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Geologic Guide to the Central Wasatch Front Canyons

Salt Lake County, Utah

Contents

Introduction

Striking beauty, abundant recreational opportunities, historic mining and pioneer locales, and a unique geologic story stretching back over one billion years make Salt Lake County's Wasatch Front canyons a world-class attraction.

This guide highlights the six canyons open to vehicles. Topical pages present the region's fascinating geologic history and active processes, while descriptions and maps with road mileage further explain each canyon's geology.

Enjoy your tours.

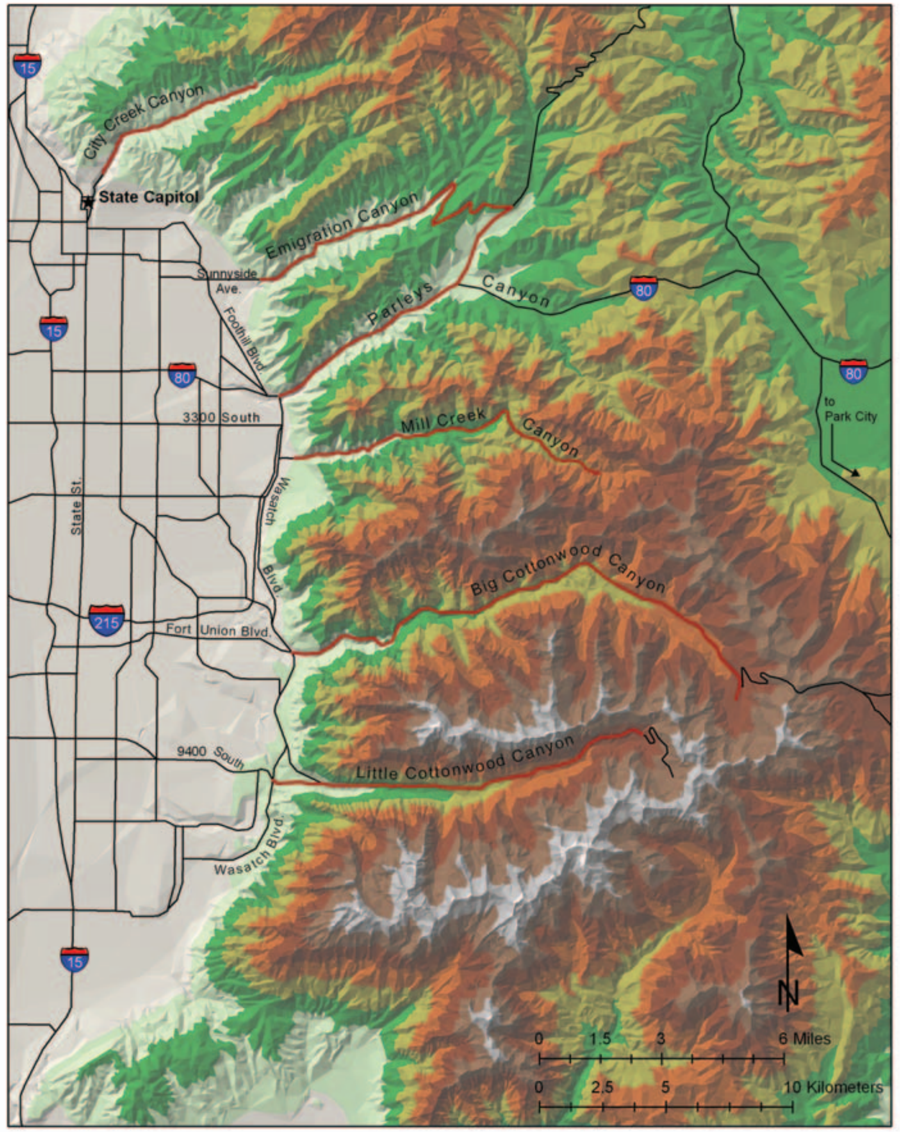
William F. Case – Emigration, Parleys, and Mill Creek Canyons
Sandra N. Eldredge – Big Cottonwood Canyon
Mark R. Milligan – City Creek Canyon
Christine Wilkerson – Little Cottonwood Canyon

Driving conditions to be aware of include narrow roads combined with heavy bicycle traffic in City Creek, Emigration, and Mill Creek Canyons; and high-speed highway traffic in Parleys Canyon.

No dogs are allowed in Big Cottonwood, Little Cottonwood, and upper City Creek Canyons because the areas are culinary watersheds.

For other regulations regarding recreation:
Contact the Salt Lake Ranger District of the Wasatch-Cache National Forest for Mill Creek, Big Cottonwood, and Little Cottonwood Canyons.
Contact the Salt Lake City Department of Public Utilities for City Creek Canyon.

Overview Map



Geologic tours highlighted in red.

(Elevation model created by Dan Smith; additional roads and labels created by Lucas Shaw.)

Geological Story

The central Wasatch Range displays over 1 billion years of Earth history during which oceans repeatedly came and went; mountains rose and wore down and rose again; sand dunes migrated across the lands; and rivers, glaciers, and lakes appeared and disappeared. Although there are some gaps in the rock record (called unconformities) resulting from erosion or no sediment deposition, the canyons in this part of the range display world-class exposures that, together with regional geologic information, provide an excellent outline of the area's geologic past.

The oldest rocks in this guide are **Precambrian**-age metamorphic schist and gneiss of the Little Willow Formation found at the mouth of Little Cottonwood Canyon. These rocks were metamorphosed some 1.6+ billion years ago by intense pressure and heat deep in the Earth's crust.

1 bya – 850 mya

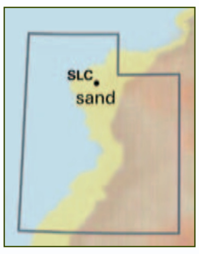
The next oldest rocks suggest an ocean shoreline extended across this area beginning about 1 billion years ago (bya). For over 100 million years, tides and associated shoreline processes deposited layer upon layer of sand and clay that are now exposed as quartzite and shale of the Big Cottonwood Formation.

850 – 800 mya

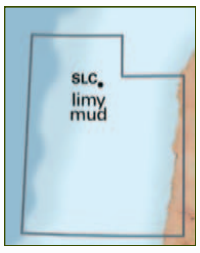
Approximately 850 million years ago (mya), continental glaciers abutted the ocean shore, revealed by the Mineral Fork Tillite found in Big and Little Cottonwood Canyons.

600 – 570 mya

Braided river plains are recorded next by the shale and sandstone of the Mutual Formation.

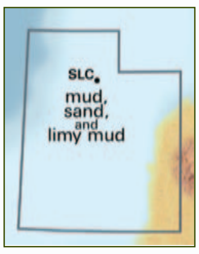


540 – 535 mya



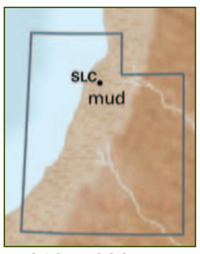
535 – 525 mya

About 540 million years ago (**Cambrian Period**), abundant sand was deposited on beaches and in the shallow water along the margins of an eastward-encroaching ocean, forming the Tintic Quartzite. As the sea moved farther eastward, this area was under deeper water where mud and silt collected - now preserved as the Ophir Shale. When adjacent land to the east supplied little sediment, chemical reactions between ocean water and biological activity precipitated limy mud that is now the Maxfield Limestone.



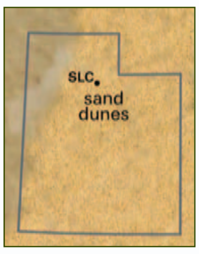
365 – 250 mya

The Cambrian sea retreated as the land rose and an unconformity skips our story ahead about 160 million years to the **Devonian, Mississippian, Pennsylvanian,** and **Permian Periods** when an ocean once again covered the area. Fluctuating sea level and sediment input resulted in deposition of a variety of rock types, including limestone, sandstone, and shale (see *Descriptions of Map Units* for formation names).



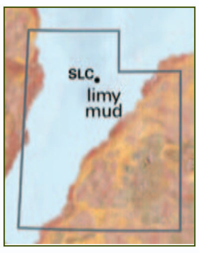
248 – 220 mya

Once more the sea retreated, and **Triassic**-age red rocks of the Woodside Shale tell of tidal mud flats that were later flooded by deeper ocean water in which limy mud of the Thaynes Formation was deposited. The Thaynes sea retreated after a few million years and river flood plains dominated the landscape (Ankareh Formation).



