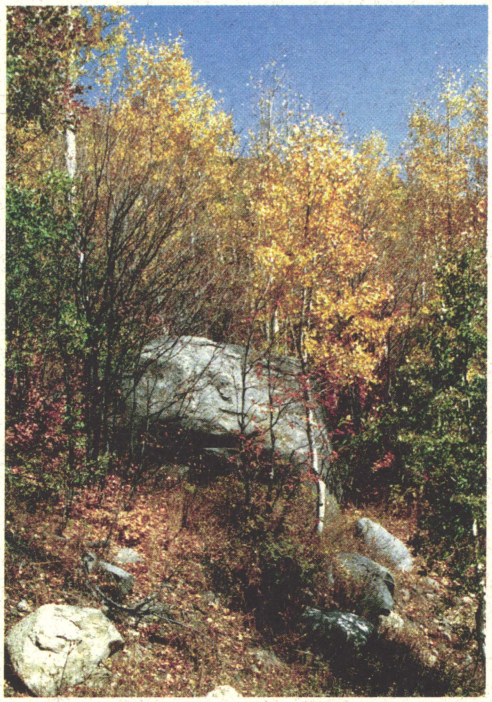
A Geologic Tour Through
Wasatch Mountain State Park



Julie B. Willis and Grant C. Willis

Willis & Willis

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Miscellaneous Publication 93-6

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UTAH GEOLOGICAL SURVEY
a division of
UTAH DEPARTMENT OF NATURAL RESOURCES

About the Authors

Julie and Grant Willis both grew up in southeastern Idaho. Though they had yet to meet, they shared many interests – exploring lava beds, hiking in the mountains, and collecting rocks. Their love of the outdoors and of science led them to study geology at Brigham Young University where they met – and earned M.S. degrees.

Julie and Grant live in Heber City, Utah, with their children Tyler, Emily, and Jacob. Grant works for the Utah Geological Survey and has authored numerous geologic maps and technical papers. Julie has a successful career as a designer of educational computer software. They combined their interests in education, the outdoors, and geology to write this guidebook, their first collaborative effort.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

This book was made possible by a Mineral Lease Grant from the Utah Geological Survey.

Lehi Hintze and Grant Willis conducted critical reviews of the geology. Elizabeth Barrott, Dan Cortsen, Steve Hunt, Holly Poloncic, and Bryce, Stephanie, and Winona Willis provided insightful reviews of the content and design from a non-technical perspective.

A special thanks goes to Tyler and Emily for their good-natured field assistance, willingness to provide scale in the photographs, and patience. Thanks also to Betty and Lloyd Barrott for their support, and to Grant for his endless encouragement, critique, and assistance.

Illustrations and photographs are by Grant Willis.

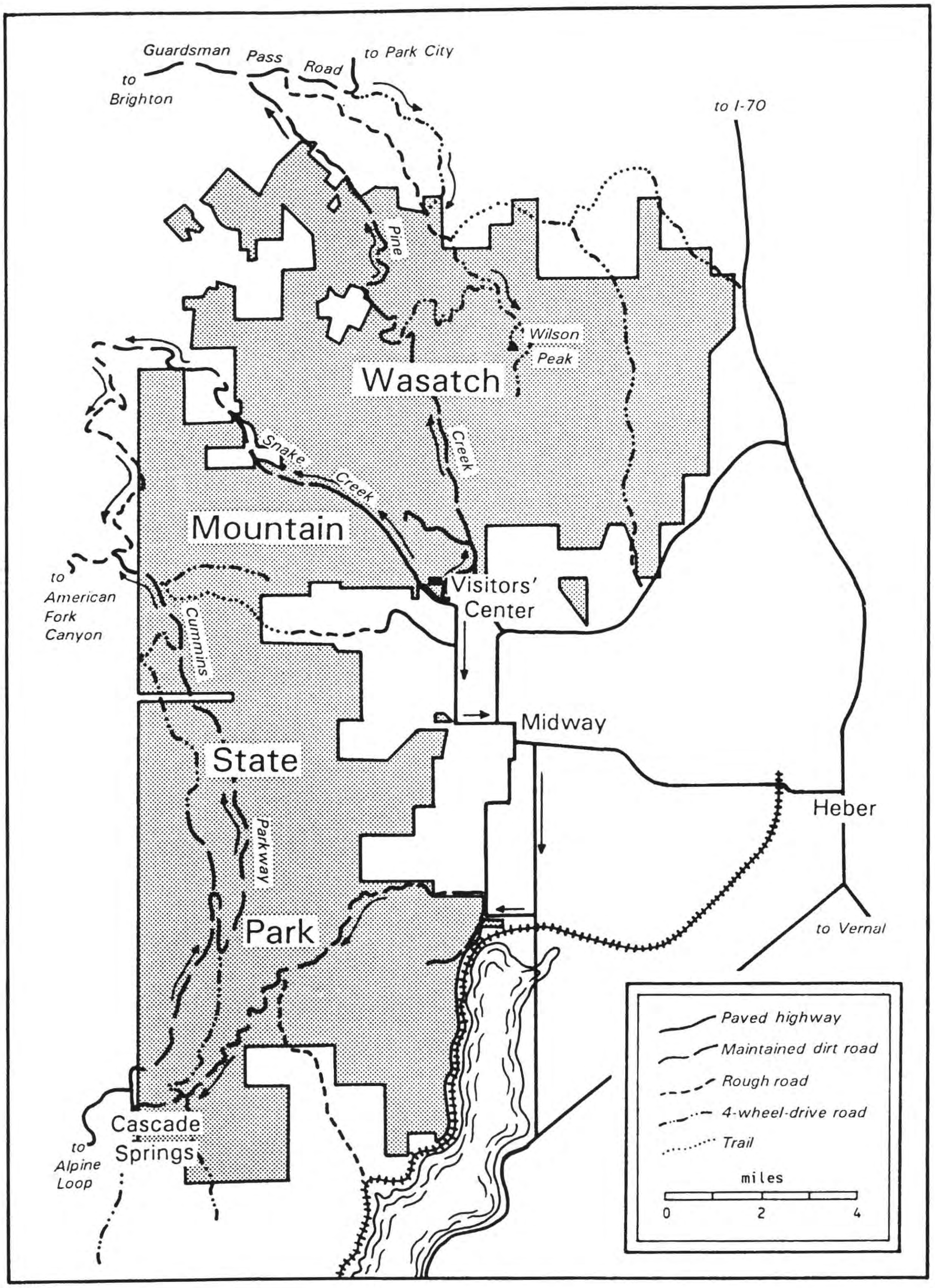
INTRODUCTION

Did you know

- that hot springs near Wasatch Mountain State Park are heated by deeply buried magma?
- that Utah once lay far south of the Equator?
- that glaciers flowed down canyons in and near the Park?
- that huge sheets of rock were pushed 20 to 40 miles eastward to overlie what is now the Park?
- that Utah was covered by shallow oceans for hundreds of millions of years?

These questions are all part of the drama written in the rocks in Wasatch Mountain State Park. The purpose of this guidebook is to introduce you to the geologic phenomena that shaped the Park into what it is today--a scenic textbook waiting to be read by the keen observer.

Geology is exciting because of change. The earth may seem like a mass of lifeless rock to most people, but to geologists, rocks are books that come alive when they are read. The rocks are the record of over 4 billion years of changes. From them, we learn where ancient mountains formed, when oceans swept the continent, and how glaciers, earthquakes, volcanoes, and erosion shaped the land.



Wasatch Mountain State Park

USING THIS GUIDE

Key geologic concepts are explained in the section titled, *Getting Started*. You will want to read it if you are unfamiliar with fundamental principles of geology.

The rest of the guidebook is divided into four sections. A few minutes spent reading Section I, *A Tour through Time*, will make the others more meaningful.

The sections are:

I. A Tour through Time.
Tells the story of the major geologic events that molded the Park. It builds event by event from the distant past to the present.

II. Road and Hiking Tours.
Helps observers identify and understand geologic features that are near Park roads. It includes four tours; three that start at the Visitors' Center and one that starts at the Guardsman Pass Road (Figure 1). The tours can be enjoyed in any order as you drive, bicycle, or hike in the Park.

III. Scenic Views.
Briefly explains the geology of prominent features that can be seen from viewpoints in the Park.

IV. Appendix.
Contains three parts:
1) Descriptions of rocks and minerals found in the Park.
2) Descriptions of geologic formations in the Park. (Provided for those who want to explore the geology on their own.)
3) References.

Figure 1 (opposite page). Map of Wasatch Mountain State Park. Routes of road and hiking tours are: Tour 1--Visitors' Center to Cummins Parkway via Cascade Springs; Tour 2--Visitors' Center to Guardsman Pass Road; Tour 3--Guardsman Pass Road to Wilson Peak; Tour 4--Visitors' Center to Cummins Parkway via Snake Creek Canyon.

GETTING STARTED:
A FEW GEOLOGIC CONCEPTS

Understanding a few fundamental keys about geology will help you decipher the rocks in Wasatch Mountain State Park, and read their story.

Key 1: Rocks. Rocks are divided into three main groups: **sedimentary, igneous and metamorphic**. Their names provide clues to their origin:

"Sediments" are fragments of older rocks (such as sand) or plant and animal parts (such as sea shells). **Sedimentary** rocks form when sediments accumulate and are cemented together.

"Igneous" comes from the Latin word for fire. **Igneous** rocks form when hot, molten rock (magma) cools. If the magma cools below the ground it is intrusive rock; if it cools on the surface, it is volcanic rock.

"Metamorphose" means change. **Metamorphic** rocks form when intense heat and pressure change one type of rock into a different type.

Each group is divided into several different types based on composition and texture. Rocks referred to in this guidebook are listed in the table below.

Rocks found in Wasatch Mountain State Park

Sedimentary	Igneous	Metamorphic
limestone sandstone shale mudstone conglomerate quartzite dolomite breccia tufa	intrusive granodiorite volcanic	quartzite marble gneiss

For further information about these rock types, refer to the *Appendix*.

Key 2. Geologic Formations. Geologists divide rocks in an area into manageable packages called formations. Each formation has unique variations in rock types, mineral content, age, or fossils. A formation may be thin or thick (formations in the Park vary from a few feet to about eight thousand feet thick), and may be local or extend for hundreds of miles. Formations are named after a feature, like a town, near where they are first defined (for example, the *Park City Formation*).

Figure 2 lists the formations found in the Park and correlates them with major geologic events discussed in Sections I and II. A brief description of the formations is given in the Appendix.

Key 3. Sedimentary Environments of Deposition. Sediments accumulate in low areas protected from erosion. Most commonly, they are deposited in oceans, lakes, or plains by rivers, glaciers, wind, evaporation, or chemical precipitation.

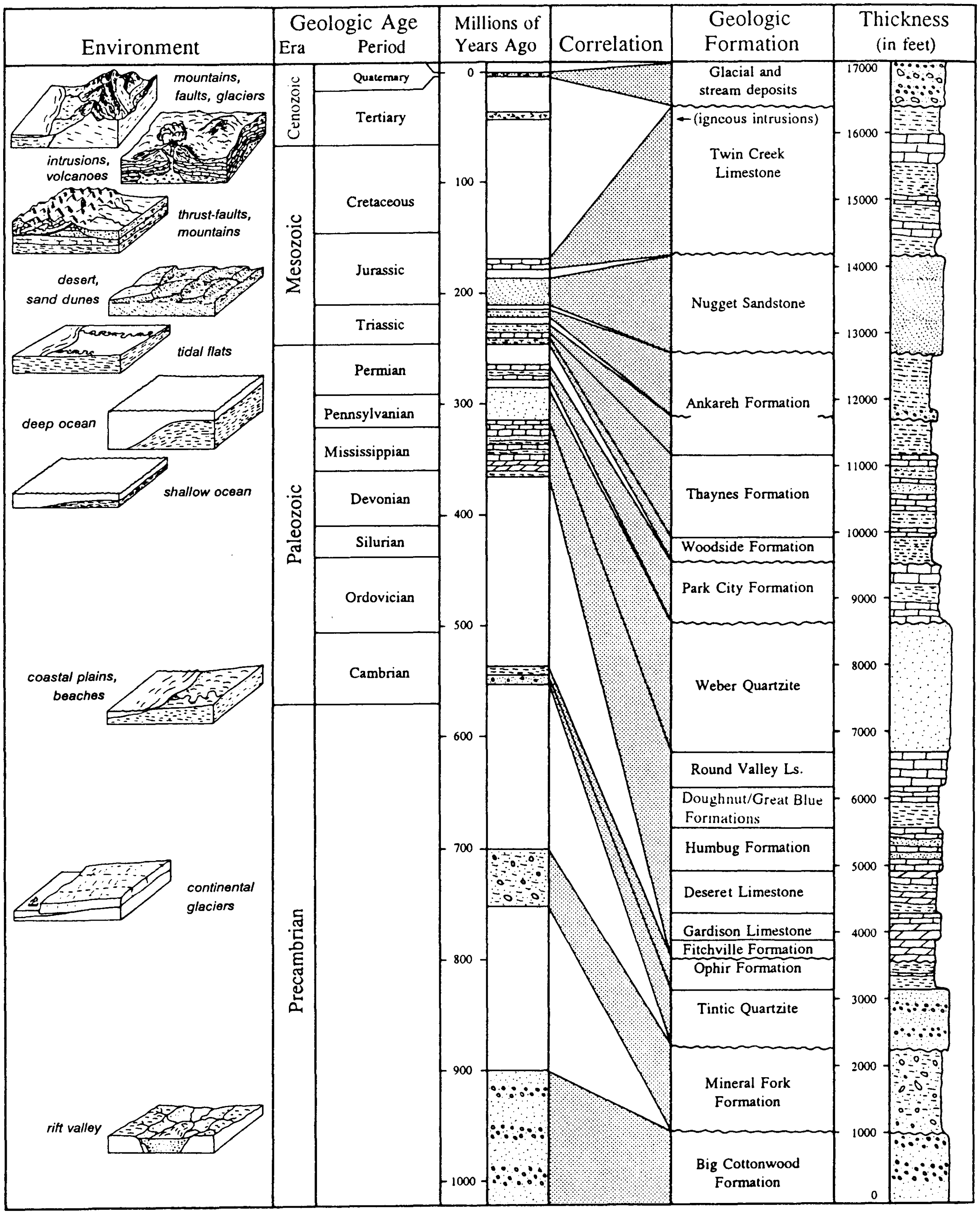
Every rock tells something about the environment in which it formed. As you read Section I, *The Park Through Time*, try to visualize the types of rocks that were deposited in each setting. In the *Road Tours*, look at the different rocks and try to visualize the area at the time they formed.

Key 4. Geologic Time. How does a person with an 80-year life span comprehend the age of the earth--4.65 billion years? It's difficult! To help, geologists have divided geologic time into named blocks. The major divisions are called eras, and they are further subdivided into periods. The divisions are based on major changes in the fossil record. The table below lists geologic eras and periods and their time range.

Geologic Time

ERA/PERIOD	TIME*
Cenozoic	
Quaternary	0-1.6
Tertiary	1.6-66
Mesozoic	
Cretaceous	66-144
Jurassic	144-208
Triassic	208-245
Paleozoic	
Permian	245-290
Pennsylvanian	290-320
Mississippian	320-360
Devonian	360-408
Silurian	408-435
Ordovician	435-505
Cambrian	505-570
Precambrian	570-4650

*millions of years ago


Environment
Geologic Age
Era
Period
Millions of Years Ago
Correlation
Geologic Formation
Thickness (in feet)
mountains, faults, glaciers
intrusions, volcanoes
thrust-faults, mountains
desert, sand dunes
tidal flats
deep ocean
shallow ocean
coastal plains, beaches
continental glaciers
rift valley
Cenozoic
Mesozoic
Paleozoic
Precambrian
Quaternary
Tertiary
Cretaceous
Jurassic
Triassic
Permian
Pennsylvanian
Mississippian
Devonian
Silurian
Ordovician
Cambrian
0
100
200
300
400
500
600
700
800
900
1000
Glacial and stream deposits
←(igneous intrusions)
Twin Creek Limestone
Nugget Sandstone
Ankareh Formation
Thaynes Formation
Woodside Formation
Park City Formation
Weber Quartzite
Round Valley Ls.
Doughnut/Great Blue Formations
Humbug Formation
Deseret Limestone
Gardison Limestone
Fitchville Formation
Ophir Formation
Tintic Quartzite
Mineral Fork Formation
Big Cottonwood Formation
17000
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0

I. A TOUR THROUGH TIME

When the earth formed, it was little more than a hot, barren mass. As time passed, continents grew, mountains rose and were eroded flat, glaciers and rivers shaped the land, and plants and animals evolved. The rocks found in Wasatch Mountain State Park span almost a billion years, and tell a story of many changes.

Earth's Beginning
4.65 to 3 billion years ago
(Early Precambrian)

Most scientists believe the earth formed about 4.65 billion years ago, though its oldest preserved rocks are only about 4 billion years old. The first life forms, one-celled organisms that didn't need oxygen, developed near the end of this period. No rocks found in Wasatch Mountain State Park reflect this early period in earth's history.

Building the North American Continent
3 to 1 billion years ago
(Middle Precambrian)

During this time, the area that is now the Park was near the edge of the early North American continent. The continent was much smaller than it is now. Most of the western United States, including the southern two-thirds of Utah, did not exist.

Continents "grow" during major geologic events. Geologists know that the outer layer of the earth is made of numerous large plates or slabs that fit together like pieces of a jigsaw puzzle. Unlike a puzzle, however, the earth's plates are constantly in motion, and the boundaries between them are involved in intense collisions. During the collisions, mountains are built and continents increase in size.

Rocks from the Middle Precambrian are not exposed in the Park, but are probably buried deep beneath it. These rocks were originally volcanic and sedimentary rocks. They were later metamorphosed (changed by intense heat and pressure) during plate collisions about 2.5 and 1.8 billion years ago. By the end of these collisions, North America was much bigger than before, and included all of Utah.

Figure 2 (opposite page). Time relationships and thicknesses of rocks found in Wasatch Mountain State Park. Major geologic events are also illustrated. Gaps in the time line represent times when rock either was never deposited, or was eroded away before deposition of overlying rock.

Rifting and Glaciation
1000 to 570 million years ago
(Late Precambrian)

The oldest rocks exposed anywhere in the Park are about a billion years old. These rocks, called the Big Cottonwood Formation, were deposited in a great rift or break that slowly opened, threatening to split the continent in half.

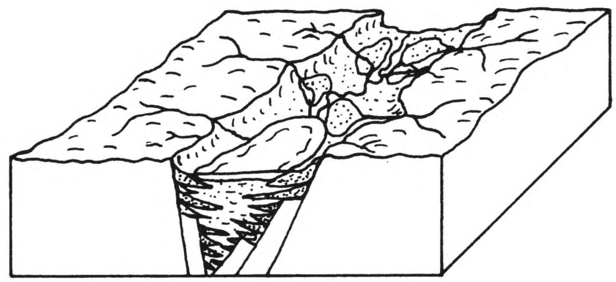


Figure 3. This sketch shows how a Precambrian rift valley may have looked.

The rift looked like a big valley (Figure 3). It extended from west of what is now Salt Lake City, through the Park, to the eastern end of the Uinta Mountains. As the rift deepened, it filled with thousands of feet of coarse debris (Figure 4). Over time, the debris consolidated into rocks up to 25,000 feet thick. The rift was aborted before the continent split, but it remained a natural line of weakness along which the Uinta Mountains were later pushed up.

Figure 4. Boulder of the Big Cottonwood Formation which was deposited in a large rift valley about 1 billion years ago. The white spots are pebbles deposited by a stream or river. The quarter gives a sense of scale.

About 300 million years after the rift filled with sediment, the North American continent underwent two or more episodes of glaciation. Glaciers are indicative of a cold climate, and it is thought that at this time the North American continent lay far south of the equator. The Mineral Fork Formation (Tour 3, Stop 8) was deposited by glaciers that melted in a shallow ocean near the Park about 700 million years ago.

Shallow Seas and Deep Basins
570 to 245 million years ago
(Paleozoic Era)

During the Paleozoic, the western part of North America was quiet. (By comparison, the east coast was colliding with the European and African continents, forming huge mountains.)

Even periods of relative quiet leave a mark in the rock record. Most of the western United States was a broad continental shelf, that was usually covered with warm, shallow sea water. Limestone, dolomite, and shale were deposited in the seas (Figure 5). Occasionally the ocean receded and beach sands and silts were deposited, or the land was eroded.

During the Paleozoic, Utah was part of the continental shelf. Marine deposits are thick in western Utah, and thin or missing in the eastern half of the state. The Park is within the transition between the thinner and thicker sediments.

From 360 to 250 million years ago, unique, fault-bounded ocean basins formed within the continental shelf. These basins filled with sediments as rapidly as they deepened. One of the basins, centered in the Oquirrh Mountains area west of Salt Lake City, collected over 29,000 feet of sedimentary rocks! The Park was near the edge of this basin, as evidenced by a dramatic westward thickening of the Weber Quartzite

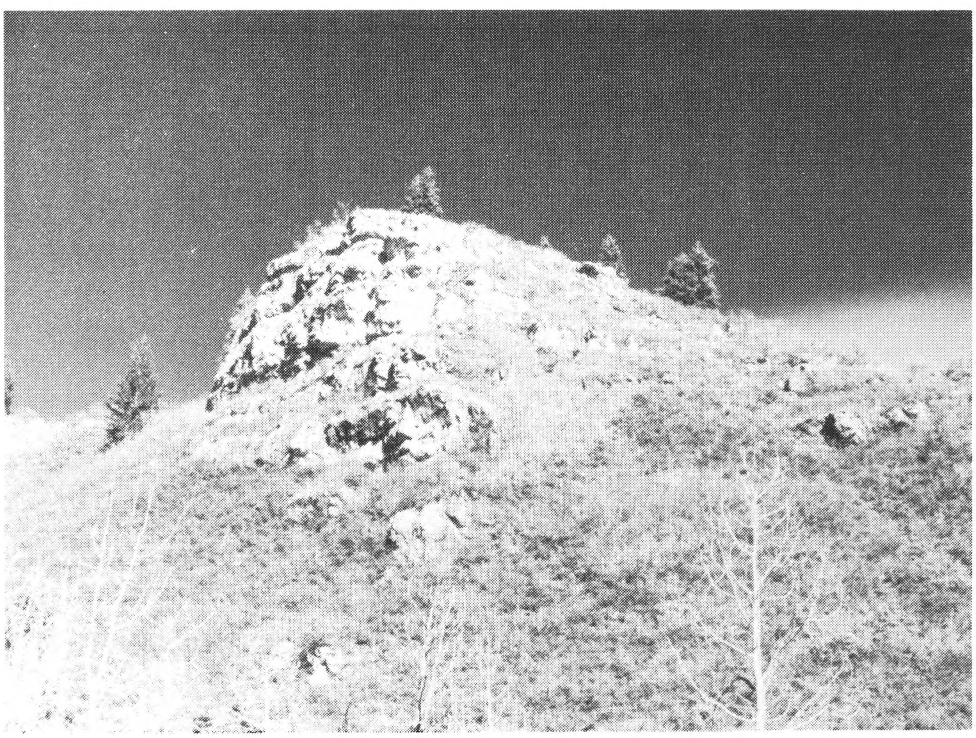


Figure 5. Limestones, such as the Round Valley Limestone, were deposited in a shallow, warm ocean that covered Wasatch Mountain State Park about 320 million years ago.

