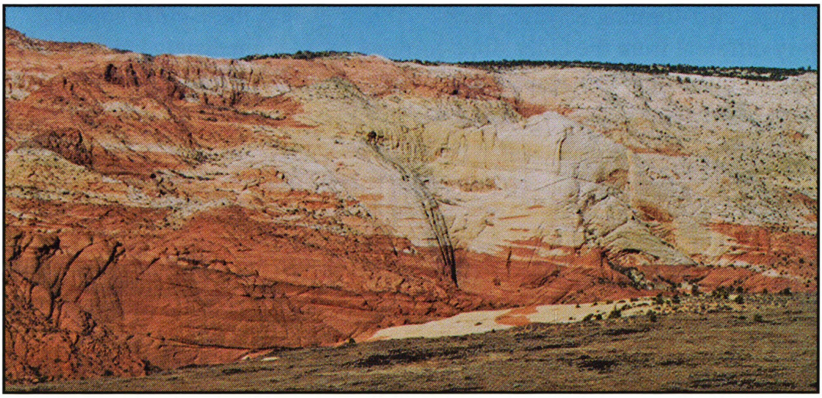


Figure 7. Rocks in upper part of Snow Canyon's Navajo Sandstone are white but the older rocks in the formation have a reddish-orange color. Between these distinctly colored rocks is a zone where the colors interfinger as if a gigantic paintbrush stained the cliff faces. The color changes are puzzling since they occur without regard to cross bedding or other obvious geologic features. Red colors are caused by the presence of an iron oxide (rust) mineral called hematite. Yellow colors are caused by a different iron oxide mineral, limonite. Except for the absence of iron oxide minerals, the white rocks appear to have the same components as the colored rocks.

Exactly why iron oxide is present in the lower part of the formation, but absent in the upper part, is not resolved. One of several theories, however, is that the color-producing minerals came from the same source as the dune sands. As time progressed, the source rocks continued producing the sands, but grew barren of iron minerals. This explanation for the older red rocks and younger white rocks is debated by those who think that when deposited, all the rocks were red, but waters percolated down through the formation and leached the iron from the top portion and concentrated it in the lower portions. Another theory speculates that the iron minerals were brought in by iron-rich waters that circulated through the rocks after they were deposited.

Although thick layers of Navajo Sandstone are thought to extend diagonally across Utah from northeast to southwest, rock layers from subsequent environments have buried much of it. Only where extensive erosion and uplift has denuded younger rocks are we able to see small portions of this vast, ancient desert (Zion National Park and Snow Canyon State Park).

The majority of sedimentary rocks in Snow Canyon State Park are Navajo Sandstone. As the rocks of the Navajo get progressively younger, their colors change and the cliffs and domes of “petrified” sand dunes range from orange-red, to orange, to yellow, to cream, to white. A wide array of fabrics and textures enhance the appearance of the sandstone. Time, erosion, and other forces have battered it into intensely broken and fractured zones, molded it into smooth rounded hummocks, and etched patterns resembling the skin of an alligator onto its surfaces.

Thin limestone lenses are sometimes found in Utah’s Navajo Sandstone. They probably formed in ponds and lakes that infrequently accumulated in the depressions between dunes. Modern deserts also contain playas or desert lakes but they are thought to comprise less than one percent of all desert surfaces.

Dark, blackish-red, wavy looking rocks with varying thicknesses are also found in some areas of the park. Good examples of these can be found on the nature trail located across the road from the campground. Several theories have attempted to explain the origin of these contorted features. They have been described by some as petrified algal (water plants or pond scum) deposits that grew in desert waters. Still others postulate that the sediments were deformed or contorted before they were cemented into rocks.

