The Geology of Zion National Park:
A Monument to Erosion

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Zion National Park and the surrounding area expose much geologic history, and is a beautiful display of recent erosive forces according to geologic time, still at work. Zion Canyon is part of the Grand Staircase. The North Fork Virgin River has cut through millennia of strata, exposing at least eleven formations or sedimentary layers. Part of what is revealed is the interaction between Navajo Sandstone and Kayenta Formation in the form of weeping rocks. And as the river cuts, weathering and mass wasting continues to widened Zion Canyon. Recent volcanic activity and landslides have contributed to periodic damming of the canyon, leaving behind evidence of lacustrine deposition and frozen lava flows. I observed remnants of these basalt flows just outside the park, where I collected a sample. [Figure 6]

The Grand Canyon, Zion Canyon, and Bryce Canyon together expose much of Earth's history. This area is made up of primarily continental deposits, with cliff and canyon walls made bare by erosional and wasting forces. From the bottom-up, on this Grand Staircase we have the Vermillion Cliffs, which expose Triassic depositions (< 250 MA), the White Cliffs expose Jurassic depositions (< 200 MA), Gray Cliffs expose Cretaceous depositions (< 79 MA), and the Pink Cliffs expose Tertiary deposition (< 65 MA). These cliffs are all connected by relatively flat areas in between. Within Zion National Park are exposed enormous erosional forms in the White Cliffs, carved by the North Fork Virgin River. (Stokes, 1986)

The North Fork Virgin River cuts down Zion Canyon at a rate of 1.5 inches per hundred years, or about 1,000 feet in the last million years. As a result of higher snow and rainfall during the Pleistocene (, downward cutting of the canyon may have been faster during that period. Zion Canyon is part of a larger structural block. The Hurricane Fault Zone forms the western border of this block. It is important to note that the Hurricane Fault Zone is believed to have started moving in the Pliocene epoch, less than three million years ago. To the east, it is the younger

Sevier Fault Zone which borders the block. Erosion of the block began with headwaters eroding the first fault scarps of the Hurricane Fault Zone, probably beginning in the Pliocene (< 5 MA). If not for this fault, Zion Canyon might not even exist. (Biek, Willis, Hylland, & Doelling, 2003). And, while canyon cutting at Zion Canyon is the work of river erosion, canyon widening is due to wasting in the form of rock falls and landslides. (Chronic & Chronic, 2004)

Navajo Sandstone is the predominant sedimentary rock in the region, and it is only present in the western half of the Colorado Plateau. (Baars, The Colorado Plateau; A Geologic History, Revised and Updated, 2000) The depositional environment of this sandstone is aeolian in nature. (Geology and Geophysics Department, Navajo Sandstone (in Glen Canyon Group), 2010) . Interestingly, studies of the cross-bedding of the Navajo Sandstone revealed a south-southwest (SSW) wind directional trend in the Zion National Park region. (Stokes, 1986) It is the most prominent lithology with the greatest thickness within the park, with a maximum thickness of 2,000-2,200 feet. (Chronic & Chronic, 2004) (Stokes, 1986) The Kayenta Formation is another important stratum within the canyon. It lays directly below and adjacent to the Navajo Sandstone. The Kayenta Formation is the result of fluvial deposition, and is comprised of siltstones and mudstones. (Geology and Geophysics Department, Kayenta Formations (in Glen Canyon Group), 2010) (Chronic & Chronic, 2004)

The exposed strata at Zion National Park contains the following, in order from oldest to youngest (bottom → up): Toroweap Formation (early Permian), Kaibab Formations (early Permian); Moenkopi Formation (early to middle Triassic), Chinle Formations (late Triassic); Moenave Formation (early Jurassic), Kayenta Formation (early Jurassic), Navajo or Nugget Sandstone (early Jurassic), Temple Cap Formation (middle Jurassic), Carmel Formation (middle Jurassic); Dakota and Cedar Mountain Formations (late Cretaceous); and, finally, basalt flows, lake deposits, landslides, and alluvium forming from the Pliocene to the present. This comprises almost 7,000 feet and 290 million years of sedimentary deposition, cut into and exposed by the eroding forces of a river over only about the past 2 million years. (Biek, Willis, Hylland, & Doelling, 2003)

The Kayenta Formation is responsible for most slides within the park. There is a line of springs along contact between Navajo Sandstone and the Kayenta Formation. This is because water has infiltrated the highly permeable and porous Navajo Sandstone, and moves in a downward direction because of gravity. Then water reaches the relatively impermeable siltstone and mudstone of the Kayenta Formation, which effectively causes the groundwater to then push in a lateral direction toward the exposed cliff face. Thereby creating a line of seeping springs along this meeting of the two depositional strata. Water weakens the rock, and the Kayenta siltstones and mudstones are the first to give. Groundwater freezing and thawing as the season go causes mechanical weathering. Additionally, lichen and the vegetation growing along these springs further cuts into the rock. This continuous weathering action facilitates the forming of arches and alcoves in the Kayenta Formation rock, such as the one at Weeping Rock. (Chronic & Chronic, 2004) [Figures 1, 4]