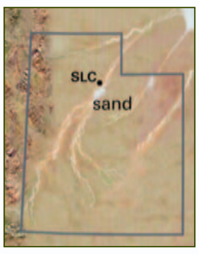
200 – 190 mya

During the **Jurassic Period**, sand dunes of the Nugget Sandstone document a sea of a different kind. Similar to the dune areas of the modern Sahara, this ancient sand sea extended through southern Utah where it is preserved as the Nugget's equivalent – the famous Navajo Sandstone exposed in national parks such as Zion and Capitol Reef.



164 and 105 – 100 mya

Another shallow sea then extended into central Utah from the north and flooded the wind-blown sands. In this area, the Twin Creek Limestone was deposited in the western part of this sea. The marine waters withdrew and would not flood western Utah again. Following this retreat, rivers deposited the sand and gravel that forms the Preuss Sandstone.



187 – 164 mya

Beginning about 105 million years ago, **Cretaceous** rivers flowed northeastward and deposited sediments across a broad coastal plain. These sediments comprise the conglomerate, sandstone, and siltstone of the Kelvin Formation and, where lakes existed, limestone of the Parleys Member.

No rocks are preserved in the area dating from about 120 million to 50 million years ago. During this time, a mountain-building event called the Sevier Orogeny changed the landscape. Regional-scale plate motions compressed the Earth's crust in an east-west direction causing the canyons' rock units to tilt, fold, and move along faults from their original horizontal positions to near their current variety of angles and contortions.

40 – 30 mya

By the end of the Sevier Orogeny, during the **Tertiary Period**, compression had greatly thickened the crust. The deeply buried masses of crustal rock were heated and melted. The resulting magma then began to rise toward the surface concurrently with a shift from crustal compression to crustal extension. Between 40 and 30 million years ago, some molten rock spewed out of volcanoes (demonstrated by the volcanic breccia in City Creek Canyon) and some cooled and hardened beneath the surface (intrusive igneous rocks). Today, granitic intrusive rocks form some of the high peaks in Big Cottonwood Canyon and canyon walls of much of Little Cottonwood Canyon.

12 mya – 10,000 yrs ago

Crustal extension is still ongoing, from the Wasatch fault westward 400 miles to the Sierra Nevada, and is responsible for creating the Wasatch Range. About 17 million years ago, these mountains started rising along the eastern side of the fault while the adjacent Salt Lake Valley started dropping. This vertical movement along the fault created much of the local landscapes we now see. Lake Bonneville in the valleys and glaciers in the mountains further modified the landscape 30,000 to roughly 10,000 years ago during the **Quaternary Period**.

The geologic story continues in these mountains today as earthquakes cause them to rise, while landslides, debris flows, and streams erode them down.

Lake Bonneville was a huge freshwater lake that existed from approximately 28,000 to 10,000 years ago and covered about 20,000 square miles of western Utah and smaller parts of eastern Nevada and southern Idaho. A shift to a wetter and colder climate triggered its expansion from the location of the present Great Salt Lake to surrounding valleys, reaching a depth of over 1,050 feet. While at its highest level, the lake eroded through a sediment dam at Red Rock Pass in Idaho and catastrophically dropped over 300 feet. Thereafter, a climatic shift to warmer and drier conditions (similar to present) caused Lake Bonneville to shrink, leaving Great Salt Lake as a saline remnant.

The shorelines left by Lake Bonneville can be seen around Salt Lake Valley like rings around a bathtub. These shorelines are both erosional where wave action carved into rock and sediment, and depositional where sediments collected in beaches, spits, bars, and deltas.

Lake Bonneville at its largest extent approximately 15,000 years ago. White areas show glaciers.

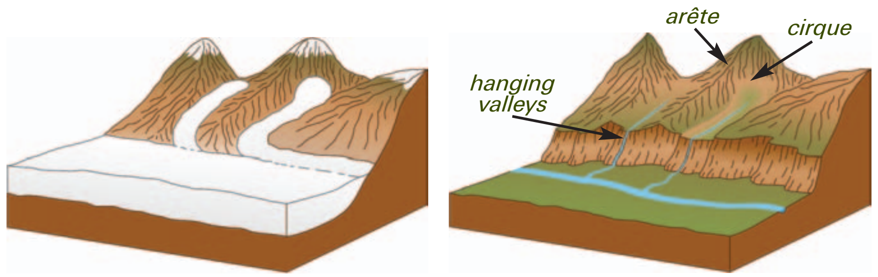
Deltas were created where streams flowing down Wasatch Front canyons entered the standing water of Lake Bonneville and then dropped their sediment load. As the lake began to shrink and lake level dropped, streams cut across and through these deltas and redeposited their sediments farther basinward. However, remnants of these deltas can be seen at the mouths of Parleys, Big Cottonwood, and Little Cottonwood Canyons.

Glaciers covered parts of the Wasatch Range during the most recent Ice Age when the climate was colder and wetter than today. These glaciers were at their maximum about 24,000 to 18,000 years ago and dramatically reshaped the higher reaches of Big Cottonwood and Mill Creek Canyons, as well as the entire length of Little Cottonwood Canyon. The other canyons in this guide (City Creek, Emigration, and Parleys) were not glaciated due to their lower elevations and lesser snow accumulation.

Glaciers are moving masses of ice and snow that form when enough snow accumulates to compress the lower layers into ice. Gravity forces the thick, heavy ice to slowly flow downslope.

These powerful erosion machines pluck, scrape, and grind rocks from the canyon walls and floors. At their heads, they carve out crescent-shaped rock basins bounded by high, steep walls (**cirques**). Where two glaciers in adjacent valleys erode both sides of the intervening divide, they form a knife-edged ridge (**arête**). These features are visible in Big and Little Cottonwood Canyons. The moving masses of ice and rock debris scour the valley bottom and walls, leaving striated, grooved, and polished rock in their wake.

The plowing glaciers deepen and widen the typical "V-shaped" stream valleys (see photo on Mill Creek Canyon map) into wide **U-shaped valleys** (see photo on Little Cottonwood Canyon map). The U-shape is visible throughout all of Little Cottonwood Canyon and the upper part of Big Cottonwood Canyon. Some tributary canyons end up "hanging" (**hanging valleys**) above the deeply scoured main canyon. Waterfalls now cascade over these hanging valleys on the south side of Little Cottonwood Canyon.



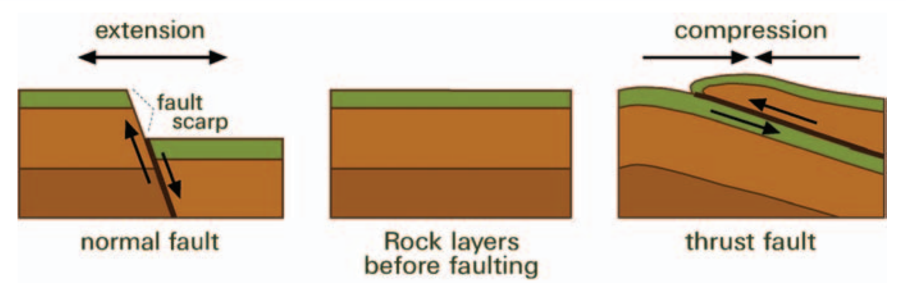
Glaciers transport a chaotic mix of huge boulders, rocks, and fine sediment (called **glacial till**) that is deposited along the sides (**lateral moraines**) and at the ends (**terminal moraines**) of glaciers where melting occurs. Moraines are present in the three glaciated canyons.

Glacial erratics are the isolated rocks and boulders carried by glacial ice down from the higher reaches of the canyons. Erratics are often striking contrasts to the material they are resting on, and are evident at the mouth of Little Cottonwood Canyon and in parts of Big Cottonwood Canyon.

Glacial erratics at the mouth of Little Cottonwood Canyon, north side.

Faults

A fault is a break in the Earth's crust along which slippage or displacement has occurred. Abrupt movement along the fault causes earthquakes. Two types of faults are common in Utah: normal and thrust faults. Of these, many of the normal faults are younger (have moved more recently) and it is the youngest ones – called active faults – that are of most concern for generating future earthquakes.



Normal Fault

A normal fault results from extensional forces that pull the crust apart. The movement is predominantly vertical; one side moves upward relative to the other moving downward.

