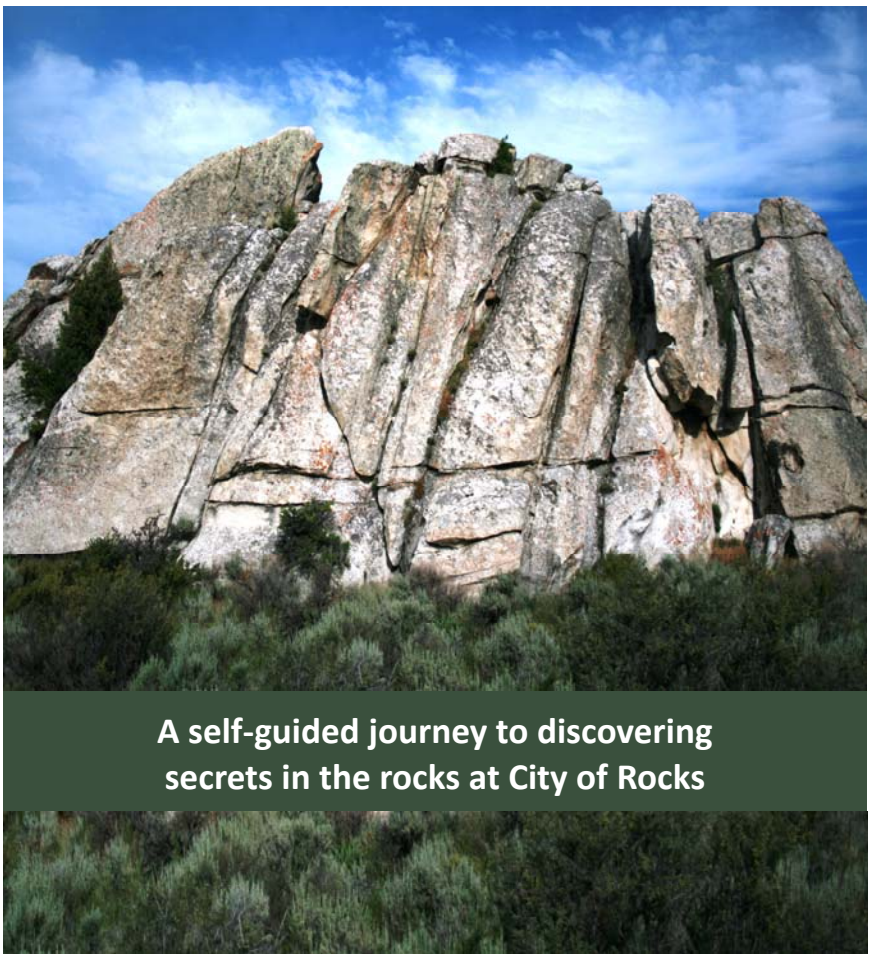
# Geological Interpretive Trail

## City of Rocks National Reserve



**A self-guided journey to discovering secrets in the rocks at City of Rocks**

City of Rocks National Reserve is a partnership between the National Park Service and the Idaho Department of Parks and Recreation

# Geological Interpretive Trail

## City of Rocks National Reserve

**A self-guided journey to discovering the secrets in the rocks of City of Rocks**

Prepared by
Idaho Department of Parks and Recreation
and the
National Park Service

City of Rocks National Reserve
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www.nps.gov/ciro

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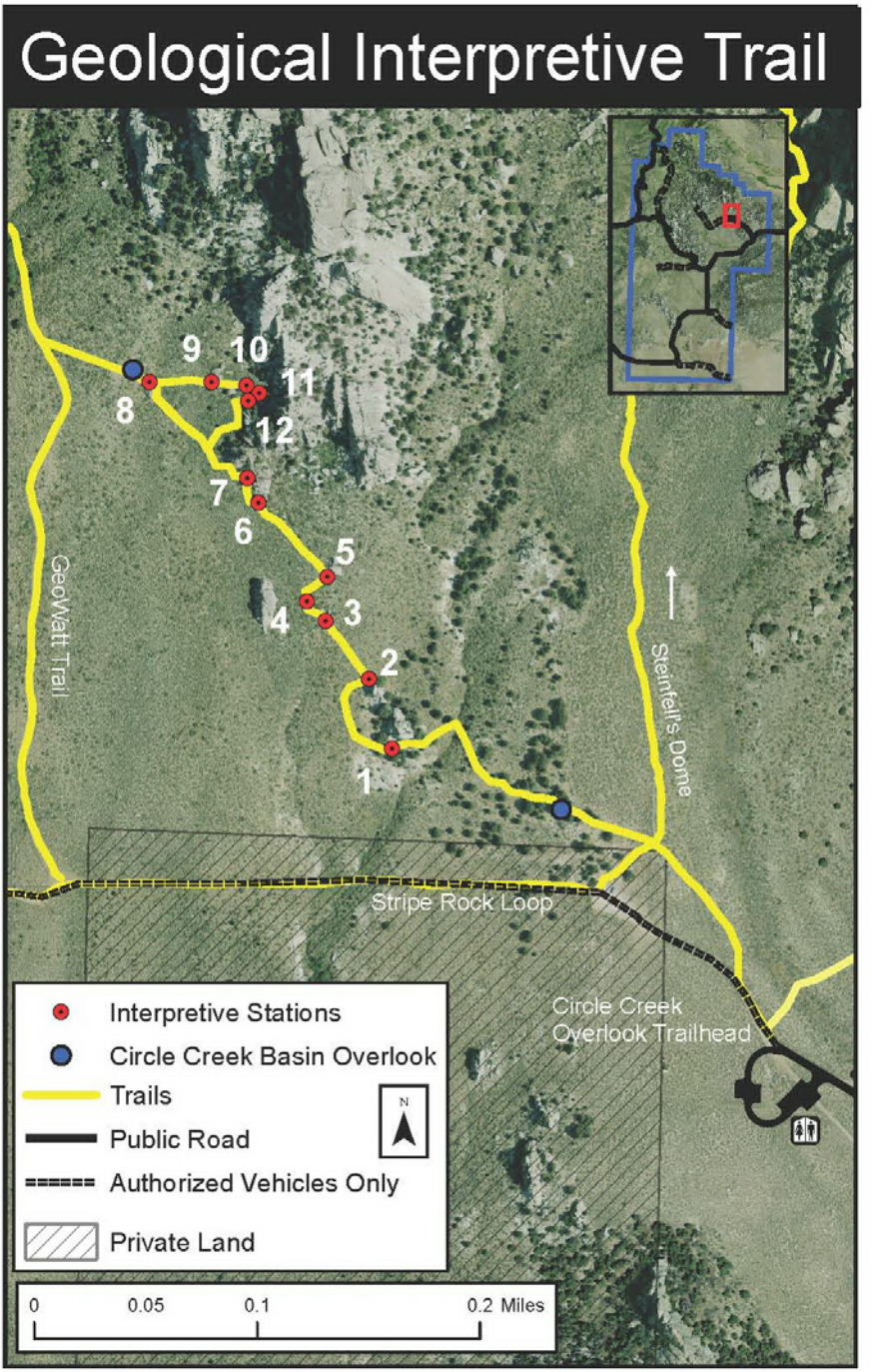
## Contents

*What's in store before you explore?* There are twelve interpretive stations along the 0.6 mile trail. The trail rises 160 feet in elevation, makes a loop at the end, and retraces much of the same route for a total of 1.2 miles.


Geological Interpretive Trail
9
10
11
8
12
7
6
5
4
3
2
1
GeoWatt Trail
Steinfell's Dome
Stripe Rock Loop
Circle Creek
Overlook Trailhead
Interpretive Stations
Circle Creek Basin Overlook
Trails
Public Road
Authorized Vehicles Only
Private Land
N
0
0.05
0.1
0.2 Miles

## Introduction

City of Rocks National Reserve is part of the Basin and Range geologic province. Basin and Range topography results from crustal extension. As the crust is stretched (pulled apart), high angle faults develop. Along these faults, mountains uplift and valleys drop, creating the distinctive mountain ranges and wide valleys of the Basin and Range province.

As rocky ranges rise, the newly exposed rock is immediately subjected to weathering and erosion. This rock is attacked by water, ice, wind, and other erosive agents, that have produced many of the geologic features visible today.

