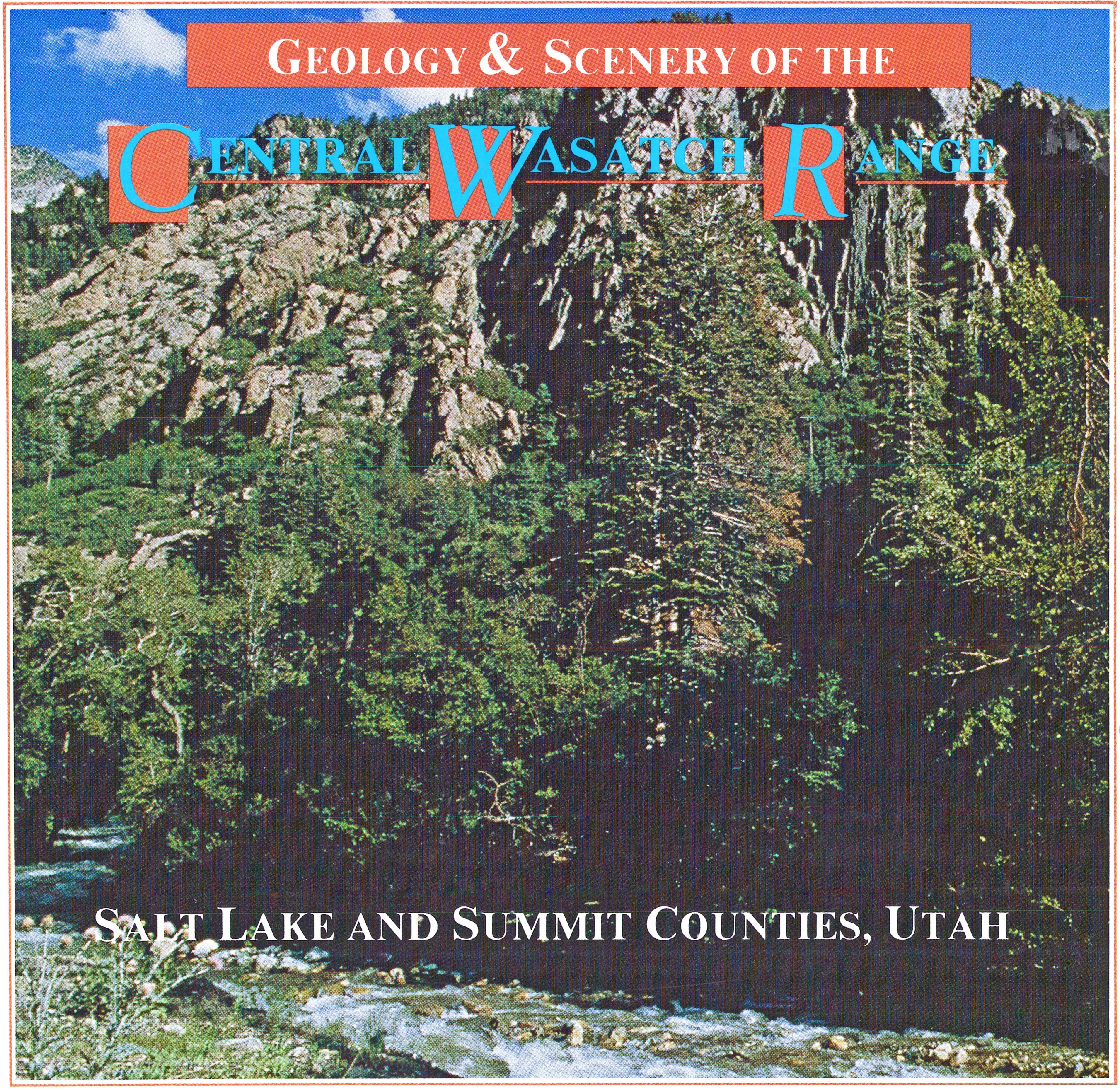
Geology & Scenery of the Central Wasatch Range

Salt Lake and Summit Counties, Utah



Big Cottonwood Canyon/Courtesy Utah Travel Council/Steve Greenwood

by Miriam Bugden, Information Geologist, Utah Geological and Mineral Survey

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UTAH GEOLOGICAL AND MINERAL SURVEY
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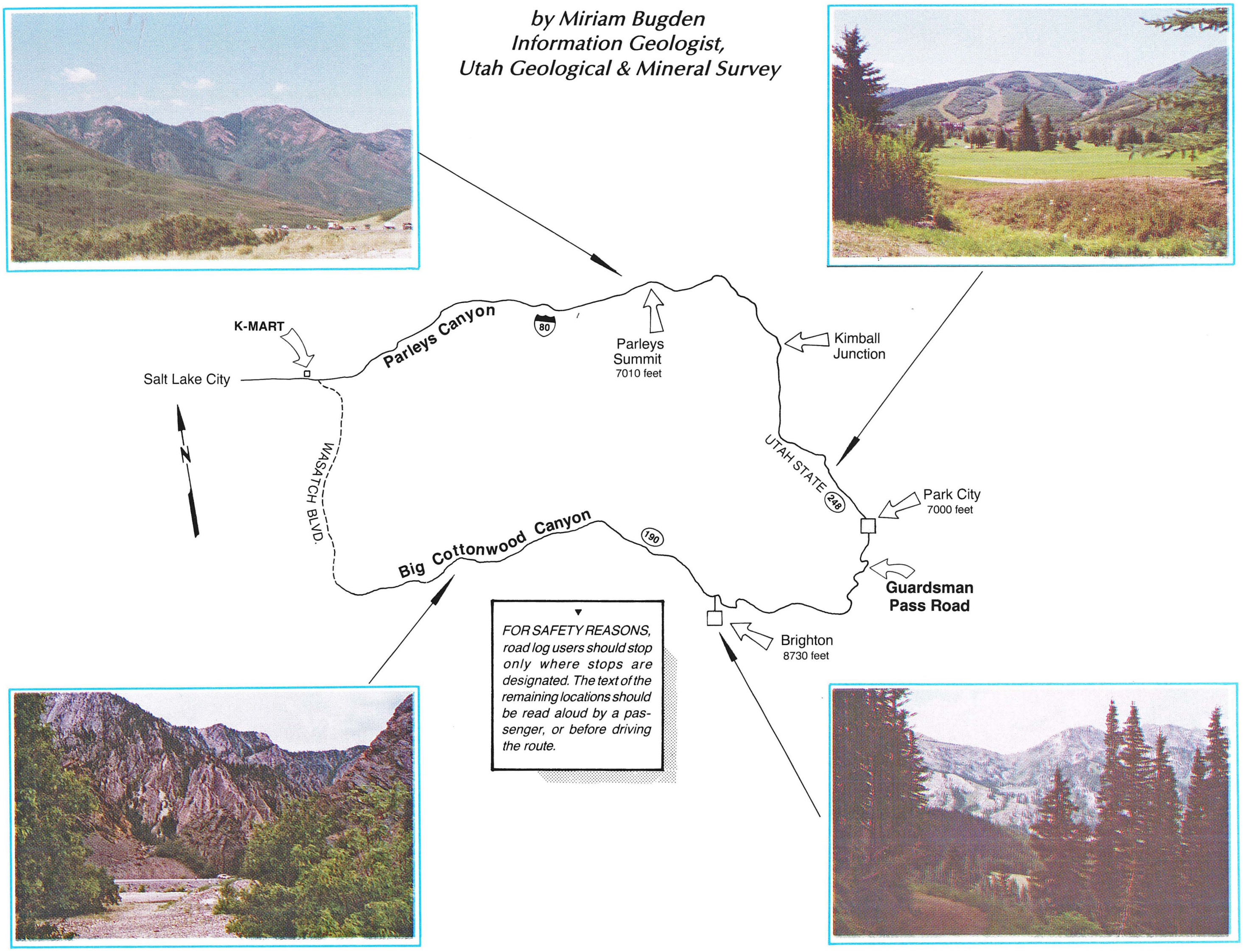
Geologic Journey Through The Central Wasatch Range

by Miriam Bugden
Information Geologist,
Utah Geological & Mineral Survey



FOR SAFETY REASONS, road log users should stop only where stops are designated. The text of the remaining locations should be read aloud by a passenger, or before driving the route.