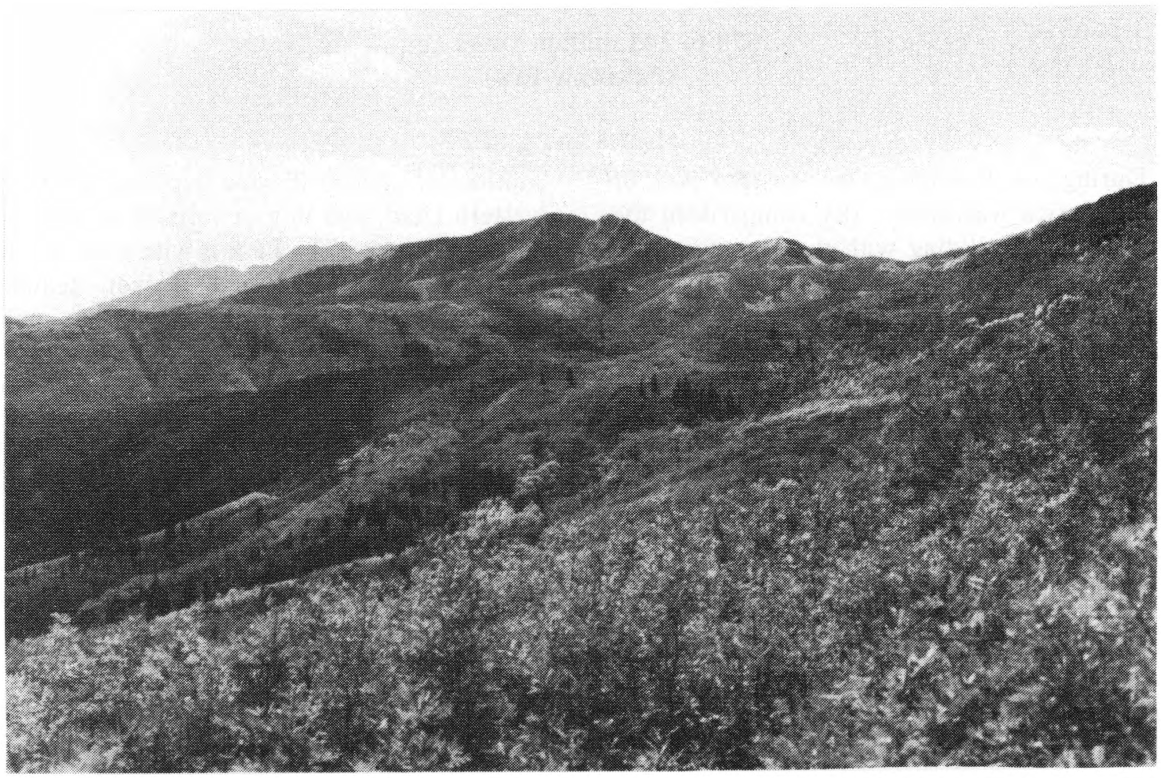


Figure 6. Mill Canyon Peak is composed almost entirely of Weber Quartzite, which was deposited on the edge of a deep ocean basin about 300 million years ago.

across the width of the Park (Figure 6).

The Paleozoic marks a time when plant and animal life began to thrive and diversify. Life evolved from simple marine organisms to complex plants and animals. Fossil fragments, the preserved remains of this ancient life, are relatively abundant in rocks of this age in the Park. The fossil record indicates that the climate was much different than it is now. Not only was Utah at or below sea level, but it was in the tropics! In fact, the equator crossed through Utah part of the time (Figure 7). In this warm, moist environment, jungles and swamps flourished on the land, while marine life thrived in the shallow seas.

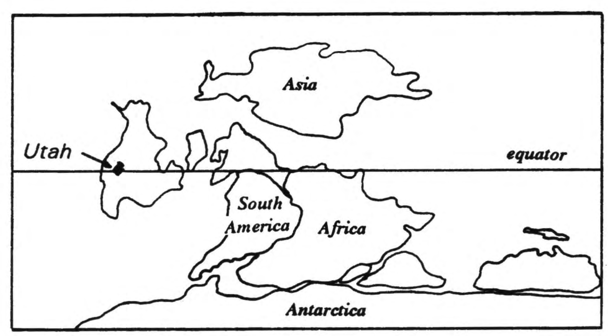


Figure 7. During part of the Paleozoic era, the equator crossed through Utah (from Hintze, 1988).

Deserts and Mountains
245 to 66 million years ago
(Mesozoic)

Early to Middle Mesozoic--Time for a Change. Early in the Mesozoic, western North America was still a flat continental shelf covered with shallow, warm sea water. But that didn't last for long--after more than 500 million years of relative calm, it was time for a change. The North American continent reversed directions, and plowed westward into the Pacific ocean "plate." The heavier Pacific plate plunged beneath the lighter continent (Figure 8). The results were immediate and dramatic. The collision faulted and deformed the western continental margin, forming a chain of large mountains and many volcanoes.

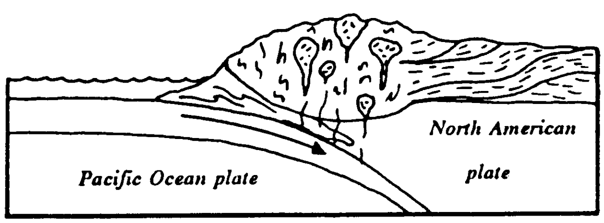


Figure 8. When plates collide, the ocean plate, which is heavier, plunges beneath the continental plate.

During this time of upheaval, the continent gradually moved northward into the hot, dry trade winds belt. In addition, the western mountains blocked most of the precipitation. Consequently, the climate changed from tropical to desert conditions.

For much of the Mesozoic, Utah was covered by a hot desert, or by salty, shallow, restricted seas. From about 200 to 190 million years ago, a huge, sandy desert spread across Utah and surrounding states (Figure 9). This desert was responsible for much of the scenic sandstone in southern Utah's National Parks. However, the land was not always inhospitable. At times there were plains, rivers and lakes. Dinosaurs were common, and thousands of dinosaur bones and tracks are found in rocks of this age in eastern Utah.

Late Mesozoic--Sevier Mountain Building. One of the most dramatic events in Utah's geologic history was an episode of intense mountain building that started about 100 million years ago. At that time, plate collisions along the west coast intensified. Tremendous compressional forces extended over 500 miles inland. Along the collision boundary, which reached from Mexico to Alaska, immense sheets of rock were folded, buckled, and broken. Some sheets of rock were thrust eastward as much as 40 miles (Figure 10).

This great mountain-building event is known as the Sevier orogeny. (The word "orogeny" is derived from the Greek "oro" meaning mountain and "gen" to build. This orogeny was named after the Sevier River region in central Utah.) The Sevier orogeny holds economic interest because oil and gas are trapped in many of the folds that formed near the front edges of the "thrust sheets," and precious metals are concentrated along many of the faults. Contemporaneous with the mountain-building in the west, the central continent bowed down, and

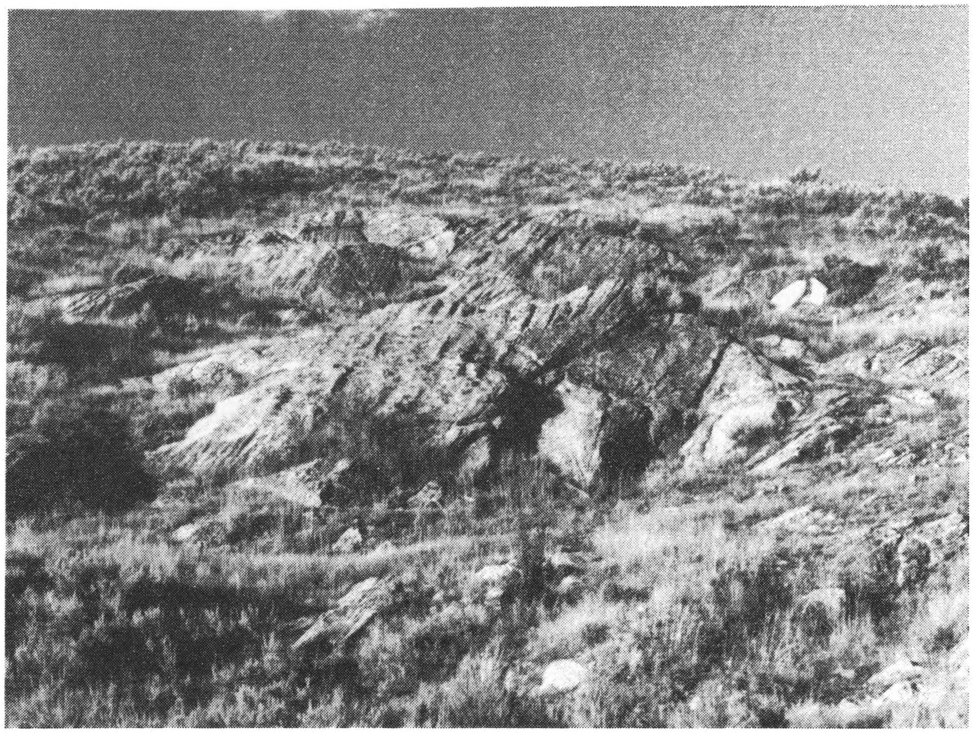


Figure 9. The Nugget Sandstone was deposited during the Jurassic (about 200 million years ago) when a large, sandy desert covered most of Utah.

an ocean spread across central North America.

Wasatch Mountain State Park was near the front edge of the "thrust belt," and also bordered the ocean to the east. Near the end of the Sevier orogeny, about 60 million years ago, the land lifted enough that the ocean receded; this was the last time that the Park would be "ocean-front" property.

Mountains, Intrusions, Glaciers, and Erosion 66 million years ago to present (Cenozoic Era)

Laramide Mountain Building. Near the start of the Cenozoic era, the thrust-fault mountain building of the late Mesozoic was waning. But it was replaced by the Laramide orogeny, a mountain-building event that lasted about 30 million years. (The Laramide orogeny was named after the Laramie Mountains in Wyoming.) During the Laramide, compression from the "plate" collisions on the coast still affected the western United States, but in a slightly different manner. Mountains formed as large, fault-cored folds were pushed up, rather than as sheets of

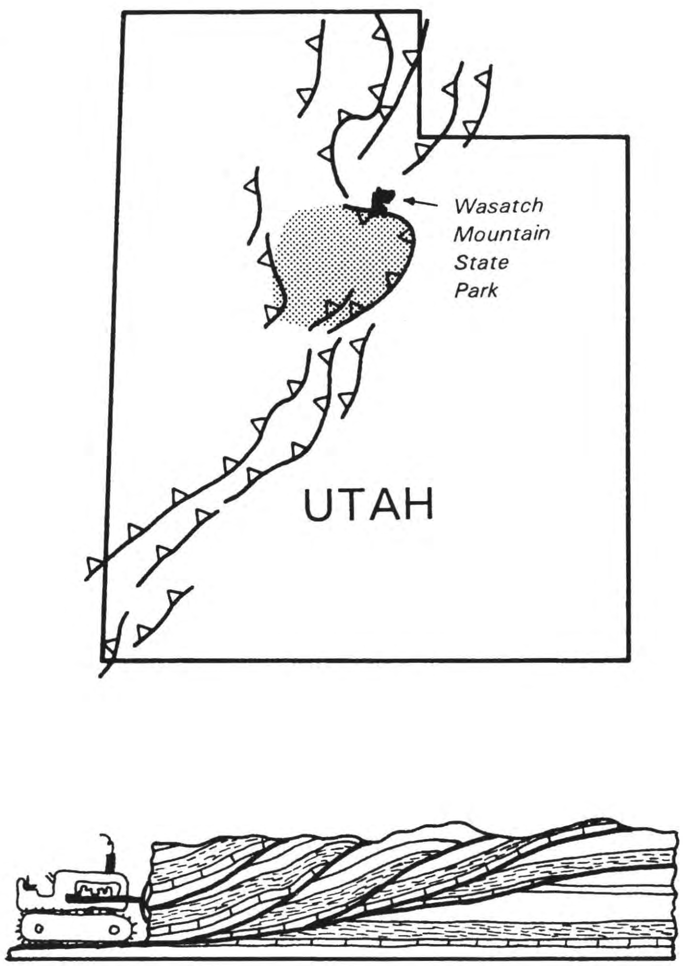


Figure 10. During the Sevier Orogeny sheets of rock were shoved 20 to 40 miles eastward on thrust faults (barbed lines). The Charleston-Nebo sheet, which crosses the Park, is shaded. The lower sketch shows how the thrust zone might look in "cross-section."

rock were thrust on top of each other. Lakes filled the areas between the folds.

The Park lies on the western edge of a large uparched fold that formed the Uinta Mountains during the Laramide orogeny. Oil shale accumulated in a lake in the adjacent Uinta basin.

Igneous Intrusions. When the Laramide orogeny ended about 40 million years ago, Utah entered a new stage. Rocks buried deep in the crust were intensely heated and melted to form magma. The hot magma rose, pushing its way upward through overlying sedimentary rock. Some of the magma found avenues to the surface, and formed volcanoes that vented great volumes of hot ash and lava. (These eruptions were hundreds of times larger than the 1980 Mount St. Helens explosions.) Other magma cooled and solidified before it reached the surface, forming "igneous intrusions."

The northern part of the Park is centered along an east-west-trending belt of igneous intrusions (Figure 11); some of which may be the solidified "roots" of ancient volcanoes. The intrusions are the youngest "bedrock" in the Park. They played an important part in the Park's recent history, for they brought silver and gold--the source of much excitement when discovered about 35 million years later!

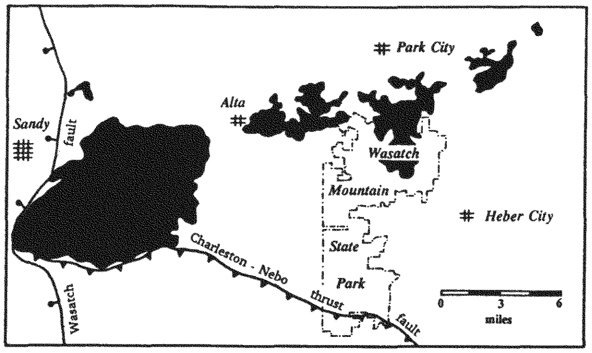


Figure 11. The black areas show the location of Cenozoic igneous intrusions that lie in an east-west-trending belt. Mineralization along this belt brought prospectors into the area 120 years ago. (After John, 1989.)

Extension, Uplift, and Faulting. Ten to twenty million years ago the western U.S. began to bulge upward and tear away from the rest of the continent. Instead of being compressed, Utah was now stretching, and rising to nearly a mile above sea level!

When the earth's crust is stretched, it fractures, forming a series of parallel mountains and valleys that are bounded by faults. The topography of Nevada and western Utah is dominated by many such extensional mountain ranges and basins (Figure 12).

Wasatch Mountain State Park sits astride the uplifted side of one of Utah's most impressive extensional ranges--the Wasatch Range. Uplift along the Wasatch fault, the most active fault in the mountain west, has helped shape the Park's rugged mountains and deep canyons.

Geologists have used igneous intrusions near the Park to determine the amount of uplift along the Wasatch fault. Microscopic inclusions in the intrusions indicate that rocks now exposed at the tops of the mountains cooled as much as 36,000 to 40,000 feet below the ground surface (from John, 1989; Naeser, and others 1983). Of course, the mountains never reached a height of 40,000 feet because they erode almost as fast as they rise.

The Wasatch fault is as active today as it ever was, much to the chagrin of city planners. The range continues to rise and the valley continues to subside, earthquake by earthquake. Geologists have determined that there is a major earthquake along the fault about once every 400 years. The absence of a major earthquake in the historic past is good reason for concern today.

Glaciation. Glaciers invaded the Rocky Mountains several times during the recent geologic past. The last two glacial episodes ended about 60,000 and 12,000 years ago. In Utah, the glaciers were accompanied by large fresh-water lakes in the basins west of the Wasatch Range; the latest was Lake Bonneville, a precursor of the Great Salt Lake.

The glaciers that developed in Wasatch Mountain State Park were relatively small. Thus, their features are poorly defined when compared with nearby areas, such as the Uinta Mountains or Big and Little Cottonwood Canyons (Figure 13). The glaciers were small for two reasons: first, the Park, on average, is at a lower elevation than

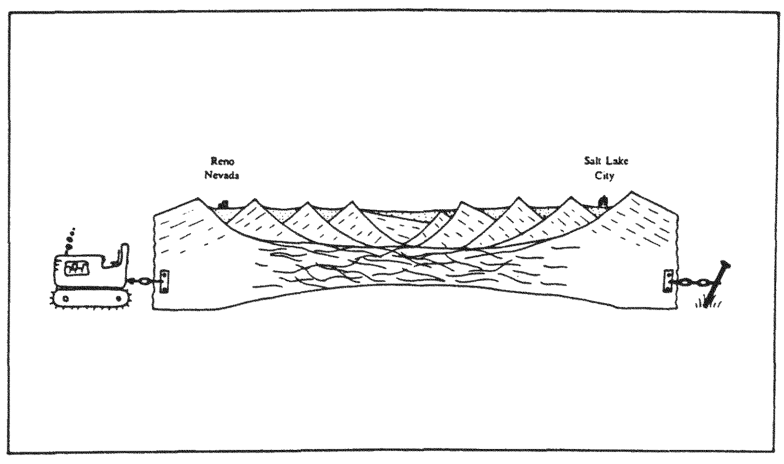


Figure 12. Fault-bounded basins and ranges form as western North America pulls away from the rest of the continent. Reno, Nevada moves about 4 inches away from Salt Lake City every 10 years.

the other areas; and second, Bonanza Flat, the primary area of glacial accumulation, faces southeast, the direction that receives the strongest sun. As you travel through the high mountains near the Park, watch for U-shaped valleys, polished rock, and angular, poorly sorted sediments as evidence of recent glaciation. Glacial features in the Park are pointed out on Tours 2 and 3.

Shaping the land. The Wasatch Range is a dynamic system of uplift and erosion. Movement along the Wasatch fault raises the mountains and erosion wears them down (Figure 14). Streams, seeking to establish equilibrium, cut down quickly through the uplifted terrain. Over hundreds of thousands of years, streams, glaciers, and frost action shaped and carved the high ridges and deep picturesque canyons seen in the Park (Figure 15).

Canyons often form in rocks that are naturally weak. For example, Pine Creek Canyon (Tour 2) formed in sedimentary rocks that were weakened by an igneous intrusion. And Provo Deer Creek Canyon (Tour 1), formed in shale, a rock that is relatively weak compared with other rock types (Figure 16). Other canyons, such as Snake Creek, may have formed in weak rock thousands of feet above that through which they now cut. Once established, streams cut down through underlying rock regardless of relative strength or weakness.

Figure 13. Glacial features. Bonanza Flat, near the north end of the Park, was shaped mostly by glaciers. The glacial pond near the center of the photo was dammed by glacial debris.

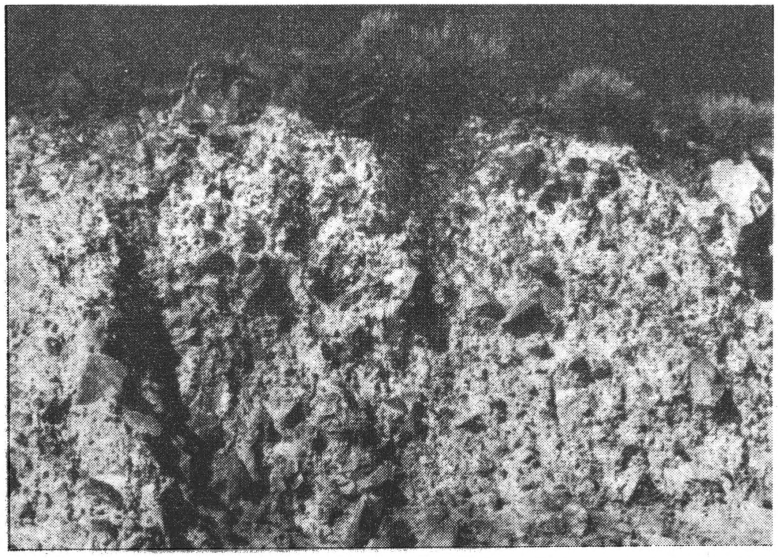


Figure 14. Coarse weathered debris, called colluvium, erodes off mountains and is deposited at the base of slopes.

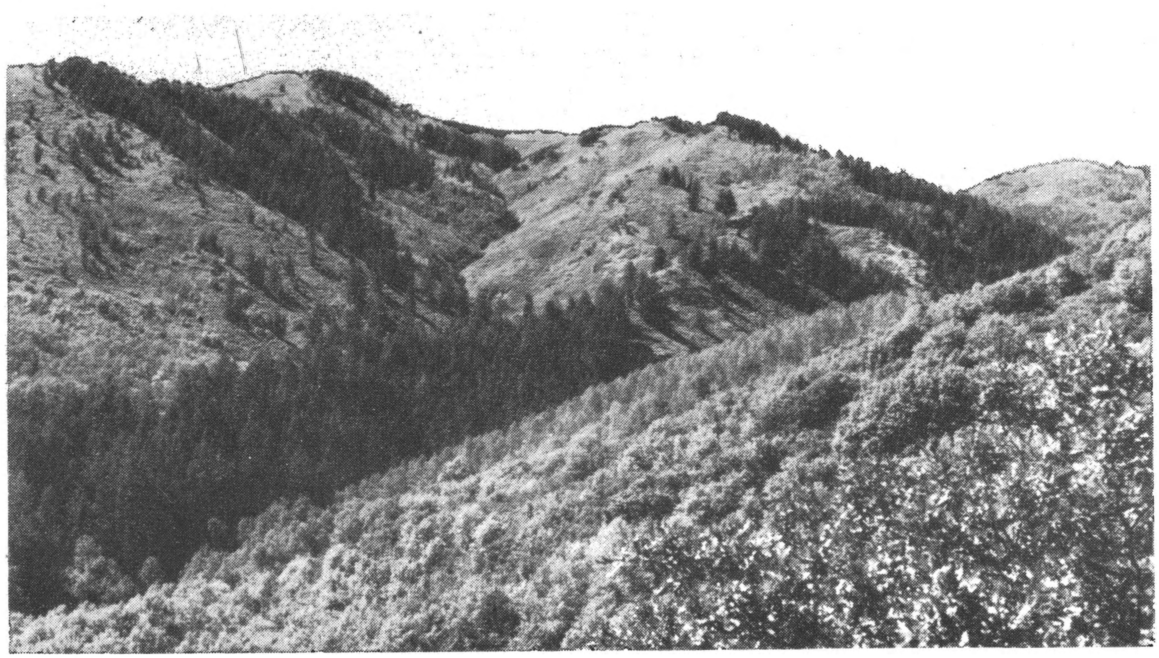


Figure 15. Deeply eroded canyons form much of the spectacular scenery in Wasatch Mountain State Park. The deep erosion is caused as streams cut downward through rapidly uplifted mountains.