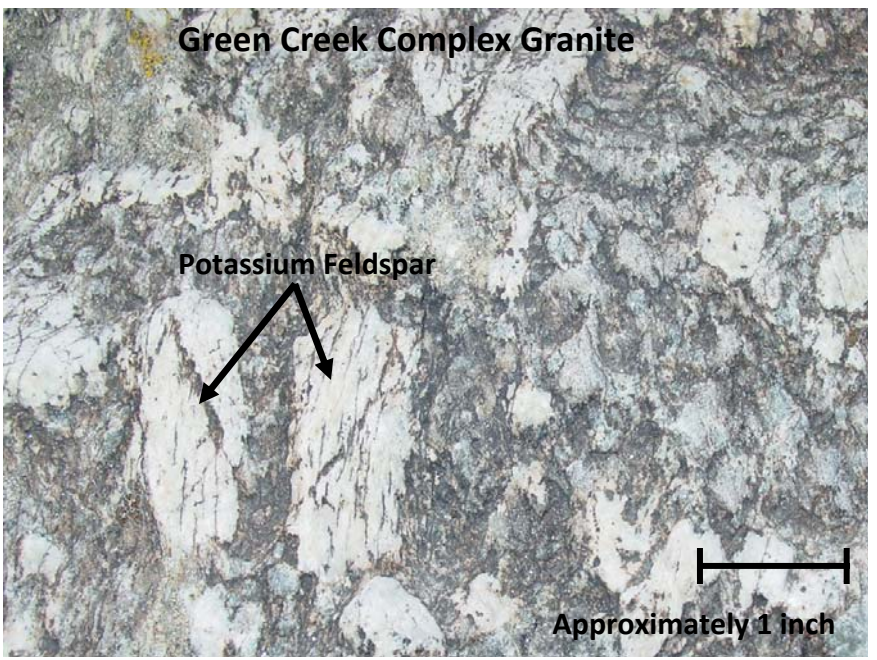
The majority of outcrops at City of Rocks, and all of the pinnacles, consist of intrusive igneous rock with a granitic composition. Geologists have mapped the two different types of granitic rock within the Reserve as the Green Creek Complex and the Almo pluton.

Circle Creek Basin

## Green Creek Complex

The Green Creek Complex is an assemblage of metamorphic rocks consisting of granite, granitic gneiss (metamorphosed granite), schist and a few other rock types. Radiometric analysis indicates that the Green Creek granite may be as old as 2.5 billion years (Archean) and is considered to be some of the oldest rock exposed on the continent west of the Mississippi River. This granite has a porphyritic texture, meaning it is composed of crystals of two distinct sizes. The larger crystals are potassium feldspar. They are embedded in a matrix of smaller crystals consisting of quartz, biotite, and plagioclase feldspar.

Feldspars are the most common family of silicate minerals. They are broadly divided into two groups: sodium and calcium-bearing feldspars, called plagioclase, and potassium-bearing feldspars, called orthoclase, microcline or sanidine, depending on their crystallographic structure.

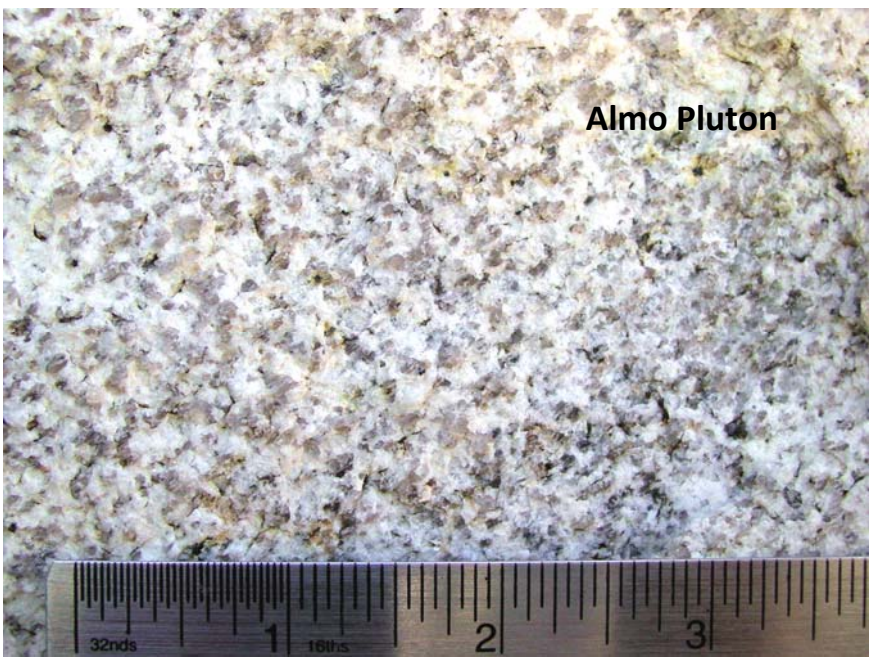


## Almo Pluton

Most of the pinnacles at City of Rocks and Castle Rocks are made of granite from the Almo pluton. The pluton started out as an intrusive body of magma and has a convoluted contact with the Green Creek Complex. It is the youngest rock at City of Rocks and formed about 28 million years ago.

Unlike the granite of the Green Creek Complex, the Almo pluton has an equigranular texture. Notice in the photograph below the small uniform size of the crystals in the Almo pluton in contrast to the variety of sizes in the Green Creek Complex (previous page).

Both types of granite are cut in many places by dikes of pegmatite, a very coarse-grained granitic rock that usually forms during the last stages of crystallization of a large granitic pluton. The pegmatites at City of Rocks contain large quartz and feldspar crystals about the size of a fist.

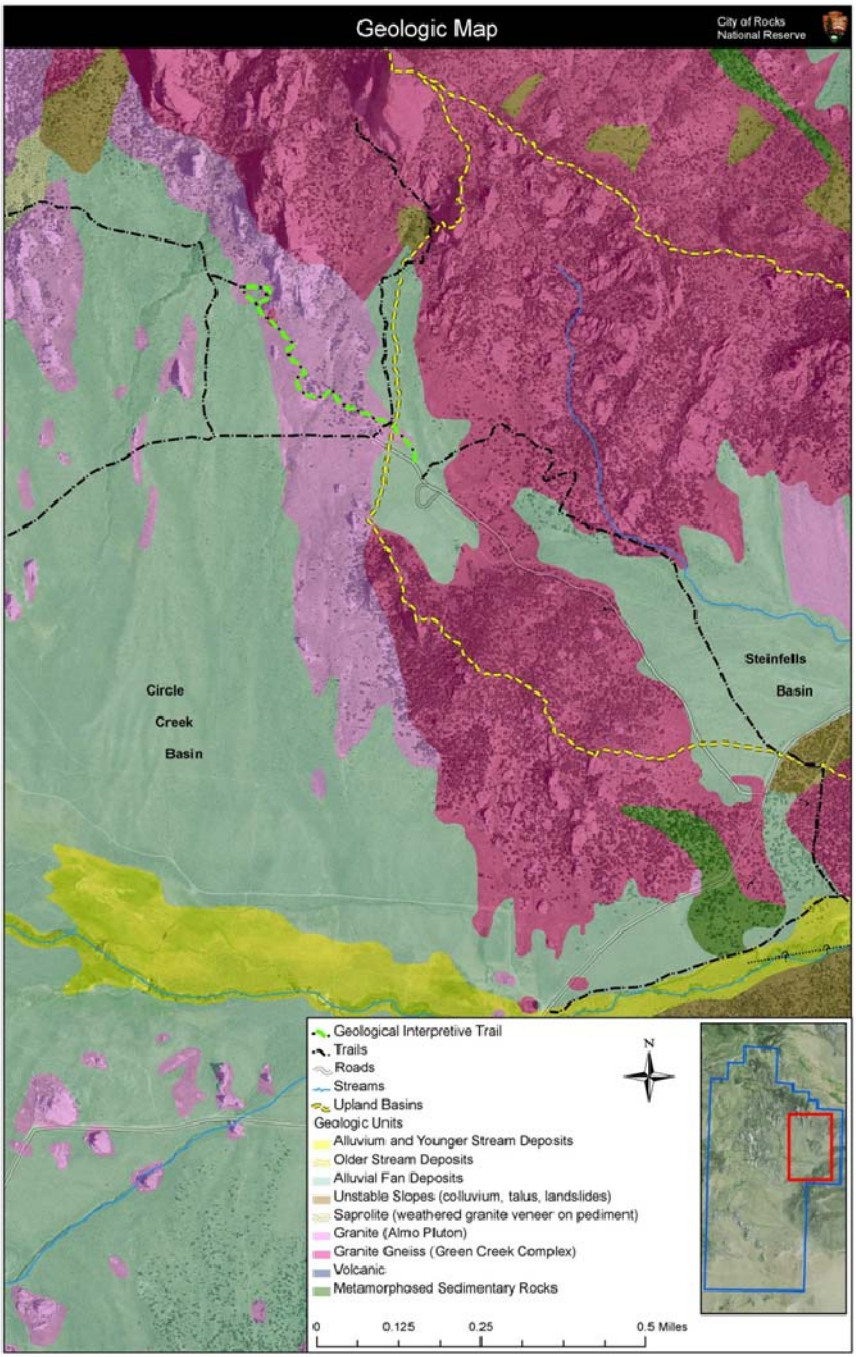


## Where Granites Meet

The granites of the Green Creek Complex and the Almo pluton look similar from a distance; however, the Green Creek granite can easily be distinguished by the large crystals of potassium feldspar and its darker (reddish-brown) color and ragged appearance. The Almo pluton in most places appears smooth and gray. The Green Creek granite has a higher concentration of iron-bearing minerals. Oxidation of the iron stains the rock rusty brown.