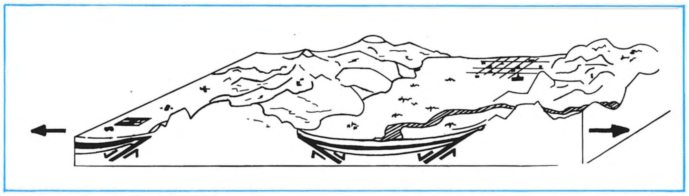
This self-guided geologic trip will lead you through times when inland seas, ancient mountains, vast mud flats, sandy deserts, and massive glaciers ruled Utah's landscape. You will learn how colliding crustal plates changed Utah's face, how the metallic ores of the Park City and Big Cottonwood Canyon mining districts formed, how regional geological structures affect our local geology, and why the sheer walls of Big Cottonwood Canyon are so different from the tame, rolling hills of the Park City area.

The route begins in Salt Lake City, enters Parleys Canyon, continues east to Park City, along the Guardsman Pass road through Ontario Canyon (Park City mining district), into Brighton Canyon, and down glacial and stream-cut Big Cottonwood Canyon. The text is written to encourage driving the log from either direction or for those who wish to begin the drive at any point along the way. You will span a part of the earth's history from over 700 million years ago to the present, observing evidence of past and present erosional and depositional events.

Begin your journey by setting or noting your automobile's odometer in the K-Mart parking lot located at the mouth of Parleys Canyon, 2705 East Parley's Way, Salt Lake City, Utah. Exit the lot from the east onto Foothill Boulevard.

If you choose to drive the log in the opposite direction, begin at the mouth of Big Cottonwood Canyon. Set (or note) your odometer at the first stop (located in the parking lot on the north side of Utah Highway 190, immediately east of the Wasatch Boulevard/Highway 190 junction). This road log has marked miles in parentheses for those beginning this route in Big Cottonwood Canyon. Please note that this road is marked as Highway 152 on some older maps.

References listed at the back of this document are meant to **be used as recommended reading. Please note the list of geological maps that cover the area.**



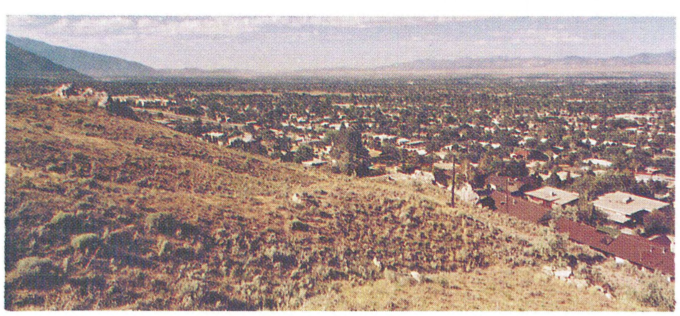
Normal faults caused by stretching or uplift of the earth's crust.

INTRODUCTION
K-Mart Parking Lot

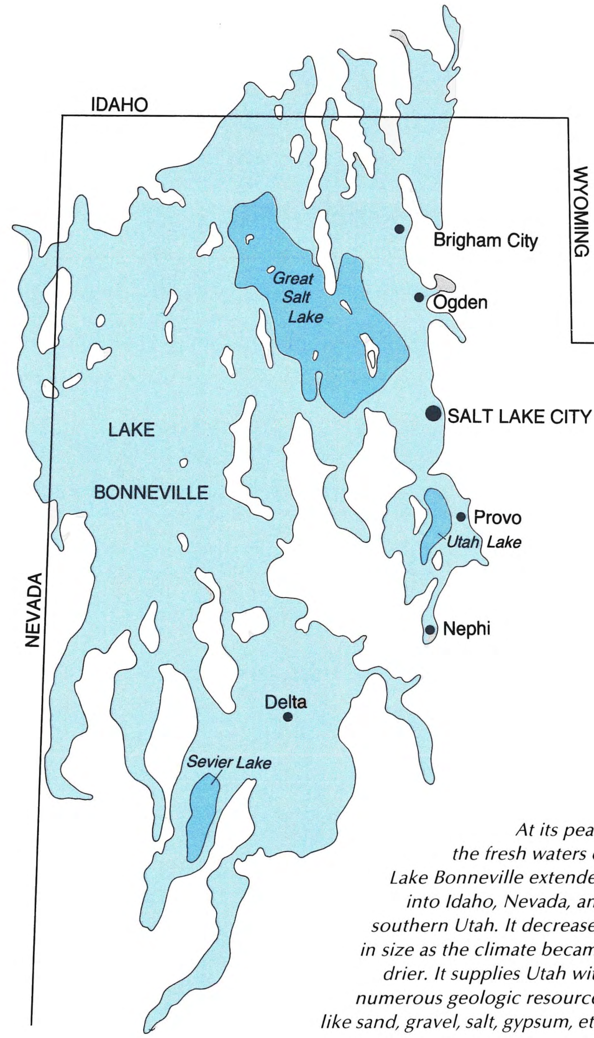
The view west from the parking lot includes numerous large geologic features. The Salt Lake Valley is bounded on the west by the Oquirrh Mountains and on the east by the Wasatch Range. This mountain-valley-mountain topography is an example of how the earth's crust reacts when it is subjected to stretching or "extensional" forces. Beginning about 10 to 15 million years ago (current research indicates that extension may have begun as early as 35 million years ago) and continuing today, the western U.S. began stretching in an east-west direction, causing the earth's crust to pull apart in large blocks. Some blocks moved down along faults while adjoining blocks moved up. The valleys represent areas that moved down and the mountains are blocks that moved up. These "extensional" features are called horst (mountain) and graben (valley).

The Wasatch Range and Oquirrh Mountains are horsts and the Salt Lake, or Jordan Valley, is a graben. The Wasatch fault is the zone along which most of the motion has occurred between the Wasatch Range and Salt Lake Valley. It is important to remember that a fault zone is not one line upon which movement has occurred, but a series of breaks or faults. Frequently, faults are not recognized because they are covered by soils or urban activity. West of this stop, one branch of the fault, the East Bench fault, crosses 2100 South near 1100 East, but is masked by soil and buildings.

Other obvious topographic features are the "benches" of Lake Bonneville. Between 30 and 10 thousand years ago, a great inland, fresh-water lake covered an area of approximately 20,000 square miles. The ancient shorelines, or benches, of this massive body of water were etched onto our mountains and can be seen today. Like rings in a bathtub, these indicate depths at which the lake level stabilized temporarily. At its



Salt Lake Valley — basin-and-range geography.



At its peak, the fresh waters of Lake Bonneville extended into Idaho, Nevada, and southern Utah. It decreased in size as the climate became drier. It supplies Utah with numerous geologic resources like sand, gravel, salt, gypsum, etc.

deepest stage, Lake Bonneville deposited sands and gravels at what is known as the Bonneville level (5,200 feet elevation). The Provo level is at 4,800 feet and Stansbury level is at 4,470 feet. The Great Salt Lake, the remnant of Lake Bonneville, is about 4,200 feet.

On the south side of the highway is a large sand and gravel deposit. This feature is called a delta. It formed during Lake Bonneville time when Parleys Creek carried soils, rocks, and debris out of the mountains and deposited them under the surface of the lake waters (a similar, but larger delta is forming today as the Mississippi River dumps its sediment load into the Gulf of Mexico). When Lake Bonneville waters receded, Parleys Creek began cutting through this delta, forming the prominent ridge we see today. Ancient lake deposits similar to this one are mined for sand and gravel and have helped Salt Lake County become Utah's leading producer of both commodities.