The best known normal fault in Utah is the **Wasatch fault**, which crosses or passes near the mouths of the Wasatch Front canyons. The Wasatch fault, along with many other normal faults in Utah, is capable of generating earthquakes as large as magnitude 7.5.

The Wasatch fault is 240 miles long; most of it traces along the western base of the Wasatch Range. For 17 million years this fault has been active, creating **fault scarps** when large (magnitude 6.5 and greater) earthquakes rupture the ground surface.

The Wasatch fault scarps are best seen at the mouth of Little Cottonwood Canyon (see photo on canyon description).

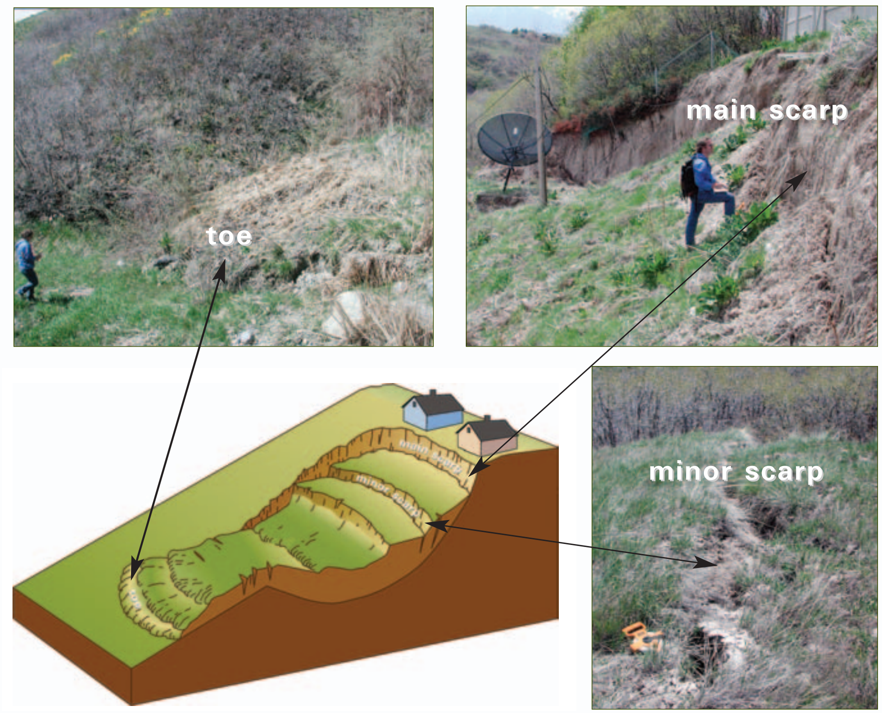
Thrust Fault

A thrust fault results from compressional forces that shorten and thicken the crust. The movement is predominantly horizontal; older rock units may be pushed many miles up and over younger rock units.

A local example is the **Mt. Raymond thrust fault** that trends through Big Cottonwood and Mill Creek Canyons. About 85 million years ago, layers of rocks from the northwest were pushed tens of miles along the thrust plane and now lie atop younger rock layers.

Landslides

Landslides are the downslope movement of a mass of soil and rock, occurring when gravitational forces exceed the strength of materials in a slope. Thus, they are most likely to occur on or near steep slopes and in weak geologic materials. The addition of water in such areas can trigger landslides. All of the canyons in this booklet contain potential landslide conditions, and most show geologic evidence of prehistoric landslides. Historical landslides have occurred in City Creek, Emigration, Parleys, and Mill Creek Canyons (many are too small to show on the maps). At least one landslide in City Creek Canyon was active at the time (2004) of writing this guide.



Landslide at mile 0.7 on Bonneville Blvd. in City Creek Canyon. Photos taken May 2002.

Landslides can be triggered by:

- rising ground-water levels due to heavy rainfall, rapid snowmelt, consecutive wet years, agricultural or landscape irrigation, roof downspout flow, septic-tank effluent, canal or sewer-line leakage.
- earthquakes.
- grading or erosion that removes material from the base, loads the top, or otherwise alters a landslide or pre-existing slope.

Prospectors searching for riches have scrambled throughout the canyons and mountains along the Wasatch Front for over a hundred years. The richest mineralization is in Big and Little Cottonwood Canyons due to the heat of igneous intrusions that drove mineral-rich fluids and created ore deposits.

Big and Little Cottonwood Canyons

Although silver-lead ore was first discovered along the Wasatch Front in Little Cottonwood Canyon in 1864, major mining in the canyon did not begin until 1868 with the discovery of rich ore at the Emma mine, located north of Alta. Soon after, prospectors spread northward into Big Cottonwood Canyon. Mining in these two canyons produced mostly silver and lead with minor quantities of copper, zinc, and gold. Both areas prospered in the late 1800s and early 1900s, and mining continued in the canyons until the 1960s.

Alta, the largest mining town in Little Cottonwood Canyon, flourished in the 1870s and had thousands of inhabitants, twenty-six saloons, seven restaurants, two drug stores, and even a Chinese laundry. The former town of Argenta, located midway up Big Cottonwood Canyon, was that canyon's major mining town and had up to 200 inhabitants.

Mouth of Little Cottonwood Canyon (Little Willow area)

Claims were staked north of the mouth of Little Cottonwood Canyon (Little Willow area) as early as 1870 and farmers were rumored to have found gold nuggets in streams, but not until the 1890s did this area experience increased activity by prospectors. Minor gold deposits were discovered, but no major ore bodies were ever found, even though thousands of feet of tunnels and shafts were dug. Minor sporadic gold production continued until 1946.

Mill Creek Canyon

Although recorded as being part of the Big Cottonwood mining area, a few prospects and mines were located on the Mill Creek Canyon side of the ridge line between the two canyons. These small prospects yielded some lead and silver, and one report indicated some gold and copper.

City Creek Canyon

Most of the mining activity in City Creek Canyon took place between 1870 and 1880 in the upper part of the canyon, and extended over the ridge into Davis County. Small quantities of lead and iron were produced with minor amounts of silver, gold, copper, and zinc.

Stone from canyons along the Wasatch Front has been used for construction since the onset of pioneer settlement in 1847, probably beginning with cobbles gathered from City Creek Canyon to build stone walls.

Emigration Canyon

During the mid-1800s through the early 1900s, numerous buildings in Salt Lake City were constructed using Nugget Sandstone from several quarries located within the Wasatch Range. In upper Emigration Canyon, blocks of both white- and red-colored Nugget Sandstone were quarried at the Brigham Fork Quarry. Wagons hauled the stone out initially, until the electric Emigration Canyon Railroad was built in 1907. A decade later concrete had become the desired foundation material and the railroad was dismantled.

Stone (possibly Nugget Sandstone) being transported by Emigration Canyon Railway Company to the Salt Lake Valley, July 1901. Photo courtesy of the Utah Historical Society.

Parleys Canyon

Excavation of the Twin Creek Limestone from the rock quarries located along the north side of Interstate 15 in Parleys Canyon began in the late

1800s for use in cement. Today, the stone is used as landscape rock and as crushed stone for road work and construction backfill. Small amounts of Nugget Sandstone were also quarried from the Pharaohs Glen Quarry on the south side of Parleys Canyon (see Parleys Canyon map).

Portland Cement Company quarry excavation site in Parleys Canyon, 1912. Photo courtesy of Utah Historical Society.

Little Cottonwood Canyon

The Temple Quarry, located at the mouth of Little Cottonwood Canyon, was established in 1861 to excavate quartz monzonite, a granite-like rock, to build the Salt Lake LDS* Temple. Working in pairs, skilled workmen equipped with a sledgehammer and a hand-held drill bit cut the stone from enormous boulders at the canyon's base. At first hauled to the city by ox teams, the blocks later traveled by rail cars after completion of a railroad track to the quarry in 1873. Several other buildings in Salt Lake City were also built of this stone, including Utah's Capitol (1913-15) and more recently the LDS Conference Center (1997-2000). The stone for this new construction was quarried from loose boulders farther up the canyon.