At stations 6 and 7 the granites can be compared where they are in contact. One of the most dramatic comparisons of these two granites is the Twin Sisters. This feature was the iconic landmark for California-bound emigrants from 1843 to 1882. Twins in size and shape, but not in age; the south Sister formed from the Green Creek granite and the north Sister formed from the Almo pluton. The contact between the two granites runs through the saddle between these two monoliths.


Look across the landscape of the Reserve and see if you can find other places where the two granites are in contact.


Geologic Map
City of Rocks
National Reserve
Circle
Creek
Basin
Steinfells
Basin
Geological Interpretive Trail
Trails
Roads
Streams
Upland Basins
Geologic Units
Alluvium and Younger Stream Deposits
Older Stream Deposits
Alluvial Fan Deposits
Unstable Slopes (colluvium, talus, landslides)
Saprolite (weathered granite veneer on pediment)
Granite (Almo Pluton)
Granite Gneiss (Green Creek Complex)
Volcanic
Metamorphosed Sedimentary Rocks
N
0
0.125
0.25
0.5 Miles

## Overlook: *Anticlines, Hogbacks & Upland Basins*

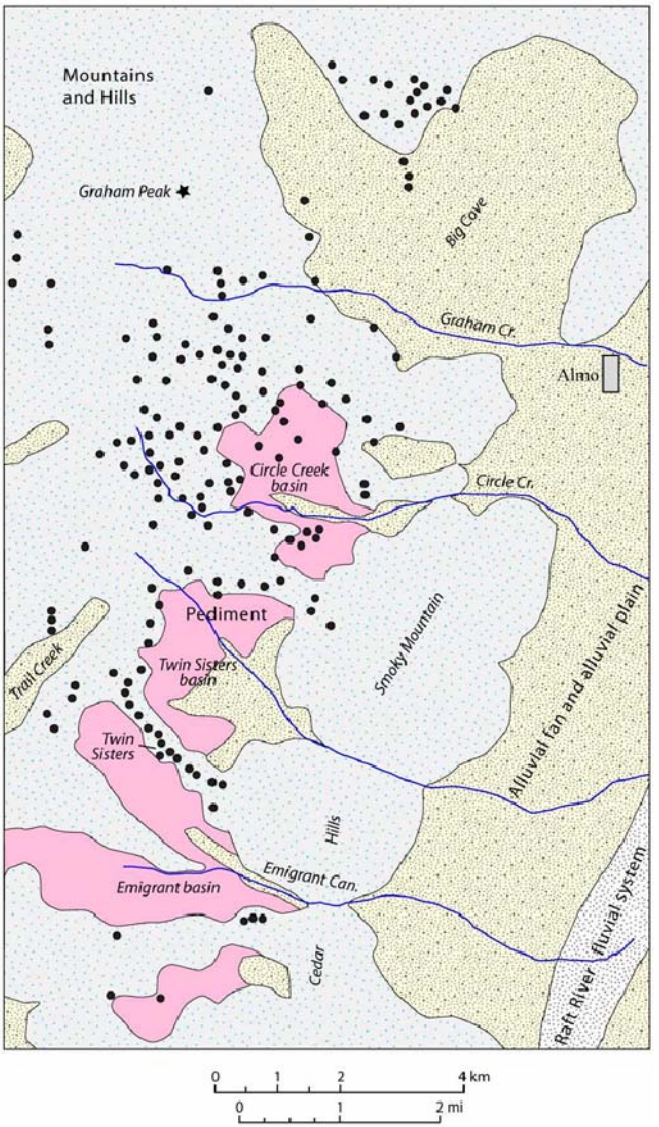
The City of Rocks anticline is an elongated structural dome of the Green Creek Complex and overlying metasedimentary rocks. Like an over-turned stack of bowls the rock layers dip away from the crest of the Albion Range toward the intermountain basins to the east and west. This is most noticeable by the eastward sloping hogback ridges along the east side of the mountains of which Smoky Mountain is the largest.

Three other gneiss-cored structural domes mantled by meta-sedimentary rocks occur in the Albion Range. All are aligned in a chain-like fashion roughly NNE with the anticline. To the north Big Bertha dome and Independence dome form topographically high promontories that undergird Mount Harrison and Mount Independence. The smallest dome, Moulton dome, lies just south of City of Rocks. Of these four structural domes, City of Rocks is the largest, stretching from the south end of the Reserve northward to Castle Rocks on the south slope of Cache Peak.

The Almo pluton intruded into the core of the southern two domes, where differential weathering between the softer granite and harder metamorphic rocks has hollowed out the arch of the anticline, forming topographic upland basins within the mountain range that markedly contrast with the high relief of the two northern domes.

Four prominent upland basins (Big Cove, Circle Creek Basin, Twin Sisters Basin and Emigrant Basin) are separated by lateral ridges extending from the crest of the Albion Mountains much like ribs from a spine. These upland basins are drained by streams that flow through “water gaps” that eroded through the hogback ridges. Erosional breaching of the anticline and removal of sediment through the water gaps set the upland basin backdrop for the picturesque granite spires.

## Geomorphology of City of Rocks and Castle Rocks

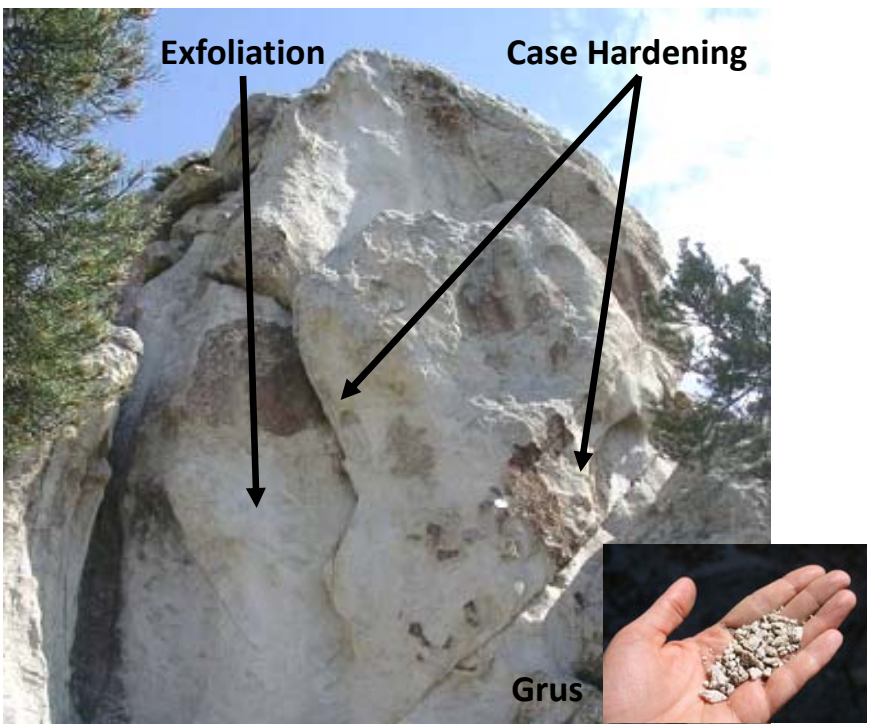



On the map: Pink—upland granite pediments; gray speckles—mountainous terrain underlain by bedrock; black dots—pinnacles; blue lines—major creeks.

Taken from Figure 3. in Miller et al. Geologic map and digital data base of the Almo quadrangle and City of Rocks National Reserve, Cassia County, Idaho, USGS Open-File Report 2008-1103, 2008.