Another weathering feature on display at Zion Canyon is Checkerboard Mesa near the eastern entrance to the park. Here the characteristic crossbedding of the Navajo Sandstone is evident, and here it has been eroded by wind and rain in a way that forms small, vertical gullies in the Sandstone, resulting in the checkerboard pattern. Interestingly, this weather pattern appears limited to north facing slopes. (Baars, A Traveler's Guide to the Geology of the Colorado Plateau, 2002) (Chronic & Chronic, 2004) [Figure 3]

Zion National Park is within the Western Grand Canyon basaltic field. Most basalt flows in this region are very young according to the geologic time scale, ranging in age between 7 million and 500 years old. The Zion basalt flows are between 1.4 million to about 100,000 years old. Several of these flows originated at cinder cone volcanoes outside park boundaries to the north and to the west (Biek, Willis, Hylland, & Doelling, 2003). On Utah Highway 9, west from Zion National Park's south entrance, near milepost 25, volcanic rocks are on display immediately off the road on the mountain side to the north and west. (Baars, A Traveler's Guide to the Geology of the Colorado Plateau, 2002) This is where I collected my basalt rock sample. The stuff is everywhere. [Figures 5, 6]

These basaltic lava flows and landslides have periodically stemmed the Virgin river and some of its tributaries over the past 1.5-2 million years. Because of the damming effect of landslides and basalt flows in a canyon region, small lakes and ponds have historically formed within Zion Canyon. Lacustrine deposits relating to at least 14 lakes have been identified. (Biek, Willis, Hylland, & Doelling, 2003)

Erosion has dominated and shaped the landscape here at Zion Canyon and surrounding areas for the past two million years. Zion National Park attracts nearly three million visitors every year, (Smith, 2008) and it is popular largely in part because of the geology on display. It is a beautiful, very colorful landscape. The Grand Staircase, including the region of Zion National Park, is a prime example of geology exposed and in action. [Figure 2]

RESOURCES:

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Baars, D. L. (2002). *A Traveler's Guide to the Geology of the Colorado Plateau.* Salt Lake City, Utah: The University of Utah Press.

Biek, R. F., Willis, G. C., Hylland, M. D., & Doelling, H. H. (2003). Geology of Zion National Park, Utah. In D. A. Sprinkel, T. C. Chidsey, Jr., & P. B. Anderson, *Geology of Utah's Parks and Monuments* (pp. 106-137). Salt Lake City, Utah: Regal Printing Limited through QuinnEssentials Books and Printing, Inc.

Chronic, H., & Chronic, L. (2004). *Pages of Stone, Geology of the Grand Cayon & Plateau Country National Parks & Monuments, Second Edition.* Seattle, WA: The Mountaineers Books.

Geology and Geophysics Department, T. U. (2010). *Kayenta Formations (in Glen Canyon Group)*. Retrieved from Utah.edu: http://sed.utah.edu/Kayenta.htm

Geology and Geophysics Department, T. U. (2010). *Navajo Sandstone (in Glen Canyon Group)*. Retrieved from Utah.edu: http://sed.utah.edu/Navajo.htm

Smith, T. (2008). Hikers Impact on the North Fork of the Virgin River, Zion National Park, Utah. *The American Midland Naturalist*, 392-400.

Stokes, W. L. (1986). *Geology of Utah.* Salt Lake City, Utah: Utah Museum of Natural History (University of Utah), and Utah Geological and Mineral Survey Department of Natural Resources.

Field Observations Form: (to be completed by hand in the field during site visit)

Your Name: Ana Hoerner Site Name: Zion National Park

Date of Site Visit: 15-18 March 2017 Other People Present: my children + ~1million other park visitors

Rock Samples Collected:

Basalt from outside the park. Cannot collect anything from inside the park according to the rules.

Human/Cultural Observations: (such as past industry, past usage, current usage)

Indians used to avoid the canyon.

Currently, too many people visit the area.

Observations of Physical Geologic Elements: (such as rocks; sediments (silt, sand, and gravel); lava flows; old volcanoes; coastal features; wetlands; landslides or slump scars; faults; landscapes; industrial and mine activities and contamination) Sandstone, sandstone, and more sandstone. Noticed lava flows as I drove into South Entrance. Steep cliffs within park, cut by N. Fork Virgin River. Seeping ground water is a thousand years old, according to ranger.