Figure 16. The valley of Provo Deer Creek formed by erosion of relatively weak layers of rock.

Mining and Recreation the last 150 years (Historic Time)

The historic story of Wasatch Mountain State Park is essentially one of mining and prospecting. The first settlers in Utah were more interested in growing food than in mining, so it was about 20 years after their arrival before gold and silver were discovered near the Park (in 1869). Within weeks of the discovery, prospectors swarmed over the region, which became known as the Park City Mining District (Figure 17). Virtually all important surface discoveries were made within the first few years. The first shipment of silver-lead ore was in 1871 from the Flagstaff mine near the north end of the Park (Tour 3, Stop 2).

The Park sits on the edge of the mining district, and many claims were located within its present boundaries. Most productive mining, however, was done one to three miles to the north (Figure 18). Undoubtedly, the Park would still be in private ownership if significant amounts of silver, gold, or other metals had been discovered within its borders. The Park's irregular boundary is mostly due to the shape and location of early mining claims.

Virtually every exposure of rock in the Park

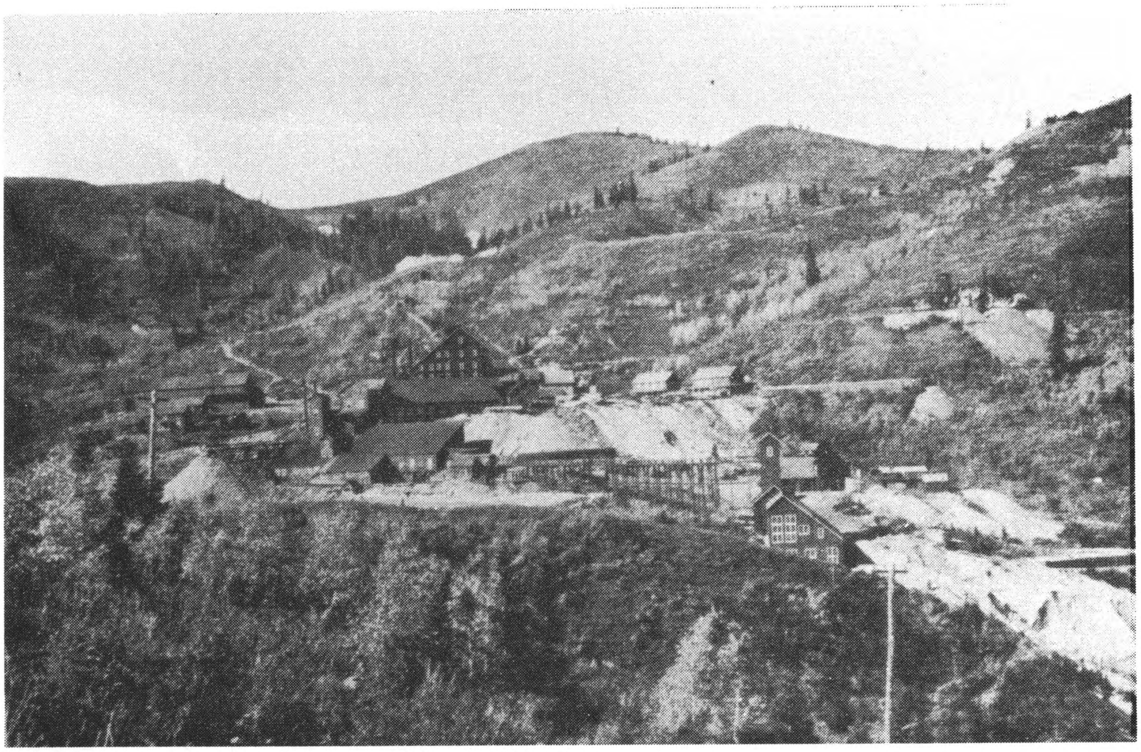


Figure 17. Mills, mine offices and housing sprang up near the openings of major mines. This historic photograph shows mill workings near the Silver King mine, which was located north of Bonanza Flat (from Boutwell, 1912).

has been examined for mineral potential many times. As you travel through the Park, look for piles of freshly broken rock that indicate where a prospector dug. Several prospect pits can be seen along Tour 3. Some of the pits were simply "shots in the dark" -- an attempt to see the bedrock under a weathered cover. However, most pits were located where the rock gave some hint of mineralization. The prospectors were mostly uneducated, but they quickly learned what to look for. Any hint of rust-brown, red, green, or blue stain was enough to entice them to dig. There are thousands of these "teasers" in the district. Some yielded just enough ore to lure the prospector on, and others yielded nothing but a yearning to try again. Only a few dozen sites ever paid out more than they cost to develop. The prospector was truly the "eternal optimist".

Today, the value of the Park lies in its scenic beauty, a wide variety of recreational opportunities, and in its role as a critical water shed.

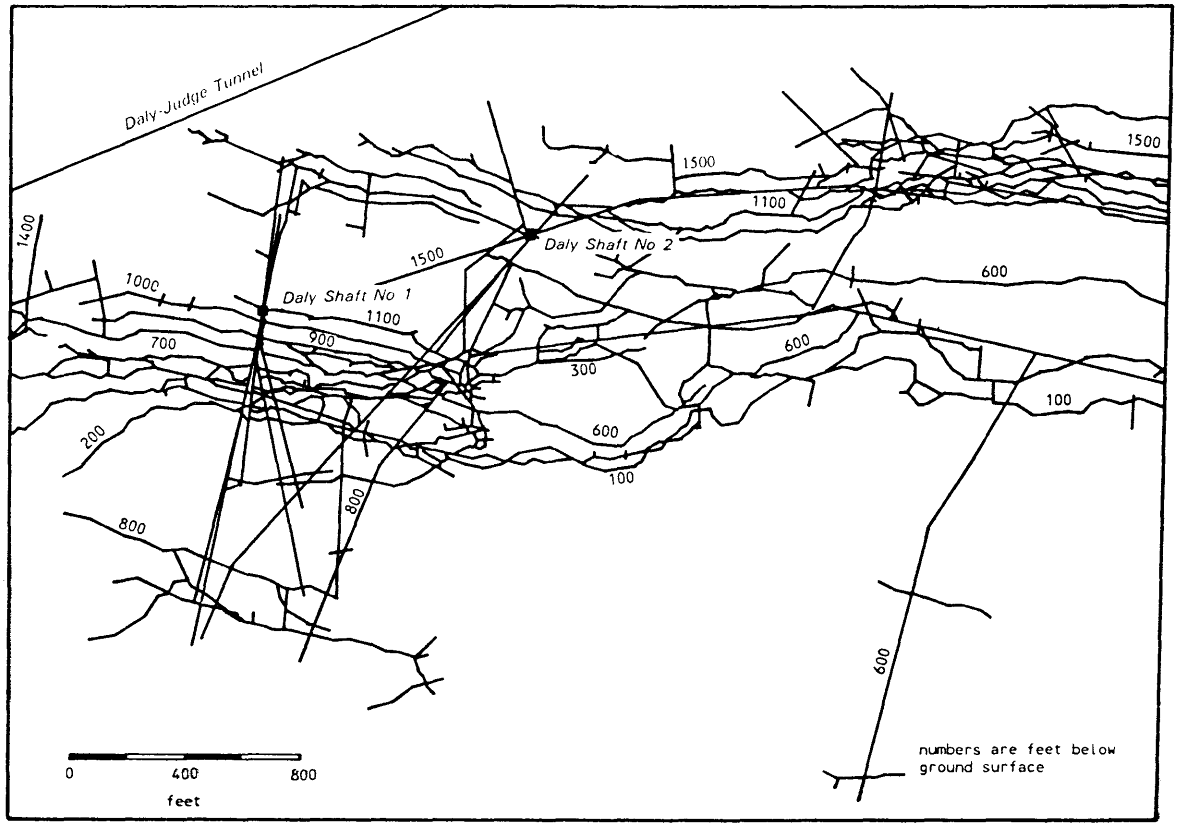


Figure 18. Map showing a network of mine tunnels north of Bonanza Flat. People standing on a ridge north of the Park would be astounded if they could see the hundreds of miles of mining tunnels beneath their feet (from Boutwell, 1912).

II. ROAD TOURS

The *Road Tours* describe the geology along major routes in Wasatch Mountain State Park. Each Tour consists of geologic discussions at designated stops and short explanations of features seen between stops.

All Tours, except Tour 3, start at the Park Visitors' Center, where you should set, or note, your odometer. Cumulative mileage is given in the text. Landmarks are noted to help adjust for differences in odometer readings.

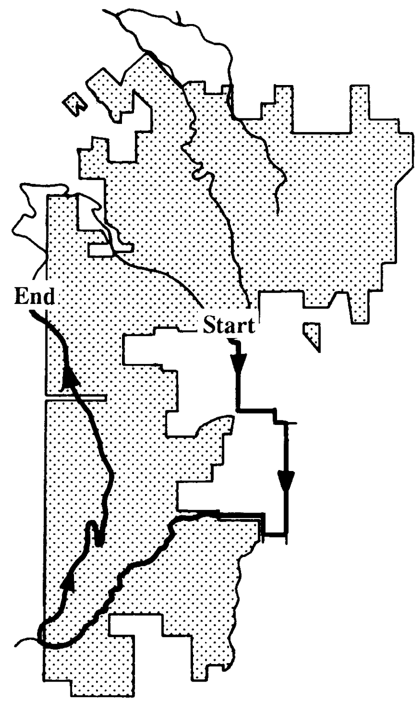
To gain the most from the Tours, pull your vehicle well off the road at each stop, then read the discussions and explore highlighted features. Have a passenger read explanations between stops, or read ahead before leaving a stop. Do not attempt to read while driving as the roads are narrow with many blind curves.

The Park has a very irregular boundary. This is primarily because much of it was originally mining claims. In order to take advantage of existing roads, the Tours extend slightly outside of actual Park boundaries.

Note: If you have not already done so, you may want to take a few minutes to read Section I, A Tour Through Time, before you begin a Road Tour. That section overviews the geologic history of the Park and will help you better understand features pointed out on the Tours. Section III, Scenic Views, describes views from within the Park. The Appendix contains more information about rocks and geologic formations.

TOUR 1

TOUR 1 Visitors' Center to Cummins Parkway via Cascade Springs	
Length:	18 miles
Driving Time:	2 hours (minimum)
Road Conditions:	graded dirt roads; can drive in a passenger car when dry.
Features:	• landslides • normal faults • thrust fault • Cascade Springs • Paleozoic rocks • Mesozoic rocks • petroleum source rocks



Tour 1 explores geologic features along Cascade Springs Drive, Provo Deer Creek Canyon, and the Cummins Parkway (a high ridge road with spectacular views).

The Tour ends at a junction with roads to American Fork Canyon (west) or to the Park Visitors' Center through Snake Creek Canyon (northeast); a high-clearance vehicle is recommended if you choose to continue on those roads. Tour 1 meets Tour 4 at this junction, making a loop trip back to the Visitors' Center possible.

Mile 0.0: Start Tour 1

Visitors' Center. Turn left (east) out of the Visitors' Center parking lot onto Snake Creek Road. Proceed east, then south, toward the Homestead and Midway.

Mile 0.5: Stop 1

Tufa mounds and hot springs.

The small mounds on the west side of the road once overflowed with hot water from underground springs (Figure 19). Each drop of water that flowed from the springs deposited a small amount of calcium carbonate, which over time, built the mounds. Some of the mounds are quite large, such as the one at the Homestead Resort.

The rock that forms the mounds is called tufa. It has the same composition as stalactites and stalagmites in caves. When Midway was first settled, many buildings were built of tufa. People continue to use it today for fences and decorative stone (Figure 20).

The temperature of the water as it comes from the ground varies from spring to spring, but is as hot as 110°F. That's pretty hot for spring water! Resorts in the area divert the hot water and use it for swimming. Although the water is not hot

Figure 19. One of many "tufa" mounds formed by hot springs near Midway. Tufa deposits are as much as 90 feet thick in this area.

Figure 20. The Midway City Hall is constructed of shaped blocks of tufa. As you drive through town and along State Highway 113, look for other structures made from this unusual building material.

enough to generate electricity, some people use it to heat their homes. (See Tour 2, Stop 1.)

Mile 0.75

The Homestead Resort.

Mile 1.25

Turn east (left) onto 200 North in Midway.

Mile 1.9

Turn south (right) onto 100 West in Midway.

Mile 2.1

Turn east (left) onto Main Street in Midway.

Mile 2.3

Turn south (right) onto State Highway 113.

Mile 4.1

Turn west (right) onto Tate Lane (State Highway 220).

Mile 4.6

Junction. Follow Tate Lane around to the north (right). The road to the south leads to the Chalet, part of Wasatch Mountain State Park. From the Chalet, you can hike along the Heber Creeper railroad track (Figure 21) to see outcrops of the Big Cottonwood Formation, Nugget Sandstone, and Twin Creek Limestone. In that area, the Big Cottonwood was "thrust" over the Twin Creek and Nugget during the Sevier orogeny. (See Section I, Late Mesozoic.)

Figure 21. The Heber Creeper is a historic train that operated near the southern edge of Wasatch Mountain State Park. The train was originally used to transport sheep.

Mile 4.9

Junction. Turn west (left) onto Cascade Springs Drive.

Mile 5.8

The road passes over "hummocky" terrain of an ancient landslide for the next three miles. Evidence for the landslide is pointed out along the route. Much of the vegetation along this road was burned off by a large range fire in 1990.

Mile 6.5

Thaynes Formation. Most of the rocks exposed along Cascade Springs Drive are part of the Thaynes Formation (Triassic). When they were deposited over 240 million years ago, the Park was part of a broad continental shelf that was usually covered with warm, shallow sea water. As water level in the "Thaynes" sea fluctuated, and as the amount of nearby erosion changed, different types of rocks were deposited. In general, limestone (the most common type) was deposited when water covered the land, and shale was deposited when the water was shallow or absent. Sandstone, which interfingers with the other rock types, was carried in during erosion of an inland area. As you look at outcrops along Cascade Springs Drive, use the table below to help you identify the rock types.

Mile 6.7: Stop 2

Differential weathering. The different rock types of the Thaynes Formation vary in their ability to withstand weathering. Shale is soft and weathers easily, while sandstone and limestone are more resistant. As you look at rocks exposed in this road cut, you will see that thin beds of shale are weathering away, leaving small sandstone overhangs. This is called differential weathering. On a larger scale, less resistant beds such as shale often become valleys while the more resistant beds form ridges. (See Figure 16 and Mile 11.4)

Landslides in the Thaynes Formation. The eastern slope of this mountain is an ancient landslide. Tilted beds of shale, interlayered with fractured sandstone and limestone, caused the landslide. Water, percolating through fractures, altered the shale to clay. The overlying rocks slipped on the slick, tilted, clay surfaces--and the landslide was born.

Rocks in the Thaynes Formation

Rock Type	Description
limestone:	brownish-gray, blocky, "sugary" texture on fresh surfaces, scratches easily with a knife
sandstone:	light-brown to gray, grainy feeling rock (look closely-you can see the tiny sand grains)
shale:	reddish, purplish, or greenish rock; commonly thin, platy, papery, or crumbly

Mile 7.0 to Mile 8.9

For the next few miles, no specific stops are indicated. However, many interesting features related to landsliding can be seen in the road cuts. Stop at one of the sites titled "Landslide Evidence" to see what happens to rocks during a landslide.

Mile 7.0: Landslide Evidence.

Faulted rocks. Faults develop when masses of rock break and shift along fractures. In several of the road cuts, small faults, related to the landsliding, cut the Thaynes Formation (Figure 22). Look for places where layers of rock abruptly terminate against a different type of rock. (See Mile 11.4).

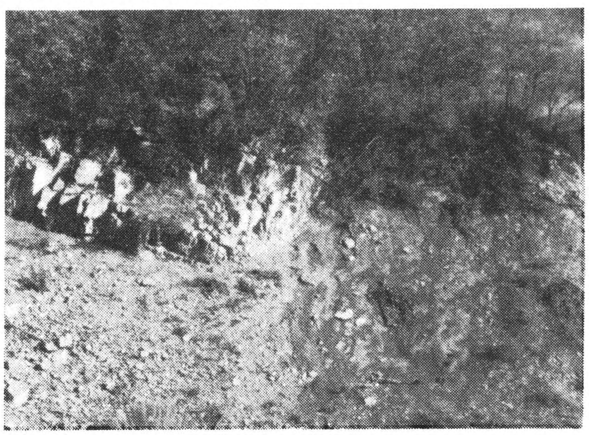


Figure 22. Jumbled and faulted rock in the Thaynes Formation near Mile 7.0. Sandstone on the left is faulted down against purple shale and siltstone on the right. Landsliding caused the deformation.

Mile 7.2: Landslide Evidence.

Folded rock. Strong compressional forces during landsliding folded these rocks (Figure 23).

Mile 7.7

The road crosses onto the Ankareh Formation

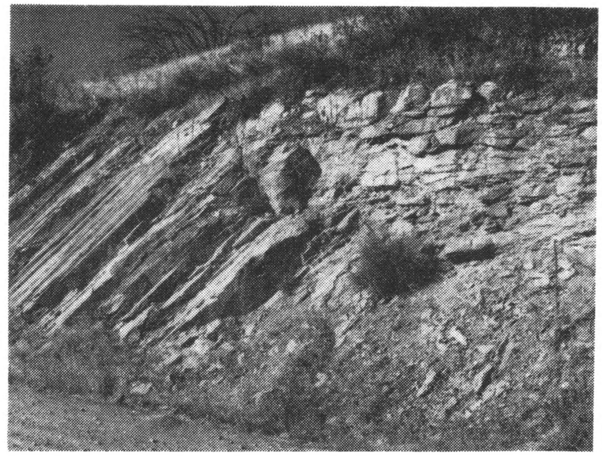


Figure 23. Folded rocks in the Thaynes Formation near mile 7.2. These beds are folded into an open, inverted v-shape.

Mile 7.8

Junction. Continue on the main road. The side road leads to Deer Creek Reservoir.

Mile 7.9: Landslide Evidence.

The road crosses back onto the Thaynes Formation.

Jumbled rocks and changing dip. As "beds" of rock slide downhill in a landslide, they are jumbled and broken. In this road cut, beds dip (tilt) in several different directions--some dip west and others dip east or northeast. Compare these beds with those in the next road cut.

Mile 8.2

The Thaynes Formation in this roadcut consists of one- to two-foot-thick beds of limestone. The beds dip steeply west.

Mile 8.4: Landslide Evidence.

These shattered and deformed beds of Thaynes Formation are interlayered sandstone, reddish siltstone, and shale.

Mile 8.9 to 9.3: Stop 3

The road follows a continuous exposure of the Thaynes Formation. Take a short walk along it, and look at the features described below.

Nature of the Outcrop. Note how different this outcrop is from the others seen so far along Cascade Springs Drive. The beds are continuous and are not faulted or folded. The landslides you saw earlier are shallow and only affect this hill to the northeast where they take advantage of the natural dip of the beds.

Varied rock types. Look for the rock types explained at Mile 6.5. Try to identify shale, limestone, and sandstone.

Weathering of shale. Note how easily the shale weathers compared to the other rock types. Pick up some of the extremely thin-bedded shale near the start of the outcrop and crumble it in your hand. This rock is known as paper shale. Can you see why it might weather more easily than the limestone or sandstone?

Fossils. Several thin beds of limestone and limy sandstone in the Thaynes Formation are fossil-bearing. Of particular note are some well-preserved echinoderm spines (Figure 24). Echinoderms are small sea animals that have a spiny exterior; sea urchins are modern echinoderms. One fossiliferous bed is located about 100 feet east (right) of the jointed rocks in Figure 25 (near mile 9.2).

As you look for fossils, you may see "dendrites" (black, fern-like patterns that form on rock surfaces). Some people mistake dendrites for fossil plants. Actually, they are inorganic manganese crystals that "grow" in a branching pattern.

Figure 24. Fossil echinoderm spines found in the Thaynes Formation near the joints at Mile 9.2.

Note: Fossil collecting is prohibited in the Park. If you find any fossils, please leave them for others to enjoy; they are not of collecting quality.

Joints are nearly parallel cracks in the rock. Faulting, folding, or simply removing the weight of overlying rock can create joints. They are of economic importance because they provide avenues for the migration and accumulation of water, petroleum, and minerals.

Mile 9.5: Ankareh Formation. At this point, the road leaves the Thaynes Formation (early Triassic) and crosses onto the Ankareh Formation

Figure 25. Numerous "joints sets" intersect, making a crisscross pattern in limestone beds near mile 9.2.

(middle-late Triassic). A change from one formation to the next usually means a significant change in rock type, and thus in depositional environment. The lower Ankareh Formation is primarily red sandstone and siltstone, and was deposited on tidal flats. Limestone, which is dominant in the Thaynes, is not present in the Ankareh. This change in rock type correlates with a withdrawal of the "Thaynes" sea, and the start of mountain building west of Utah. (See Section I, Early to Middle Mesozoic).

Mile 9.6

Top of the pass. Junction with sideroads to north and south. Continue on main road.

[If you hike along the four-wheel drive road to the south watch for these features: Near mile 0.3 is an outcrop of the Gartra Grit Member of the Ankareh Formation. This rock forms a white ledge of well-cemented gritstone (coarse sandstone) east of the road. Surfaces of the rock have slickensides (scratches polished by rocks rubbing together) that were made during thrust faulting. At about 0.4 miles, the road crosses the Charleston-Nebo thrust fault. The only evidence of the fault is a few obscure pieces of shattered rubble on the road. Unfortunately, the faulting weakened the rocks so much that they erode easily.]

Mile 10.3: Stop 4

Junction. Turn left, and follow the paved road to the parking lot at Cascade Springs.

Cascade Springs. Cascade Springs is a natural spring whose numerous waterfalls and lush vegetation draw thousands of visitors each year. Award-winning walkways and bridges make it easy to enjoy the beautiful surroundings (Figure 26.

Charleston-Nebo Thrust Fault.

After you visit Cascade Springs, cross the parking lot to the outcrops on the southeast side.