Across the valley in the Oquirrh Mountains is the Bingham Copper Mine. Discovered in the early 1860s, it was the first to use open-pit methods beginning around the turn of the century. Since open-pit operations began, over five billion tons of material have been removed to create a crater that is 2.5 miles across and 0.5 miles deep.

MOUTH OF PARLEYS CANYON
View to the East

The earth's crust, like a sleeping giant, is constantly moving and shifting as it seeks a comfortable position. These dynamic movements create "pushing" and "pulling" forces within and against the earth's layered skin. This skin (or crust) is made of numerous types of materials with a variety of compositions and properties. Rocks with "ductile properties" stretch and bend like salt water taffy and rocks having "brittle properties" break and shatter like peanut brittle.

Like a stack of papers, sedimentary rocks are initially deposited as flat-lying layers of sediments or soils. A combination of time, pressure, and elevated temperatures (associated with burial) causes sediments to harden and the particles to cement together. Horizontal stratification, or layering of the rocks, not only represents the way in which sedimentary rocks are deposited, it is the foundation for our interpretation of geologic time. Each successive layer of sediment that is deposited is younger than the layers beneath. Frequently, however, rocks are not found in simple layers but are complexly contorted or folded.

The multi-colored entrance to Parleys Canyon is an example of a large geologic feature called a fold. Folds are creases or wrinkles in the rock layers, similar to folds in the blankets of a rumpled bed. This particular fold is called a syncline. A syncline forms when rocks are forced to bend into a U-shape where the rocks in the center are younger than the rocks on the edges. This syncline formed about 65 million years ago as the result of the collision of two of the earth's crustal plates (see **mile 17.6 detailed explanation). The pressures that were** created when these plates ran into each other caused portions of the earth to bend and wrinkle. The ages of the rocks involved in the fold at the mouth of the canyon range from 245 to 145 million years old (Triassic to Jurassic) and are described below.

JURASSIC *— The Jurassic Period lasted for about 64 million years (from approximately 208 to 144 million years ago) and, in Utah, was characterized by a combination of marine and non-marine environments. Early Jurassic rocks formed from wind-blown sands of a large inland desert. Middle Jurassic time was characterized by a series of shallow marine invasions. The end of the Jurassic Period hosted extensive river systems and fresh-water lakes.*

TRIASSIC *— The Triassic Period lasted for about 37 million years (from approximately 245 to 208 million years ago) and, in Utah, was characterized by both invasion and retreat of marine seas. These events left central Utah with a variety of rock types ranging from deep sea shales, claystones, and siltstones, to shallow marine limestones and sandstones, to mud and delta-flat muds, and to conglomerates from nearby highlands (probably the Uncompahgre uplift in Colorado).*

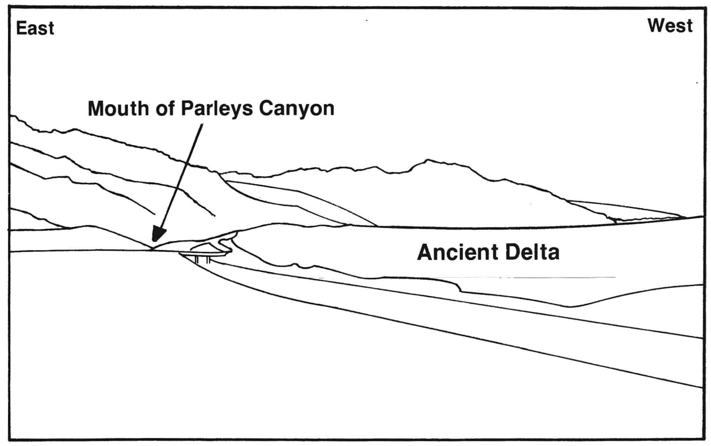
Twin Creek Limestone. *The light gray, rounded, slope-forming rocks on the north side of the canyon were deposited in shallow seas that invaded Utah from Canada and extended south to the area near Zion National Park. These limes and marine oozes contain clam and oyster (pelecypoda) fossils, sea lilies (crinoids), and prehistoric squids (cephalopoda). The rocks of this formation are also oil and gas reservoir rocks of Utah's thrust belt.*

Ankareh Formation. *Rocks on the south side of the gully and part of the north side of Parleys Canyon are red muds and silts of the Ankareh Formation. They were deposited on mud flats and deltas when the Triassic seas began retreating to the west. Ankareh is the word "red" in the Uinta Ute dialect. Three distinct formation members can be seen here. The lower Mahogany Member on the south of the gully contains mudstones, shales and sandstones. It is separated from the upper reddish-brown sandstone, mudstone, and shale-bearing member to the north by the light-colored Gartra Grit Member. This quartzite forms ridges and is known locally as Suicide Rock.*

Nugget Sandstone. *On the north side of Parleys Canyon are the buff colored, cross-bedded sand dune deposits of the Nugget Formation. These same rocks form the massive, smooth cliffs in southern Utah's Canyonlands and Zions National Park. These rocks are also oil and gas reservoir rocks of Utah's thrust belt.*

Gartra Grit Member. *This "member" or rock unit within the Ankareh Formation is the prominent "Suicide Rock" seen in the bottom of the canyon. These rocks were deposited in an arid or semi-arid environment. The coarse clastic deposits probably came from eroding highlands located to the east, south, and southwest.*

0.7 miles
(50.3)

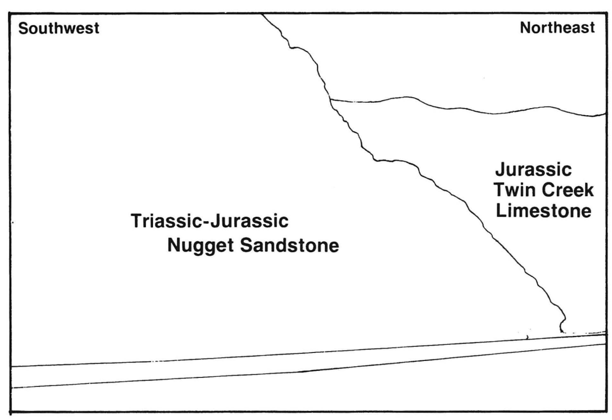


From the parking lot, enter Foothill Boulevard going east, then take the I-80 (Cheyenne, Denver) exit. Pause momentarily at 0.7 miles on the side of the road. Across the ravine to the south is the delta described in the introduction to this log. When the delta formed below the waters of Lake Bonneville, Parleys Creek flowed over the top of this hill. Now, thousands of years later, the creek has gouged through the sediments, picking up small particles along the way and re-depositing them in the Salt Lake Valley. Erosion of this planar slab of sediments is, in essence, a clock reflecting the slow passage of time from Pleistocene to the present.

Geo-scientists believe that "the present is the key to the past." By comparing rocks and features that are fossilized in the rock record with present geologic processes, geologists can unlock secrets of past environments and gain a better understanding of the age of our planet.

Like slowly dripping sands of the earth's clock, grain by grain reconstruction of the growth and development of specific landforms teaches us to understand how, and over what period of time, our current landforms evolved. Rebuilding a part of the earth's history at this stop, we see particles deposited in mudflats, sand dunes, or sea floors; later pressed into rocks; squeezed into folds; uplifted into mountains; eroded, carried by streams, and redeposited in a delta; further eroded, carried by streams, and re-deposited on the valley floor where millions of years from now a mountain may once again form.

1.7 miles
(49.3)
STOP



Notice the massive, sheer cliffs of the buff-colored Nugget Sandstone on both sides of the road. Above the Nugget, notice the rounded slopes of gray Twin Creek Limestone. Sedimentary rocks, named for their content and grain size, have a variety of colors. Colors are one of many clues that geologists use to understand rocks. Together with other clues locked in the stones, colors lend hints as to the mineral content, environment of deposition, and erosional history. The reddish-brown or "buff" color of the Nugget is due to the presence of iron and oxygen. Like a child drawn to candy, oxygen loves to attach to iron. When it does, the result is the color of rust. Consequently, we know that the sediments in the Nugget Sandstone contain iron and were deposited in, or later exposed to, an environment rich in oxygen.