Figure 8. Between 200 and 173 million years ago, an extensive desert covered parts of Idaho, Wyoming, Utah, Arizona and New Mexico. Winds blew from the north-northwest and swept great expanses of sand into the west-central United States. Piled into dunes, and eventually cemented into rocks, remnants of this sand sea can now be seen as "frozen" or "petrified" sand dunes in the rock walls of Snow Canyon State Park. The curved lines seen in the rocks are called cross beds. They formed when ancient winds lifted grains off of one side of a pile of sand and dropped them on the other side. Over time, several thin layers of grains built up to form a dune. The horizontal lines in the rocks represent slight erosional periods and changes in wind directions. Winds of Navajo Sandstone time blew a sandy desert over an extensive, thick sequence of sediments deposited by meandering rivers. These rocks of the Jurassic Kayenta Formation are seen in the southern end of the park. These too are cross bedded, but the size is much smaller than the enormous sets seen in this view of the Navajo Sandstone.

There are numerous theories on how uncemented desert sediments can, through natural processes, become jumbled. A few of these include: avalanching or flowing sands on over-steepened dune faces; growth, shrinkage, and movement of salts in and around desert lakes (probably driven by changes in temperatures and availability of water); deformation of sediments when gases (methane) escape from buried organic lake muds; and sediment collapse caused by earthquakes.

Once the winds stopped blowing over the sand-imbued Jurassic lands, this area experienced a period of erosion. No new rocks formed until later in Jurassic time and they are only visible to the north of the park (rocks of the Temple Cap and Carmel Formations represent a dramatic change in depositional styles from a sandy desert to shallow seas). More recent periods of erosion have stripped these and younger rocks from the top of the Navajo Sandstone in the park. Now, as we look at the eastern wall of the canyon, the suture between 173 million year old Navajo Sandstone and Quaternary basalts records an extensive period of erosion that geologists call an unconformity.

Figure 9. Hard, dark rocks called Moki marbles or ironstone concretions, are found in piles on top of the sandstones and are slowly eroding out of the sandy matrix. Nodules are concentrations of iron and manganese oxide. More resistant to erosion than the surrounding rocks, they weather out of the Navajo and are found strewn about throughout the canyon. Their origin is uncertain, but may be attributed to oxidation of different mineral grains that were blown into the area along with the quartz sands.

Figure 10. Along with a wide spectrum of colors, one of the unique features of southwestern Utah's Navajo Sandstone is the intensity of its fracturing or breaking. Rocks break or weaken for many reasons. Often, however, they break in patterns that, when studied, can determine their causes. This knowledge helps geologists understand more about the forces that shape our earth.

The sedimentary rocks in the park display two sets of near-vertical fractures. The northwest-trending set is often deeply eroded and forms the canyons in the area. Less deeply eroded but very well pronounced are the northeast-trending fractures. Like scales on fish, they form fins that seem to spall from the canyon walls. Locating fractures and discerning the intensity of breaking is important when drilling for water, building effective wastewater disposal systems, and determining locations of future rockfall hazards.

Figure 11. Desert varnish is the common name for the hard, blackish-maroon polish found on cracks and smooth surfaces on the sandstone in the park. Rain or ground waters carrying minute particles of iron and manganese flow over the sides of cliffs and into cracks and fissures. When the newly washed rocks dry, the metals are left behind forming a thin coat. Iron and manganese are colorful and their accumulations will stain or "paint" the rocks. Darker streaks form where waters have coursed for many years. Some rock cracks host thick, dark veneers of desert varnish. This fact may serve as one piece of evidence for the important role water plays in eroding small cracks into large fissures and ultimately into canyons.

Basalts
3 Million to 2 Thousand Years Ago

About 3 million years ago, after erosion coupled with regional uplift profoundly denuded the area of overlying rocks, volcanic eruptions began spitting scalding, pungent, black seas of basalt onto the land. Fiery channels of hot, molten rocks snaked their way over the earth and down into stream beds, valleys, and canyons; enveloping all that stood in their paths. These rivers quickly hardened into rocks, forming resistant, thick sheets of basalt that invaded and obstructed paths of rivers and streams. Seeking avenues of least resistance, drainages continued along their courses by shifting to the edges of the basalt flows (that now filled the earlier channels) and slicing new routes through the softer sedimentary rocks of the Navajo Sandstone.