This hillside is the best place in the Park to see relationships along a principal thrust fault (Figures 10 and 27). The fault, called the Charleston-Nebo thrust, formed during a major mountain-building event about 80 million years ago. A huge sheet of rock was shoved 20 to 40 miles eastward along this fault, stacking older rocks on top of younger ones. At this location

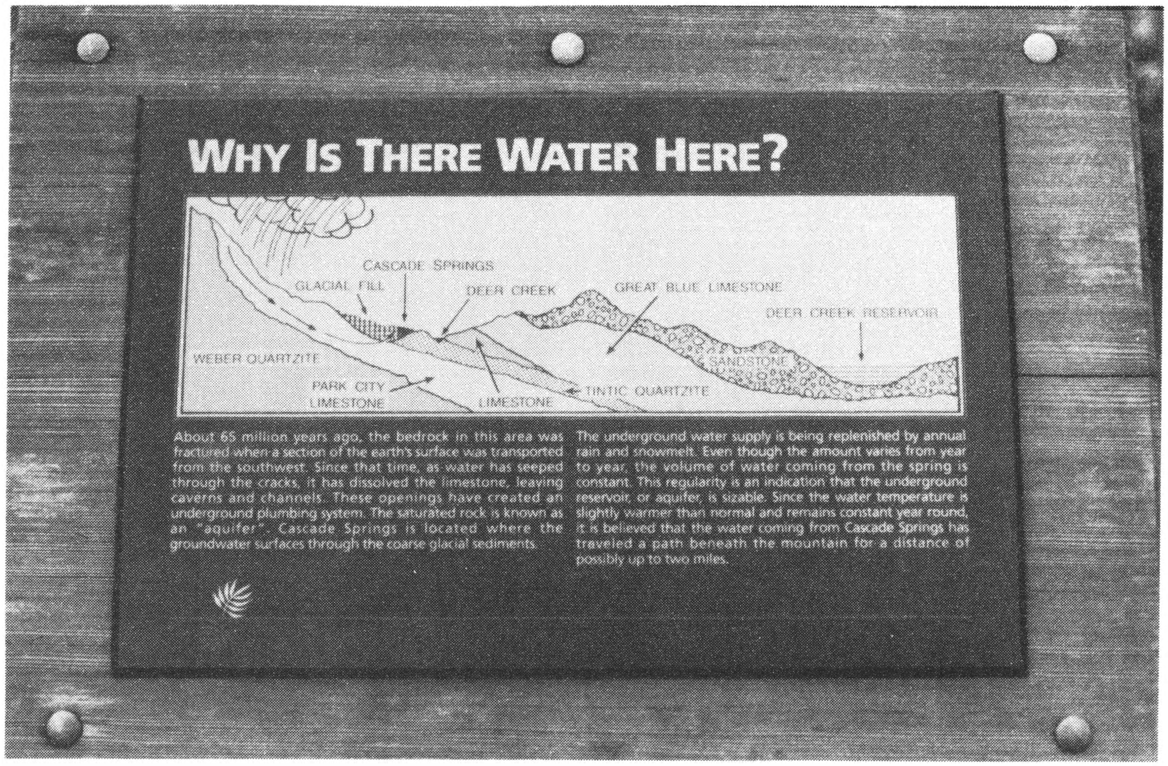


Figure 26. Cascade Springs. Signs along the path describe the plants and animals and explain the geologic controls of this natural wonder.

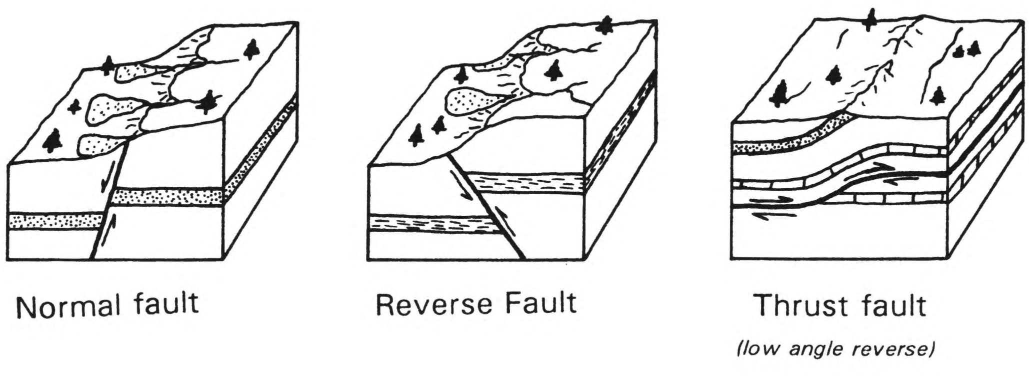


Figure 27. Diagram of normal, reverse, and thrust faults. Note that most of the movement is vertical on normal and reverse faults, while most is horizontal on thrust faults.

the Tintic Quartzite a Cambrian formation) was pushed over the Thaynes Formation (which is 300 million years younger. (See Section I, Late Mesozoic.)

Look at the outcrop of Tintic Quartzite near the southeast corner of the parking lot (Figure 28). Note how shattered it is. The rock was ground up by fault movement until it resembles a gritty flour. It is held together by natural cement that fills the spaces between the shattered particles.

Other rocks close to the fault were also shattered, so they erode easily and are poorly exposed. This makes it difficult to locate the fault and to distinguish rocks involved in the thrusting. Figure 29 marks the locations of the thrust fault and rock formations. The older rocks (south part of hill) moved eastward, away from you, lapping over the younger rocks.

To further complicate the geology at this location, about 50 million years later, "normal" faulting paralleled the thrust fault. Rocks on the south side (right) of the fault zone were lowered relative to the rocks on the north (left).

From this point you have several options:

- *Continue on Tour 1. Proceed north up Provo Deer Creek Canyon to the top of Cummins Parkway.*
- *Turn around and return to the Visitors' Center.*
- *Follow the paved highway west to the Alpine Highway. If you choose this option, stop 1.5 miles beyond Cascade Springs and look back at the Park. The position of the Charleston-Nebo thrust fault is easier to discern from that point. Use Figure 24 to guide you.*

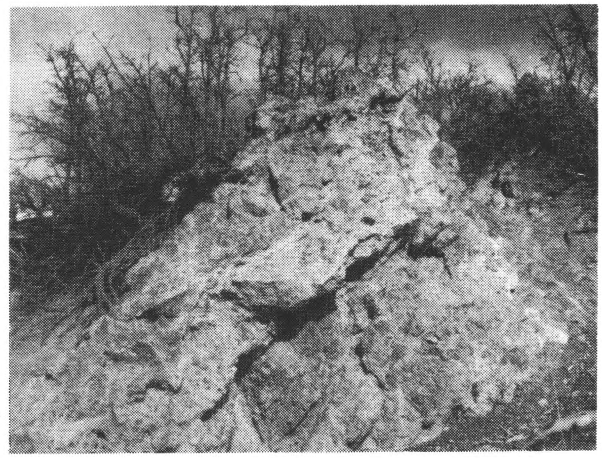


Figure 28. The Tintic Quartzite was intensely shattered during transportation along the Charleston-Nebo thrust fault. This outcrop of the Tintic is near the southeast corner of the parking lot at Cascade Springs.

Continuation of Tour 1

Mile 10.4

Burrowed Limestone. These limestone outcrops of the Thaynes Formation have distinctive burrows. The burrows were made by soft bodied animals, such as worms, that lived in the limy mud. Fossil shell fragments are also in the rock.

Mile 10.6

Junction. Turn onto the dirt road that leads north along Provo Deer Creek Canyon to Deer Creek Campground. The paved road leads to the Alpine Highway.

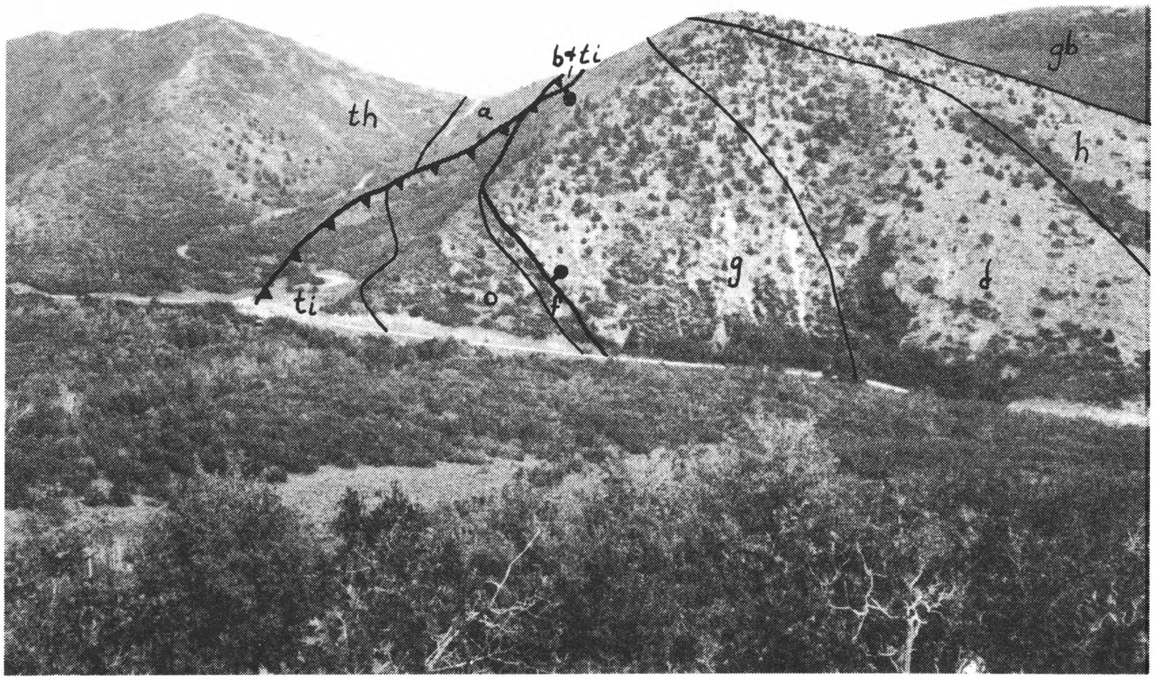


Figure 29. The relationship between rock formations and the Charleston-Nebo thrust fault east of Cascade Springs. The position of the thrust fault is shown by the heavy barbed line. Formations that were pushed 40 miles eastward are: b-Big Cottonwood Formation; ti-Tintic Quartzite; o-Ophir Shale; f-Fitchville Formation; g-Gardison Limestone; d-Deseret Limestone; h-Humbug Formation; gb-Great Blue Limestone. Formations beneath the thrust fault are: th-Thaynes Formation; a-Ankareh Formation. The heavy line with the bar and ball is a later normal fault (Figure 27).

Mile 11.0

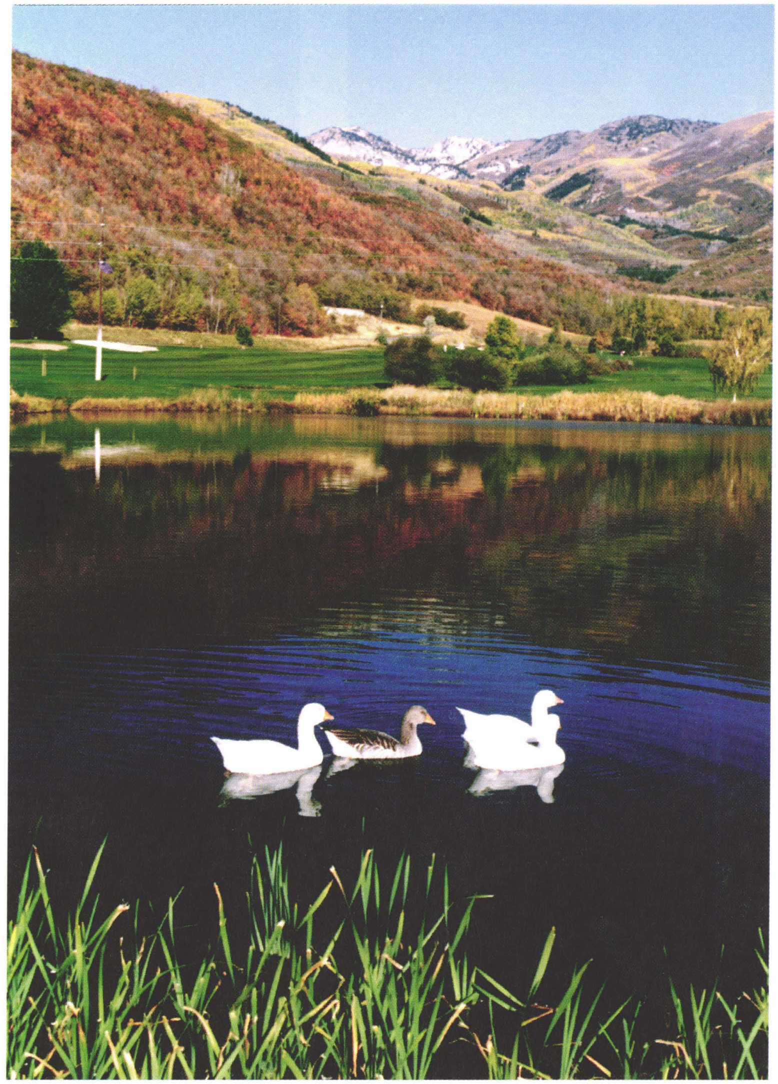
Mill Canyon Peak. Mill Canyon Peak is the prominent peak to the northwest. The lines near the top of the peak are erosion control ditches dug by the Civil Conservation Corps (CCC) during the Great Depression. The mountain is composed entirely of Weber Quartzite (Pennsylvanian/ Permian). This great thickness of rock is unusual for any formation in the Wasatch Mountains. Many geologists think that the Weber was deposited near the edge of a rapidly subsiding basin about 300 million years ago. Over 29,000 feet of rock was deposited in the deepest part of this basin! (See Section I, Paleozoic).

Mile 11.4

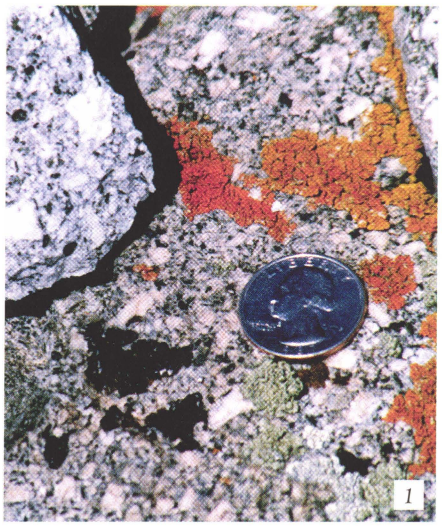
Differential Weathering. The hill to the east is relatively resistant limestone of the Thaynes Formation. The valley formed in the more easily eroded shale of the Woodside Formation. (See Figure 12). This is a large-scale example of differential weathering as explained at Mile 6.7.

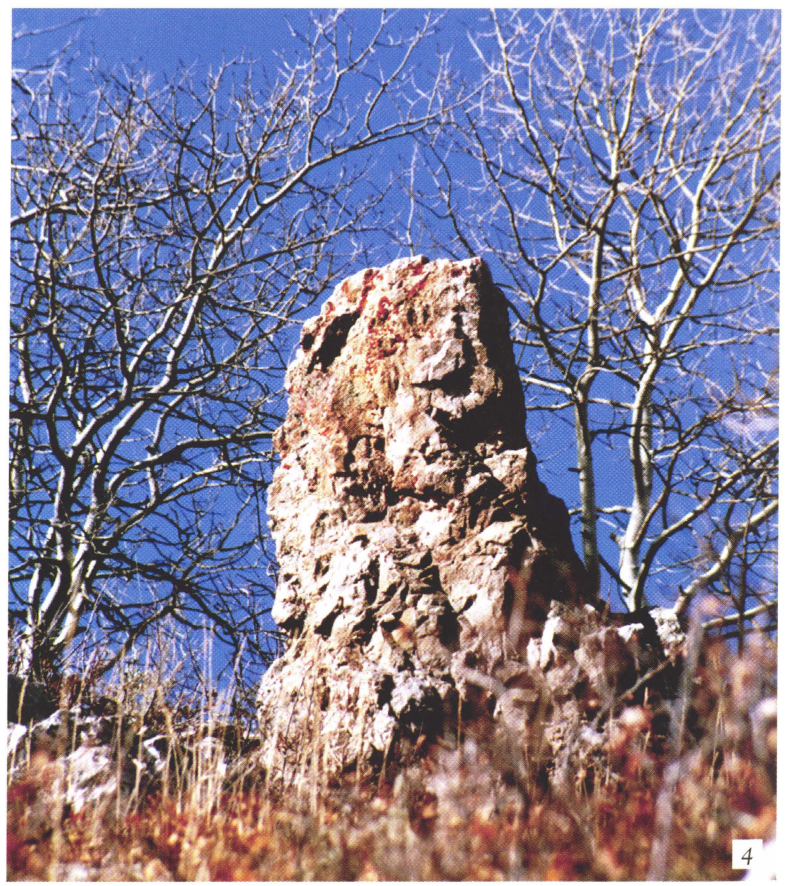
Visitors often come to Wasatch Mountain State Park to golf or cross-country ski beneath the crystal blue skies. Nestled on the backside of the Wasatch Range, the park is known not only for golf and skiing, but also for high mountain vistas, rugged canyons, and brilliant autumn foliage.

The photos in this section feature a variety of scenes in Wasatch Mountain State Park. Geologic processes – oceans sweeping over a featureless landscape, molten rock forcing its way to the earth's surface, faulting and mountain building, and sculpting by glaciers and water – are the threads that wove these varied scenes.



Every rock contains clues of its past. Geologists study rocks to unravel the clues locked inside them.





1. Large crystals such as the quarter-sized ones in this igneous rock are evidence of magma that cooled slowly deep beneath the earth's surface. 2. Recycling is not a new concept – rocks have been doing it for millions of years! The rounded pebbles in this block of Tintic Quartzite were eroded from an older rock formation, deposited along a river, and then buried and cemented to form this rock. The cycle continues today as water, plants, and ice fracture the rock again. 3. These autumn leaves and ferns may someday be fossils giving geologists a clue about an ancient environment – ours!

4. Why did this pillar of Gardison Limestone form? Perhaps it has more natural cement or fewer internal fractures than the surrounding rocks. 5. These ripple marks imply a watery past. The Woodside Formation was deposited in shallow water near the edge of a vast ocean. 6. Angular, poorly sorted grains in this boulder of Big Cottonwood Formation reveal that they were carried a relatively short distance by a swiftly moving stream. 7. These muddy limestones of the Thaynes Formation were deposited in a shallow sea.

Whether mountain biking, snow-mobiling, or sightseeing, visitors to Wasatch Mountain State Park have access to mountain scenery that rivals the Alps.

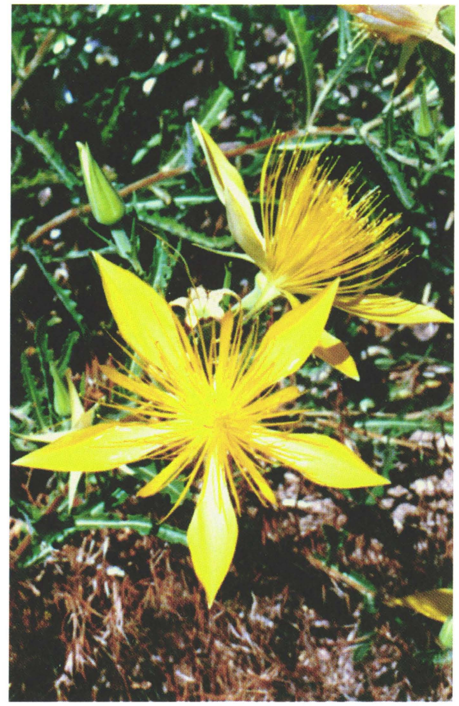
The geologic processes that wove these scenes include earthquakes, which lifted up the mountains, and glaciers, which shaped the craggy peaks and ridges.

1. Mt. Timpanogos is made of thousands of feet of limestone, evidence of an ancient ocean basin. 2. The Park Visitor's Center contains displays on wildlife, geology, and plant life. 3. Autumn colors frame Flagstaff Peak.

4. Mill Canyon Peak, an impressive mountain just west of Wasatch Mountain State Park, is primarily quartzite.
5. Cascade Springs is a natural spring whose numerous waterfalls and lush vegetation draw thousands of visitors each year. Terraces form from the deposition of calcium carbonate in the water.
6. Pioneer and Sunset Peaks are framed by Snake Creek Canyon and are part of an historical mining center.

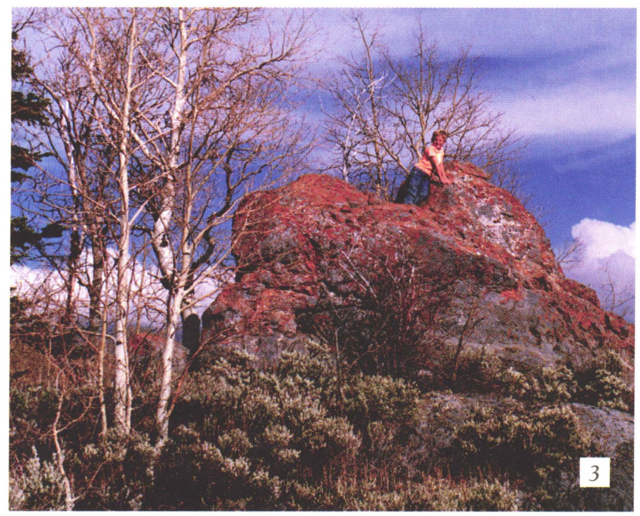
Forces deep in the earth can move rocks along faults or melt them into magma. The rocks pictured here record brutal encounters with some of these forces.

1. These fossil-bearing boulders of Gardison Limestone are in amazingly good shape considering there were once surrounded by a rising body of hot, molten rock. Deep erosion has now exposed the boulders to stresses of another kind - freezing and thawing. 2. Natural fractures form as igneous rocks cool from hot, molten magma. Such fractures aided workers who quarried this attractive crystal-rich rock for buildings in the Heber Valley. 3. As blocks of rock slip past each other, the powerful grinding



forms smooth, polished surfaces called "slickensides". The best slickensides form quartz-rich rocks such as this coarse sandstone bed in the Ankareh Formation. 4. Breccia, or shattered rock, records tremendous forces inside the earth. Quartz and calcite fillings in fractures like these sometimes host silver and gold. 5. This striking fault near Provo Deer Creek marks a place where rocks fractured and moved. The fault was unknown until road construction stripped away overlying soil and vegetation.

The tapestry of a rock's past begins to unravel when it is exposed on the surface of the earth where freezing and thawing water, glaciation, and other erosional forces gradually wear the rock into soil.



1. The curves of these aspens reflect the nearly imperceptible creep of soil down an oversteepened slope. Soil creep, an important erosional process in the mountains, is enhanced by freezing and thawing of water - and by road cuts. 2. Thousands of years ago this serene setting was covered by hundreds of feet of glacial ice. Soil from weathering rock and plant debris is gradually burying the huge boulders left behind by the melting glacier. 3. Orange lichen blanket this outcrop of Gardison Limestone. Lichen are one of the first plants to grow on barren rock. Acids they secrete aid in the slow process of weathering rock to soil. 4. Rock fragments, embedded in a flowing glacier, polished this jutting buttress of Weber Quartzite.

Mile 12.7

Junction. Turn east (right).

The ditch along the hillside was built to carry water from Provo Deer Creek across the low pass in the ridge to farming areas in Heber Valley.

Mile 12.8 to 13.0: Stop 5

The Woodside Formation (Triassic) is well exposed in this road cut. Take a short walk along it and look for the features described below.

Rock Type. Note how similar the red to red-brown shale and siltstone of the Woodside Formation (Triassic) is to the Ankareh Formation seen at Mile 9.5. This is because the Woodside was deposited in a tidal flat environment very similar to the one in which the Ankareh was deposited.