*Church of Jesus Christ of Latter-Day Saints

IGNEOUS ROCKS	SEDIMENTARY ROCKS		METAMORPHIC ROCKS
form from hot magma that solidifies on (extrusive) or within (intrusive) the Earth's crust.	are accumulated and consolidated sediments.		form from pre-existing rocks that have been altered by heat, pressure, and/or chemical reactions at depth.
	Rocks that form from eroded rock fragments are called **Clastic**	Rocks that form from minerals precipitated in water are called **Chemical**	
Quartz Monzonite (intrusive, granitic) contains large mineral crystals of mostly clear (quartz), white (feldspar), and black (biotite) colors. The light-gray rock, with fist- and larger-size dark-gray inclusions of fine-grained hornblende, is found in Little Cottonwood Canyon.	**Conglomerate** contains rounded, pebble- to larger-size rock fragments. Red, white, and brown conglomerate is found in Emigration & Parleys Canyons.	**Limestone** is composed mostly of calcium carbonate. Gray to white limestone layers are found in all the canyons.	**Quartzite** is metamorphosed quartz-rich sandstone. White, red, and brown quartzite is found in Mill Creek, Big & Little Cottonwood Canyons.
Granodiorite (intrusive, granitic) contains medium to large mineral crystals of clear (quartz), gray (feldspar), white (feldspar), and black (biotite and hornblende) colors. The light- to dark-gray rock is found in Big & Little Cottonwood Canyons.	**Tillite** contains a chaotic mix of rock fragments cemented in a black, sandy matrix in Big & Little Cottonwood Canyons.	**Dolomite** is similar to limestone except that it has less calcium and more magnesium. Gray and white dolomite is found in Little Cottonwood Canyon.	**Marble** is a metamorphosed limestone or dolomite that looks like melted sugar or has very large shiny crystals. White to light gray marble is found in Big & Little Cottonwood Canyons.
Diorite (intrusive) is red- to dark-colored in dikes and sills in Big Cottonwood Canyon. Minerals include dark-colored hornblende.	**Sandstone** consists of mostly sand-size quartz particles. Brown and red sandstone is found in Emigration & Parleys Canyons.		**Argillite** is a slightly metamorphosed mudstone or shale. Fine-grained red, purple, and black argillite is found in Big Cottonwood Canyon.
Volcanic Breccia contains angular particles of volcanic (extrusive, andesitic) rock up to 16 inches in diameter in a fine-grained matrix. The light gray to dark purplish gray rock is in City Creek Canyon.	**Siltstone** is fine (silt-size) grained. Red and brown siltstone is found in Emigration & Parleys Canyons.		**Slate** is highly metamorphosed shale that is very fine grained and can easily be split into thin sheets. Black slate is found in Big Cottonwood Canyon.
	Shale, which splits into thin layers, is formed from clay or mud and is fine grained. Red shale is found in Mill Creek Canyon. Purple, green, gray, and black shale layers are found in Big Cottonwood Canyon.		**Gneiss** is a coarse-textured rock made up of alternating layers of light and dark minerals. Brown to gray-weathering gneiss is found in Little Cottonwood Canyon.
			Schist is medium to coarse textured and consists of large mica crystals. Brown to gray weathering schist is found in Little Cottonwood Canyon.

(open to motor vehicles on holidays and even-numbered days from late May to late September; open to pedestrians all year)

City Creek Canyon is the northernmost canyon in Salt Lake County and the closest to downtown Salt Lake City. Due to this proximity, City Creek heavily influenced the development of Utah's capitol city. City Creek provided water for drinking, crop irrigation, and power to run grist, saw, turning, cording, and woolen mills. To this day, City Creek supplies water to Salt Lake City. However, with the water come geologic hazards such as floods, debris flows, and landslides. In 1983 for example, the creek flooded its banks in Memory Grove Park and thousands of volunteers slung sandbags along State Street to channel the racing water.

View from City Creek south towards downtown.

Three roads are located in City Creek Canyon. Bonneville Boulevard is a one-way road that wraps around the lower canyon from 11th Avenue on the east to 500 North on the west. Canyon Road parallels the lowermost reaches of City Creek and is closed to motor vehicles. City Creek Canyon Road follows the creek upstream of the intersection with Bonneville Boulevard.

In the lower part of the canyon are three debris catchment basins designed to prevent debris flows from reaching downtown. Upstream at mile 3.0 on City Creek Canyon Road, a good example of a prehistoric debris-flow deposit can be seen.

Along Bonneville Boulevard you can see at least two active landslides (miles 0.5 and 0.6), outcrops of both fine- and coarse-grained Lake Bonneville sediments (miles 0.4 and 1.0, respectively), and the remains of an ancient debris flow of volcanic (andesitic) rock and mud (mile 0.9). This volcanic rock came from a volcano that violently erupted some 35 to 39 million years ago, probably in the vicinity of either Little Cottonwood Canyon, Park City (about 25 miles southeast), or Bingham Canyon (about 25 miles southwest).

Upstream of Bonneville Boulevard at mile 1.2 on City Creek Canyon Road, the canyon topography changes from relatively narrow and steep to broad and more rolling. This change reflects a transition of the bedrock from conglomerate that can stand as steep slopes, to weathered volcanic rock (similar to that seen at mile 0.9 on Bonneville Boulevard) that is unstable on steep slopes and has formed a large landslide. This prehistoric landslide appears to have crossed the creek and may have temporarily dammed it. Landslide dams are unstable and can fail catastrophically, releasing a flood of water.

A second major change in the canyon is found at mile 4.5 where the road crosses the presumably inactive Rudy's Flat fault, transitioning from the near-horizontally bedded, less than 40-million-year-old conglomerate to near-vertical, 300- to 400-million-year-old limestone beds that form large fins. This limestone was originally deposited in horizontal layers in an ancient ocean and later tilted to near vertical during the Sevier mountain-building event.

City Creek flood water channeled down State Street in 1983. Wooden vehicle and pedestrian walkways were built over the new "river" that persisted for several weeks. Under normal conditions, City Creek water flows in a culvert beneath the city. Photo courtesy of Utah Historical Society.

This Is The Place Heritage Park is situated on the north side of Sunnyside Avenue near the mouth of Emigration Canyon to commemorate pioneer emigration. It is a fitting start to the Emigration and Parleys (named after Mormon pioneer Parley Pratt) Canyons geologic road log. The route climbs up Emigration Canyon Road to Little Mountain Summit, descends to SR-65 and I-80, and ends at the mouth of Parleys Canyon.

The roads pass through sedimentary rocks of Triassic, Jurassic, and Cretaceous ages. Much of the route is in the Jurassic Twin Creek Limestone, which includes oolitic, sandy, silty, fossiliferous, massive, and/or shaley (some intensely shattered) limestone. The formation also consists of small amounts of red siltstone and shale. The red shale at mile 0.9 may be a remnant of an ancient soil or erosion surface.

The next unit encountered in Emigration Canyon is the Jurassic Preuss Sandstone, which consists of chocolate-brown sandstone and fine-grained brown and white conglomerate. In places near Little Mountain Summit, the river-deposited sandstone shows cross-beds and drag-marks made by driftwood or other objects.

The white limestone portion of the Cretaceous Kelvin Formation, which was probably deposited in shallow lakes near a source of sand and fine-grained gravel, locally contains scattered black pebbles.

The Triassic Ankareh Formation can be seen at the mouth of Parleys Canyon where the red and white rock layers are steeply tilted on the southeast flank of the Parleys Canyon syncline. The red rocks on the north side of the canyon mouth contain mud cracks and small ripple marks, which were created by shallow water that gently lapped back and forth across a mud flat that occasionally dried up. The large ripple marks on the white quartz conglomerate indicate energetic currents in stream channels.