## Station 1
## *Granitic Weathering*

Weather is the agent responsible for creating the bizarre and fantastic shapes that characterize the area. Weathering occurs on the surface of outcrops by granular disintegration (one layer of crystals after another are removed from the surface). This weathering leaves the newly exposed surface in a smooth rounded condition with no sharp or ragged edges. The detrital material is carried by wind and water to low areas among the prominent outcrops. The detrital material (granitic sand) that is found at the base of most outcrops, is called grus. Weathering-related features seen here include case hardening, exfoliation, and grus (located at the base of the outcrop).



## Station 2
## *Panholes*

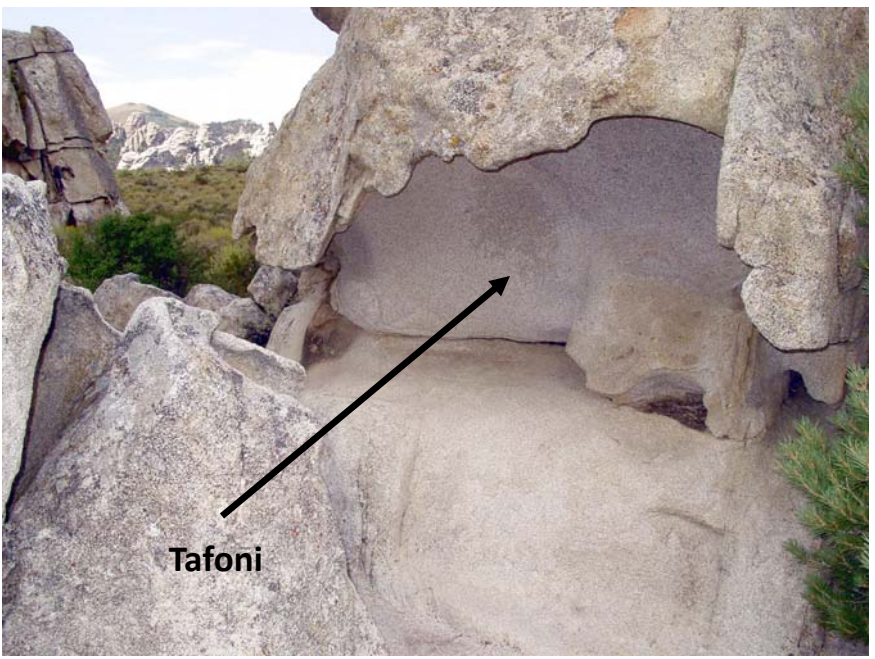
Panholes begin as tiny depressions or cracks where water remains for long periods of time. The longer water remains on the granite surface, the greater the dissolution of minerals by acidic water. One way that rainwater becomes acidic is when it mixes with decaying vegetation. Another way is when minerals in the rock leach into the water.

Panholes are sometimes incorrectly called potholes. Actually, a pothole is formed in the rocky bed of a stream by the grinding action of stone(s). There are no known potholes within the Reserve. One of the nearby locations to easily find potholes is in the basaltic bedrock of the Snake River, 50 miles north of here.

## Station 3
## *Tafoni*

Cavernous weathering creates small hollows on joint surfaces. These hollows gradually enlarge through the creation of a sheltered micro-climate that facilitates the accumulation of salt. Salt is a corrosive agent that expands when dry and breaks apart the granitic minerals. While salt minerals do occur naturally in the granite, they are more likely transported by wind and rain from the playas of the Great Salt Lake basin, only 30 miles south of here.

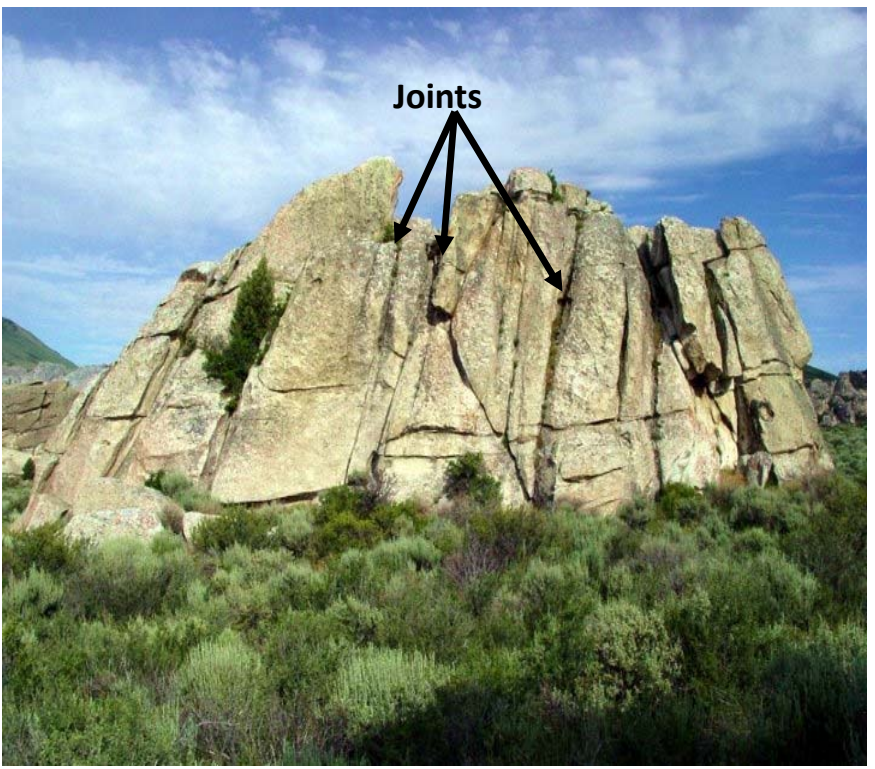
As salt eats away the interior, the case-hardened outer layer or shell erodes much slower, creating delicate arches, windows, and honeycombs.