Observations of Environmental Issues: (such as soil or groundwater contamination, or protection of any endangered species) Predatory mammals (cougars) have about been run out of the area, and now there are too many deer!

Photograph Log:

Photo Number	Photo Time and Date:	Photo Description:
1	2:50pm 16 Mar 2017	From Alcove at Weeping Rock
2	11:25 am 17 Mar 2017	The Watchman
3	1:25 pm 17 Mar 2017	Checkerboard Mesa
4	2:09pm 17Mar 2017	Arch/Alcove near The Tunnel Switchbacks
5	10:40am 18Mar 2017	Cinder Cone? Definitely Basalt. Young Rocks Rock!
6	3:49 pm 17Apr 2017	Basalt sample taken from above location off Utah 9.
7		
8		
9		
10		
11		
12		

Zion National Park

Map by Ana Priscila Hoerner

17 April 2017

Zion NP Borders

Rivers

Faults

F1 Figures / Photo locations

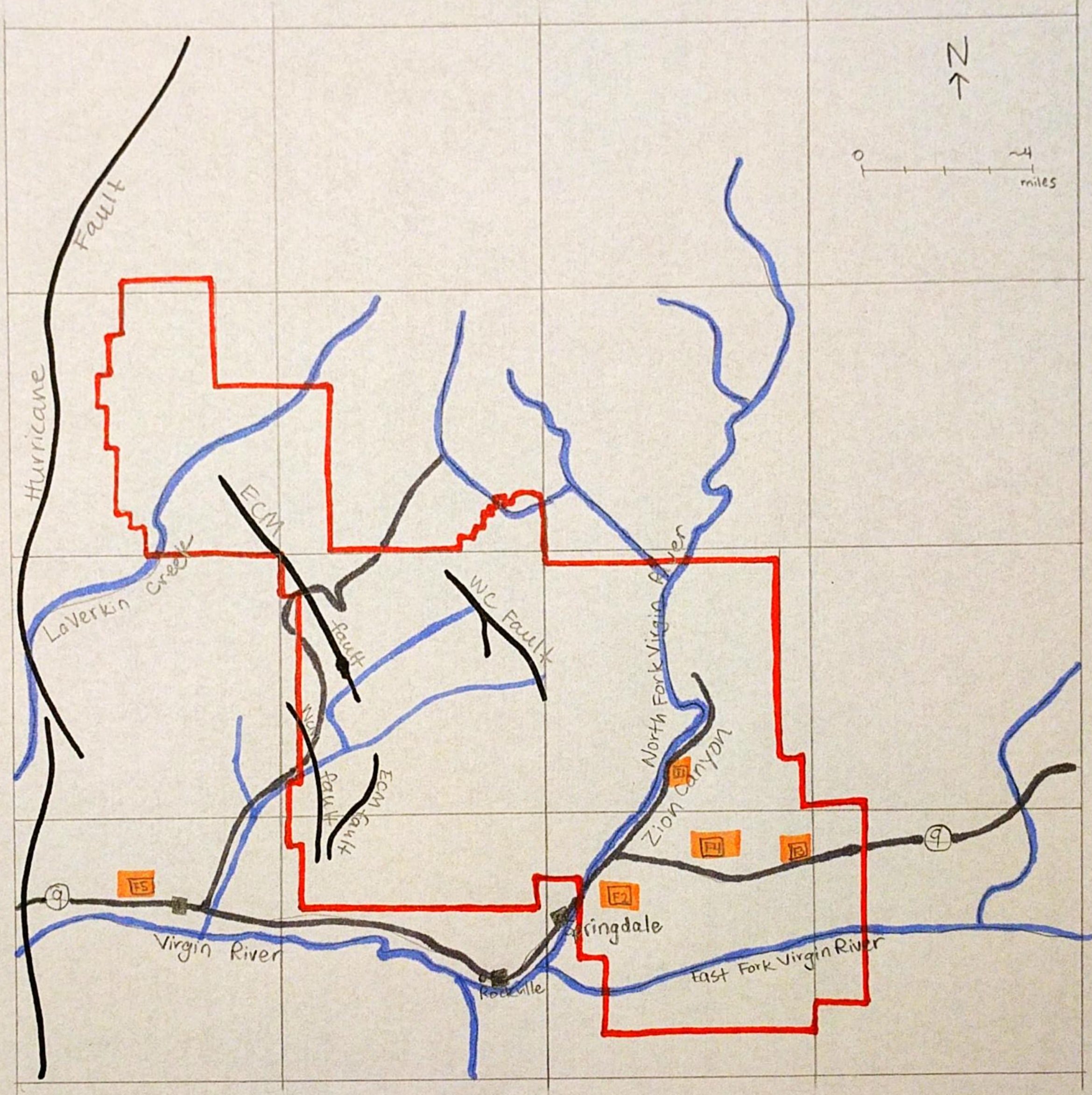

Figure 1 From the point of view inside the alcove at Weeping Rock, looking out past the seeping water curtain to Zion Canyon.