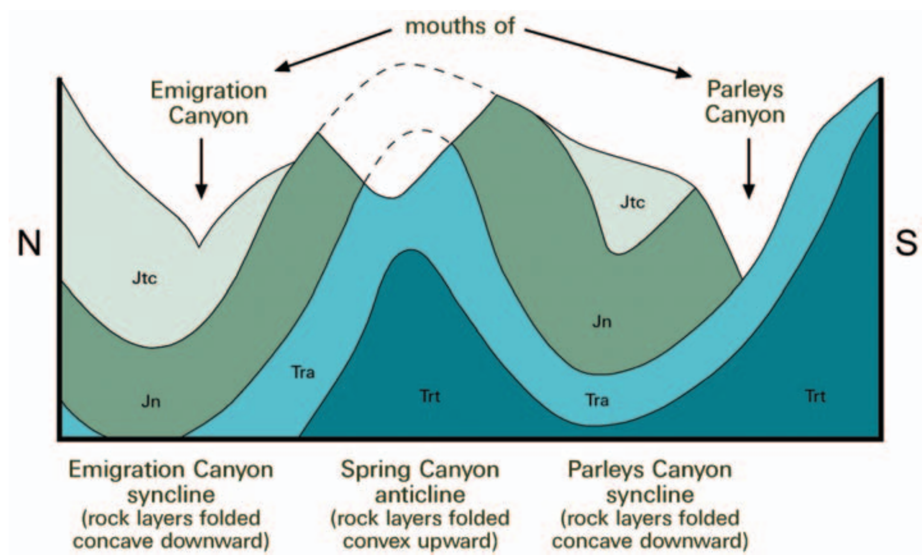
The rocks of Emigration and Parleys Canyons are folded into northeast-trending troughs (Emigration and Parleys Canyons synclines) on either side of a folded ridge (Spring Canyon anticline). The rocks were gently to intensely folded and faulted during the Sevier Orogeny 120 to 50 million years ago in this area.

Pioneer history

Emigration and Parleys Canyons have provided access to the Salt Lake Valley since pioneer times in the mid 1800s. In 1846, the Donner Party carved their way through Emigration Canyon on their way to California. To clear the canyon's trees and brush for the wagon passage required so much work that by the time the party reached the narrow, highly thicketed gorge at the canyon mouth they were so frustrated that, in desperation, they pulled the wagons over a ridge to bypass the gorge. The Donner Hill monument (mile 0.7) commemorates this effort.

In 1847, Mormon pioneers followed the Donner Party trail but cleared a way through the thicket instead of going over Donner Hill. Trail markers show the "Pioneer Trail" from Little Dell Reservoir, across Little Mountain Summit and into Emigration Canyon.

Wagons were unable to pass through Parleys Canyon until 1850 when Parley Pratt cleared the last three miles through a deep, winding gorge with a rough bottom. Stagecoaches began to use the canyon in 1858 and the Pony Express in 1860, but the services were dropped by 1869 when the Transcontinental Railroad was completed.



See page 23 for description of map units.

(a vehicle fee is charged to drive in the canyon)

Mill Creek Canyon contains Mississippian- to Triassic-age marine and shoreline marine rocks and Jurassic-age sand-dune rocks. The following descriptions begin with the oldest rocks.

The oldest rocks in Mill Creek Canyon are visible from the road only by looking through the trees toward the south ridge skyline. These rocks are part of the Mississippian- and Pennsylvanian-age formations including Deseret and Round Valley Limestones and Humbug and Doughnut Formations, and are combined into one unit on the map.

The Pennsylvanian Weber Quartzite, originally a sandy marine beach, is common in the canyon particularly at its western end and mouth. Locally, the brown quartzite was dramatically folded and crushed by thrust faulting during the Sevier Orogeny about 85 million years ago.

The Permian Park City Formation is a dark gray limestone that contains fossil shells (brachiopods) in Rattlesnake Gulch at mile 0.7. The best exposure of the Park City Formation is in a road cut at mile 4.8, near the White Bridge Picnic Area.

The Triassic Woodside Shale is a reddish siltstone and fine-grained sandstone deposited in layers up to several inches thick. The Woodside Shale is exposed in road cuts partly covered by vegetation near mile 6.8 and the Clover Springs Picnic Area.

The Triassic Thaynes Formation contains abundant marine fossils such as corals, shells, and other marine animal parts on trails north of Camp Tracy scout camp. The most visible feature of this gray limestone is a massive limestone ridge that juts above vegetation on the north side of the canyon. The massive limestone meets the road at mile 5.5 where the road makes a sharp turn to the southeast.

The Triassic Ankareh Formation and Jurassic Nugget Sandstone are the youngest bedrock units in this canyon. They are seen near the northern-most ridge skyline of the canyon, and red Nugget Sandstone boulders are in debris-flow gravel near mile 4.8.

During the recent Ice Age, glaciers carved some of the upper Mill Creek tributaries and deposited moraines, such as the one seen at mile 7.1. Glaciers did not flow down the main canyon, thus, the canyon maintains the characteristic "V-shape" caused by stream erosion (see photo on map).

Mill Creek near Fir Creek Picnic Area.

(Geologic signs are in place in Big Cottonwood Canyon. These signs are marked on the map and provide good stops to get out of your car. Beware of rock falls, especially between miles 4.3 and 6.0 where you should not stop along the road.)

This tour begins 1 billion years ago when the area was a tidal environment at an ocean shoreline. The tidal environment is preserved in the now-tilted layers of quartzite and shale that make up the canyon walls for the first 6 miles. In some areas, the shale is metamorphosed into argillite or slate. Traveling farther up the canyon, you progress through times when different ancient seas covered the area; the sediments left on the ocean shore and floors are now the 600- to 100-million-year-old sandstone (and quartzite), shale, and limestone. Fingers of magma intruded up through these rocks about 70 million years ago, and can be seen between miles 7.3 and 8.3 where the red- to dark-colored intrusions contrast with the white limestone and marble. These intrusions are called dikes when they cut perpendicular through the limestone/marble layers or sills when they parallel the bedding.

The head of the canyon reveals 35-million-year-old igneous activity where a large body of magma intruded into the surrounding rock and, while beneath the Earth's surface, then cooled and hardened into a gray granitic rock called granodiorite. Millions of years later, after the overlying softer sedimentary rocks eroded, the granodiorite was exposed and now makes up the peaks surrounding Brighton.

About 30,000 to 8,000 years ago, Brighton was buried under hundreds of feet of glacial ice. The main glacier flowed down the canyon 5 miles where it abruptly ended at Reynolds Flat (mile 9.0). At this point you can see an obvious difference in topography: a narrow, twisting canyon below Reynolds Flat and an open, straight canyon above. This illustrates a classic example of a river-carved "V-shaped" canyon (below Reynolds Flat) and a glacier-carved "U-shaped" canyon.

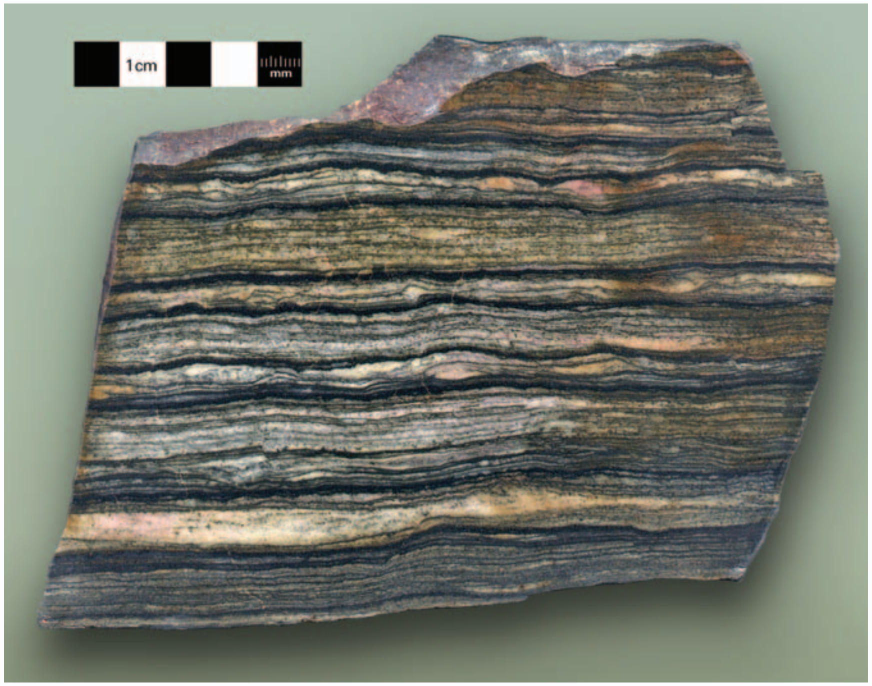
Tidal Rhythmites

One-billion-year-old records of the rhythm of ancient ocean tides

One of the best documented and oldest known records worldwide of tidal rhythmites is in Big Cottonwood Canyon. Discovered in the 1990s, this record is enthusiastically being researched, in large part to provide clues to ancient lunar cycles. Yearly, monthly, and even daily and semi-daily tides are recorded in the black shale of the 850-million to 1-billion-year-old Big Cottonwood Formation. Within the shale are thin, alternating layers of light-colored sand and dark-colored silt and clay. The sand was carried by peak (strong, dominant) flows and the silt and clay by slack (weaker, subordinate) waters at changing tides. Thus, these thin individual bands record daily tides and can be counted much like we count tree rings.