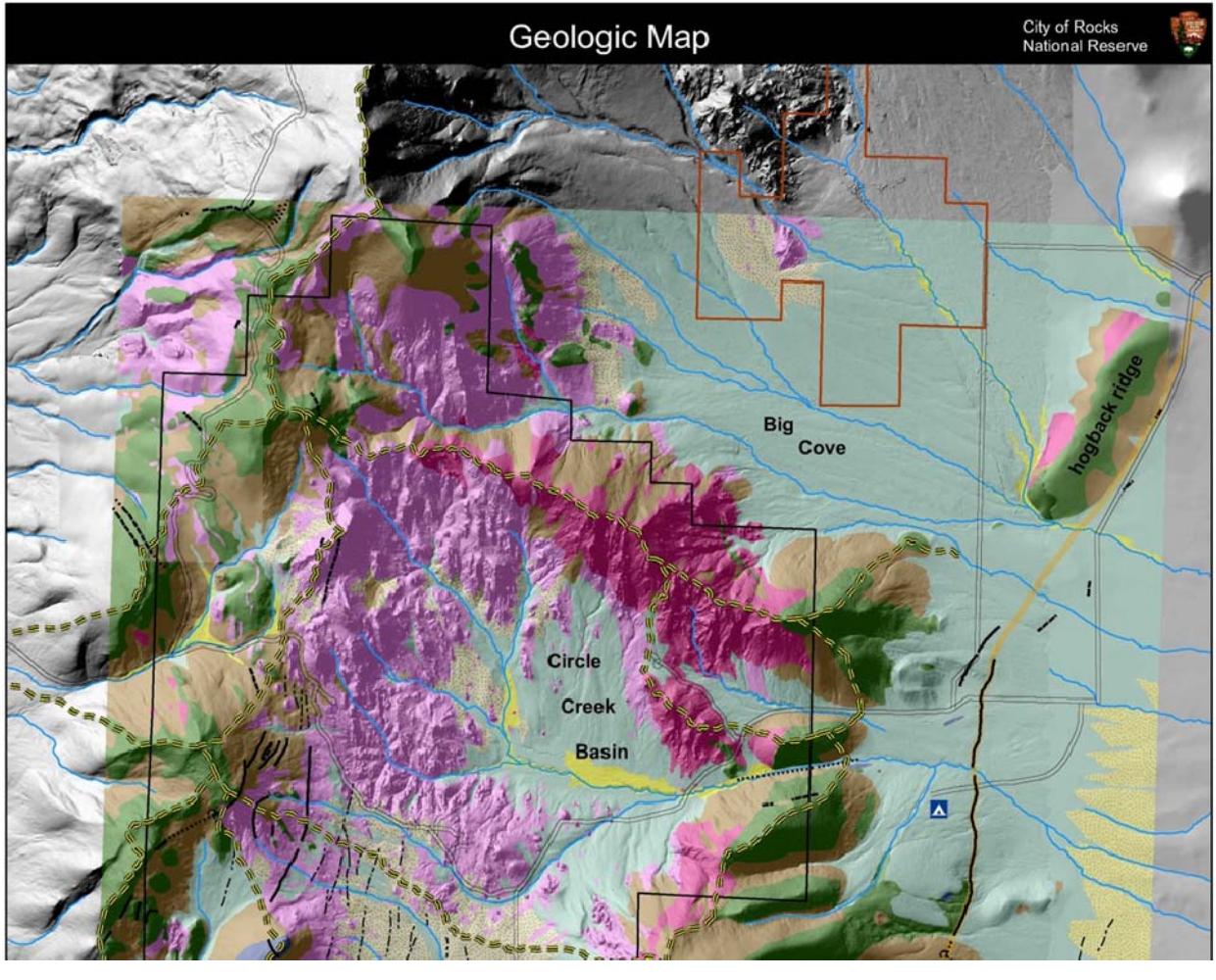


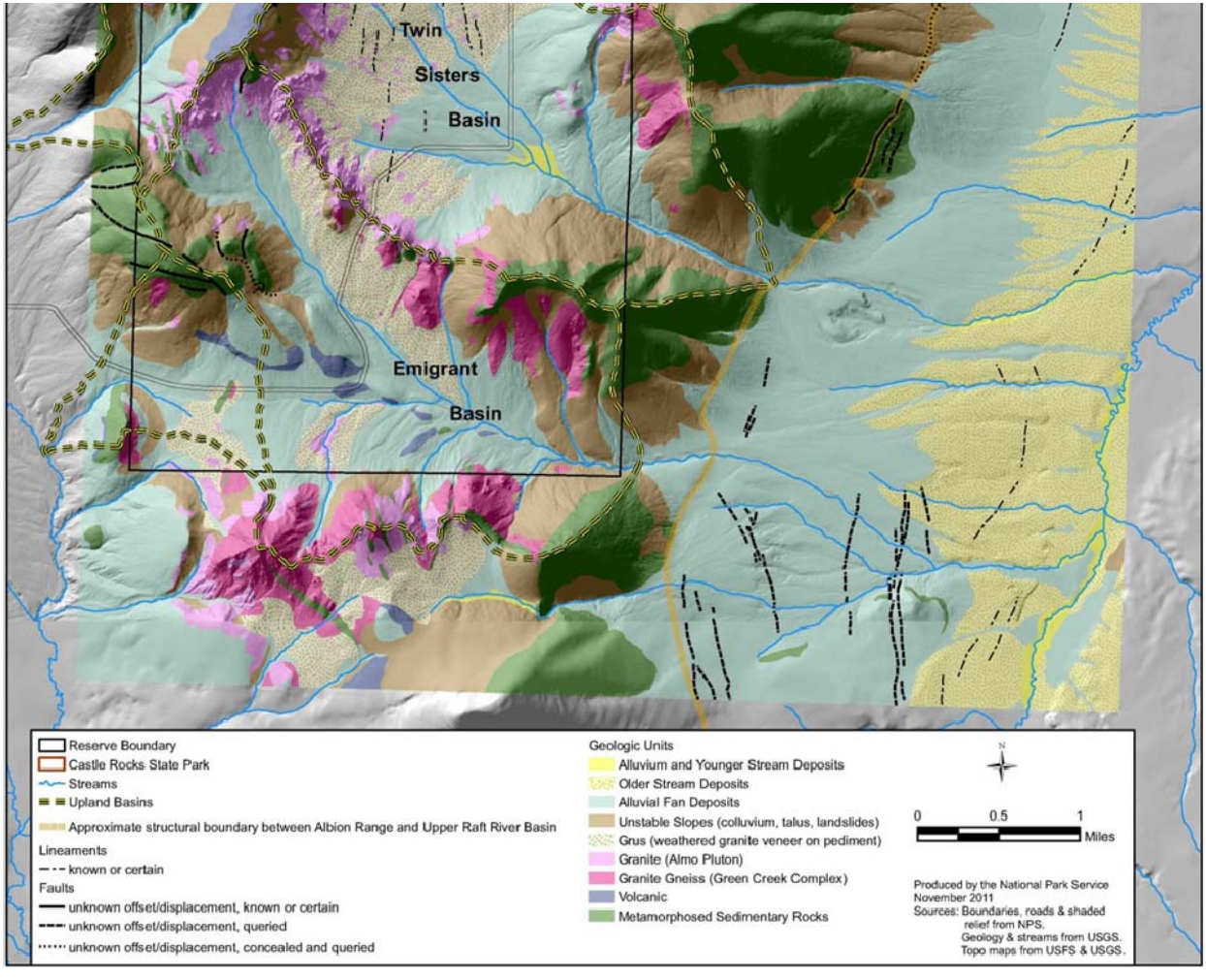
## Station 4
## *Joints*

Joints control the shape and distribution of most pinnacles at City of Rocks. A joint is a type of extension fracture formed by movement of the rock in a direction perpendicular to the plane of fracture. Joints form in solid rock that is stretched and its brittle strength (the point at which it breaks) is exceeded When this happens, the rock fractures.

The presence of joints allows water to infiltrate the rock and makes the granite vulnerable to weathering. The joints also trap soils, creating micro-habitat for a number of cliff-loving plants, such as ferns, limber pine, and pink alumroot.




Geologic Map
City of Rocks
National Reserve
Big
Cove
hogback ridge
Circle
Creek
Basin

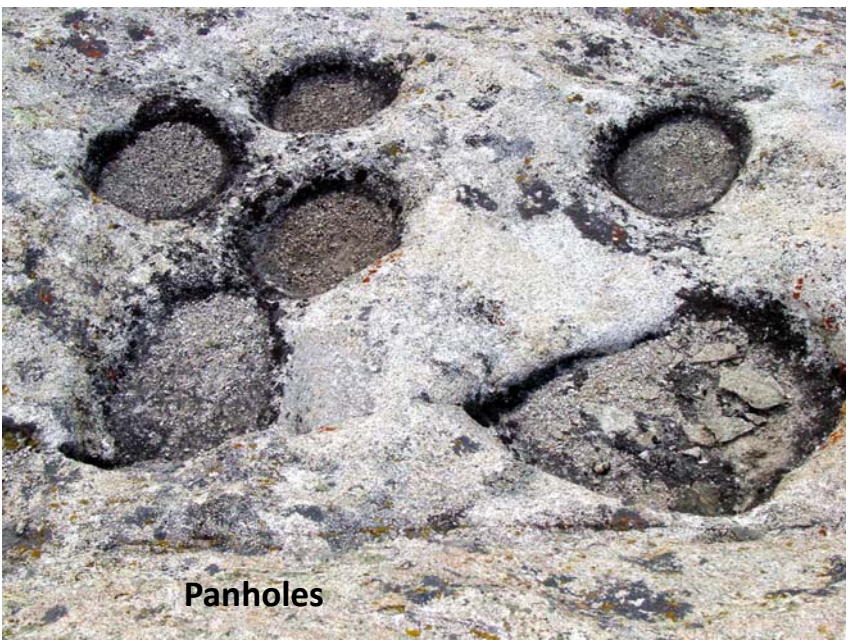

Twin
Sisters
Basin
Emigrant
Basin
Reserve Boundary
Castle Rocks State Park
Streams
Upland Basins
Approximate structural boundary between Albion Range and Upper Raft River Basin
Lineaments
known or certain
Faults
unknown offset/displacement, known or certain
unknown offset/displacement, queried
unknown offset/displacement, concealed and queried
Geologic Units
Alluvium and Younger Stream Deposits
Older Stream Deposits
Alluvial Fan Deposits
Unstable Slopes (colluvium, talus, landslides)
Grus (weathered granite veneer on pediment)
Granite (Almo Pluton)
Granite Gneiss (Green Creek Complex)
Volcanic
Metamorphosed Sedimentary Rocks
N
0
0.5
1
Miles
Produced by the National Park Service
November 2011
Sources: Boundaries, roads & shaded relief from NPS.
Geology & streams from USGS.
Topo maps from USFS & USGS.

## Station 5
## *Panholes*

Panholes often contain quartz and feldspar sand as residual detritus from in situ chemical weathering of the granite. Panholes also catch water after a storm and when snow melts.

One of the larger panholes at City of Rocks is located on top of Bath Rock. At times this panhole can hold water up to a depth of two feet. According to folklore, Bath Rock served as a place of bathing for shepherds or cowboys who remained out on the range for several days.

In 1937-38, the Bath Tub Rock Bathing Beauty Parade was held at City of Rocks, further establishing the connection between bathing and Bath Rock.