Erosion continued along the new channels until the water routes grew in size from stream beds, to ravines, to deep canyons. The sheets of basaltic rocks that initially filled low areas, cooled into resistant masses and eventually stood in relief as high ridges and plateaus. New volcanic eruptions occurred with lavas again invading flat lands, furrows, gullies, and depressions. This second blanket of basalt covered an area topographically lower than the first. Three distinct phases of this INVERTED TOPOGRAPHY are evident in Snow Canyon State Park. The oldest layer forms the plateau to the east of State Highway 18 (the road from St. George to Vejo). The next forms the plateau on which the highway is built, and the third forms the floor of Snow Canyon itself.

Figure 12. The origin of these dark, contorted layers within the Navajo Sandstone is a topic of speculation.

Figure 13. This scenic view and stark contrast in rocks holds clues to the secret forces that continually carve our landscape. Ancient streams sliced gouges and canyons through the Navajo Sandstone and Kayenta Formation as waters made their way from highlands down to the Virgin River. About 3 million years ago, molten rock began pouring onto this part of the land and, like water, flowed into the low areas and covered stream beds and channels. The hot masses cooled and formed rocks more resistant to weathering. Existing streams shifted to areas adjacent to the flows and carved new channels through the softer sedimentary rocks. Over time, erosion sculpted steep-walled canyons. What was once a topographic low is now a topographic high and geologists refer to this as inverted topography. This process continues today as streams carve new channels along the edges of the lava flows that presently line the floor of Snow Canyon. Eventually, these canyons too will stand high in relief.

Figure 14. Cinder cones are distinct landforms found in the north part of the park. They formed when volcanic materials were explosively ejected from openings or vents in the earth's crust. The unique profile of the cones forms when expelled fragments accumulate around vent openings and assume the angle of repose. Large fragments are usually found near the source of the vent with particles getting smaller with increased distance from the source.

Sometime between 1,000 to 10,000 years ago (these rocks have yet to be conclusively dated, but geologists estimate their ages based on their fresh appearances and well-preserved textures) the youngest series of volcanic eruptions began emanating from volcanoes (cinder cones) and vents in the north section of the park. Following drainage channels etched in soft sandstones along the sides of solidified volcanic flows, the new, scalding flows crept south onto the floor of Snow Canyon and nearby areas. Today, these flows line the canyon floor stretching south to the Santa Clara River. Numerous features and textures characteristic of volcanic flows are well preserved in the park.

For example, visitors to West Canyon can see motionless black cascades of basalt, and areas where the flows encircled mounds of Navajo Sandstone and cascaded down steep embankments onto the canyon floor. Hikers will notice that these black falls appear to have ended abruptly when they touched the floor of West Canyon. In truth, however, they extended across the canyon and, in places, may have touched the walls on the opposite side. Shifting desert sands and flash-flood debris of more recent times have obscured floor basalts in most areas.

Although precise ages of the basalts have yet to be defined, they are geologically young and erosional forces have not had enough time to severely alter them. Black, rough, ropy looking mounds and flows of these olivine (a mineral, also called peridot that, when found as higher quality occurrences, was historically used in jewelry) basalts display many interesting textures and features characteristic of these types of volcanic rocks.

Figure 15. Like a waterfall, (above) the youngest lava flows in Snow Canyon cascaded over and around domes of Navajo Sandstone. Close inspection of the "frozen" basalt-falls yields a rough, ropy, broken surface with numerous dark ridges. The ropy textures are called pahoehoe (right). They develop in basalts that flow easily. Pressure ridges are similar to lava tubes. As a river of lava flows, the surface cools and forms a thin rind or crust. The underlying hot basalt and trapped gases continue flowing through this fragile tunnel and eventually leave a cavity behind. Unlike lava tubes, gases in pressure ridges push against the surface rind causing the surface to buckle or arch. The resulting feature looks like long sinuous finger of lava.