Because the gravitational pull of the moon and the sun cause tides, the length of an ancient day and lunar month can be determined from these tidal rhythmites. Long ago, the moon took less time to orbit the Earth, the Earth was spinning faster, and thus the days were shorter and there were more of them in a year. These records in stone indicate that one billion years ago, a day on Earth lasted only 18 hours, there were 13-plus months in a year, and about 481 days in a year!

(Information supplied by Marjorie A. Chan, University of Utah and Allen W. Archer, Kansas State University).



Multiple light (sand) and dark (silt and clay) bands in this piece of shale from the Big Cottonwood Formation indicate the varying energy of rising and falling tides. Photo courtesy of Marjorie A. Chan, Dept. of Geology & Geophysics, University of Utah.

This road tour begins at a Salt Lake County geologic view park, located just north of the intersection of Wasatch Boulevard and Little Cottonwood Road. From here you can view evidence of prospectors seeking riches, glaciers creeping down the canyon, and earthquakes rupturing the ground.

North of the canyon mouth are mine dumps located in the oldest rocks ($\geq$ 1.6 billion years) in the canyon: the schist and gneiss of the Little Willow Formation. Prospectors mined minor gold deposits within this formation.

A massive glacier carved the canyon into its classic U-shape over thousands of years beginning about 30,000 years ago. This 12-mile-long glacier, the longest and largest in the Wasatch Range, stretched from Albion Basin down to Lake Bonneville's shores. The boulder-strewn ridge on the south of the canyon mouth is the left-lateral moraine; the right-lateral moraine is pushed up against the hillside on the north. As you drive up the canyon, additional glacial evidence can be seen: hanging valleys between miles 4.6 and 6.3 on the south side of the canyon, and moraine remnants.

Repeated large earthquakes in the past tens of thousands of years created the long, steep slope cutting across the canyon mouth. In this area, the Wasatch fault contains some of the largest geologically recent fault scarps in Utah.

The darker rocks at the mouth of the canyon, together with the darker (shale) and lighter brown (quartzite) rock layers along most of the northern ridge line up to Snowbird, were deposited as clay and sand in a

View of north side of canyon from Snowbird Ski Resort shows the contact between the Precambrian Big Cottonwood Formation above the quartz monzonite (granite) of the Little Cottonwood Stock.

(not completed at press time, 2005)

The Wasatch fault cuts across the canyon mouth and splays into multiple fault traces that slice through the moraine left by the Little Cottonwood glacier. This fault is capable of producing large earthquakes at any time.

marine tidal environment 1 billion to 850 million years ago. Unconformably abutting these oceanic deposits (near mile 8.6) is a dark-colored rock unit called glacial till that contains a hodgepodge of boulders, cobbles, and pebbles abandoned by continental glaciers around 850 million years ago. The light-colored quartz monzonite (granite) that forms the majority of the canyon walls intruded as magma and hardened underground about 31 to 30 million years ago.

The buff-colored quartzite, brown shale, and black and white limestone seen in the upper third of the canyon record the advances and retreats of multiple, long-lasting oceans present between 540 and 330 million years ago. Originally layered horizontally from oldest to youngest, these rock layers have been disarrayed by folding, tilting, and faulting.

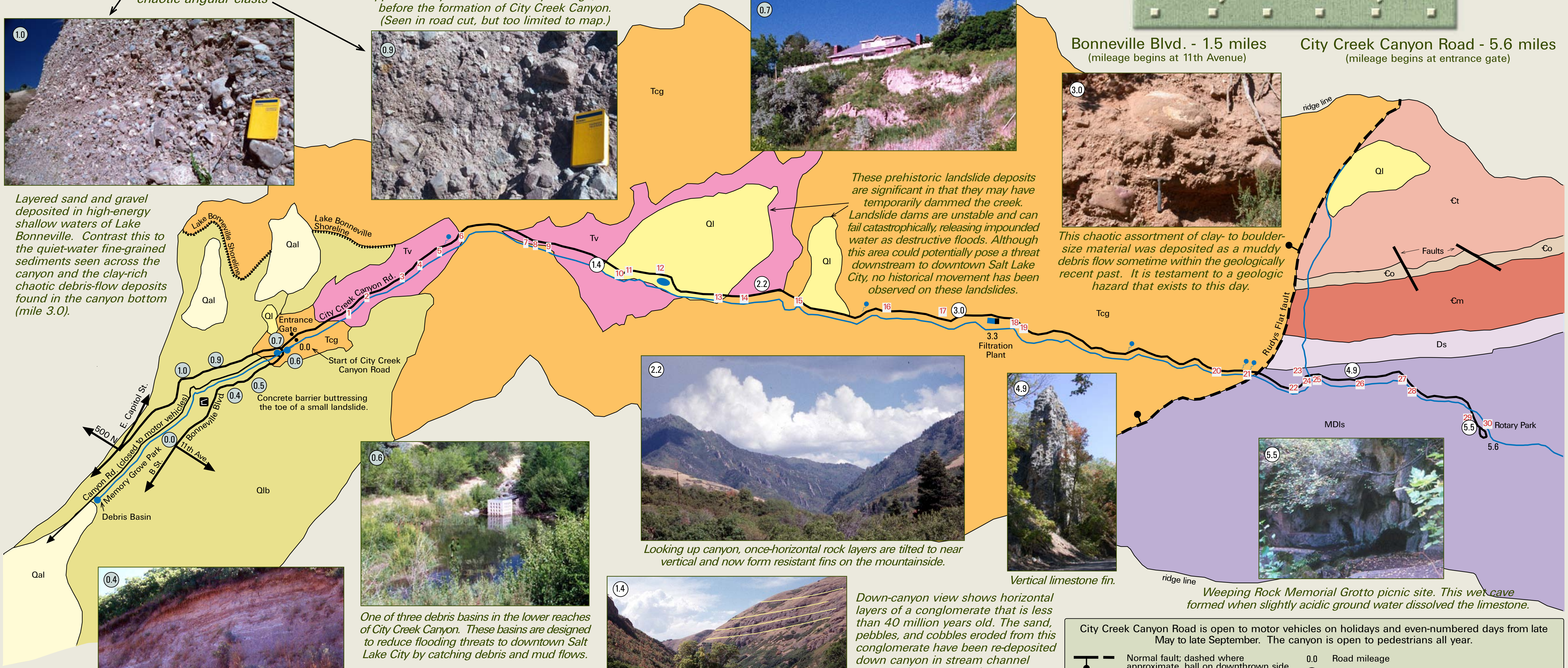
Located at the head and along the eastern ridge line of the canyon is another intrusive igneous rock. This magma body intruded about 35 to 33 million years ago and hardened into a granite-like rock called granodiorite. Both intrusives in this canyon aided in creating the rich mineralization found in Little Cottonwood mines. Numerous mine dumps dot the mountainsides surrounding Alta, evoking images of the once-lively mining district.