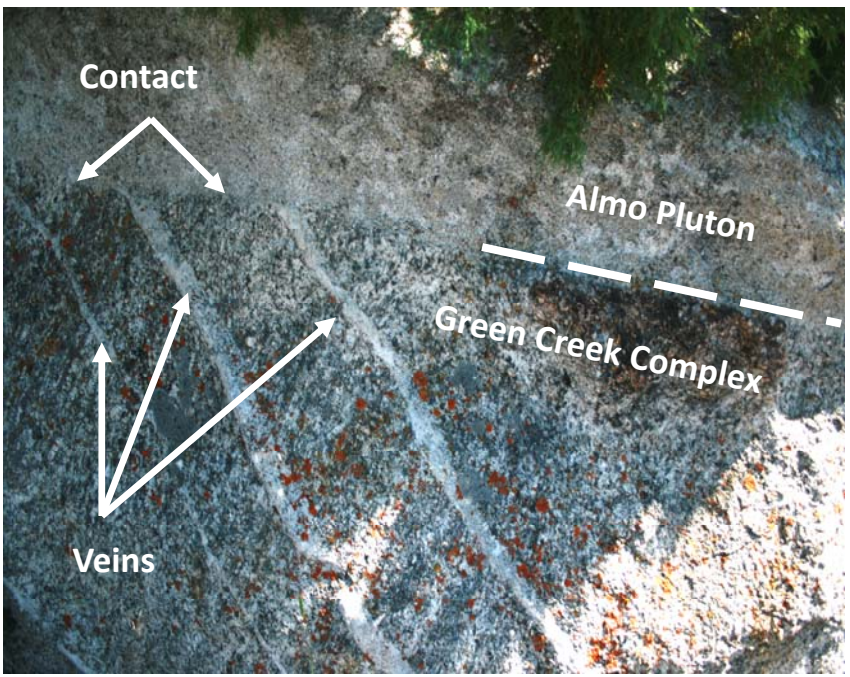


**Panholes**

## Station 6
## *Intrusive Contact*
## *of the Almo Pluton and Green Creek Complex*

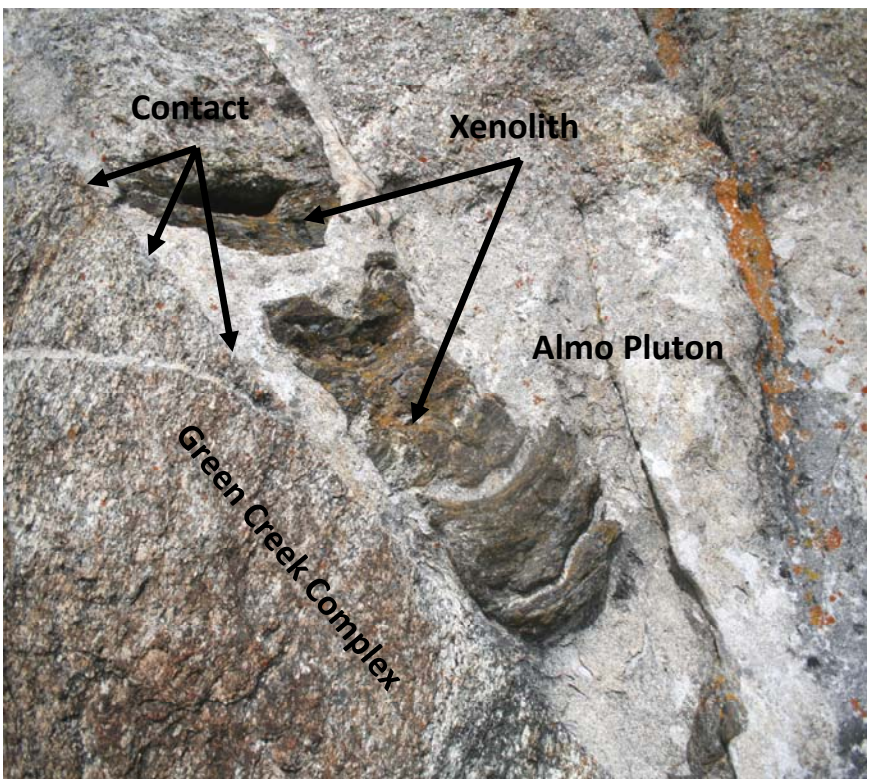
The Almo pluton originated as an intrusive body of magma and has a convoluted and sometimes obscure contact with the surrounding Green Creek Complex. Here, one can see the contact clearly. As the Almo pluton intruded, it wedged its way into weaknesses formed by bedding planes, joints and metamorphic layering. Huge slabs of the Green Creek Complex detached completely or swung down into the magma like trap doors.

Veins are thin dikes formed by igneous intrusions into cracks. Some of the veins are made of pure quartz while others are composed of a mixture of fine-grained quartz and feldspar called aplite (seen here).



## Station 7
## *Xenolith/Contact*

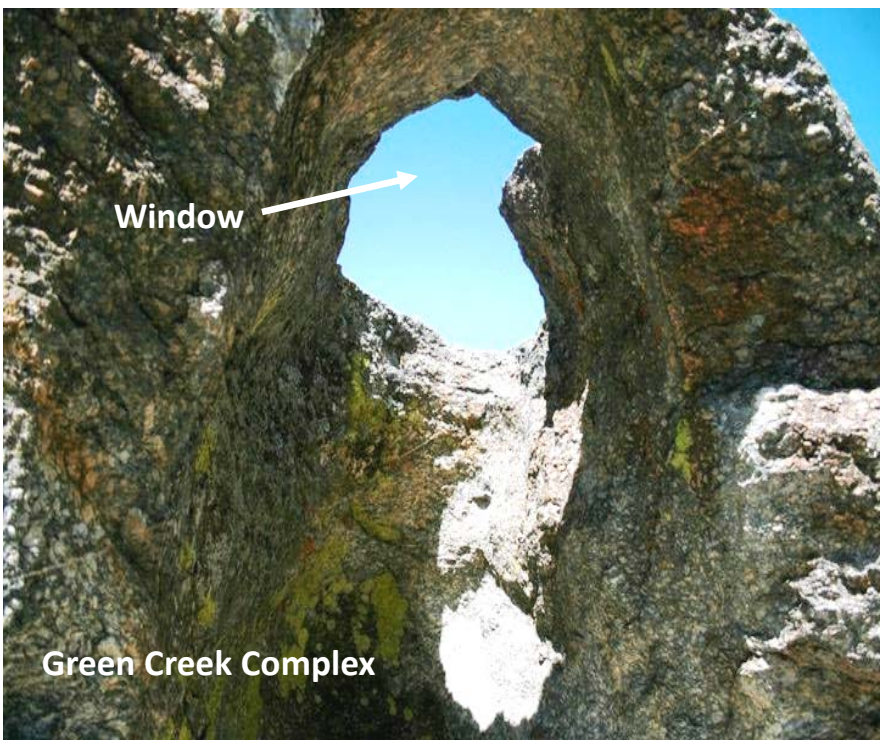
The word *Xenolith* comes from two Greek words: *Xeno*, meaning foreign, and *lithos*, meaning stone. A xenolith is formed when a rock fragment becomes enveloped in magma. The rock fragment is incorporated in the newly formed plutonic rock as the magma cools and crystallizes. Here, the xenolith fragment is biotite schist, enveloped in the Almo pluton. Just below the xenolith, is rock from the Green Creek Complex, giving us another view of the contact between the older and younger granites.



## Station 8
## *Green Creek Complex Window*

Features produced by cavernous weathering such as tafoni (Station 3) are well developed throughout City of Rocks, often resulting in windows. This type of weathering is common in the Almo pluton, but rarely so large as here in the granite of the Green Creek Complex. Look closely at the bottom of this boulder and you will see that it is resting on the younger granite of the Almo pluton.