The murky gray color of Twin Creek Limestone is in part the result of the depth of the waters in which it was deposited. Water depth helps dictate the chemistry of the sediments, the amount of organic materials and calcium carbonate present, and the level of burrowing activity that occurs through the sediments (animals living on or near the ocean floor disturb the sediments, introducing higher levels of oxygen to the muds). All of these factors contribute to the final color of the limestones.

As you drive east, you will be leaving the wind-swept, dry, Jurassic deserts for the relief of a gentler, wetter climate. This drive up through geologic time will take you into life-filled seas preserved in the Jurassic Twin Creek Limestone.

3.2 miles
(47.8)

Since the last stop, you've been driving through thousands of feet of marine fossil-rich limestones laid down in a shallow sea that reached from Canada to southern Utah. The steep-walled cliffs of Twin Creek Limestone can be seen on the north side of the freeway in the abandoned portland cement quarry pits.

This portland cement quarry is an historic mining site. Operations began here in the late 1800s and continued until the 1980s. Concrete, the most commonly used construction material in the world, uses limestone as a primary component.

9.1 miles
(41.9)

This area of chronic slope failure is a good example of how civilization attempts to tame the forces of nature. Plaguing the highway department since the freeway was first constructed, the area has had drain pipes installed on the uphill side to capture and divert moisture away from the unstable sediments. Water is one of the main causes of slope failures. By diverting the excess water, engineers hope to stop the bothersome movement.

12.9 miles
(38.1)

The elevation of Parleys Summit is 7,016 feet. You have continued to journey through the earth's historical record, from the distant past toward the present. Red-colored sediments of the Preuss Sandstone are visible on the north side of the freeway. About 160 million years ago, the Jurassic seas slowly evaporated and withdrew (to the north) leaving lagoons, estuaries, and mudflats. This change in environments caused different types of sediments to cover the layers deposited by the Twin Creek Limestone, and the land donned the mask of the Preuss Sandstone. Yet another disguise for this and surrounding areas of the western U.S., Preuss rocks are typically red (indicating the presence of iron), contain evaporites (salts, gypsum, and other brines that settle to the bottom of the water-filled basins as the water dries up), and are referred to as "restrictive marine" rocks.

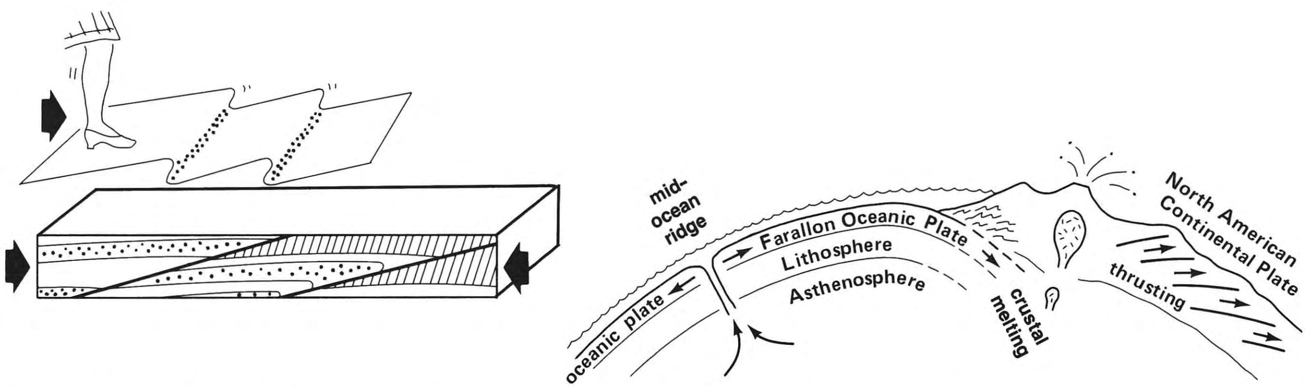
As the road log continues toward Park City, exposed rocks become older instead of younger. Proceeding through continually older rocks is referred to by geologists as "going down section."

15.1 miles
(35.9)

The Gorgoza ski area on the south is also known as Parley's Park Resort. This area was settled in 1889. It was named after Rodriguez Velasquez de la Gorgozada, a Spaniard who invested thousands of dollars in a narrow-gage railroad from Park City to Salt Lake City. John W. Young, son of Brigham Young, traveled to Europe to seek financial support for the project and met Rodriguez. Young convinced Rodriguez to contribute funds by promising to name the area after him.

The Nugget Sandstone is once again visible in the hills surrounding Gorgoza. Fossilized reptile and amphibian tracks have been found in the Jurassic desert sands at this location, one of very few such localities in Utah. Blocks of Nugget have been quarried from this site for use in construction. Numerous home foundations, stone walls, and many of the buildings of Salt Lake City's historic Fort Douglas were built of Nugget Sandstone.

17.6 miles
(33.4)



Like a wrinkled rug, layers of rock fold, break, and slide on top of each other when pushed together. About 65 million years ago, a large oceanic plate of the earth's crust (Farallon Plate), colliding with the continental plate on which we ride (North American Plate), caused "pushing" forces that forced wrinkling or thrusting to occur in the area we now call Utah.

Movement of the earth's layers of skin, the crustal plates, often involves collisions. Like stacks of paper pushed together, crashing plates create wrinkles (folds) and breaks (faults and fractures) within the layers of the earth's shell. In the end, some layers are creased and folded, while others have slid onto and over the adjacent stack.

Crossing the freeway immediately before the Park City off-ramp, an immense geologic feature has been recognized by geologists and named the Mount Raymond thrust fault. It cannot be seen in this area, as it is covered by recent stream deposits (Quaternary alluvium) and other erosional debris. Its approximate position can be determined where 290 to 245 million-year-old rocks of the Permian Park City Formation have been thrust over (and are now on top of) 200 to 145 million-year-old rocks of the Jurassic-age Nugget Sandstone and Twin Creek Limestone.

This relationship can only be seen at high elevations on the mountain. This structural feature resulted from a mountain-building era that occurred about 65 million years ago. Referred to as the Sevier orogeny, this event was caused by the collision of the earth's crustal plates. During this time, thick sequences of rock were moved nearly 50 miles from west to east from their original areas of deposition. The planes along which they moved are called thrust faults.

Exit Interstate 80 at Kimball Junction and Drive Toward Park City on Utah Highway 248.

20.7 miles
(30.3)

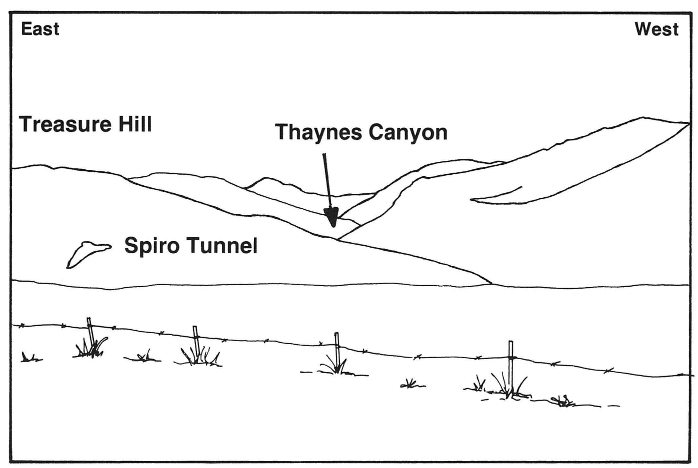
Dutch Draw is the canyon to the west at this stop. The highest peaks in the background are 230 to 190 million-year-old rocks of the Triassic and Jurassic periods. During the Sevier orogeny (see explanation at stop 17.6), the rocks in these formations were pushed together and bent. The resulting "folds," a U-shaped syncline (rocks on the limbs are older than the rocks in the center) and an upside down U-shaped anticline (rocks on the limbs are younger than the rocks in the center), are part of large sheets of rocks that were moved here during thrusting.