Figure 2 View of The Watchman, which sits high above the Navajo Sandstone stratum, at the mouth of Zion Canyon.

Figure 3 Checkerboard Mesa, exposed north face of this sandstone formation shows vertical gullies crossing the sandstone cross-bedding at near perpendicular angles.

Figure 4 Alcove formed in the Kayenta Formation, which sits in contrast with the thin layer of near-white Navajo Sandstone on the upper left at this particular location.

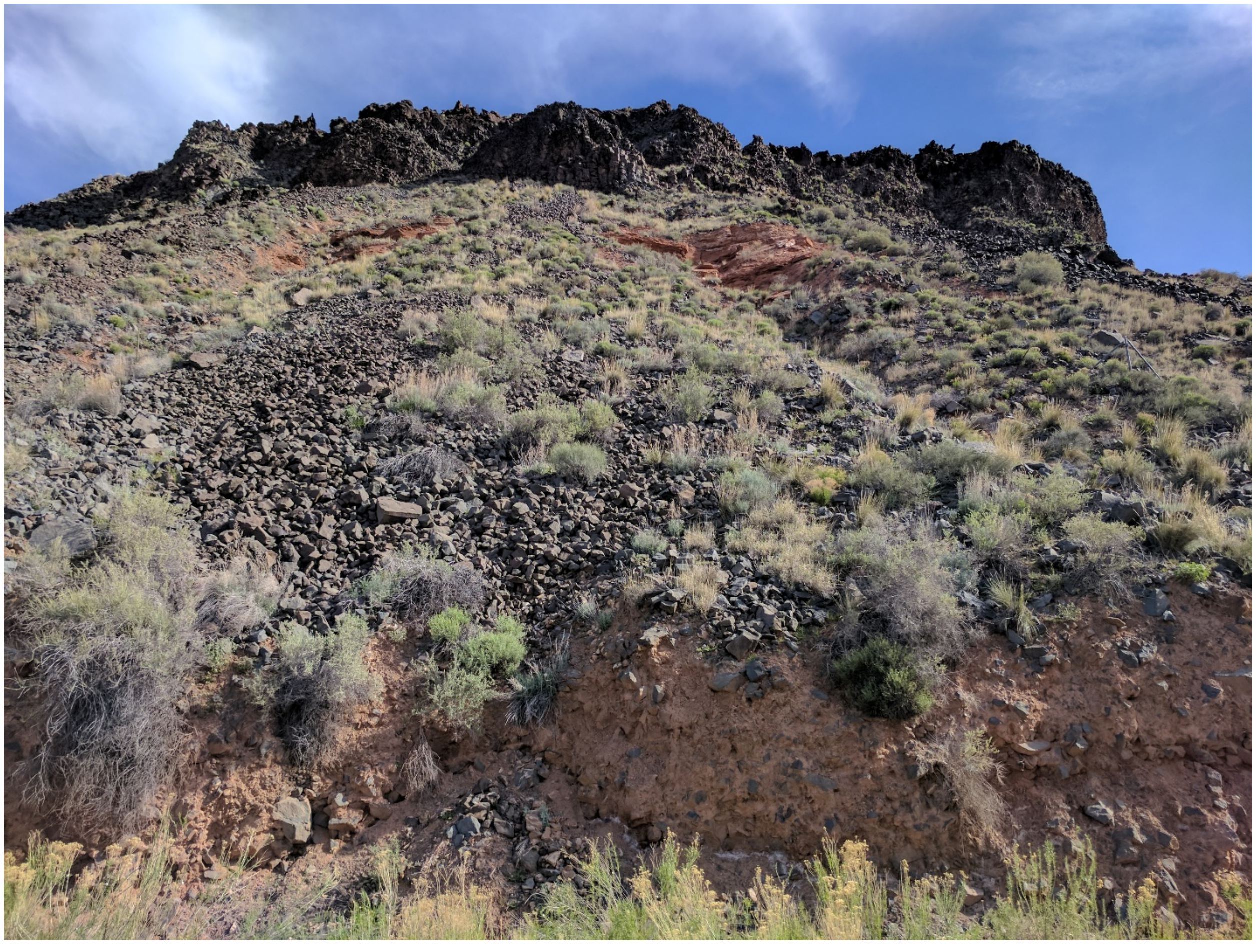

Figure 5 Basalt flow debris field west of Zion National Park's south entrance.

Figure 6 Basalt rock sample that I took from the above pictured field.