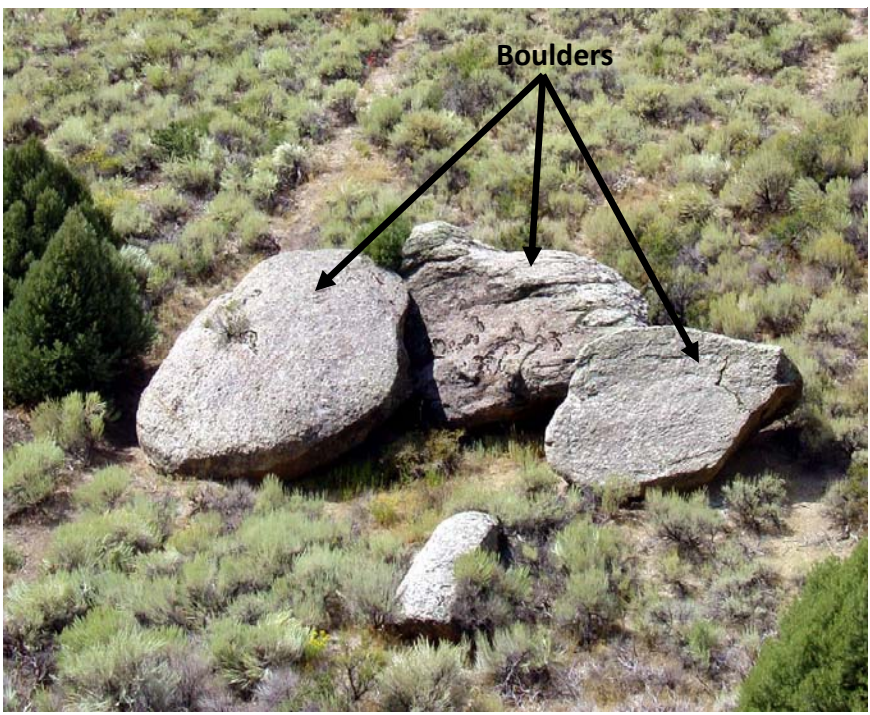
NOTE: Just beyond the boulder at the highpoint of the trail, stay left for a short distance on the Geo Watt Connector Trail and visit Circle Creek Basin Overlook. Two miles south is Smoky Mountain (elevation 7,560). This mountain is capped by eastward dipping layers of Elba Quartzite, a metamorphic rock which once covered the entire area.



## Station 9
## *Boulders*

Boulders break from an outcrop when they are weathered to the point of instability or toppled during an earthquake. Earthquakes of low magnitude are not uncommon, but large-scale land shifts or movements have not occurred here in recorded history. A fault near Smoky Mountain Campground is estimated to be as recent as 10,000 years ago.

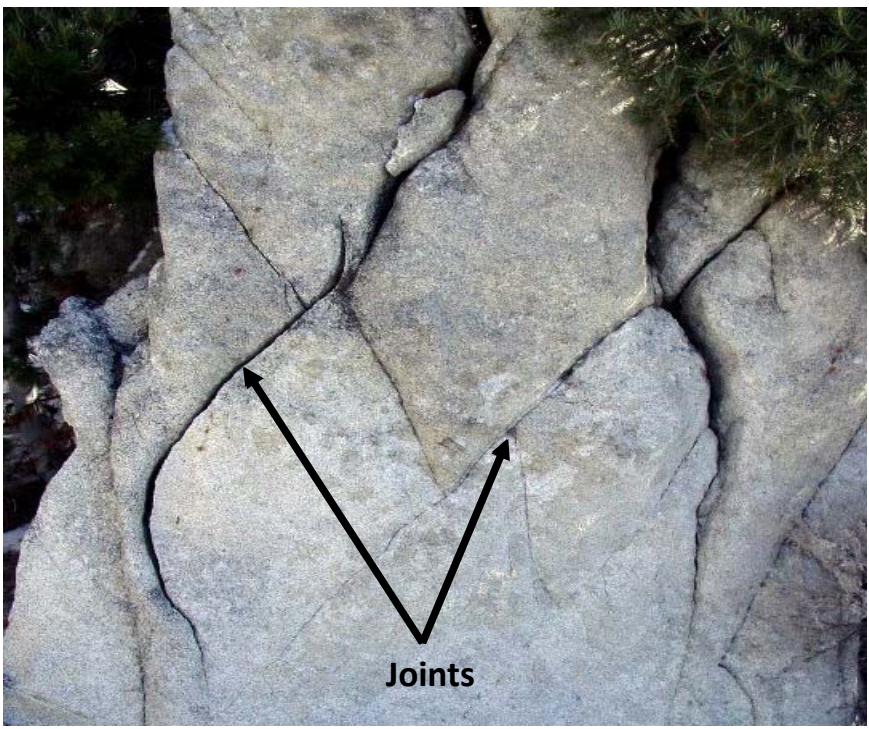
Many climbers prefer granite of the Green Creek Complex over that of the Almo pluton because the large potassium feldspar crystals make for great holds. Take note of these crystals as you pass by.



## Station 10
## *Joints*

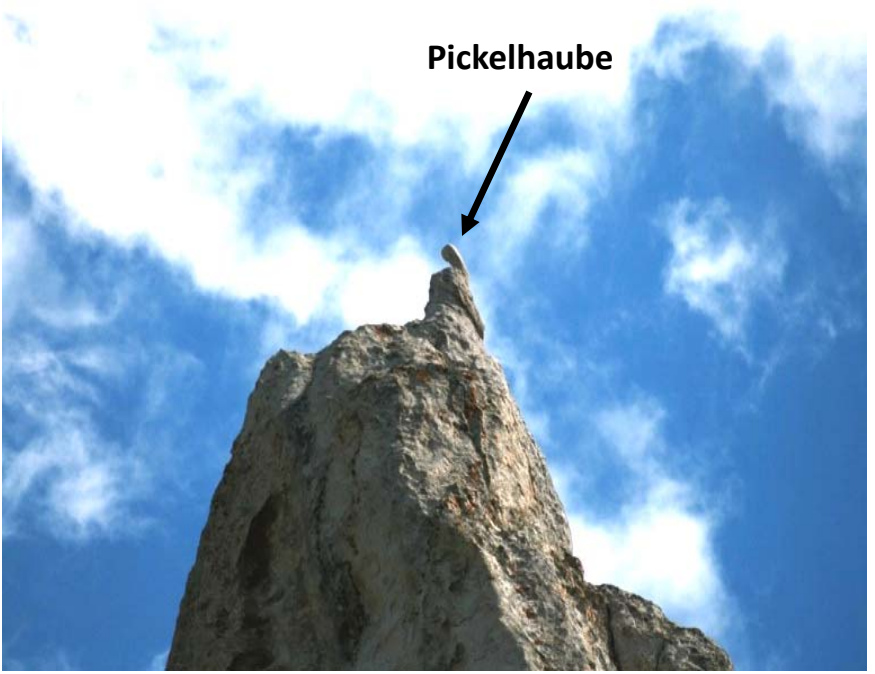
Joints are one of the more obvious features of the Almo pluton. Joints result from stresses produced by thermal expansion/ contraction related to a decrease in overburden pressure, and plate tectonics. Perhaps the most common joint-producing stress is thermal contraction that occurs as the pluton cools deep underground. Granite contracts as it cools, and the joints are produced as these stresses pull the minerals apart.

Scientific explanations aside, the artistic patterns of these joints within the Almo pluton make it worthy of second look. Notice that the joints range from a hairline to more than two inches wide. Each year the joints widen until the outcrop becomes little more than cobbles and grus.



## Station 11
## *Pickelhaube*

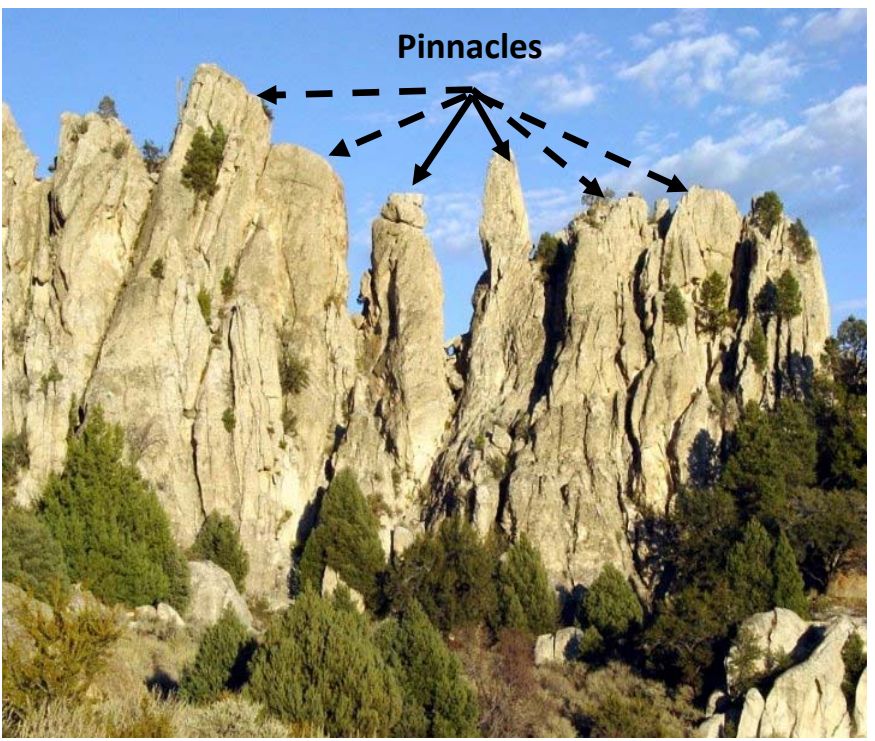
A pickelhaube is an erosional remnant of a case-hardened surface that protects the softer rock beneath from eroding as quickly or evenly. A spike-like protuberance on or near the summit of a pinnacle results. The very top of many pickelhauben are coated with bird droppings from raptors, rock doves, and other birds that frequently use them as perches. This hard coating may play an additional role in protecting the pickelhaube from weathering. Arguably the most famous pickelhaube within the Reserve sits atop the monolith named Kaiser's Helmet, located south of Treasure Rock along the City of Rocks Back Country Byway.