Future Rock Formations

Ours is a vibrant planet, continuously transforming the configuration of its oceans, continents, mountains, and valleys. Climates and other phenomena responsible for shaping the land may change through time, but forces of erosion and deposition are ongoing. Understanding these earth-shaping processes is best attained through first-hand observations and for these, geologists turn to their laboratory, the land.

Since modern-day soils and sediments will eventually be cemented into future rock layers, examination of the movements and characteristics of today's erosional and depositional materials helps us decipher events that may have occurred in the past to form the earth's geologic formations. For example, on a very small scale, wind and water compete today, as they did

Figure 16. Mimicking Navajo times, modern desert sands form miniature dunes that slowly migrate along the west side of the canyon road during windy seasons. A fun recreational spot, these drifting dunes are a potential nuisance for road maintenance crews and park officials.

during Kayenta and Navajo times, to etch the modern panorama of Snow Canyon. Wet seasons bring streams that explode through the canyon scouring, carrying, and dropping their sediment loads along their paths. Dry seasons bring winds that lift and blow small, light sands and silts and re-deposit their air-born loads in dunes and sheet sands often covering stream beds that once spouted water.

The study of geologic events that began about 1.8 million years ago and stretch into the present is called Quaternary geology. Sediments deposited by these geologically recent environments have not cemented together sufficiently to harden into rocks. Instead, they form loose, unconsolidated soils, sands, clays, muds, and dusts. Over time, these too will either be eroded and transported elsewhere or buried by ongoing deposition. After burial, the Quaternary sediments and soils may eventually be cemented and hardened, forming rocks.

Figure 17. The processes that created inverted topography are active and visible today. Year after year, rain and melt waters gently course along the edge of Snow Canyon's basalt flows. This seemingly innocuous activity slowly chisels against the soft sedimentary rocks adjacent to the flows and forms ruts and ditches. Although a small ravine, someday this may erode into a wide, scenic canyon like Snow Canyon.

We also strive to understand Quaternary events in order to eliminate or minimize potential problems that may result from natural disasters. Visitors should be aware of unstable slopes and areas that are susceptible to rock falls and flash floods. Intense spring, summer, and autumn rainfalls result in rapidly moving, deep waters that violently course their way through the canyon. Sudden torrents of water are most destructive in the fragile environment of the desert. They can trigger extensive erosion of the canyon walls, movement of unstable sections of talus and loose rocks, and mudflows.

ENDING

The geological activities described above have not stopped, but continue carving new dramatic vistas. Observing and understanding modern depositional and erosional processes helps unlock our planet's past and furnishes us with respect for the fragile nature of our environment. Geological knowledge allows us to see so much more than the scenery, vegetation, wildlife, skies, and colors. It is our ticket into the earth's past, and an avenue for our imaginations to travel into the future.

As a visitor to Utah's state lands, it is important to be a responsible user and be aware of and prepared for potential natural hazards. Be observant and you will see so much more.

Numerous publications were employed in preparing this brochure. A limited list is supplied below for readers interested in pursuing further research.

Anderson, J.J., and Rowley, P.D., 1975, Cenozoic stratigraphy of southwestern high plateaus of Utah, *in* Anderson, J.J., Rowley, P.D., Fleck, R.J., and Nairn, A.E.M., eds., Cenozoic Geology of Southwestern High Plateaus of Utah: Geological Society of America Special Paper 160, p. 1-52.

Averitt, Paul, Detterman, J.S., Harshbarger, J.W., Repenning, C.A., and Wilson, R.F., 1955, Revisions in correlation and nomenclature of Triassic and Jurassic formations in southwestern Utah and northern Arizona: American Association of Petroleum Geologists Bulletin, v. 39, p. 2515-2524.

Best, M.G., Brimhall, W.H., and Hamblin, W.K., 1969, Late Cenozoic basalts on the western margin of the Colorado Plateaus, Utah and Arizona: Research Rept., Department of Geology, Brigham Young University, no. 69-1, 39 p.