Weathering horizon. This is one of many places in the Park where you will see "white wash" coating on rocks. The coating is caliche (calcium carbonate) (Figure 30). In arid climates, caliche is a common part of soil development. The caliche comes from wind blown dust, and is leached down through the soil horizon by rain water.

Normal Fault. Faults form when rocks break and shift along a fracture, juxtaposing rocks of different ages or types. Partway up this road cut is a fault (Figure 31). Note the abrupt change in rock type and the "gouge" zone of shattered rocks.

This particular fault is a "normal" fault, meaning that one side moved down and pulled away relative to the other (Figure 27). In this case, the Thaynes Formation (south) moved down relative to the Woodside Formation (north).

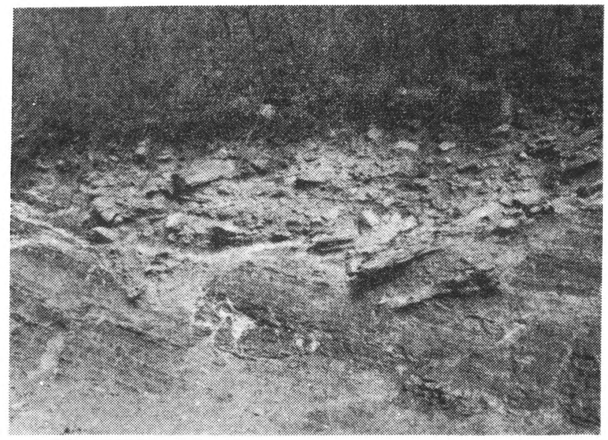


Figure 30. Weathering horizon in the Woodside Formation at mile 12.9. The rubble fills a shallow wash cut into the underlying bedrock. White "caliche" has accumulated in most of the open spaces around the rubble and in fractures in the bedrock.

Knowing which side is down helps geologists determine what happens to the fault and affected rocks beneath the surface. This knowledge is particularly important in oil and mineral exploration because faults often control the concentration of economic deposits.

Effects of faulting on different rock types. Note that most of the material in the gouge zone of the fault is limestone of the Thaynes Formation. The limestone is shattered several feet away from the fault, while shale and mudstone of the Woodside Formation are relatively unaffected. This is because limestone is more brittle than shale and mudstone. Shale bends under stresses that cause limestone to shatter.

Cross-bedding. As you walk along, watch for cross-beds in sandstone of the Thaynes Formation (Figure 32). Cross beds are inclined beds formed by moving water or wind. They have a shallow slope on the "up-stream" side and a steep slope on the "down-stream" side. Thus geologists can

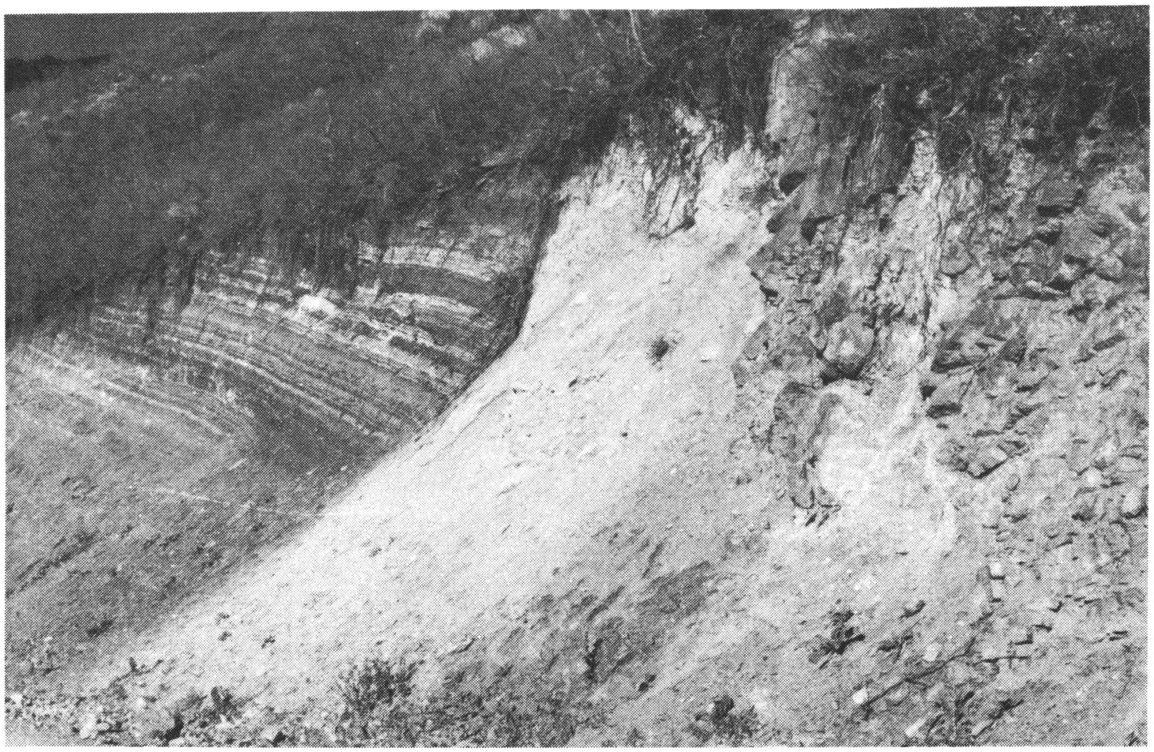


Figure 31. This impressive normal fault moved the Thaynes Formation down relative to the Woodside Formation. Reddish siltstone of the Woodside is on the north side (left) of the fault, and brown limestone of the Thaynes is on the south side (right).

determine the direction of flow. Many flow measurements allow them to determine the source area of sediments or the prevailing wind direction.

Mile 13.2

The reddish rocks seen in the road cut are in the middle part of the Thaynes Formation. Note how similar they look to the Woodside and Ankareh Formations. This interval represents a brief time during which the level of the "Thaynes" sea dropped and the area became a tidal flat. It was not divided out as a formation because this zone is relatively thin and does not persist for many miles.

Mile 13.4

Top of the pass.

The rest of the route follows the Cummins Parkway along a high ridge. The views are excellent. Section III, *Scenic Views*, briefly explains the geology of mountains and other prominent features outside the Park.

Mile 14.1: Stop 6

View of the Charleston-Nebo thrust fault. From this vantage, look toward Deer Creek the

Figure 32. Cross-bedding in sandstone of the Thaynes Formation near mile 13.0. The angle of the sloped beds indicates that water flowed to the right.

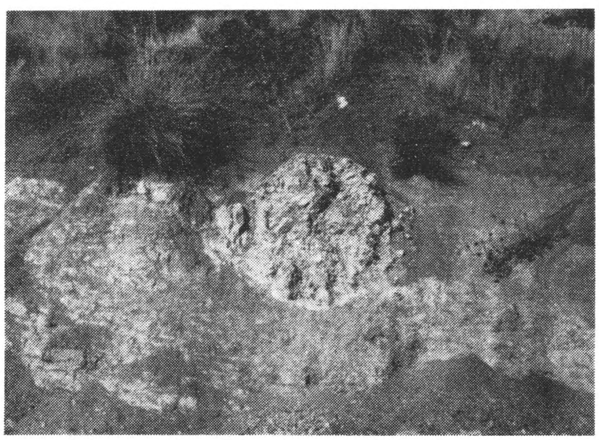


Figure 33. Thrusting contorted and crushed rocks. This unique "ball" of Twin Creek Limestone was shattered and shaped during faulting. It is located just a few feet below the thrust fault near Deer Creek Reservoir.

path of the Charleston-Nebo thrust fault (Figures 33 and 34). The huge sheet of rocks transported by the thrust is almost 50 miles across (Figure 10). Virtually all of the mountains you can see to the south, southwest and west are part of this immense sheet.

Mile 15.4

For the next 1.5 miles the road weaves in and out of the Thaynes and Woodside Formations. A reddish color indicates that the road is on the Woodside, and a brown or brownish-gray color indicates the Thaynes.

Mile 15.5: Stop 7

Fossil ripple marks. Several of these thin beds of the Woodside Formation contain excellent fossil ripple marks (Figure 35). These marks were made the same way that ripple marks are made today--by waves washing back and forth across the sediment beneath a body of water. This is a good example of the principle "the present is the key to the past." Geologists assume that the laws of nature operated in the distant past the same as they operate today. The intensity may have varied, but the processes themselves have always had the same results. By using this principle, many things can be learned about the geologic past.

If you find any ripple marks, please leave them for others to enjoy. Rock and fossil collecting are prohibited in the Park.

Mile 17.0: Stop 8

Petroleum in the Park City Formation. The rocks on the east side of the road are marine limestones of the Park City Formation (Permian). Break one of the rocks and smell a fresh surface. Does it smell like money to you? The strong petroleum odor is caused by organic material and phosphate in the rock. In some areas, the Park

Figure 34. Charleston-Nebo thrust fault. The line on the photograph shows the path of the fault near Deer Creek Reservoir.

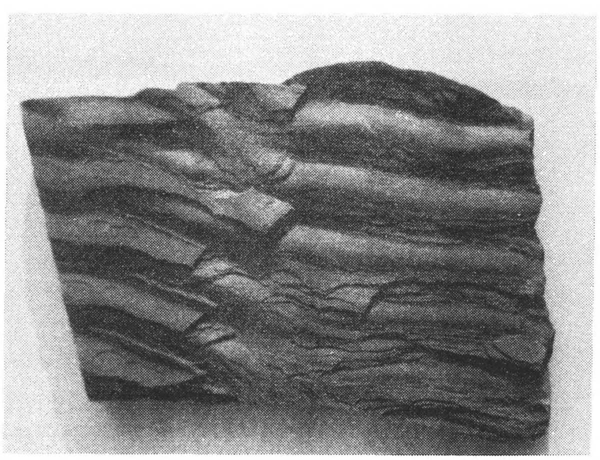


Figure 35. Ripple marks in the Woodside Formation.

City Formation has been mined for phosphate, which is then used to make fertilizer. The Park City is also an important source of petroleum in some of Utah's oil and gas fields.

Mineralization in the Park City Formation. There are many quartz-filled vugs (holes) in this outcrop (Figure 36). The vugs formed as water moved through fractures, dissolving and replacing some of the limestone with quartz. A similar zone of replaced limestone is found in mines a few miles north of here in the Park City Mining District. In those mines however, the limestone was replaced by precious metals such as silver, lead, gold, and zinc. (See Tour 3, Stop 2.)

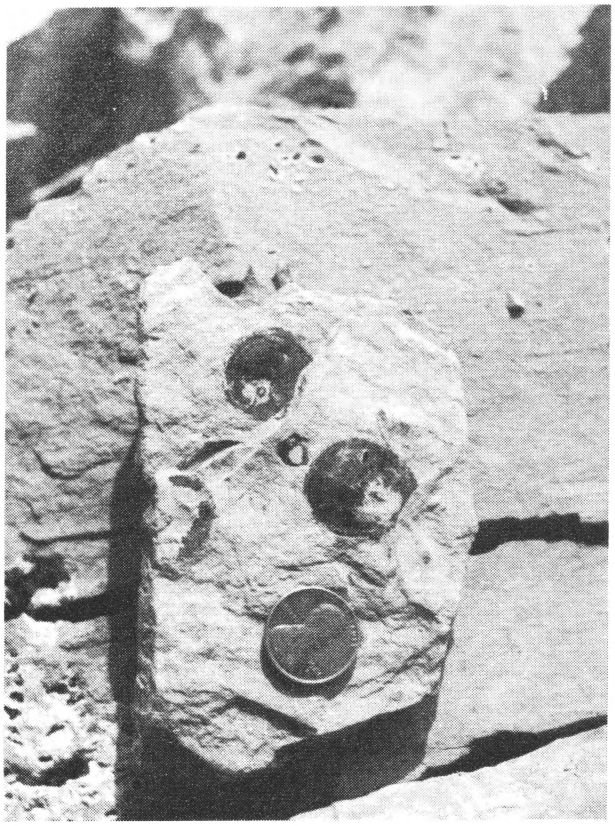


Figure 36. Fossil brachiopods and quartz-filled vugs in the Park City Formation. The fossils are from the genus *Orbiculoidea*.

Mile 17.6

Leave Wasatch Mountain State Park.

Weber Quartzite. The outcrops found near the Park boundary are part of the Weber Quartzite. These rocks are unusual for the Weber because they are sandstone, not quartzite. In most places the Weber is a sedimentary quartzite, which means it is densely welded by strong quartz cement.

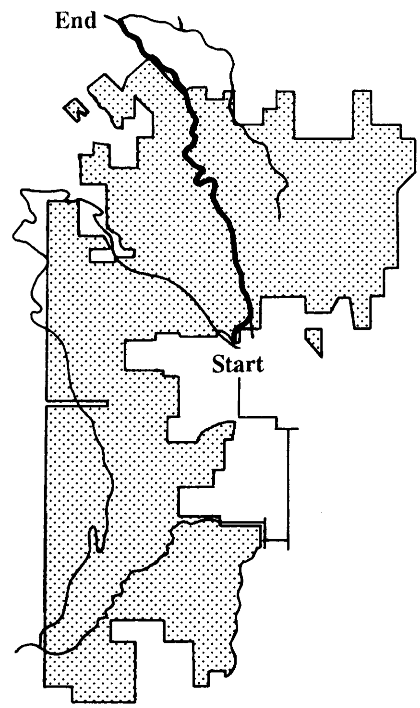
Mile 18.0: End Tour 1.

Junction. At this junction you have several options:

- *turn around and return to Cascade Springs, thence to the Visitors' Center or the Alpine Loop highway.*
- *turn to the right and join Tour 4, which leads to the Park Visitors' Center via a rough road through Snake Creek Canyon. (A high-clearance vehicle is recommended.)*
- *turn to the left and proceed down a rough road to American Fork Canyon. (A high-clearance vehicle is recommended.)*

TOUR 2

TOUR 2 Visitors' Center to Bonanza Flat via Pine Creek Canyon	
Length:	8 miles
Driving Time:	45 minutes (minimum)
Road Conditions:	graded dirt roads; can drive in a passenger car when dry.
Features:	• hot springs • glacial pond • glacial debris • igneous rock



Tour 2 explores geologic features in Pine Creek Canyon and Bonanza Flat. Views along the route are excellent, particularly in the autumn when the trees are in color. Tour 2 connects with the Guardsman Pass road between Brighton and Park City. Roadside geology along that route is described in the Geology and Scenery of the Central Wasatch Range, Wasatch and Summit Counties, Utah, by Miriam Bugden, available at the Utah Geological Survey. Tour 2 also leads to Tour 3, an excellent route for hiking, biking, and 4-wheeling.

Mile 0.0: Start Tour 2

Wasatch Mountain State Park Visitors' Center. Turn left (north) out of the parking lot onto Warm Springs Road. Pass the pond and the end of the Golf Course.

The ponds on both sides of the road are supplied by warm spring water.

Mile 0.6

Junction. Turn right on Pine Canyon road, drive 0.2 mile, then pull off the right side of the road for Stop 1.

Mile 0.8: Stop 1

Tufa deposits and hot springs. Walk toward the south end of the low rise west of the road. The rock that you are walking on is called tufa and was deposited by one of several hot springs in the Midway area (Figure 37). Scientists think that a small body of magma (hot, molten rock) heats the water. Some think the magma is buried beneath Midway, others think it lies deep beneath the Mayflower mine a few miles north of here. Once heated, the water travels along faults and fractures until it surfaces in the hot springs (from Kohler, 1979). (See Tour 1, Stop 1.)

Look around the area east and south of here, and you will see many small tufa mounds. These mounds can be thought of as "hard water" deposits, because they were built in the same way that calcium carbonate collects in water pipes. The largest tufa mound is at the Homestead Resort. Memorial Hill, an isolated hill to the south (encircled by a road), looks like a large tufa mound; actually it is made of shale and limestone like that in mountains to the north.

Scenic View. A few of the features visible from this stop are: Heber Valley, Daniel's Canyon, and a beautiful view of Sunset and Pioneer Peaks

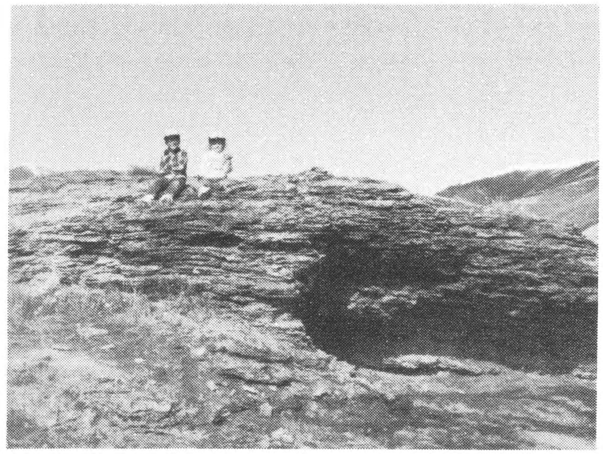


Figure 37. This ledge of tufa is about 9 feet thick; some tufa deposits are as much as 90 feet thick. Tufa is quarried for building stone in the Midway area.

up Snake Creek Canyon to the west. To the north you can see Pine Creek Canyon. (Refer to Section III to locate and learn more about these features.)

After you complete this stop, turn your car around and drive up Pine Creek Canyon.

Mile 1.1

Junction. Continue north up the canyon.

Mile 1.3

Golf Course Drive.

Mile 1.5

Entrance to the Pine Creek Campground.

Mile 2.2

The hill directly to the east is called "The Peak." It is composed of limestone (the Mississippian Gardison and Deseret Formations) that was deposited in a shallow sea about 340 million years ago. A fault runs through the saddle just north of "The Peak."

Mile 3.0: Stop 2

Pine Creek intrusion. On the west side of the canyon is an excellent outcrop of the Pine Creek intrusion (Figure 38). This formation is named after Pine Creek Canyon and is called an "intrusion" because it was once magma (hot, molten rock) that intruded upward into overlying rocks. The magma originated deep within the earth, tens of miles below the surface. Because the magma was more buoyant than overlying rock, it forced its way toward the surface until it reached a depth where it stabilized and cooled.

If you look at a piece of this "granite-like" rock, you will see that it contains many crystals. Crystals such as these were analyzed by scientists to determine how long ago and at what depth the magma cooled. This rock solidified almost 35 million years ago about 5000 feet below ground surface (John, 1989). Before it cooled, the magma may have fed ancient volcanic eruptions.

Most magma originates at levels where the surrounding earth is solid. The process by which solid rocks become molten is very complex, and is commonly associated with movement along earth's crustal plates.

Quarrying the intrusive rocks. The crystals in this rock make it attractive, and at one time people thought it would work well as building material. Similar rock from intrusions near the Wasatch Front was successfully quarried and used to construct many buildings, including the Mormon Temple in Salt Lake City. Look around for evidence of quarrying; there are many drill holes in rock faces and several broken slabs of

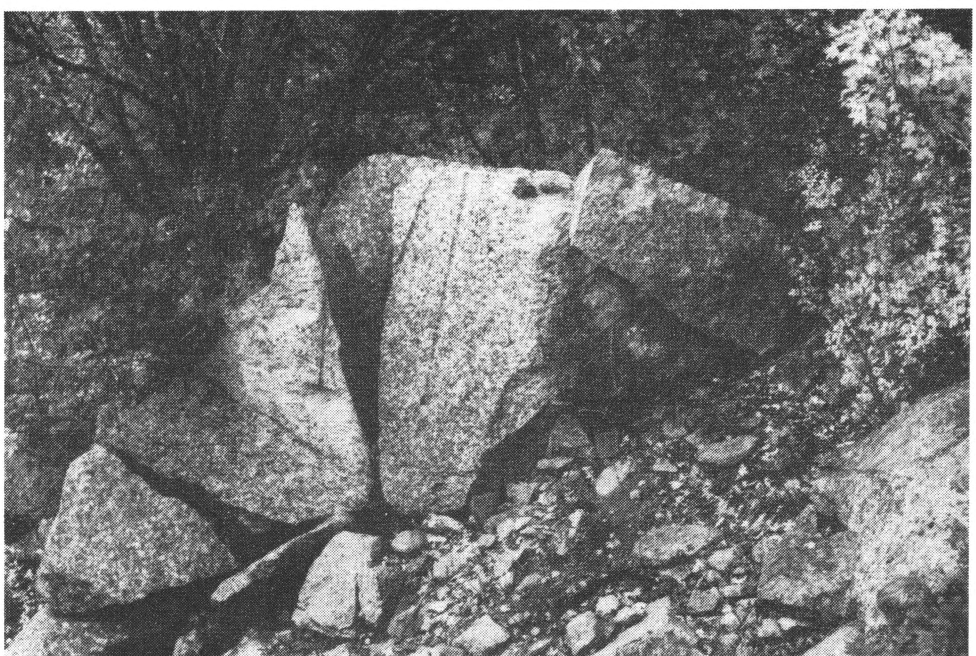


Figure 38. These boulders were discarded from a quarrying operation. People liked the pleasing color and coarse texture of this "granite-like" rock.

rock (Figure 38). This quarry was abandoned soon after it was started. Nearby tufa, which is plentiful and much easier to cut and shape, probably made these igneous rocks uneconomical to quarry.

Lichen. Rock surfaces at this location are covered with lichen (patches of small primitive plants). There is even lichen growing in some of the drill holes! Geologists use plants, such as lichen, to help them date very young land forms such as landslides and rock falls.

Mile 5.5: Stop 3

Glacial deposits. Notice the many different sizes of rocks exposed in the road cut on the north side of the road. Large angular boulders, small rock fragments and finely ground rock "flour" are all mixed together. Glaciers are noted for this kind of poorly sorted deposit. A glacier can move pebbles as easily as it can move large boulders, and it grinds the rocks underneath it into a fine flour. As the ice melts, it drops all the unsorted material it is carrying. By contrast, if this road cut were through a river deposit, the sediments would be nicely sorted by size.

The glacier carried the dark-colored igneous rocks seen here from the Clayton Peak intrusion, located several miles to the northwest.

Valeo intrusion. A few hundred feet up the road is a good view to the east of a hill of the Valeo intrusion (Figure 39). The Valeo is a crystal-rich igneous rock that formed when a body of magma cooled beneath the earth's surface about 35 million years ago. (See Tour 3, Stop 7.)

Freeze-thaw weathering. Note the thick pile of boulders on the lower slope of the hill; it is typical of igneous rock. Igneous rock has many joints and pores that collect water. Each time the water freezes (almost daily in this high country) the ice expands, prying the rock apart. Eventually blocks break off and fall down the slopes. Freezing and thawing of water is the dominant type of weathering in the high country in temperate latitudes.

Mineralization. Look at the ridge to the east. One hundred and twenty years ago it was alive with activity. Silver and gold had been discovered in a vein on its north end! The vein was associated with an igneous intrusion, and since this ridge consists of several intrusions, every part was scrutinized by prospectors. These intrusions are part of an east-west belt of igneous rocks that extends from the Uinta to the Oquirrh Mountains. Scattered mineralization along this belt brought wealth to a few and broken dreams to many. (See Tour 3, Stop 2.)