The rounded hills in the foreground are made from debris that once was part of the mountains in the background. Between 30,000 and 8,000 years ago, glaciers formed and began flowing (much like a stream, although slower) through these mountains. As they moved, they scraped or shaved rocks off of the mountain's face. When the ice began melting about 13,000 years ago, rocks carried in the glacial ice melted out as rock "flour" silts, muds, pebbles, boulders, etc. Today, sediments (or till) from these rounded hills of glacial debris are slowly eroding and re-depositing on the flats on which we stand. The

earth's resources continue their non-ending cyclical journey of erosion and deposition.

From here to Park City, the Jurassic rocks along the road display various "attitudes" (they are seldom flat lying; instead, they slope in various directions). These "dips" are evidence of the syncline and anticline mentioned above.

23.0 miles *STOP*
(28.0)



Visitor Information Center. The view west is of Thaynes Canyon, Crescent Ridge, and Treasure Hill. These areas were important silver, lead, zinc, gold, and copper prospecting areas during the boom years of the Park City mining district. The Spiro Tunnel can be seen at the base of Crescent Ridge (across the golf course).

Initially driven into the foot of Treasure Hill to drain the Silver King Consolidated Mine, this old tunnel was once regarded as one of the world's most unusual ski lifts. During the winter of 1964-65, skiers rode in enclosed mine cars through the tunnel to the center of the mountain. There, they connected with the Thaynes Canyon shaft where they were hoisted in a mine cage to the snows on the surface.

Drive into Park City and through historic Main Street. Notice numerous buildings constructed during the mining years. Many buildings used stone quarried from the area hills. Continue through the city following signs to Guardsman Pass by way of Ontario Canyon.

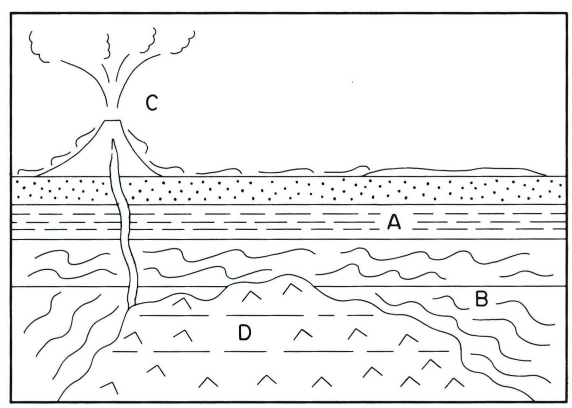
25.8 miles (25.2) STOP

The view north from the intersection of Hillside Avenue, Prospect Avenue, Marsac Avenue, and Ontario Canyon is of historic Park City. Like many western resort towns, Park City has its roots in mining. Although the precise story of the first discovery of metals in the district is unknown, one legend is that in 1869 soldiers stationed in the area discovered quartz veins rich in silver, lead, and gold. Other discoveries quickly followed. The district operated almost continuously until 1982 when the operations closed due to economic and environmental factors. Total ore values from the district exceeded $476 million.

The Park City district is on the north side of a large east-west upwarp known as the Uinta uplift. This massive bulge in the earth's crust has been extensively studied by geologists searching for explanations for its existence. At the intersection of the Wasatch and Uinta mountains, the uplift terminates against the eastern edge of another interesting geologic feature. This feature is an extensive metallic mineral belt that, in western Utah, begins with mining districts in Utah's Deep Creek Mountains; extends east and slightly north into the Tintic district of the Tintic Mountains; east again into the Ophir, Mercur, and Bingham districts in the Oquirrh Mountains; and ends in the Wasatch Range where economic deposits have been mined in Little and Big Cottonwood Canyons as well as in the Park City district. This grouping of economic deposits is characterized by the occurrence of numerous igneous intrusions ranging in age from about 144 to 25 million years old (Cretaceous to Tertiary).

Between 320 to 290 million years ago, the sedimentary rocks in this area were deposited in a shallow sea (the Oquirrh basin) located west of here. During the Sevier orogeny, these Pennsylvanian-age rocks were carried eastward to their current locations on thrust sheets (see mile 17.6 for further explanation).

Most of Park City's ore was found along veins, faults, fractures, and bedded replacements in metamorphic or sedimentary rocks. Scientists believe that buried igneous activity, between 144 and 25 million years ago, either introduced the metallic minerals to the existing rocks or served as the heating system that mobilized and re-concentrated minerals that already existed in the sediments.



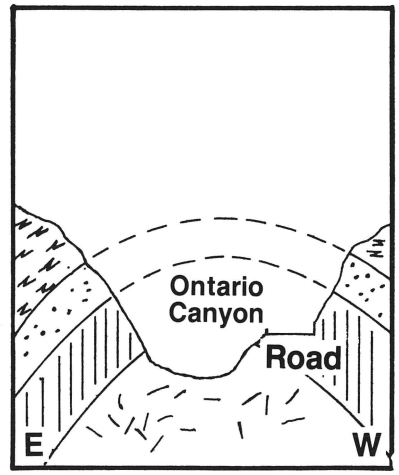
Three general classes of rock are: (A) sedimentary, (B) metamorphic, and (C and D) igneous. Igneous rocks are divided into extrusive (C) and intrusive (D). Extrusive rocks spew onto the earth's surface and are usually molten, or flow onto the ground before they cool and solidify. Volcanic lavas are extrusive.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

26.5 miles
(24.5)

Ontario Canyon. This is the first view of the Ontario Mine. In this part of the canyon, the rocks on the surface are Pennsylvanian Weber Quartzite.

Originally deposited as sediments adjacent to the Oquirrh basin, the Weber Quartzite was metamorphosed by heat and pressure related to deep burial, tectonic activities, and igneous activity.

Metamorphism, like baking, changes the physical properties and chemistry of the materials being "cooked." When baking chocolate chip cookies for example, the oven's heat partially melts the chocolate bits and causes the flour, sugar, spices, oil, etc. to mold together and form a cohesive solid that is much different than it was when it first went into the oven. Originally, the Weber Quartzite was a quartz-rich sandstone. Metamorphism caused the quartz grains in the rock to fuse together, forming a much harder, slightly different rock.



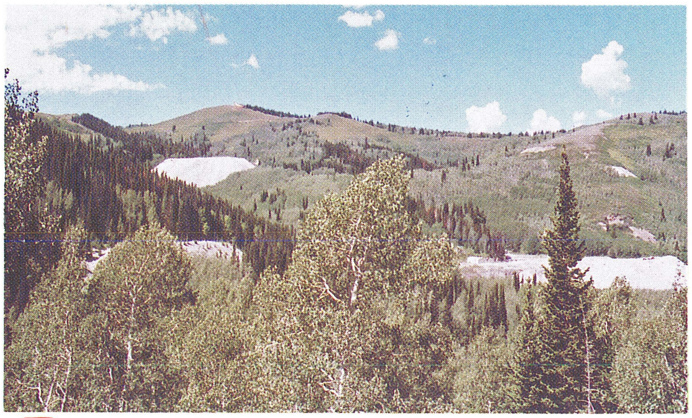
The road up Ontario Canyon follows the west limb of the north-south-trending Park City anticline. An anticline is wrinkled or folded layers of rocks that look like an upside-down bowl. Anticlines can form by compressional forces within the earth (see mile 20.7 for more details on geologic folds).

27.4 miles ***STOP***
(23.6)

The Ontario Mine was one of the largest ore producers in the history of the district. From 1875 to 1967, it produced over 46,800 ounces of gold, 56,960,000 ounces of silver, 199,090,000 pounds of lead, 257,430,000 pounds of zinc, and 4,740,000 pounds of copper. Most of the ore was found in bedded replacement and fissure ore bodies in 360 to 320 million-year-old (Mississippian) rocks of the Humbug Formation. These rocks consist of alternating layers of sandstones and limestones, suggesting a time when marine waters alternated cycles of invasion and retreat.