Best, M.G., and Hamblin, W.K., 1970, Implications of tectonism and volcanism in the western Grand Canyon, *in* Hamblin, W.K., and Best, M.G., eds., The Western Grand Canyon District: Utah Geological Society Guidebook 23, p. 75-79.

Blakey, R.C., Peterson, Fred, Caputo, M.V., and Voorhees, B.J., 1983, Paleogeography of Middle Jurassic continental shoreline and shallow marine sedimentation, southern Utah, *in* Reynolds, M.W., and Dolly, E.D., eds., Mesozoic Paleogeography of West-Central United

States: Rocky Mountain Section of Economic Paleontologists and Mineralogists, p. 77-100.

Gregory, H.E., 1950, Geology and geography of the Zion Park region, Utah and Arizona: U.S. Geological Survey Professional Paper 220, 200 p.

Hamblin, W.K., 1970, Late Cenozoic basalt flows of the western Grand Canyon, *in* Hamblin, W.K., and Best, M.G., eds., 1970, The Western Grand Canyon District: Utah Geological Society Guidebook 23, p. 21-37.

Hintze, L.F., 1986, Stratigraphy and structure of the Beaver Dam Mountains, southwestern Utah, *in* Griffen, D.T., and Phillips, W.R., eds., Thrusting and Extensional Structures and Mineralization in the Beaver Dam Mountains, Southwestern Utah: Utah Geological Association Publication 15, p. 1-36.

Hintze, L.F., 1988, Geologic history of Utah: Brigham Young University Geology Studies Special Publication 7, 202 p.

Imlay, R.W., 1980, Jurassic paleogeography of the conterminous United States in its continental setting: U.S. Geological Survey Professional Paper 1062, 134 p.

Rowley, P.D., Steven, T.A., Anderson, J.J., Cunningham, C.G., 1979, Cenozoic stratigraphic and structural framework of southwestern Utah: U.S. Geological Survey Professional Paper 1149, 22 p.

Stokes, W.L., 1987, Geology of Utah: Utah Museum of Natural History and Utah Geological and Mineral Survey Miscellaneous Publication S, 305 p.