Scenic Views. This is a good place to get a panoramic view of the valley to the south and the surrounding mountains. The following features described in Section III, *Scenic Views*, can be seen from this point: Heber Valley, Daniel's Canyon, surface above Daniel's Canyon, Deer Creek Reservoir, Provo Peak, Provo Canyon, Mt. Timpanogos, Cascade Mountain, and Mill Canyon Peak. In addition you can see down Pine Creek Canyon to the Park Visitors' Center and across the valley to Round Valley near Wallsburg.

Mile 5.9

Front edge of a glacier. The steep slope you just drove up consists entirely of poorly sorted glacial sediments. The top of this abrupt slope marks the front edge of the glacier that once occupied upper Pine Creek Canyon. As glacial ice advances it acts as a conveyor belt, transporting large amounts of rock debris toward

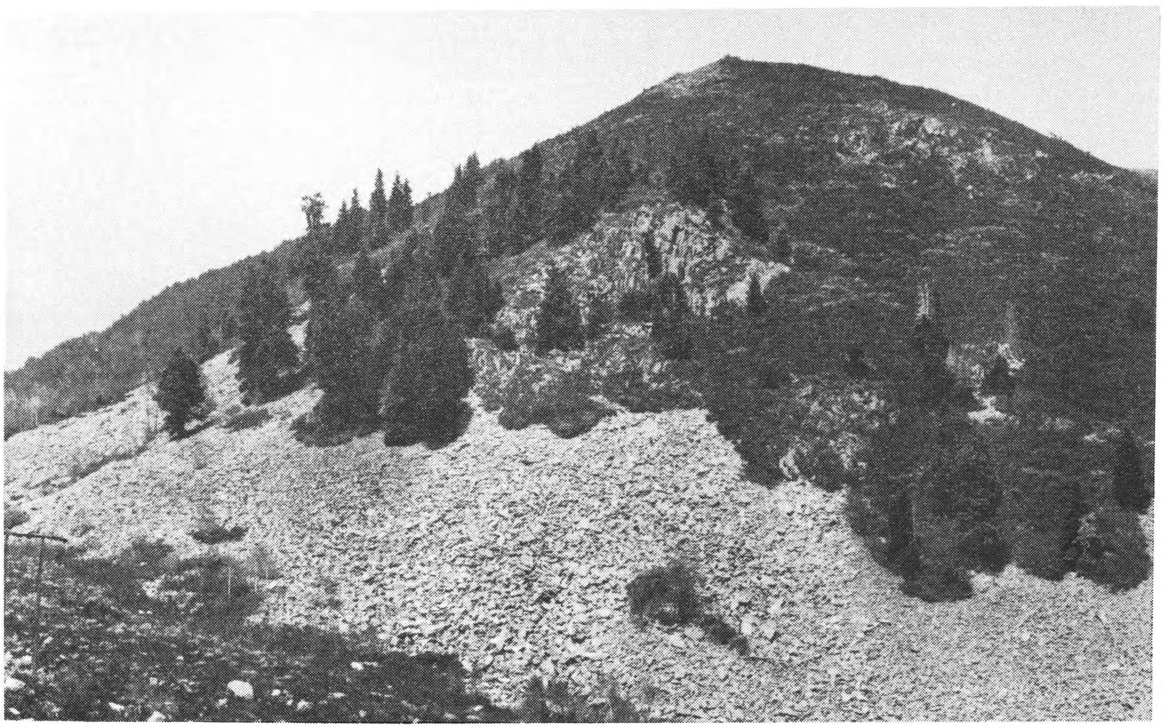


Figure 39. This rocky hill is composed of the Valco intrusion. Freeze-thaw weathering pried loose the thick pile of boulders on the lower slope.

its front edge. At the front margin, the ice melts as fast as it advances, and the rock debris forms an ever growing mound. This mound is called the "terminal (end) moraine" of a glacier (Figure 40).

Mile 6.3: Stop 4

Take a short walk down the side road to the east.

Glacial pond. This type of pond is a common glacial feature. The end moraine of the glacier created a natural dam behind which meltwater from the ice accumulated (Figure 41). This glacial pond has been enhanced to form a reservoir, and is replenished by melting snow each spring. Beavers make their home in the pond and can be seen by quiet observers in the evening and early morning.

Mile 6.7

Exit Wasatch Mountain State Park

Mile 7.0

Glacial accumulation basin. Bonanza Flat, the large basin through which you are driving, is an area where glaciers formed. More snow collected in this basin than could melt in the cool summers

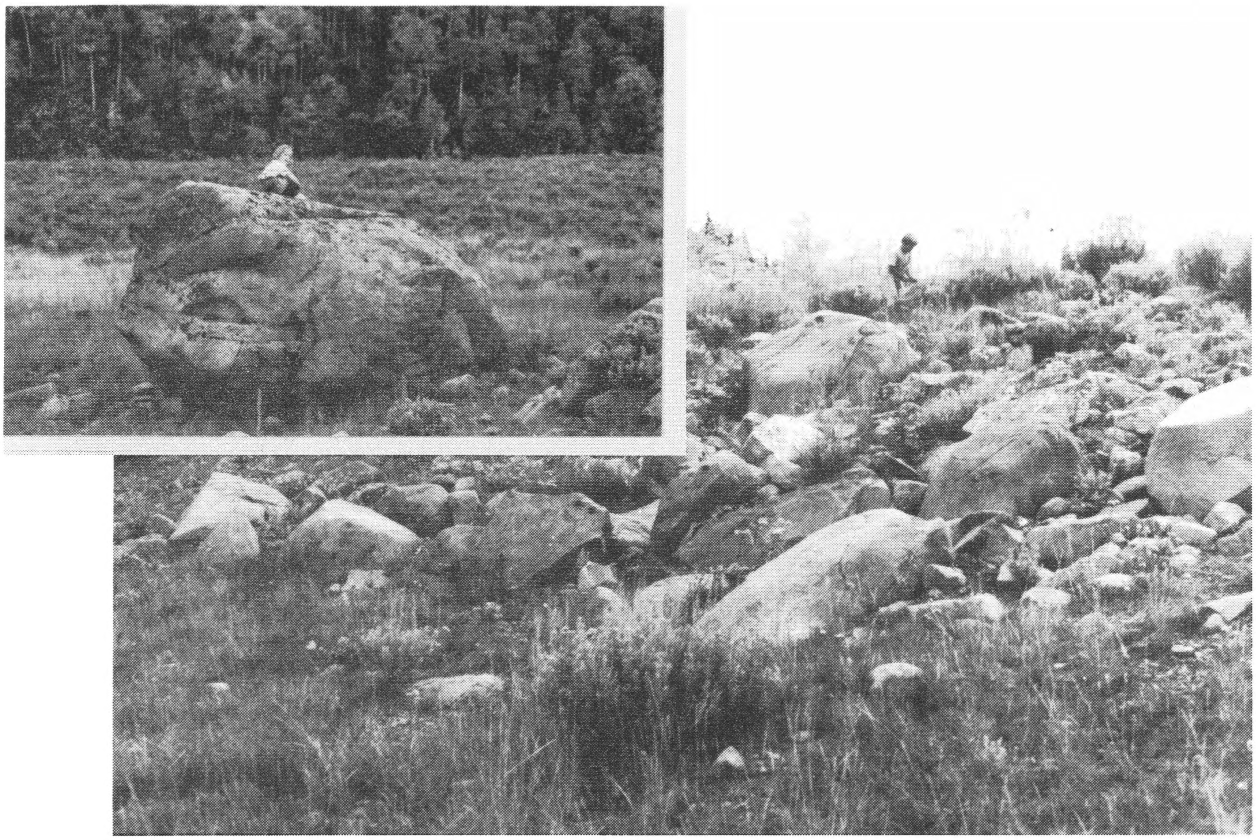


Figure 40. Glaciers can transport huge boulders (left). This moraine of poorly sorted sand- to boulder-sized material was deposited at the melting end of a glacier by the "conveyor-belt" action of the advancing ice (right).

of an ice age. Eventually, deeply buried snow recrystallized into small ice granules. When the ice was 90 to 100 feet thick, it was no longer able to support its own weight, and began to flow down the canyon. Glacial ice filled this basin to a depth of over 400 feet. The glacier shaped the steep sides of the hills north and northeast of Bonanza Flat by "plucking" out pieces of rock and carrying them down the canyon.

Mile 7.9: End Tour 2

Junction with the Guardsman Pass Road, which connects Brighton and Park City. At this point you have several options.

- *Turn right and follow a graded dirt road to Park City.*
- *Turn left and follow a graded dirt road to Brighton and Big Cottonwood Canyon.*
- *Turn right, drive 1 mile, and then continue with Tour 3.*
- *Turn around and return to the Visitors' Center.*

Figure 41. Pond formed by a glacial moraine dam. It was modified by man to make a reservoir.

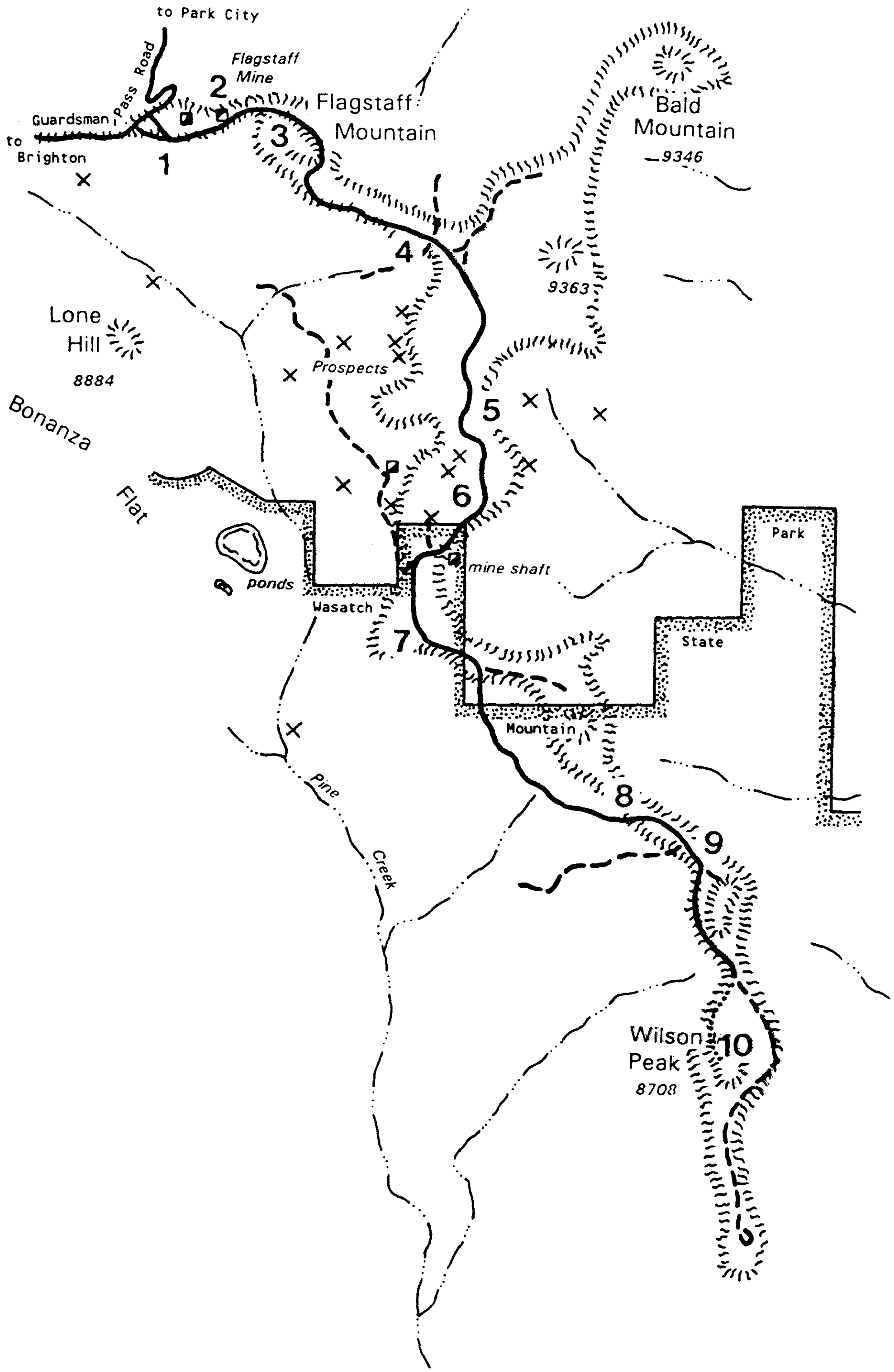
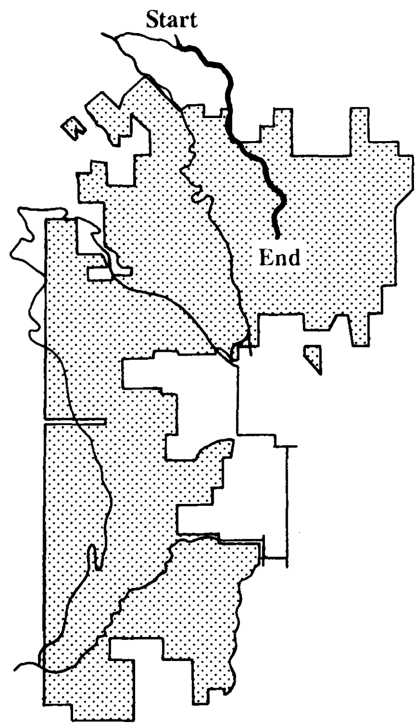


Figure 42. Map showing the route and locations of stops in Tour 3.

TOUR 3

TOUR 3 Hike from Guardsman Pass Road to Wilson Peak	
Length:	4 miles (one way)
Travel Time:	6 hours hiking (round trip)
Road Conditions:	rough dirt road good for hiking and mountain biking
Features:	• mining • igneous rocks • force of intrusions • 700 million year old rocks



Tour 3 explores geologic features along a ridge road in the northeastern part of the Park. The tour is designed as a hike, but most of it is also excellent for mountain biking. The easy to moderate trail follows an unmaintained jeep track for much of its length. The track is occasionally used by vehicles to which hikers and bikers should give right-of-way. Water is not available along the route.

The northern half of Tour 3 lies outside of park boundaries. Please observe no trespassing signs and stay on the suggested route.

The last 1/4 mile of the Tour is an optional hike to the top of Wilson Peak. The hike is short but strenuous, and there is no marked trail so caution must be exercised. Views from the top of the peak are spectacular.

From the Visitors' Center to Tour 3.

To get to the start of Tour 3 from the Visitors' Center, travel north up Pine Creek Canyon for about 8 miles (see Tour 2). At the junction with the Guardsman Pass Road turn east (toward Park City) and travel one mile. Go across the top of the low pass. About 100 feet east of the pass, turn right (southeast) onto a side road. The junction of the side and main roads is the start of mileage for Tour 3. Hikers and bikers should drive a short distance and park off the road. Drivers should note their odometer readings.

The map in Figure 42 is provided to help hikers and bikers locate features and landmarks discussed in the text. At all junctions along the route, stay on the ridge crest and proceed generally south.

Mile 0.0: Start Tour 3

Proceed east on the rough dirt road.

Mile 0.1: Stop 1

Glacial Polish. The rocky knob just south of the road is Weber Quartzite (Pennsylvanian/Permian). It has an unusual sheen to it that was caused by glaciers polishing the rock about 20,000 years ago (Figure 43). At that time glacial ice filled Bonanza Flat and moved down Pine Creek Canyon. As a glacier moves across a rocky outcrop, rock fragments imbedded in the ice gradually grind and polish the rock to a smooth lustre.

Fault movement. About 39 million years ago, this outcrop of Weber Quartzite was buried thousands of feet below the surface. At that time, magma (hot, molten rock) forced its way up and around this rock, jostling and faulting it.

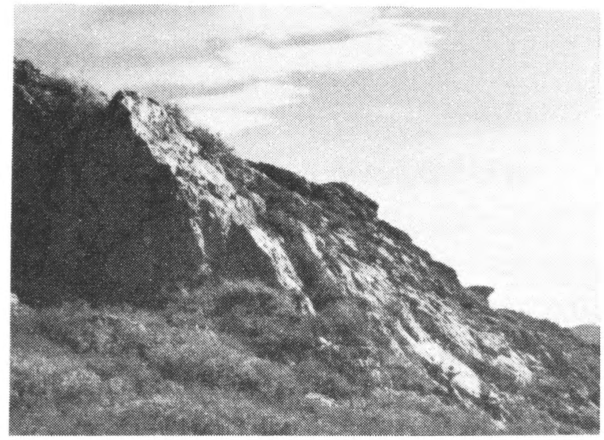


Figure 43. The sun reflects off the glacial-polished surface of this outcrop of Weber Quartzite.

Slickensides (parallel scratches found on some of the flat, smooth rock surfaces) are evidence of the fault movement. Slickensides look a lot like glacial polish. Can you tell the difference? Slickensides extend back into fractures and recesses that the glacier couldn't have reached.

Breccia (broken, angular pieces of rock that have been cemented back together) is also found here, and is another indication of the fault movement.

Mile 0.20

Outcrops of Weber Quartzite that were shattered and broken by intruding magma are exposed directly beneath the power line.

Mile 0.3: Stop 2

Flagstaff Mine. The mine tailings and abandoned shaft seen here are part of the Flagstaff Mine. The first ore shipment from the Park City District was from this mine in July of 1871. The ore was a 10-inch vein of oxidized lead-silver ore. It lay near the surface and was mined out in a few years. Additional ore has not been found at this site (from Boutwell, 1912).

From its discovery in 1868 through 1982, the Park City Mining District produced about 1.45 million ounces of gold, 253 million ounces of silver, 2.7 billion pounds of lead, 1.5 billion pounds of zinc, and 128 million pounds of copper. At today's value the total production would be worth about 38 billion dollars (From Bromfield, 1989). The district is currently inactive, but there is more ore to be mined if the price is right.

Do not attempt to enter any mine shafts. They are extremely hazardous.

Igneous intrusions. When a body of magma cools beneath the ground, the resulting rock is called an igneous intrusion. The word "igneous" is Latin for "fire" and "intrusion" means "forced into."

Mineralization. Mineralization along the edges of an igneous intrusion is common. As a body of magma forces its way towards the surface, it fractures the surrounding rocks. Hot fluids, laden with dissolved minerals, are driven off from the melted rock. As the fluids move through the fractures, they gradually deposit minerals such as silver, gold, calcite, iron, and quartz. The fractures eventually fill, forming veins of concentrated minerals. Whether the veins contain valuable minerals such as gold or silver, or relatively worthless minerals such as quartz or calcite, will make or break a prospector's dreams.

Look around the mine tailings and see if you can see any indications of mineralization at the Flagstaff Mine. The most common mineral seen is quartz, which forms the white veins in the intensely brecciated rocks near the mine. There is also some limonite (a rusty-yellow weathering iron-oxide). (See Tour 1, Stop 8.)

Mile 0.4

On this rise, there are a few low, knobby outcrops of the Flagstaff Mountain intrusion.

Mile 0.5: Stop 3

The road swings north of Flagstaff Mountain. Walk to the top of the peak (about 30 feet).

Flagstaff Mountain intrusion. These "granite-like" rocks are named the Flagstaff Mountain intrusion (Eocene). They formed about 39 million years ago when a body of magma, buried about 1.7 miles below the earth's surface, cooled. The rock is classified as granodiorite, which is similar to granite, but contains less quartz (Figure 44).

Pick up a fresh piece of the Flagstaff Mountain intrusion and try to describe what you see. What characteristics would help someone else recognize it?

When geologists describe an igneous rock, they describe its visible crystals and the "matrix" (the background in which the crystals are embedded). Note the large, white, rectangular crystals. They are plagioclase. Also note the dark-green to black, fine-grained matrix.

View from the top of Flagstaff Mountain. From the top of Flagstaff Mountain you can see north into the Park City area, south to Deer Creek Reservoir and west towards the peaks along the Wasatch front. The peak with all the antennas directly east of Flagstaff Mountain is Bald Mountain.

Mile 0.8

The outcrop on the knoll just south of Flagstaff Mountain is Weber Quartzite. It was brecciated and baked by the magma around it.

Figure 44. The Flagstaff Mountain intrusion is characterized by large rectangular plagioclase crystals (white spots) embedded in a dark-green to black, fine-grained matrix.

Mile 0.9: Stop 4

Low, broad saddle in the ridge.

Rate of Cooling. The few rocks exposed in this saddle are Flagstaff Mountain intrusion. Look at a fresh piece of the rock. Do you notice any difference between it and the rock you saw at Stop 3? In this rock, the plagioclase crystals are distinctly smaller and the matrix finer. This variation in texture probably indicates a difference in the rate the magma cooled. In general, the quicker magma cools the finer grained the rock will be. These fine-grained rocks may have cooled near the margin of the intrusion where surrounding rocks quickly chilled the magma.

Mile 1.0

Intersection with roads coming out of draws to the north and the south. Continue southeast along the main road.

Mile 1.1

Junction. Take the road that swings to the right and up a steep little bluff. The road to the north goes to Bald Mountain.

Mile 1.3

The road passes by more outcrops of Flagstaff Mountain intrusion.

Mile 1.6: Stop 5

Gardison Limestone. The outcrop on the east side of the road is Gardison Limestone (Mississippian). These rocks formed from the accumulation of calcium rich sediments on the ocean floor. They contain broken pieces of fossils. such as bryozoans (the lacy fossil), crinoids (small circular disks), and brachiopods (shells). Abundant fossil fragments indicate that the rock was deposited in a high-energy environment where wave action broke and concentrated the original animal remains.

Magma origin and ascension. This outcrop of Gardison Limestone forms an "island" of sedimentary rocks that was caught in the Flagstaff Mountain magma as it rose towards the earth's surface.

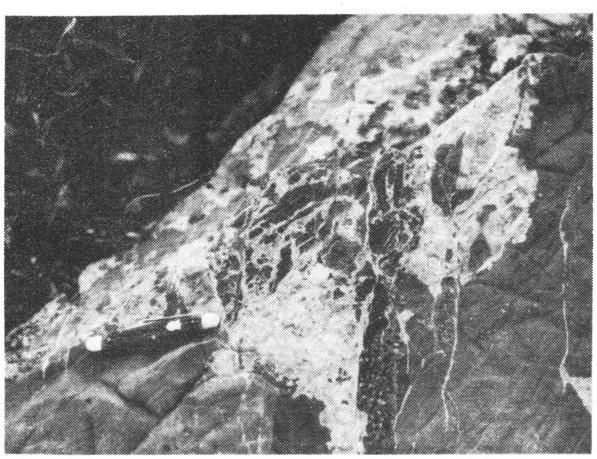


Figure 45. Limestone, west of Stop 5, was brecciated and heated by intruding magma. Quartz (milky, white veins) replaced some of the shattered limestone. The limestone was metamorphosed to marble.

Magma originates deep within the earth's crust, then rises because it is less dense than overlying solid rock. Forces exerted by rising magma are incredible. Rocks closest to the intruding magma are fractured and faulted. Some blocks are shoved aside; other blocks, such as this outcrop of Gardison Limestone, are isolated within the magma; and some blocks actually melt and mix with the magma (Figures 45 and 46). Nearby rocks may be baked by the intense heat, and changed to metamorphic rocks.