Although the Humbug is mined here, the surface rocks are 320 to 290-million-year-old Pennsylvanian-age Weber Quartzite. Pick up a a sample and look closely. On a "fresh" newly broken surface the rocks have a sugary white appearance. The orange, yellow, and brown stains on their surfaces are iron oxide minerals. Iron oxide stains occur when iron-rich minerals (pyrite, for example) become oxidized, or rusted. These colors are frequently seen in mining districts; however, the presence of iron oxides does not necessarily mean that an ore deposit is nearby.

28.7 miles (22.3)



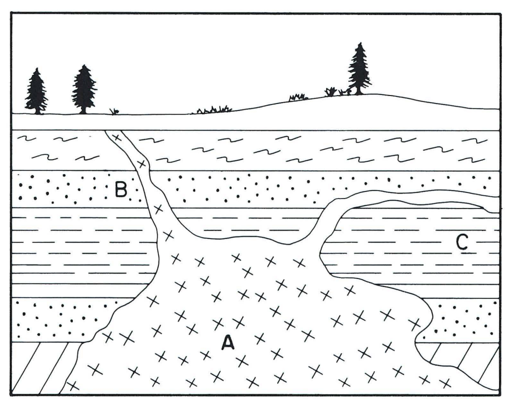
As you drive past Empire Canyon, notice the signs of past mining activity. Among them are the Daly West shaft and dump, and the Judge shaft and dump. Both operations lie on the Ontario-Daly West fault system. In the early days of mining activity, this steep fault was considered to be one of the most important ore-bearing features in the district. Most of the first ore removed from the district was mined from fractures, faults, and veins. Not until later in the district's history, however, did miners realize that the richest ores were found disseminated, or scattered, throughout the rocks or in bedding planes of the stratified layers of rocks.

29.5 miles (21.5) STOP

You are now approximately 8,850 feet in elevation on rocks of the Flagstaff Mountain stock. These gray to green rocks contain light-colored minerals (up to ½ inch long) floating in a fine-grained host. This "spotted" igneous texture is called a porphyry. The rock, named for the type of minerals it contains and how it forms, is a diorite. The Flagstaff intrusion is thought to have contributed to the emplacement of Park City district ores.

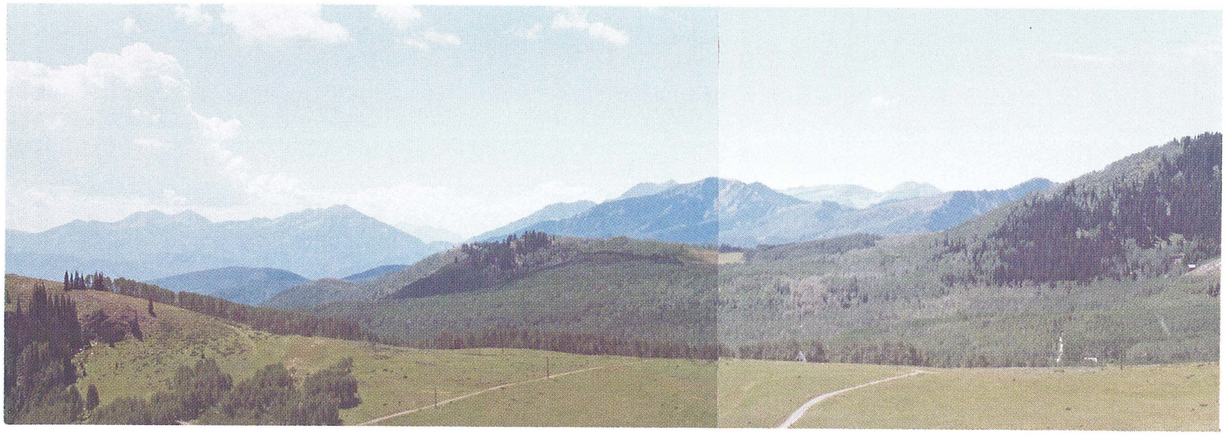
The view west of the surrounding high peaks is of the Clayton Peak stock. These intrusive igneous rocks (see schematic diagram at mile 25.8) are granodiorites, a slightly different chemical composition than granites. They have played an important role in the mineralization in the area (see explanation at mileage 25.8). Geologists believe that this intrusion occurred between 41 and 37 million years ago.

The view east is toward the western end of the Uinta Mountains (Uinta uplift). Scientists speculate on just how large a role this massive uplift played in localization of faults, intrusions, and other reoccurring geologic phenomena in this part of Utah (see discussion at mile 25.8 for further information). Mount Timpanogos can be seen on the distant southwest horizon.



Igneous rocks have many different shapes or geometries. Intrusions that are larger than 40 square miles on the surface and whose total depth is unknown are called a batholith. *If smaller than 40 square miles, they are called a* stock *(A).* Dikes *(B) are tube-like intrusions that cut across existing bedrock.* Sills *(C) have the same general shape as dikes but they parallel the bedding planes that they intrude.*

30.4 miles
(20.6)



This is the intersection of Guardsman Pass and the roads to Cloud Rim Camp and the town of Midway. This valley was glaciated between 30,000 and 8,000 years ago (Pleistocene time). Notice the low, rounded, tree-covered hills and ridges. They are made of till. Till is material that was scoured from the surrounding cliffs by slow-flowing, rock-laden glaciers. Like giant sheets of coarse sand paper, glaciers smoothed the mountain faces, widened the valleys, moved the scoured materials to lower elevations, and eventually melted and retreated, leaving behind heaps of debris, or till.

32.2 miles
(18.8) ***STOP***

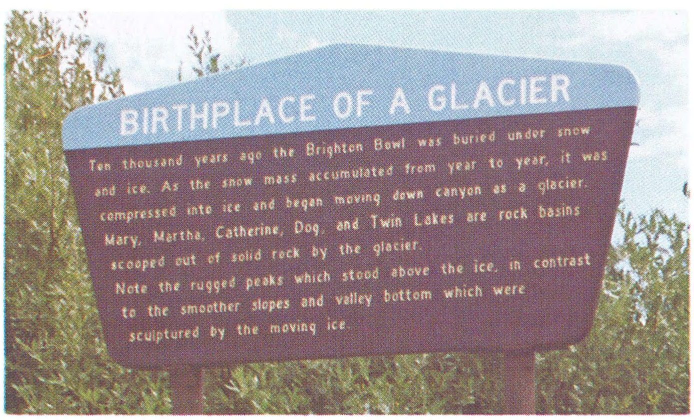
As you approached Brighton Gap from the east, you drove past a road-cut with rocks of multiple colors. These rocks alternate between sedimentary rocks and igneous dikes. Between 245 and 240 million years ago, an inland sea deposited limestones of the Triassic Thaynes Formation. At this stop, these fossil-rich limestones have been baked by "fingers" of igneous dikes (see miles 26.5 and 29.5 for explanations of metamorphism and dikes) from the Clayton Peak stock. Similar to cooking food in an oven, heat and pressures associated with metamorphism cause physical and chemical properties to change in rocks causing new, interesting minerals to form. Careful examination of these rocks will yield a shiny, silver-colored, flaky, iron oxide mineral called specular hematite.

The canyon below and to the west is Big Cottonwood Canyon. Between 33 and 32 million years ago, molten intrusive igneous rock invaded the surrounding rocks in this area. As the magma cooled and solidified, it created an environment that encouraged growth and concentration of metallic minerals in the surrounding rocks. Millions of years later, after the rocks of the Wasatch Range were uplifted and erosion began, rocks of the Alta stock were exposed at the earth's surface. Pleistocene (30,000 to 8,000 years ago) glaciers carved two magnificent peaks at the head of this canyon. Mount Wolverine (10,795 feet in elevation) and Mt. Millicent (10,452 feet in elevation) are both composed of igneous rocks of the Alta stock. In the 1860s, lead, zinc, silver, and copper were found and the Big Cottonwood mining district was officially formed. This district is similar to the Park City district in that the mineralization was related to a trend of 144 to 25 million-year-old (see mile 25.8) Tertiary to Cretaceous-age intrusions; that the ores were found along faults, veins, fissures and as bedded replacements; and that the primary ores mined from the area were silver, lead, zinc, and copper.