Map Symbols	Description
Qal	**Alluvium** - Includes gravel, sand, silt, and clay deposited in stream channels, terraces, flood plains, and alluvial fans. Locally includes wind-blown silt and sand near City Creek Canyon.
Qt	**Talus** - Loose, angular rock debris deposited at the base of steep slopes.
Ql	**Landslide** - Masses of soil and rock that have moved downslope.
Qg	**Glacial Deposits** - Silt, sand, gravel, cobbles, and boulders deposited by glaciers (8,000 to 30,000 years old).
Qlb	**Lake Bonneville** - Gravel, sand, silt, and clay deposited in Lake Bonneville (12,000 to 30,000 years old).
Tqm	**Quartz Monzonite** - Intrusive igneous rock, granite-like, light gray (30-31 million years old). Little Cottonwood stock.
Ti	**Granodiorite** - Intrusive igneous rock, granite-like, light to dark gray (33-36 million years old). Alta and Clayton stocks.
Tcg	**Conglomerate** - Rounded pebbles and cobbles of gray limestone, tan quartzite, and pieces of older conglomerate in a sandy matrix. Pale-brown to medium gray.
Tv	**Volcanic Breccia** - Angular pieces of medium to dark gray fine-grained volcanic rock (andesite) surrounded by an andesitic matrix. Clasts are up to 16 inches across. Probably deposited as a mudflow of volcanic material some 35 to 39 million years ago.
Kk	**Kelvin Formation** - Grayish-red to red siltstone, sandstone, and conglomerate. Conglomerate clasts are quartzite and sandstone up to 1 foot in diameter. Some sandstone and siltstone beds are folded and faulted.
Kkp	**Parleys Member, Kelvin Formation** - Gray to white limestone; white limestone conglomerate with scattered, black, pea-sized chert clasts; and reddish-gray siltstone.
Jp	**Preuss Sandstone** - Light-brown sandstone and conglomerate.
Jtc	**Twin Creek Limestone** - Includes gray massive limestone; sandy limestone that weathers to brown; thinly bedded red siltstone; gray shaley limestone; brown oolitic limestone; and gray, fractured and jointed, thin-bedded limestone. Fossils include star-shaped crinoids and clams.
Jn	**Nugget Sandstone** - Orange-red to red quartz sandstone. The Nugget Sandstone is the northern version of the famous Navajo Sandstone of southern Utah parks. Both were part of a tremendous sea of sand dunes that covered much of Utah.
TRa	**Ankareh Formation** - Red and purplish-red shale, siltstone, and fine sandstone (upper and lower parts). White quartz conglomerate (middle). Red beds have some mud cracks and ripple marks.
TRt	**Thaynes Formation** - Gray, weathering to brown, massive, fossil-rich limestone. Fossils include corals, brachiopods, and bryozoans.
TRw	**Woodside Shale** - Red shale. Highly fractured.
TRP	**Gray limestone and red shale and sandstone**. Includes Park City Formation, Woodside Shale, Thaynes Formation, and Ankareh Formation.
Ppc	**Park City Formation** - Dark gray limestone. Scattered shell fossils (brachiopods). Slight "organic" odor when broken. Includes some dark-colored phosphate shale in Big Cottonwood Canyon.
IPw	**Weber Quartzite** - Mostly white with local "rusty" iron-oxide stains and some tan or pale gray areas. Highly fractured.
IPMls	**Limestone** - Pale to dark gray, may weather to brown. Some ledge-forming beds; some fossil-rich beds. Includes Gardison Limestone, Deseret Limestone, Humbug Formation, Doughnut Formation, and Round Valley Limestone.
IPMꞒ	**Gray limestone, dolomite, and some shale** - Includes Ophir Shale, Maxfield Limestone, Fitchville Formation, Gardison Limestone, Deseret Limestone, Humbug Formation, Doughnut Formation, and Round Valley Limestone.
MDls	**Limestone** - Pale tan to dark gray. Ledge forming. Includes Pinyon Peak Limestone, Gardison Limestone, Deseret Limestone, Humbug Formation, and Doughnut Formation.
MꞒls	**Limestone and Dolomite** - Pale to dark gray. Includes Maxfield Limestone, Fitchville Formation, Gardison Limestone, and Deseret Limestone.
Ds	**Stansbury Formation** - Massive ledges of light gray to tan quartz sandstone. Includes a few shale, siltstone, and dolomite beds.
Ꞓm	**Maxfield Limestone** - Ledge forming, pale to medium-gray. Includes tan shale beds and dolomitic beds with mottled and twiggy structures.
Ꞓo	**Ophir Shale** - Gray to nearly black. Three parts: blocky (limy) sandstone (upper part), thin-bedded limestone (middle part), and shale (lower part).
Ꞓt	**Tintic Quartzite** - White, buff, or rusty-color quartz sandstone.
pꞒm	**Mutual Formation** - Gray shale and quartzite. Also includes Mineral Fork Tillite in Big Cottonwood Canyon.
pꞒmf	**Mineral Fork Tillite** - Cobbles and pebbles of quartzite, limestone, and granitic rock in a black sandy matrix. Deposited by a glacier 800 million years ago.
pꞒbc	**Big Cottonwood Formation** - Alternating layers of buff to red quartzite and black to purple to green shale. Includes ripple marks and mud cracks. Slightly metamorphosed.
pꞒlw	**Little Willow Formation** - Gray, weathering to brown gneiss and schist. Oldest rocks ($\geq$1.6 billion years old) in this part of the Wasatch Range.

City Creek Canyon

Bonneville Blvd. - 1.5 miles
(mileage begins at 11th Avenue)

City Creek Canyon Road - 5.6 miles
(mileage begins at entrance gate)



Rounded clasts in layers vs. chaotic angular clasts

Layered sand and gravel deposited in high-energy shallow waters of Lake Bonneville. Contrast this to the quiet-water fine-grained sediments seen across the canyon and the clay-rich chaotic debris-flow deposits found in the canyon bottom (mile 3.0).

Angular clasts of andesitic volcanic rock in a fine-grained matrix. Deposited as a debris flow approximately 35 to 39 million years ago, well before the formation of City Creek Canyon. (Seen in road cut, but too limited to map.)

This house lies just above an active landslide's uppermost boundary, or main scarp (light-colored cliff face).

These prehistoric landslide deposits are significant in that they may have temporarily dammed the creek. Landslide dams are unstable and can fail catastrophically, releasing impounded water as destructive floods. Although this area could potentially pose a threat downstream to downtown Salt Lake City, no historical movement has been observed on these landslides.

This chaotic assortment of clay- to boulder-size material was deposited as a muddy debris flow sometime within the geologically recent past. It is testament to a geologic hazard that exists to this day.

Looking up canyon, once-horizontal rock layers are tilted to near vertical and now form resistant fins on the mountainside.

Vertical limestone fin.

Weeping Rock Memorial Grotto picnic site. This wet cave formed when slightly acidic ground water dissolved the limestone.

One of three debris basins in the lower reaches of City Creek Canyon. These basins are designed to reduce flooding threats to downtown Salt Lake City by catching debris and mud flows.

Layered silt and sand deposited approximately 15,000 years ago in quiet waters of Lake Bonneville.

Down-canyon view shows horizontal layers of a conglomerate that is less than 40 million years old. The sand, pebbles, and cobbles eroded from this conglomerate have been re-deposited down canyon in stream channel alluvium (not mapped), alluvial fans (Qal), and the shallow waters of ancient Lake Bonneville (Qlb).

City Creek Canyon Road is open to motor vehicles on holidays and even-numbered days from late May to late September. The canyon is open to pedestrians all year.