The energy required to melt solid rock into molten magma is associated with collision of the earth's crustal plates. Ultimately, that energy comes from nuclear energy as radioactive elements, such as uranium, decay in the earth's interior.

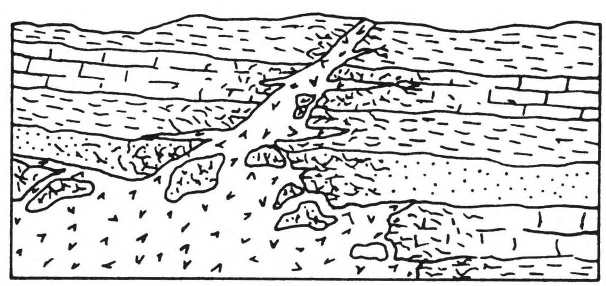


Figure 46. Diagram of the relationship between an igneous intrusion and overlying sedimentary rock.

Mile 1.9 to 2.0: Stop 6

Notice the many prospect pits (Figure 47). This was an area of much activity in the late 1800's as prospectors searched for new mines. The prospectors were not particularly sophisticated in their techniques. At the first sign of mineralization they would stake their claim. This first sign was likely limonite, an iron oxide similar to rust that stains the rocks yellowish-brown.

Tailings tell the story of a mine. An experienced geologist can tell what kind of rock

Figure 47. Tailings around an old prospect pit.

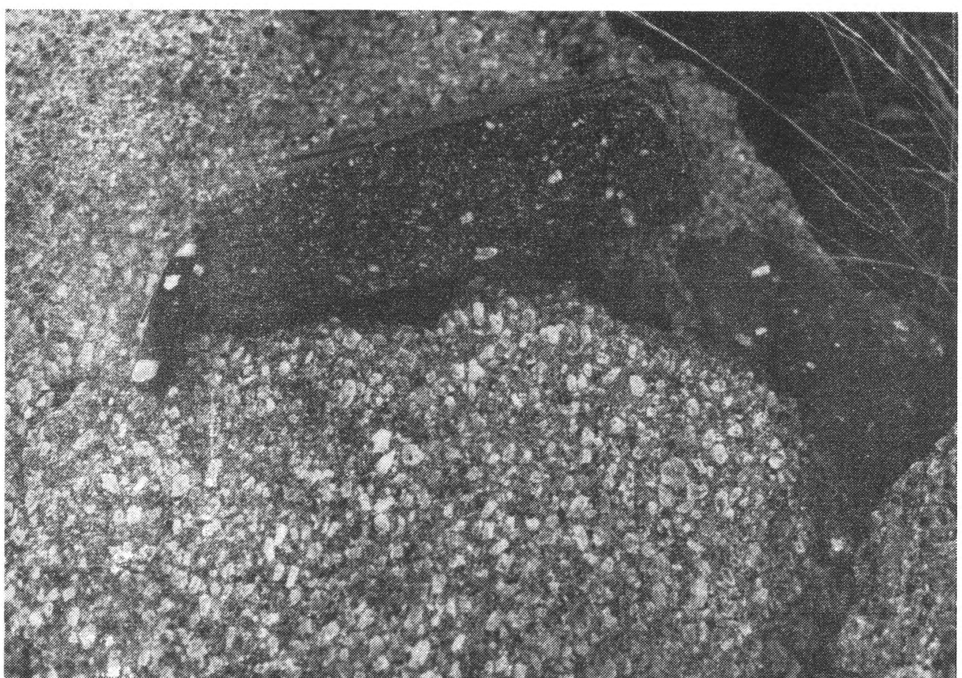


Figure 48. The Valeo intrusion (the lighter rock) is unusually crystal-rich. The dark rocks are pieces of a fine-grained igneous dike that cuts through the Valeo.

was encountered, how much was mined, and even if mineralization was found. The mine in Figure 47 encountered much altered limestone with strong limonite staining, but little economic mineralization.

Mile 2.0

Boundary of Wasatch Mountain State Park. Most of the mines within the Park boundaries were barren or produced only a small amount of precious ore.

Mile 2.1

The road crosses rubble and an occasional outcrop of the Great Blue Limestone (Mississippian). Some fossils are in the Great Blue, though most of them are broken. Knobby outcrops of Tintic Quartzite are visible to the east through the quaking aspens near the top of Dutch Hollow.

Trail to Dutch Hollow.

The open basin to the east contains a trail that leads to Dutch Hollow. The upper part of the trail is indistinct, but the trail can be found in the stream drainage farther down. An unusually well-exposed chilled margin of an intrusion is visible about 0.5 mile down the trail. It contains breccia of both the Flagstaff Mountain and Valeo intrusions.

Mile 2.2

Low saddle on ridge.

Junction. Take the road that angles to the left through the trees and up onto the ridge.
The road straight ahead angles down off the ridge and eventually back to Bonanza Flat.
(A less traveled road to the right, which splits off a short distance before the junction) leads north to mine tailings visible through the trees.

Mile 2.4: Stop 7

At the top of the low hill the road bends toward the east; at this point, walk onto a little rise to the west.

Valeo intrusion. There are excellent exposures of the Valeo intrusion in a small prospect pit near the top of the hill. The Valeo is one of four intrusions found in Wasatch Mountain State Park. These intrusions cooled at depths from 1/2 to 7 miles between 34 and 39 million years ago.

The Valeo is an unusually crystal-rich igneous rock with several distinctive characteristics (Figure 48). Look at a freshly broken piece. Note the abundant crystals--the magma from which the Valeo solidified must have been a crystal mush. See if you can identify the following:

- many unusually large plagioclase crystals (white, rectangular shape)
- small, round, glassy quartz "eyes"
- hornblende crystals (black, needle-like)
- biotite crystals (shiny, black mica, octagonal shape)

The Valeo intrusion forms most of the ridge to the south. Weathered surfaces of the rock look "vuggy" (holey) because the plagioclase crystals readily weather out.

Igneous dikes. A few igneous dikes cross the ridge to the south. A dike is a narrow band of igneous rock that "intruded" pre-existing rocks. These dikes cut the Valeo intrusion after it solidified. It is difficult to find the dikes, but as you walk along, you may notice pieces of them in the surface rubble. They are dark gray, brittle rocks with fewer crystals than the Valeo.

Mile 2.5
From the top of this ridge, look into Pine Creek Canyon to the west. Glacial ice that accumulated in Bonanza Flat (rounded valley to the northwest), once flowed part way down this canyon. The glacier shaped Bonanza Flat, deposited a moraine (pile of unsorted glacial debris) in the canyon, and formed a glacial pond. (See Tour 2, Stops 3 and 4).

Mile 2.7
Junction. Continue on the road that leads to the south. After this point, the road has some steep, rough sections and is not easily traveled in wet conditions. The road to the east leads to the base of the rounded hill. This hill is the tallest peak in the Park. Hikers may choose to climb over it rather than follow the road, but the other side is steep. Good outcrops of the Tintic Quartzite (Figure 49) are exposed on the north and west slopes, and good outcrops of the Mineral Fork Formation are exposed on the southeast slope.

Tintic Quartzite. The white rocks exposed along the hill near Mile 2.7 are Tintic Quartzite (Cambrian). About 540 million years ago this formation was deposited as beach and coastal plain sand and gravel. If you look closely, you will see that the rock is so strongly cemented, it breaks through, rather than around, pebbles.

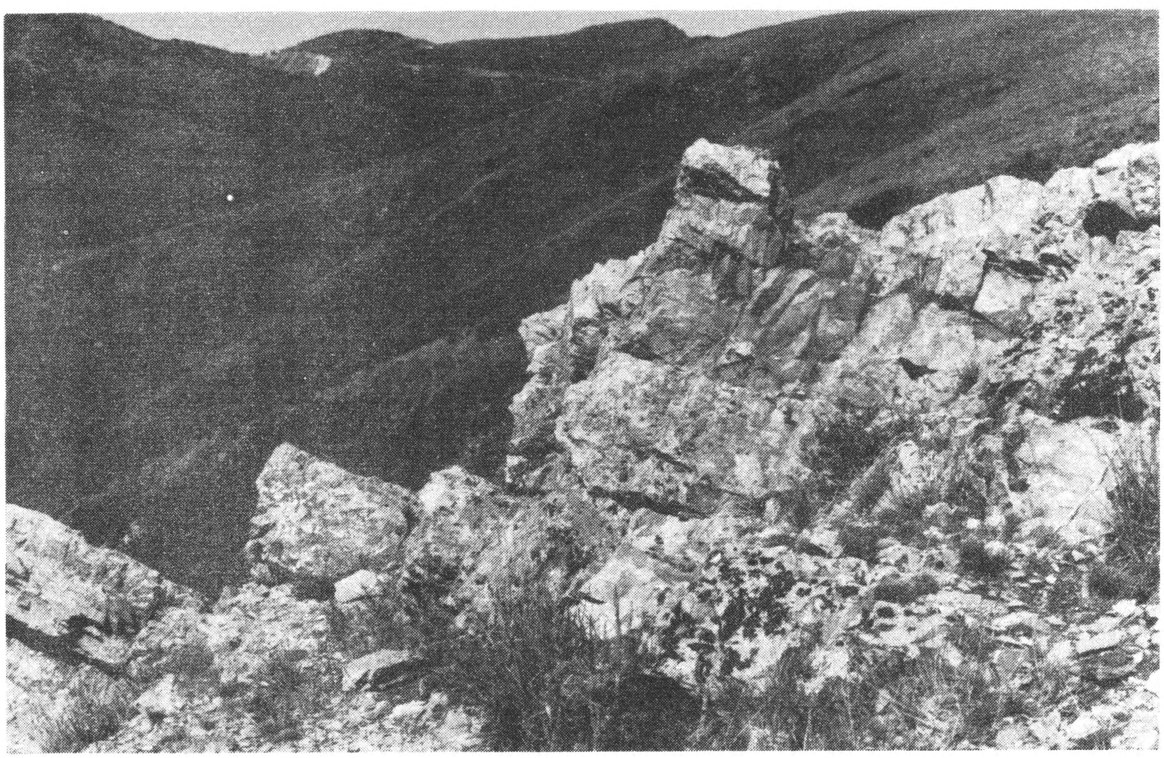


Figure 49. The Tintic Quartzite (Cambrian) forms a resistant ledge of sedimentary quartzite. Guardsman Pass is in the background.

Mile 3.0

Notice the distinct change in road color from white or tan to dark, greenish gray. This color change indicates that you have crossed the boundary from the Tintic Quartzite to the Mineral Fork Formation. The boundary marks a gap in time of over 100 million years.

Mile 3.1

The road crosses a dike of the Pine Creek intrusion that cuts into the Mineral Fork Formation.

Mile 3.3 Stop 8

Ancient Glacial Deposits. Excellent exposures of the Mineral Fork Formation are found on the hillside to the north (Figure 50). The Mineral Fork Formation is a conglomeratic rock with a clay-based, dark-greenish-gray matrix. It is interesting because:

- it is one of the oldest formations in the Park;
- it was deposited by a glacier during one of the first known glacial epochs to sweep North America (about 700 million years ago); and,
- it contains "clasts" (rounded pieces of rock) from several much older formations.

Figure 50. Glacial deposits of the Mineral Fork Formation. Most geologists think that this formation was deposited in a shallow ocean by an advancing glacier. This boulder is about 14 inches in diameter.

Take some time to walk around and explore this interesting formation. Note that the rock consists of unsorted pebbles, cobbles, and boulders embedded in a muddy-looking matrix--it is a solidified version of glacial deposits in Pine Creek Canyon. (See Tour 2, Stop 3).

As you walk around, see how many different kinds of clasts you can find. The most abundant are white and pink quartzite. Less numerous, and harder to find, are clasts of gneiss (banded metamorphic rock) and granite.

The large, loose boulders of lighter-colored quartzite conglomerate seem out of place (Figure 51). They eroded out of overlying rocks and tumbled down the slope onto the Mineral Fork Formation. Well-rounded cobbles in this

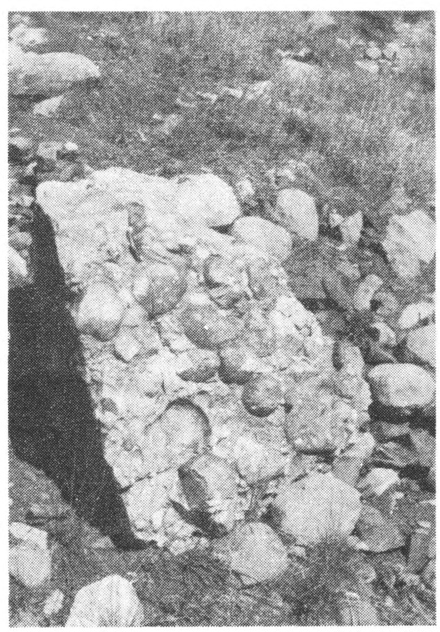


Figure 51. This boulder eroded from the hillside above, and tumbled down the slope to its present position. The cobbles in this conglomerate indicate that it was deposited by a river or stream.

conglomerate indicate that it was deposited by a stream or river.

Mile 3.4: Stop 9

Junction with a road that leads to the bottom of Pine Creek Canyon.

Pine Creek intrusion. The rocks in this saddle are Pine Creek intrusion, the largest of the three intrusions seen along this route. Like the other intrusions in the Park, the Pine Creek is a granodiorite and is "porphyritic" (has large crystals in a fine-grained matrix) (Figure 52).

Look at a piece of the rock and mentally compare it with the other intrusions seen earlier. The Pine Creek intrusion's most distinctive characteristic is large (1/4 inch) "books" of shiny, black biotite crystals. Note that the Pine Creek has fewer crystals than the Valeo intrusion, and also does not have any visible quartz. It is lighter in color and more crystal-rich than the Flagstaff Mountain intrusion.

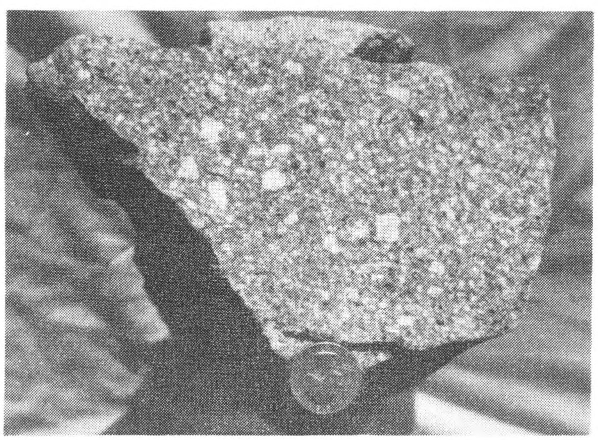


Figure 52. The Pine Creek intrusion has visible crystals of plagioclase, hornblende, and biotite. The biotite crystals are unusually large.

Igneous dike. An igneous dike about 10 feet wide trends northwest through this saddle. It forms a band of fine-grained, dark-olive-green rubble. Erosion and vegetation make it difficult to see. (See Stop 7.)

Mile 3.8

This is the end of the trail guide along the road. At this point you have these options:

- *Climb Wilson Peak, the mountain directly south of you, and enjoy the view.*
- *Turn around and return to the start.*

Note: The climb to Wilson Peak is steep and there is no marked trail. As you climb, stay to the west side and avoid the aspen trees. Bikes should be left at the base of the hill to preserve natural vegetation.

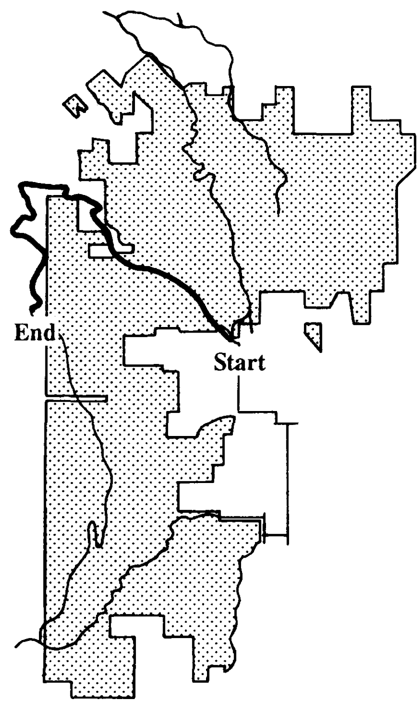
Mile 4.0

Top of Wilson Peak. Wilson Peak is composed of Pine Creek intrusion. The top of Wilson Peak is one of the best vantage points in the Park with excellent views to the east, west and south. Scenic features visible from this point are discussed in Section III, *Scenic Views*.

End Tour 3

TOUR 4

TOUR 4 Visitors' Center to Cummins Parkway via Snake Creek Canyon	
Length:	9 miles
Driving Time:	1 hour
Road Conditions:	paved and graded dirt road for 5.5 miles; rough dirt road appropriate for high-clearance vehicles for remainder
Features:	• view of Pioneer and Sunset Peak • Paleozoic marine rocks • glacial boulders



Tour 4 explores the geology of Snake Creek Canyon. The first 5.5 miles of the route follows a paved and graded dirt road. After that, the road steepens and becomes rough, and is accessible only with a high-clearance vehicle. There is a good place to turn around before the road gets bad. Tour 4 meets Tour 1 at the junction with the Cummins Parkway, making a loop trip possible.

Mile 0.0: Start Tour 4

Visitors' Center. Turn right out of the parking lot towards Snake Creek Canyon.

Mile 1.1

Utah Power and Light power plant.

Mile 2.3

Approximate boundary of Park.

Mile 2.8

Heber Power and Light power plant. Take the left fork off of the pavement.

Mile 3.1

The large pile of rock was dug from a drainage tunnel leading to a mine located 2 1/2 miles to the northwest, beneath Clayton Peak.

Mile 3.2

Humbug Formation. The Humbug Formation (Mississippian) is exposed just after the sharp, hairpin bend in the road (Figure 53). The Humbug is gray limestone that was deposited in a shallow marine environment. Some of the best ore zones in the Park City Mining District are in the Humbug Formation, where limestone has been replaced by precious metals (See Tour 1, Stop 8 and Tour 3, Stop 2.)

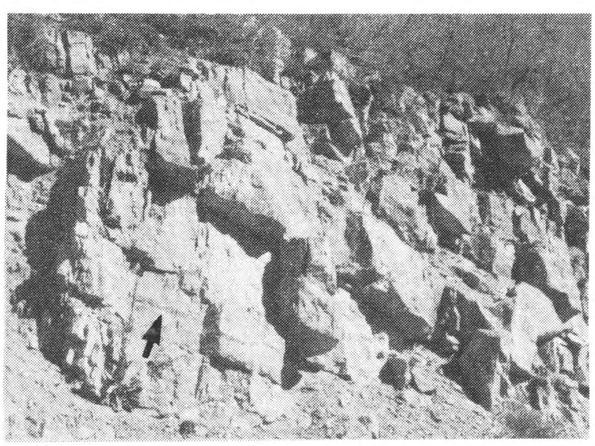


Figure 53. A black chert marker bed (arrow) in the Humbug Formation shows offset along a minor fault.

Mile 3.3: Stop 1

Pull off at the sharp bend where the road widens. From here there is a good view to the west of two prominent peaks: Sunset and Pioneer.

The prominent gray cliff that juts out of the hillside to the northwest is the Round Valley Limestone (Pennsylvanian) (Figure 5). Rocks exposed in the upper part of the road cut are the Doughnut Formation (Mississippian). You can walk back along the road to see the Humbug Formation exposed at Mile 3.2. (The contact between the Humbug and Doughnut Formations is gradational and difficult to pick out.) Together these three formations, Humbug, Doughnut and Round Valley, represent about 35 million years of deposition in a shallow warm sea that once covered this area. (See Section I, Paleozoic.)

Mile 3.5: Stop 2

The outcrops of the Doughnut Formation along the road contain a fossil hash of broken crinoid stems (tiny disk-shaped fossils), brachiopods (fossil sea shells), and a few pieces of coral.

Mile 3.6

Outcrop of the Doughnut Formation.

Mile 4.0: Stop 3

Glaciers are known for their ability to carry huge rocks long distances. Nestled among the quaking aspens on the north side of the road are some large glacier-transported boulders of the Clayton Peak intrusion, which is exposed two miles up the canyon (Figure 54). (See Tour 2, Stops 3 and 4.)

Mile 4.4
At the switchback, the road cuts through very poorly sorted glacial deposits. The dark igneous rocks are Clayton Peak intrusion.

Mile 4.5
The cliff just north of the sharp switch back is Round Valley Limestone.

Mile 4.6
Boulders of brecciated (broken up and recemented) limestone are found along the road. They are from the Round Valley Limestone (Figure 5).

Mile 5.0
Forest Service boundary.

Mile 5.3
Junction with two small 4-wheel-drive trails. Vehicles that do not intend to continue along the rougher road should turn around in the flat just past the junction.

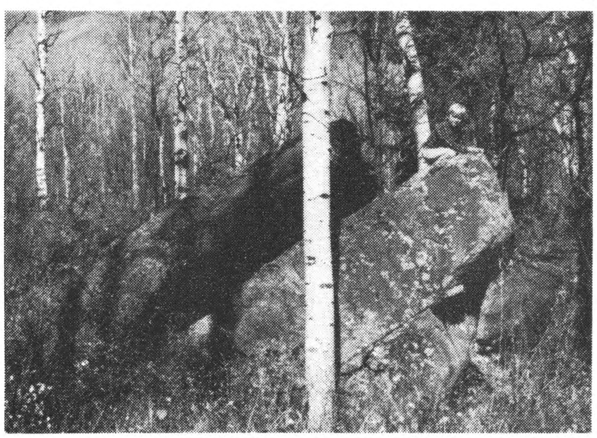


Figure 54. This large boulder of Clayton Peak intrusion was carried over two miles by a glacier. The boulder is about 10 feet tall and 12 feet across.

The best view of Pioneer and Sunset Peak is just past this junction. A small mine dump is located about 100 yards above the road on the north side.

Mile 5.5
The road begins to climb out of the bottom of the drainage. The road is very rough because it is built on top of a landslide that continues to move intermittently.

Mile 7.4
The headwall (break-away zone) of a landslide is visible just below the road on the east.

Mile 7.8
The road passes some outcrops of Weber Quartzite (Pennsylvanian/ Permian). The Weber Quartzite consists of grains of quartz sand that have been welded together by a strong quartz cement. In most places the cement is as strong as the original quartz grains and the rock breaks through the grains. (See Tour 1, Mile 17.6.)