This spectacular mountain arena is called a glacial cirque. A cirque is a spoon-shaped area in the mountains that served as the main supply of glacial ice. The movement of glaciers carves wide U-shaped valleys, like that of the upper part of Big Cottonwood Canyon. The low, rounded, tree-covered sides of the valley are made of rocks, sand, gravel, and dust that were left by retreating or melting glaciers. Debris left on the side of a glacier's path is called a lateral moraine and debris left on the front of a glacier is called a terminal moraine. Most of the till in the canyon was deposited on the canyon floor and edges about 19,000 years ago. About 13,000 years ago, the glaciers began melting and retreating from the middle of the canyon (they never reached the bottom of Big Cottonwood Canyon). The upper canyon recession of ice occurred about 8,000 years ago.

35.3 miles (15.7) At the bottom of Guardsman Pass road, turn left (south) and drive to Brighton.

36.1 miles (14.9) ***STOP***



Salt Lake area residents used Big Cottonwood Canyon as a source of lumber and for recreation long before ore was discovered. In 1874, William Stuart Brighton built and opened a hotel at the top of the canyon. The area was used by Brigham Young and followers for overnight picnic parties.

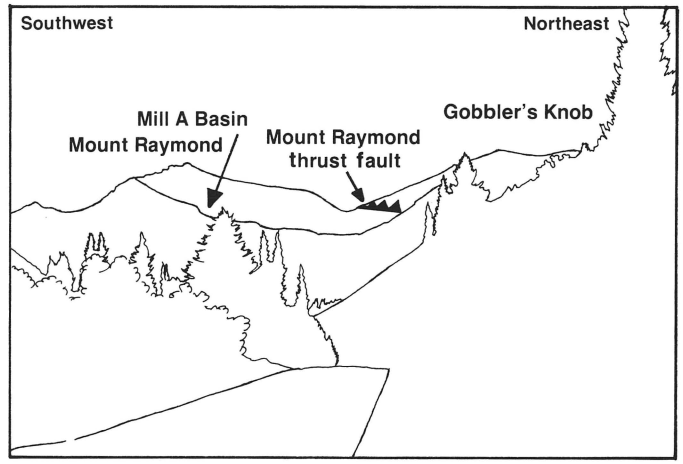
In the 1860s and 70s economic discoveries of minerals in Alta Canyon (Little Cottonwood) encouraged prospectors to spill over into Big Cottonwood. Ores were soon discovered and the area became an official mining district in March 1870. By 1872, four to five hundred people lived in the canyon. Unusually steep terrain, avalanches, rockfalls, cold and wet conditions coupled with fluctuating economic factors created a sporadic mining history that lasted for over one hundred years.

The primary use for the canyon changed in the 1940s when the first skiing facilities were developed. Recreation promises to be the main economic staple for Big Cottonwood for a long time to come.

"Birthplace of a Glacier." Glaciers are a little like igneous rocks in that both are made of fluids that turn to solids when cool. Like sedimentary rocks, they are deposited in layers. Their movements are capable of eroding the landscape or depositing new features. Like frozen rivers of ice, glaciers flow downhill. Their down-canyon extent depends on how fast the ice accumulates at the top of the canyon.

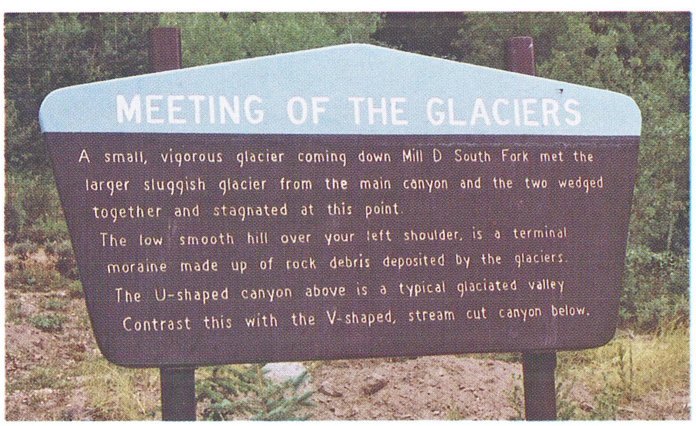
Follow the one-way road back to the Brighton Store Junction and begin driving down the canyon (west on Utah Highway 190) (152 on State Highway map).

41.2 miles
(9.8)



Looking down the canyon in a northwesterly direction one can see a good view of Mount Raymond (the 10,241 foot peak to the left); glacial till in Mill A Basin (at the base of the peak); and Gobbler's Knob (the 10,246 foot peak on the right). A large thrust fault that formed about 65 million years ago, the Mount Raymond thrust, cuts through the valley between the two peaks. This is another area where thick layers of older strata were moved over the top of younger rocks during compressional forces of the Sevier orogeny (see explanation at mile 17.6).

41.9 miles ***STOP***
(9.1)



This is the lowermost extent of Big Cottonwood Canyon glacial movement. Scientists believe that when the glacier reached this point, the climate began to change, causing the glacial ice to melt faster than it was able to accumulate. The balance of ice growth against ice melting is called the glacial budget. When a glacier adopts a negative or melting budget, it gradually begins to shrink as this one did when it reached this part of the canyon. The slowly shrinking mass of constantly moving ice left, in its wake, a mound of debris scraped from the walls and floor of the canyon. The high pine-covered hill or ridge to the west is the glacier's terminal moraine (see mile 32.2 for information on glacial features). This site also coincides with the point at which the main valley glacier met a smaller glacier. The smaller glacier originated in and carved the side canyon Mill D, immediately south of here.

The greatest early producing mine in the district was Reed and Benson Mine in Mill D South Fork (Cardiff Fork). It is up a road that is immediately south of this location. Minerals were discovered here and a mine built in 1870. A $20,000 tram was constructed to haul ore and equipment in and out of this rugged area. An assay office, boarding house, and ore storage house were also built.

For the rest of the drive, notice that the floor of the canyon takes on a sharper, V-shaped appearance instead of an open, generally straight U-shape. Narrow, steep-walled, meandering canyons are typical of those that have been cut or eroded by the worming, twisting action of a river or stream.

42.6 miles
(8.4)

This large boulder, suspended in a fine-grained, sandy matrix was transported and deposited by the melting or retreat of a small glacier that carved a side canyon.

43.7 miles
(7.3)

STOP

Originally deposited as layers of flat-lying mud, this Mississippian marble has been metamorphosed and tilted. The original layers are emphasized in the photograph.

You have been traveling "down section," or backwards through time, and are now driving through rocks deposited in a marine sea that invaded this area of Utah between 360 and 320 million years ago (Mississippian time). Metamorphosed to marble, these rocks were originally deposited as limestones (see mile 26.5 for a description of metamorphism). Fossils in the rocks tell geologists that these sediments were deposited in shallow waters. Over time, these sea water muds were compressed into rocks and pushed up to their present elevation, and overlying rocks were then eroded to create the present topography.

The drive down the canyon (east to west) continues our journey back in time through older and older rocks. From a geological perspective, the route is not a smooth continuous one. You will travel from Mississippian (360 to 320 million years ago) directly into Cambrian time (570 to 505 million years ago), skipping almost 150 million years of the earth's story. Missing rock units suggest that sediments were never deposited or that the rocks were eroded at a later date when the area was uplifted (for example, today, the Wasatch Range is being slowly eroded and little deposition is occurring in them. Millions of years from now, this area will reflect a "missing" time period). Surfaces that represent eroded or missing periods of geologic time are referred to by geologists as "unconformities."