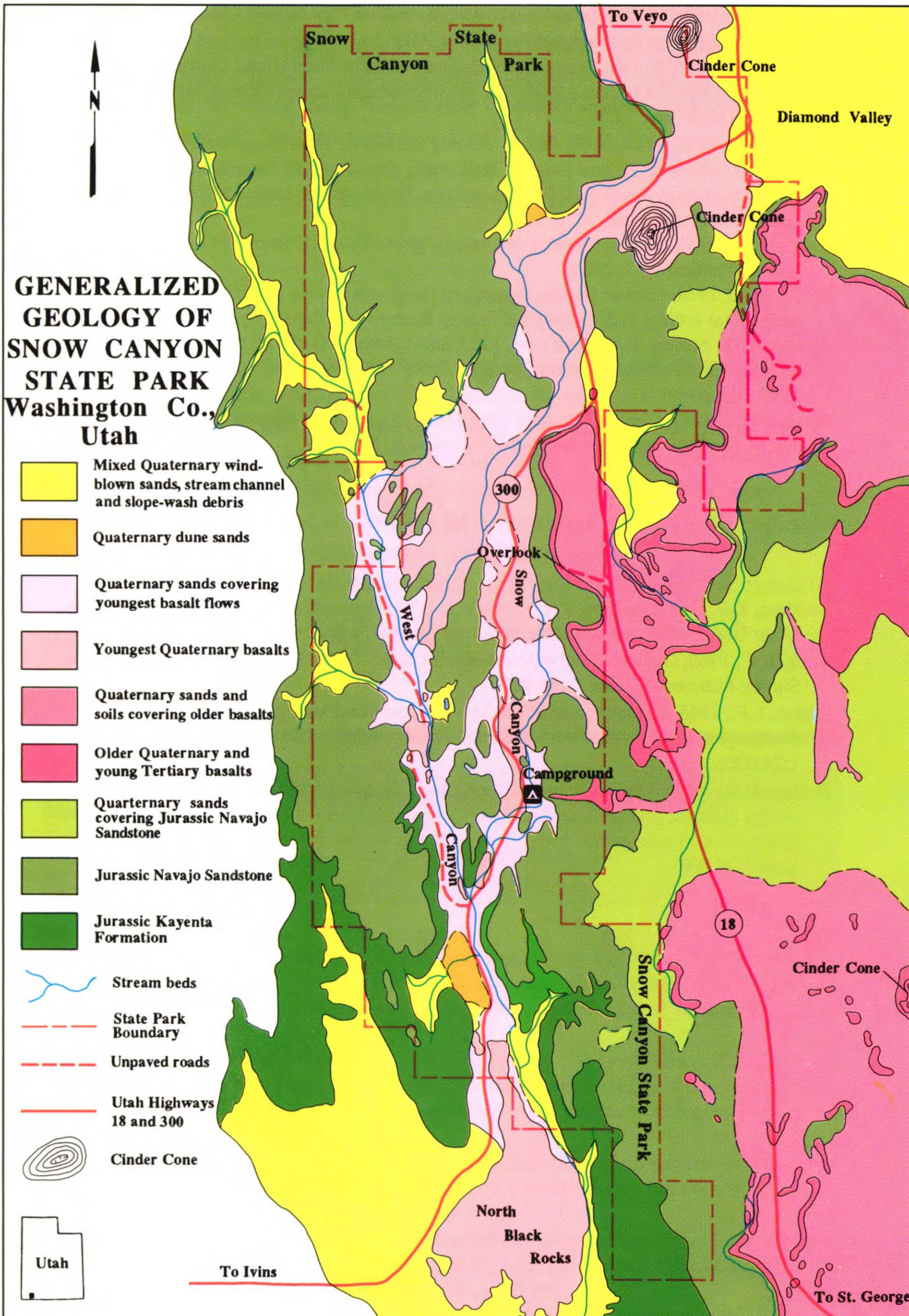
MAPS

Budding, K.E., and Sommers, S.N., compilers, 1986, Geologic map of the St. George Basin, Utah: Utah Geological and Mineral Survey Special Studies 67, plate 1, scale 1" = 1.6 mi.

Cook, E.F., 1960, Geologic map of Washington County, Utah: Utah Geological and Mineral Survey Bulletin 66, scale 1:130,000.

Hintze, L.F., 1985, Geologic map of the Shivwits and West Mountain Peak quadrangles, Washington County, Utah: U.S. Geological Survey Open-File Report 85-119, scale 1:24,000.

Houser, B.B., Jones, J.L., Kilburn, J.E., and Blank, H.R., Jr., 1986, Map showing mineral and energy resource potential, geology, and sample localities for the Red Mountain Wilderness Study Area, Washington County, Utah: U.S. Geological Survey Bulletin 1746, plate 1, scale 1:24,000.


GENERALIZED GEOLOGY OF SNOW CANYON STATE PARK
Washington Co., Utah
N
Mixed Quaternary wind-blown sands, stream channel and slope-wash debris
Quaternary dune sands
Quaternary sands covering youngest basalt flows
Youngest Quaternary basalts
Quaternary sands and soils covering older basalts
Older Quaternary and young Tertiary basalts
Quarternary sands covering Jurassic Navajo Sandstone
Jurassic Navajo Sandstone
Jurassic Kayenta Formation
Stream beds
State Park Boundary
Unpaved roads
Utah Highways 18 and 300
Cinder Cone
Utah
Snow Canyon State Park
To Veyo
Cinder Cone
Diamond Valley
Cinder Cone
300
Overlook
Snow Canyon
West Canyon
Campground
18
Cinder Cone
Snow Canyon State Park
North Black Rocks
To Ivins
To St. George

DEPARTMENT OF NATURAL RESOURCES
Utah Geological Survey
PUBLIC INFORMATION SERIES 13
1992