## Station 12
## *Pinnacles*

A pinnacle is a large, steep-sided, rock outcrop. The shape of a pinnacle is primarily controlled by weathering of vertical joints. Where the granite contains many joints, pinnacles are smaller, more numerous and more closely spaced, as seen in the photograph below. Weathering of granite with relatively fewer joints results in the larger, more common, isolated pinnacles like Chicken Rock, Lost Arrow Spire, and Creekside Tower. Rare are the pinnacles found in the granite of the Green Creek Complex within the Reserve, but they are numerous along the south slope of Cache Peak in Big Cove.

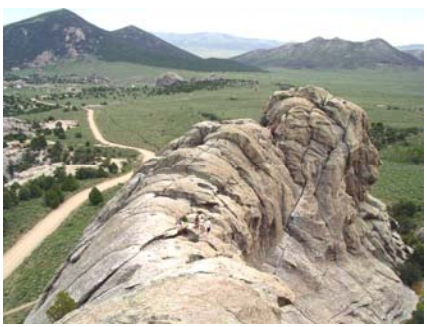
As erosion of this multi-jointed wall continues, other pinnacles will begin to form, as noted by the dashed lines below.



## Other Points of Geologic Interest

City of Rocks is a dramatic geologic landscape with naturally sculpted spires and monoliths that evoke emotional responses as recorded in emigrant diaries and from visitors of today. The Geological Interpretive Trail provides an opportunity to see many of these inspiring features and begin to understand how they came to be. A number of other locations in the Reserve are popular for observing weathered features and outcrops. You may also enjoy visiting the following sites:

***Bath Rock*** exhibits some of the largest panholes in the Reserve. The preferred route to the summit is approached from the west side. Called the *Rebar Route*, portions of the climb require great care. Climb at your own risk.



***Kaiser's Helmet*** is located on the south side of the City of Rocks Back Country Byway near Treasure Rock. It exhibits one of the more famous pickelhauben of the Reserve, as well as an excellent example of a flared slope (a concave wall that is the result of subsurface weathering).

***Stripe Rock*** is named for the very large aplite dike on the east face. Stripe Rock is easily seen from many vantage points, or can be reached by hiking 1.5 miles west from the Circle Creek Overlook Trailhead.

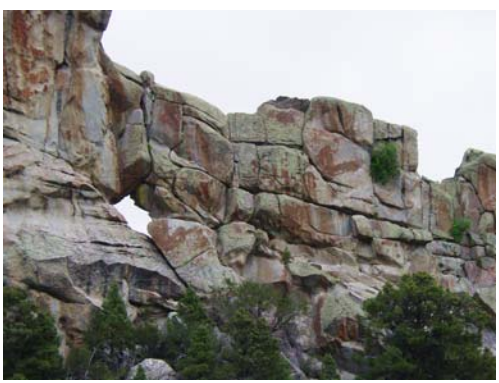
***Twin Sisters*** was the iconic landmark for California-bound emigrants in 1843-1882. The south Sister consists of the Green Creek Complex and the north Sister is of the Almo pluton, making it one of the more fascinating sites.

***Window Arch*** is one of the most popular sculpted features of the Reserve. Countless group photos have been taken in the window. The arch is located 300 feet north of campsite 37 along the granite fin.

***Indian Grove Overlook*** (below, left) lies atop the crest of the Albion Range and offers exquisite views down into the pinnacle-studded upland basins of City of Rocks. Metamorphosed rocks dipping off to the west form the western flank of the City of Rocks anticline.

***Shingle Rock*** (right) is an exemplary granite dome showing exfoliation slabs that formed along curved fractures. It can be seen from the Emery Pass Picnic area on the north end of Bread Loaves.

***Lost Horizon Arch*** and other outstanding geologic scenes and features await you in remote places along the North Fork Circle Creek Trail or the Flaming Rock Window along the trail of the same name, or hundreds of other unnamed sculptures. Some of the best adventures of the "City" are discoveries made on your own.



# Glossary

**Anticline:** a convex-upward fold of rocks. Erosion of anticlines exposes the inner core of older rocks.

**Aplite**: a light-colored fine-grained intrusive igneous rock made mostly of quartz and feldspar.

**Archean**: An eon of geologic time between 3.8 and 2.5 billion years.

**Case hardening**: A process that produces a crust on the surface of a rock that is more resistant to weathering than the underlying rock.

**Dike** : a body of igneous rock produced when magma that has intruded a crack in older rock cools and crystallizes.

**Detrital**: Loose grains that have been worn away from rock.

**Exfoliation:** The separation of thin rock plates and scales, sloughed off along joints in the rocks.

**Gneiss**: Metamorphic rock with a striped or layered appearance produced by the segregation of minerals into alternating dark and light colored bands.

**Granite**: A medium to coarse-grained, intrusive igneous rock composed of quartz, feldspars, and micas.

**Igneous**: Rock formed by the crystallization of magma or lava.

**Intrusive Rock**: An igneous rock body that has forced its way in a molten state into surrounding rock.

**Metamorphic**: A type of rock formed by the alteration of preexisting rock by heat, pressure, and chemically active fluids.

**Outcrop**: An exposure of bedrock on the Earth's surface.

**Pegmatite**: A very coarse-grained, intrusive igneous rock composed of interlocking minerals, usually larger than 2.5 cm in size.

**Pluton**: Generic term for a body of intrusive igneous rock of any size or shape.

**Schist**: a metamorphic rock consisting predominantly of aligned mica minerals.

**Weathering**: the chemical and physical processes that decompose and break apart rocks near Earth's surface.

## For Further Study

For further geological study of City of Rocks and Castle Rocks, the following publications are recommended:

Armstrong, R. L. 1968. Mantled gneiss domes in the Albion Range, southern Idaho. *Geological Society of America Bulletin* 79:1295−1314.

Miller, D. M., R. L. Armstrong, D. R. Bedford, and M. Davis. 2008. *Preliminary geologic map and digital data base of the Almo quadrangle and City of Rocks National Reserve, Cassia County, Idaho*. Scale 1:24,000. Open-File Report OF 2008-1103. Reston, VA: U.S. Geological Survey.

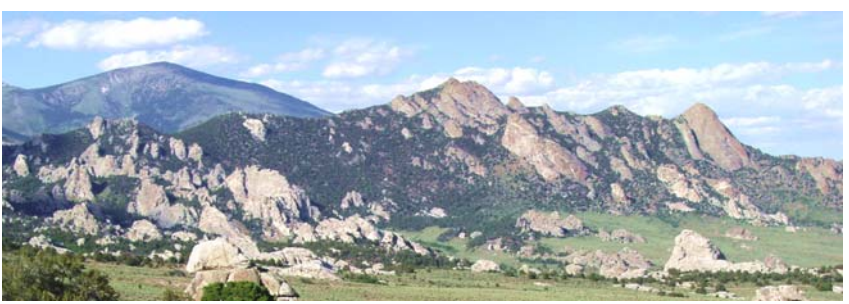
Pogue, K. R. 2008. *Etched in Stone: The Geology of City of Rocks National Reserve and Castle Rocks State Park, Idaho*. Information Circular 63. Moscow, ID: Idaho Geological Survey, University of Idaho.

## Credits

The following individuals contributed to the development and completion of the booklet and trail:

Kristen Bastis, Jim Beckwith, Marsha Davis, Adam Floyd, Kris Hawkins, Wallace Keck, Stan Lloyd, Allen McCoy, Stephen Murray, Dr. Kevin Pogue, Brad Shilling, Saxon Spillman, and the 2011 Montana Conservation Corps.

The geology trail was conceptualized during the summer of 2000 in conjunction with a Keck Geology Summer Research Project.



## Quiz: *Can you name these geologic features?*