44.9 miles (6.1) **STOP**

The Precambrian-age rocks of the Big Cottonwood Formation consist of quartzites, shales, and siltstones. This unique arrangement of rocks tells geologists that shallow water covered Utah between 1.1 billion and 850 million years ago. The water's depth fluctuated leaving beaches (now quartzites) when the water was shallow; mudflats (now argillites and slates) when the water retreated; and fine-grained deposits like ocean-bottom oozes and muds (now shales and slates) when the water deepened. Alternating layers of the different rocks suggest that several cycles of deep and shallow waters took place over millions of years. Ripple marks and mud cracks can be seen in the darker colored shales and siltstones. Originally deposited as flat-lying sediments, these Precambrian rocks have been pushed up and tilted to a steeply dipping angle.

Water can be thought of as a mirror between our world and the underwater world. Methods of deposition beneath the water are a reflection of those above. Ripple marks, for example, form in both environments. These scallop-like features or ridges of sediments move in the direction of the current flow (whether it be wind or water). When reconstructing conditions in which ripple marks were formed, geologists consider the size of grains deposited along with the size and spacing of the ripple marks to help determine current direction and energy of the wind or water.

48.2 miles (2.8) **STOP**

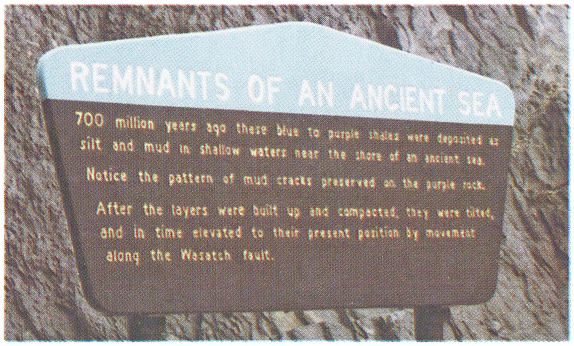
The rounded gentle hills around Park City and Bonanza Flat seem to contrast severely with the steep, rugged peaks of Big Cottonwood Canyon. How can these two extremely different and contrasting landscapes be part of the same mountain range? What makes them so different?

Scenery is a reflection of geology and erosional processes. Erosion, or breaking down of our landscape, depends on many factors including climate, the types of rocks in an area, different rates of uplift, the minerals contained within the rocks, and how those constituents are cemented together. Most of the rocks in the Park City area are sedimentary. They break down or "weather" relatively easily, because the sediment grains are not cemented together as well as the components of other rock types. Also, rocks in the Park City area have fewer "hard" minerals in them as compared to the igneous and metamorphic rocks (see schematic diagram at mile 25.8 for a description of different rock types) of Big Cottonwood Canyon. Consequently, weathering causes rocks in the Park City area to crumble into soils, forming a rounded topography.

Quartz (silica bonded to oxygen), the hardest rock-forming mineral and one of the most difficult to break apart, is a main component of all rocks in Big Cottonwood Canyon. Abundance of this mineral as grains and cement help make these rocks resistant to forces that grind rocks into soils. Extreme relief of the prominent, piercing ridges of the canyon can also be attributed to their proximity to the active Wasatch fault. Movement on the fault subjected these rocks to more extreme amounts of uplift, causing them to pierce the sky with their prominence.

48.7 miles (2.3)

STOP

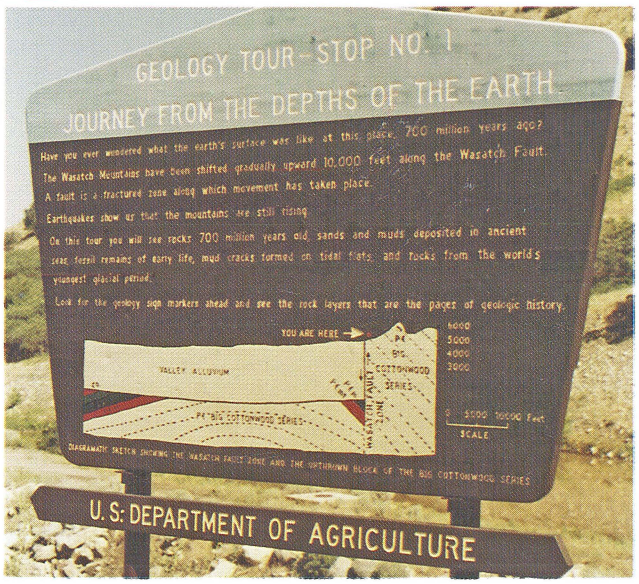


Shallow, muddy, flat-lying sediments are frequently found along the shores of a body of water. As the water dries, muds and clays shrink and crack, forming a thin broken crust. "Mud cracks" are shaped like polygons and look like pieces of a puzzle.

The geologist's theory that the "present is the key to the past" is well displayed here. Upon close examination of the "Remnants of an Ancient Sea" one can see polygonal mud cracks frozen in the dark-colored rocks of the Big Cottonwood Formation (see mile 44.9 for explanation of the depositional environment).

51.0 miles (0 mile)

STOP



The western edge of the Wasatch Range is separated from the eastern edge of the Salt Lake Valley by the Wasatch fault zone (see the road log introduciton for an explanation of how this steep zone of breaks in the earth is related to the mountains and valley). The fault cannot be seen here because it is covered by erosional debris from the mountains as well as sediments from a large delta that formed beneath the water level during Lake Bonneville time (for a discussion of Lake Bonneville, see the road log introduction. For a description of a similar delta at the mouth of Parleys Canyon see mile 0.7). Like the similar feature at the mouth of Parleys Canyon this delta has been "cut" by the erosional action of Big Cottonwood stream.

During this journey, you have traveled through mountains of time learning how erosion, deposition, compression, and extension work together to transform the earth's features. The fingerprints left by time and tectonic forces are carefully examined by geologists and other earth scientists. Hopefully, these examinations will enhance our understanding and appreciation of the dynamics and resources of the earth.

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Geologic Time Chart — Central Wasatch Range, Utah

Era	Millions of Years Ago	Period	Geologic Formations Along Road Log	Significant Geologic Events Along Route	Select Road Log Sites
CENOZOIC	1.6	Quaternary	Alluvium Flood plains Deltas Talus Glacial moraines and till	Present erosional and depositional features Lake Bonneville glaciation Basin & Range faulting continues growth of Wasatch Range	Chronic slope failure in Parleys Canyon Dutch Draw, Bonanza Flat and Big Cottonwood glaciation Deltas — Mouth of Parleys Canyon and Big Cottonwood Canyon
	66.4	Tertiary	Little Cottonwood stock Flagstaff Mountain stock Alta stock Clayton Peak stock	Basin and Range extension and faulting Intrusive activity Laramide orogeny	Brighton Guardsman Pass
MESOZOIC	144	Cretaceous	*Kelvin Formation	Sevier orogeny	Rocks in Parleys Canyon and along Highway 248 to Park City
	208	Jurassic	Preuss Sandstone Twin Creek Limestone Nugget Sandstone	Lakes, streams dinosaurs Shallow marine seas Massive sand dune field	Rocks at mouth of Parleys Canyon
	245	Triassic	Ankareh Formation Thaynes Formation *Woodside Shale	Marine waters	
PALEOZOIC	290	Permian	*Park City Formation	Oquirrh basin	Ore-bearing sediments of Park City mining district
	320	Pennsylvanian	Weber Quartzite *Round Valley Limestone	Oquirrh basin	
	360	Mississippian	*Doughnut Formation Humbug Formation *Deseret Limestone *Gardison Limestone *Fitchville Formation	Oquirrh basin begins to form	
	408	Devonian			Rocks from these periods are not found along the course of the log
	438	Silurian			
	505	Ordovician			
	570	Cambrian	*Maxfield Limestone *Ophir Formation *Tintic Quartzite		
		Precambrian	*Mutual Formation *Mineral Fork Tillite Big Cottonwood Fm *Little Willow Fm		Rocks at Storm Mountain and lower portion of Big Cottonwood Canyon

**Formations not mentioned in road log text.*

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