Mile 9.1: End Tour 4
Junction. At this point you have the following options:
- *Continue west toward American Fork Canyon.*
- *Turn south and travel along the Cummins Parkway, which is described in Tour 1.*
- *Turn around and return to the Visitors' Center.*

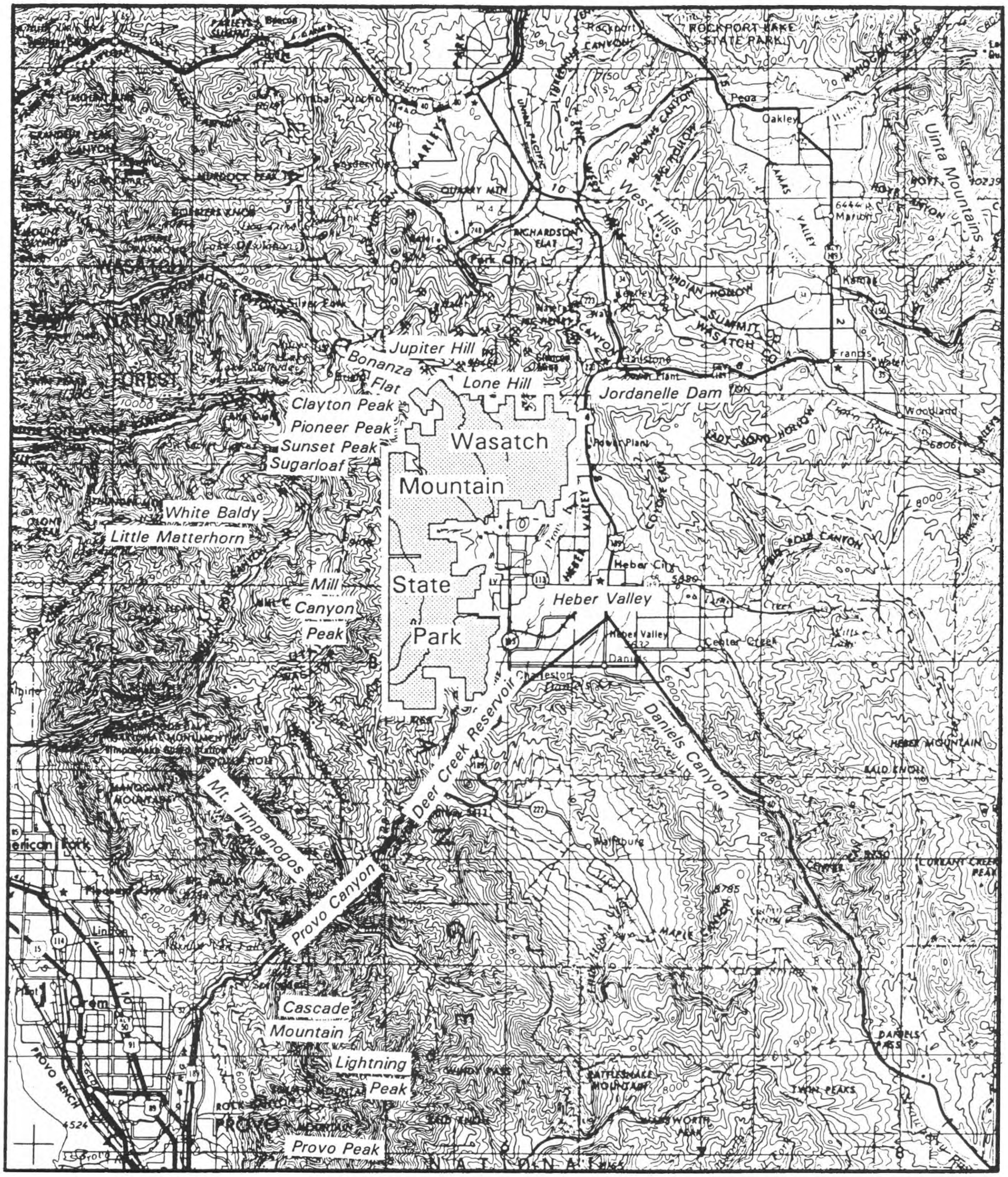


Figure 55. Map showing the location of prominent features visible from high ridges in Wasatch Mountain State Park.

III. SCENIC VIEWS

Wasatch Mountain State Park is, by its setting, a park of splendid vistas. Several roads cross or follow high open ridges with excellent views. Since the same features can be seen from so many locations, they are described here together. Most of these features are only mentioned by name in the road logs at points where they are prominently visible. The list works in a circular pattern around the Park, starting with Heber Valley (Figure 55).

Heber Valley is a high mountain valley filled with thick sediments, mostly deposited by the Provo River. It is one of several deep, fault-formed valleys that sit on the upthrown block east of the Wasatch fault.

Daniels Canyon is located on the south side of Heber Valley. This unusually straight canyon roughly parallels the front edge of the Charleston-Nebo thrust fault (See Tour 1, Stop 4). It is a geologically young canyon, as evidenced by its steep walls and narrow V-shape. It is eroding headward, capturing streams that once flowed into the Strawberry River. It is able to capture these drainages because it is at a lower elevation than the Strawberry River tributaries.

Surface above Daniels Canyon. The hills east and south of Heber Valley form a flat to gently rolling plateau cut by deep, narrow canyons. This plateau is the remnant of an older topographic surface that once extended over the region. At that time drainages throughout the area probably flowed into the Colorado River via the Strawberry and Green Rivers, rather than into the Great Salt Lake, as they do now. Continued uplift on the Wasatch Fault is providing energy to the Provo River and other Wasatch Front drainages to erode headward, enabling them to gradually capture more and more of the older drainage system.

Provo Canyon (Figure 56) is one of several deep narrow canyons that cut across the uplifted Wasatch Range. The very steep canyon walls and high relief (about 5000 feet from canyon floor to tops of adjacent peaks) attest to the river's ability to cut down as fast as the range is elevated.

Deer Creek Reservoir (Figure 56) is located in Provo Canyon south of the Park. The Deer Creek dam was built in 1941, making it one of the oldest large dams in the state. The reservoir is about 6 miles long and is at an elevation of 5417 feet when full.

Provo Peak, Cascade Mountain, Lightning Peak, and nearby peaks (Figure 56) are all composed of Paleozoic rocks pushed 20 to 40 miles from the west along the Charleston-Nebo thrust fault (See Tour 1, Stops 4 and 6). It is interesting to note that the highest peaks in the

Figure 56. View to the southwest of Heber Valley, Deer Creek Reservoir, Provo Peak, Cascade Mountain, and Lightning Peak.

Wasatch Range are adjacent to the Wasatch fault. This is because the Range is a tilted block, and the greatest uplift is closest to the fault.

Mt. Timpanogos (Figure 57) is the most impressive peak visible from the Park. It is sometimes considered the jewel of the Wasatch Range. It consists of a huge thickness of marine rocks that were deposited in a deep basin centered in the Oquirrh Mountain area (20 miles west of the Park). Eighty million years ago, these rocks were thrust into their present position by the Charleston-Nebo fault. They were uplifted to their present elevation within the last 15 million years. According to legend, the skyline of Mt. Timpanogos forms the profile of a sleeping Indian maiden.

Mill Canyon Peak (Figure 58) is an impressive mountain just west of the Park boundary. Glaciers carved its rugged peak. The Weber Quartzite, of which it is composed, is the same age as the rocks that form Mt. Timpanogos. However, the Weber lies beneath, rather than above, the Charleston-Nebo thrust fault.

White Baldy, Little Matterhorn, Sugarloaf Mountain, and Lone Peak are part of an impressive row of peaks that forms the divide between Utah and Salt Lake Counties and the south boundary of Alta and Snowbird ski resorts. These peaks are visible from high ridges in the

Figure 57. Mt. Timpanogos. The upper part of the mountain was shaped primarily by glaciers.

Park. They are part of a mineral belt that crosses the north end of the Park.

Pioneer Peak and Sunset Peak (Figure 59) form a majestic pair framed by Snake Creek Canyon. They can be seen from many places in the Park, including the Visitors' Center. Pioneer Peak, the one on the north, is the whitest peak, and is composed of Mississippian-age limestone and dolomite. Sunset Peak has a broad brownish band of Cambrian rocks that has been thrust over younger Mississippian rocks.

Clayton Peak (Figure 60) is the brownish peak located directly west of Bonanza Flat near the northwest corner of the Park. Glaciers shaped the roughly triangular peak. It is composed of granodiorite, an igneous rock, and is the source of glacier-deposited boulders in Pine Creek and Snake Creek Canyons.

Jupiter Hill is the most prominent point on the ridge line north of Bonanza Flat and the Guardsman Pass Road. It is mostly shale and siltstone of the Triassic Ankareh Formation.

Bonanza Flat is the long, broad, gentle basin at the head of Pine Creek Canyon. Several glacial lakes are located in the upper part of the basin. The lower part of the basin consists of thick, bouldery sediment dropped by melting glaciers.

Figure 58. Mill Canyon Peak; immature glacial cirques are visible near the top. Mt. Timpanogos towers in the background.

Lone Hill sits alone in the middle of Bonanza Flat. It is a resistant knob of Weber Quartzite that deflected glaciers around its flanks.

Glacial Features. All of the higher peaks in the Wasatch Range have been cut and shaped by glaciers. Many glacial features are visible from the Park. Look for the following:

- horns: steep pointed peaks cut by glaciers.
- aretes: sharp, sawtooth ridges between glacier-cut valleys.
- cirques: bowls at the head of U-shaped glacial valleys.
- roche mountonnee: polished, rounded resistant knobs in glacial valleys.
- till: poorly sorted rock debris dropped by melting glaciers.
- moraines: ridges of till deposited at the edges and front of the glacier.

Park City Mining District. From the top of Flagstaff Mountain, the surface workings of several major mines in the Park City Mining District are visible to the north. Not visible, however, is the extensive labyrinth of underground shafts and tunnels (Figure 18).

Streams in the Park City and Parleys Park area. As you look northward over this area try to follow the path of streams and rivers that begin

Figure 59. Looking up Snake Creek Canyon toward Pioneer and Sunset Peaks.

near Park City. It's not easy! This is an area of immature drainages. Stream systems are not yet deeply incised in canyons, and they easily cut off and "capture" other streams.

Hundreds of years ago all the streams around Parleys Park and Park City probably flowed northwest into East Canyon, instead of northeast through Silver Creek Canyon. Over time, Silver Creek captured many of the East Canyon tributaries, and it will capture more. Silver Creek may not be the ultimate victor, however. A tributary of the Provo River will eventually capture the upper part of Silver Creek and its tributaries. The final victory will go to the river with the ability to incise to the lowest elevation.

Provo River Drainage. Looking east from high ridges in the northeast part of the Park, it is easy to see the path of the upper Provo River. The upper Provo River once flowed northward through Kamas Valley and into the Weber River. Headward erosion of the lower Provo River cut through the ridge east of Jordanelle and captured the upper river. Over thousands of years Provo River tributaries will eventually capture most drainages in this part of the high country.

Faulted mountain valleys. Deep mountain valleys are a prominent part of the landscape in views north, east, and south from high ridges in the Park. Most of these valleys were formed by

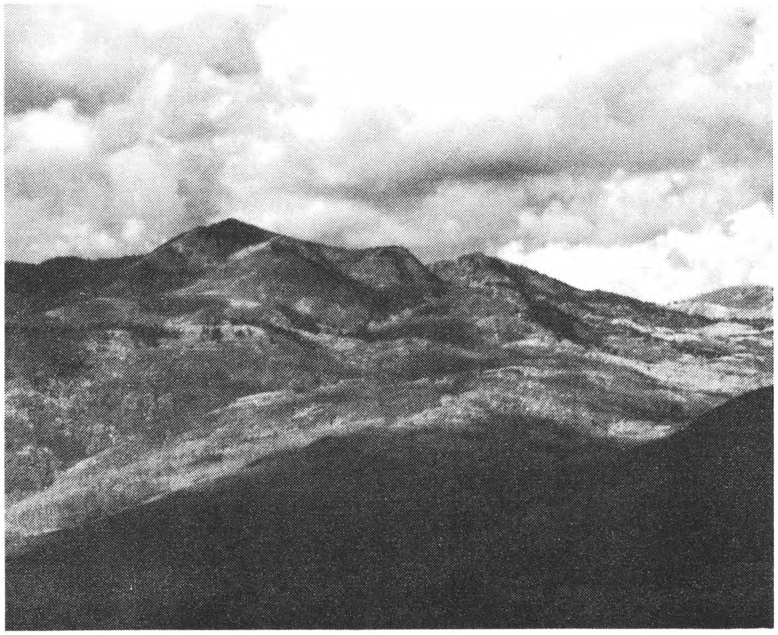


Figure 60. Clayton Peak looms over the northern part of the Park, Bonanza Flat, and Jupiter Hill.

movement on normal faults similar to the Wasatch fault, except smaller. Some geologists postulate that these small faults are evidence that the Wasatch fault is beginning to "step" eastward.

Uinta Mountains. The highest mountains in Utah can be seen in the distance, about 15 miles east of the Park. The Uinta Mountains were pushed up during a mountain-building episode about 50 million years ago, making them the oldest major range in the state. The Uintas were extensively eroded by glaciers during the recent ice ages.

The Uinta Mountains are unusual because they are oriented east-west, rather than north-south, like most other ranges in the western U.S. The faults that moved to form the Uintas followed a natural weakness, an ancient rift (break) in the continent that formed about a billion years ago.

West Hills, Kamas area, upper Provo river area. East, northeast and southeast from the Park is an area of lower rolling hills, locally accented with narrow canyons and washes. This region is blanketed with 30- to 40-million-year-old volcanic rocks.

Jordanelle Dam (JD) is visible from the eastern part of the Park. The dam is anchored against volcanic rock. When filled, it will form a 5-mile-long lake.

IV. APPENDIX

The recognition of rock types and formations helps geologists determine the geologic history of an area, the potential for geologic hazards, and the location of economic resources. This appendix will help you locate and identify the rocks, minerals, and formations found in Wasatch Mountain State Park. (Also see *Getting Started, A Few Geologic Concepts*.)

Identifying Rocks and Minerals

Minerals

Minerals are the basic building blocks of rocks. They have distinct crystalline shapes and chemical compositions. You can identify minerals by looking at their shape, color, and hardness.

Biotite is a shiny, black mineral that forms small, hexagonal crystals in intrusive igneous rocks. It is soft, and can be flaked with a knife. *(It is a hydrous potassium aluminum silicate that contains some magnesium and iron.)*

Hornblende is a black mineral that forms short, needle-like crystals in intrusive igneous rocks. *(It is a complex silicate that contains aluminum, iron, magnesium, and calcium.)*

Plagioclase forms large, white to pale-gray rectangular crystals in intrusive rocks. *(It is a sodium calcium aluminum silicate.)*

Quartz forms small, hard, glassy beads in some of the intrusive igneous rocks in the Park. Quartz is also the primary constituent of sandstone. *(It is made of silica bonded with oxygen).*

Calcite, a white to gray, sugary mineral, is the basic constituent of limestone. It is easily scratched with a knife. Crystals, when visible, have characteristic 60° and 120° angles. *(It is calcium carbonate.)*

Dolomite is a white to gray or brownish-gray mineral similar to calcite. In fact, it can only be discerned from calcite by the use of an acid test. The Table of Geologic Formations in the next section of the Appendix indicates which formations contain dolomite. *(It is magnesium, calcium carbonate.)*

Clay is actually a group of many related complex minerals. Clay minerals are soft, smooth, platy, and have an "earthy" smell when moistened. Individual crystals are so small they can only be seen under powerful microscopes. *(Clay minerals are hydrated calcium, sodium, or potassium aluminum silicates, with many different minor constituents.)*

Rocks

Rocks are aggregates of one or more minerals. In some rocks the minerals form large crystals. In others the minerals are so small that individual crystals can only be seen with the aid of a microscope. Minerals in sedimentary rocks are typically rounded fragments of the original crystals.

Igneous rocks.

Igneous rocks form when hot, molten rock, or magma, cools and hardens. If the magma cools above the ground, the rocks are called "volcanic." If the magma cools deep beneath the ground, the rocks are called "intrusive." Many intrusive igneous rocks cool slowly enough that the minerals grow into visible crystals. There is only one kind of igneous rock in the Park.

Granodiorite is an intrusive igneous rock that is similar to granite, except that it contains slightly less quartz and slightly more iron and magnesium. There are four different granodiorite intrusions in the Park. They are uniquely identified by variations in the size and relative percentages of the minerals plagioclase, quartz, biotite, and hornblende. Most of the intrusions are "porphyry" (have large crystals in a finer-grained ground mass).

Sedimentary rocks.

Sedimentary rocks are aggregates of minerals or rock fragments eroded from older rocks, of precipitated minerals, or of organic material. They are classified according to the size and/or composition of the sediments. There are several basic types in the Park.

Conglomerate is composed of relatively large, rounded clasts (pebbles or cobbles) that are cemented together by a sandy or muddy groundmass (the filling between the clasts).

Sandstone is composed of sand-sized grains of rock. Grains are most commonly quartz, but may be feldspar, volcanic rock, or other tiny rock fragments. The cement is commonly quartz, iron oxide, calcite, or clay. Sandstone exposed within the Park is typically tan, gray, light brown or reddish brown.

Siltstone is similar to sandstone except that individual grains are too small to see with the naked eye, and it generally has a higher clay content. Residual iron oxide (rust) gives siltstone in the Park a dark reddish-brown color. Greenish-gray beds have less oxidized iron.

Shale is similar to sandstone and siltstone, but has the smallest individual grains. Clay minerals are the most common constituent. Clay minerals are platy, and tend to pack together in layers, so shale typically breaks into platy pieces. It is reddish-brown, gray, greenish-gray, or purple.

Breccia is cemented angular fragments of other rock. The fragments can be derived from erosion of pre-existing rock, or from rock that is crushed in place. In the Park, breccia is found near some of the faults and around the margins of several of the igneous intrusions.

Quartzite is densely cemented or welded sandstone, conglomerate or siltstone. Sedimentary quartzite forms by infusion of large amounts of silica (quartz) cement carried by groundwater. (See also, metamorphic quartzite, below.) The quartzite in the Park is primarily sedimentary quartzite.

Limestone is composed primarily of calcium carbonate, the same material that forms hard water deposits around your faucets. Calcium carbonate is secreted by many types of plants, such as algae, and by animals such as corals and brachiopods (small sea shells). Most limestone in the Park was deposited in oceans, and is light to dark gray or brownish gray.

Dolomite (or dolostone) is similar to limestone, except that much of the calcium has been replaced by magnesium. It is discerned from limestone by the use of diluted hydrochloric acid which reacts (fizzes) in contact with limestone but not with dolomite.

Tufa is similar to limestone in that it formed by the precipitation of calcium carbonate. It is deposited by spring water and is light and full of holes.

Metamorphic rocks

Metamorphic rocks are previously existing rock altered by intense heat or pressure. Metamorphism, near the igneous intrusions, has converted some of the limestone to marble and some of the sandstone to quartzite. The Mineral Fork Formation contains clasts of gneiss.

Quartzite is densely cemented or welded sandstone, conglomerate or siltstone. Metamorphic quartzite forms by partial melting and fusion of the quartz grains.

Marble is metamorphosed limestone. It is white to light-gray, sugary, and easily scratched with a knife.

Gneiss is high-temperature metamorphosed rock that looks much like granite except that it has bands of minerals that "swirl" through the rock. It is found only in a few boulders in the Mineral Fork Formation.

Identifying Geologic Formations in Wasatch Mountain State Park

The tables that follow describe bedrock formations in Wasatch Mountain State Park. The information will help you recognize the formations at locations other than those mentioned in the Road Tours. The formations are arranged by time with the youngest rocks first. Thicknesses for intrusive igneous rocks are generally not very meaningful, and have not been given.

Geologic Formations in Wasatch Mountain State Park

Formation (Thickness in feet)	Description	Environment	Where to See
Pine Creek intrusion	light-gray granodiorite porphyry; abundant crystals of plagioclase, hornblende, and biotite "books"	igneous intrusion	Tours 2 and 3
Flagstaff Mountain intrusion	dark-gray to gray-green granodiorite porphyry; abundant crystals of plagioclase, some hornblende, rare visible biotite	igneous intrusion	Tour 3
Valeo intrusion	dark-gray granodiorite porphyry; very abundant crystals of plagioclase, lesser amounts of biotite, hornblende, and conspicuous round quartz "eyes"	igneous intrusion	Tours 2 and 3
Clayton Peak intrusion	dark-gray, medium- to fine-grained granodiorite; scarcely visible crystals hornblende, and biotite	igneous intrusion	glacial debris in Pine Cr./Snake Cr. Canyons
Twin Creek Formation (2500)	gray to buff limestone with some beds of interbedded shale and limy sandstone	shallow marine	near railroad tracks
Nugget Sandstone (1500)	homogeneous, medium-grained, buff to orange brown sandstone	arid, sandy desert	near railroad tracks
Ankareh Formation (1400-1700)	lower and upper units are thin beds of red to purplish-red shale and siltstone; middle unit is white, massive quartzite	coastal mudflats	Tour 1
Thaynes Limestone (1000-2000)	fine-grained, brown-weathering limestone and limy sandstone with a middle unit of grayish-green to reddish brown limy sandstone and shale	shallow marine	Tour 1
Woodside Formation (300-500)	red, dark-red, and purplish-red, thin-bedded siltstone, shale, and fine-grained sandstone	coastal mudflats	Tour 1
Park City Formation (800-1000)	light-gray to buff, sandy and cherty limestone with some interbedded limy sandstone and black shale	shallow marine	Tour 1
Weber Quartzite (1500-8000)	gray to buff quartzite and quartzitic sandstone with minor, interbedded cherty limestone	edge of deep ocean basin	Tours 1, 3, and 4
Round Valley Limestone (300-600)	pale-gray limestone with sparse nodules of white to orangish-red chert and silicified orangish-pink fossils; some beds of sandstone	shallow marine	Tour 4
Doughnut Formation (400-900)	black shale grading upward into thin-bedded, dark gray limestone similar to the Great Blue Limestone.	shallow marine	Tour 4
Great Blue Limestone (about 2800)	thin-bedded, dark-gray limestone with interbedded black shale and sparse beds of quartzite; weathers light gray; (partially equivalent in age to the Doughnut Formation)	shallow marine	south of Tour 1, Tour 3

Formation (Thickness in feet)	Description	Environment	Where to See
Humbug Formation (about 600 feet)	gray cherty limestone interbedded with buff-colored, limy or quartzitic sandstone	shallow marine; some inland erosion	Tour 4
Deseret Limestone (600-900)	light- to dark-gray limestone and dolomite with abundant lenses and thin beds of chert; weathers brownish gray; chert weathers black to brown	shallow marine	mouths of Snake & Pine Creek Canyons
Gardison Limestone (about 500)	thick-bedded, bluish-gray to medium-gray dolomite with upper beds of thin-bedded, fossiliferous limestone	shallow marine	Tour 3
Fitchville Formation (25-120)	medium- to light-gray dolomite	shallow marine	near Cascade Springs
Ophir Formation (300-400)	greenish-brown to brownish-yellow sandy shale with limestone and thin beds of sandy quartzite	mud flat and shallow marine	near Cascade Springs
Tintic Quartzite (about 1000)	white quartzite with some gritty to pebbly beds; weathers buff or light brown	beach and coastal plain	Tours 1 and 3
Mineral Fork Formation (est. 1000-2000)	dark olive green sandstone with unsorted cobbles and boulders of quartzite, gneiss, granite, and limestone.	glacial deposit	Tour 3, Stop 8
Big Cottonwood Formation (1000-1500)	sandy and pebbly quartzite with minor beds of sandstone and greenish shale; (is up to 16,000 feet thick regionally)	streams and rivers in a rift valley	near railroad tracks

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Miscellaneous Publication 93-6 1994
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