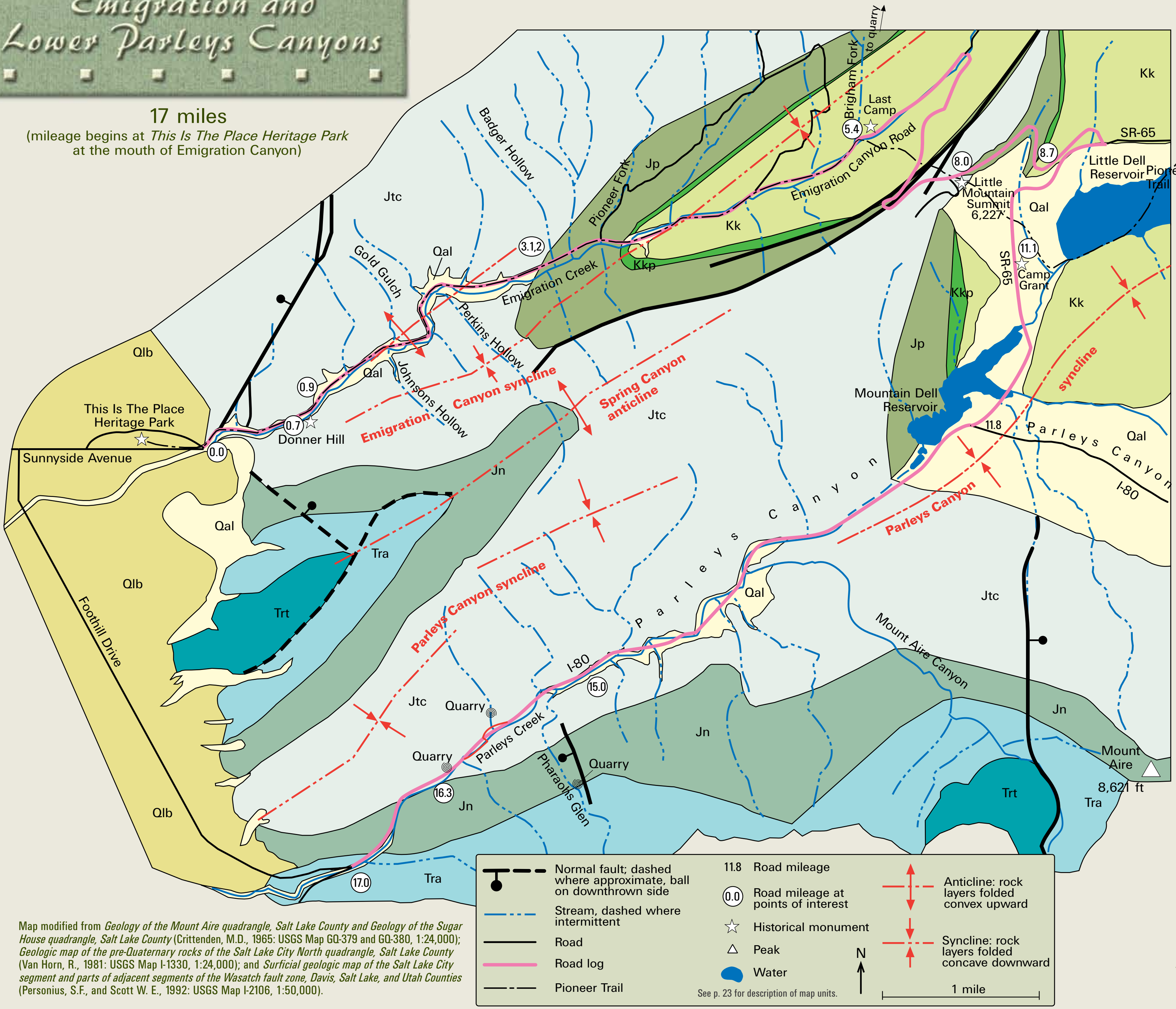
- Normal fault; dashed where approximate, ball on downthrown side
- Stream
- Spring or seep
- Road
- 0.5 mile
- 0.0 Road mileage
- 0.6 Road mileage for City Creek Canyon Rd. at points of interest
- 0.9 Road mileage for Bonneville Blvd. at points of interest
- 7 Picnic Site
- Road salt storage structure
- N

See p. 23 for description of map units. Not shown – Alluvium found along stream channels and deposits of loose soil and rock on hill slopes (colluvium).

Map modified from *Surficial geologic map of the Salt Lake City segment and parts of adjacent segments of the Wasatch fault zone, Davis, Salt Lake, and Utah Counties* (Personius, S.F., and Scott W. E., 1992: USGS Map I-2106, 1:50,000) and *Map showing surficial units and bedrock geology of the Fort Douglas quadrangle and parts of the Mountain Dell and Salt Lake City North quadrangles; Davis, Salt Lake, and Morgan Counties* (Van Horn, R., and Crittenden, M.D., 1987: USGS Map I-1762, 1:24,000).

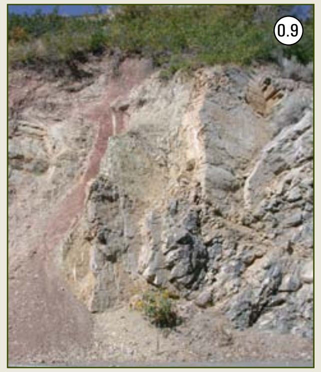
Emigration and Lower Parleys Canyons

17 miles
(mileage begins at *This Is The Place Heritage Park* at the mouth of Emigration Canyon)



Map modified from *Geology of the Mount Aire quadrangle, Salt Lake County and Geology of the Sugar House quadrangle, Salt Lake County* (Crittenden, M.D., 1965: USGS Map GQ-379 and GQ-380, 1:24,000); *Geologic map of the pre-Quaternary rocks of the Salt Lake City North quadrangle, Salt Lake County* (Van Horn, R., 1981: USGS Map I-1330, 1:24,000); and *Surficial geologic map of the Salt Lake City segment and parts of adjacent segments of the Wasatch fault zone, Davis, Salt Lake, and Utah Counties* (Personius, S.F., and Scott W. E., 1992: USGS Map I-2106, 1:50,000).

View eastward into Emigration Canyon showing shoreline deposits of Lake Bonneville at left foreground and under buildings.



Fossiliferous limestone, oolitic limestone, and red siltstone of the Jurassic Twin Creek Limestone on the north side of the road.

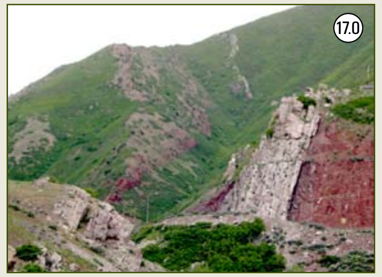
View northward of a young alluvial fan deposit that flowed out of Badger Hollow.

View northward of chocolate-brown Jurassic Preuss Sandstone.

Panoramic view to the northeast of the Cretaceous Kelvin Formation red sandstone, and conglomerate and white limestone of the Parleys Member of the Kelvin Formation.

Northward view of highly folded Jurassic Twin Creek Limestone and Nugget Sandstone exposed in landscape-rock and crushed-stone quarries.

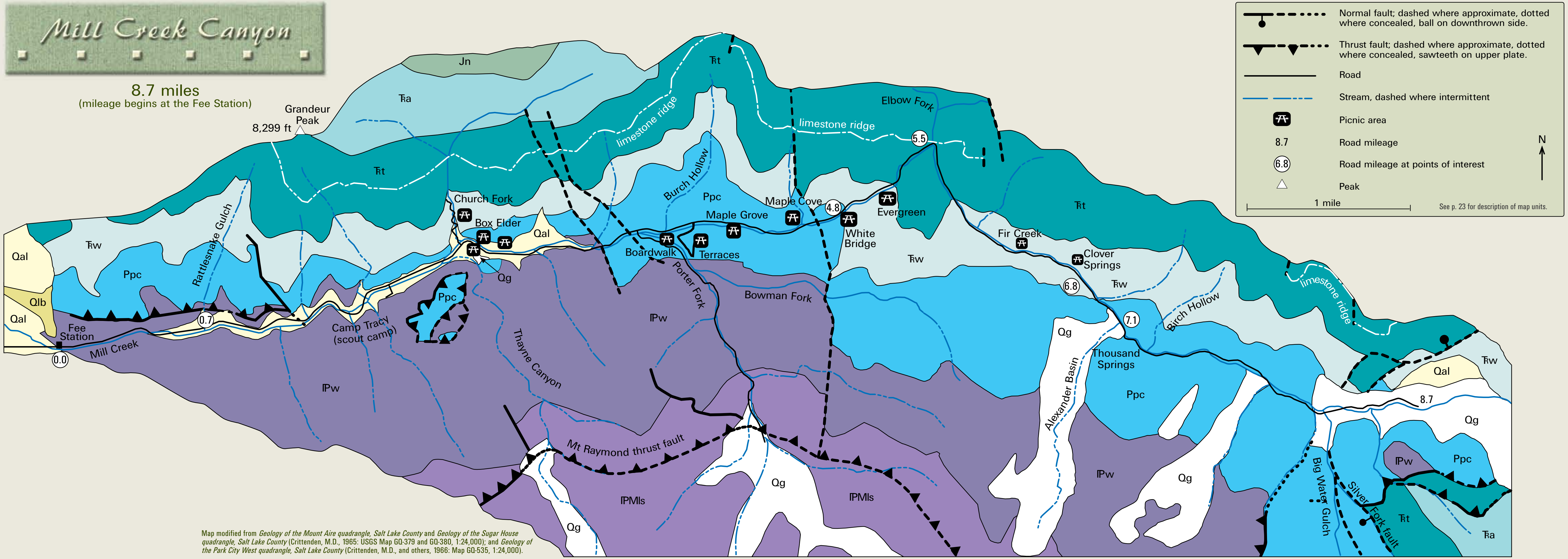
Westward view toward the mouth of Parleys Canyon showing the orange Jurassic Nugget Sandstone.



Eastward view of the tilted white and red layers of the Ankareh Formation on the southeast flank of Parleys Canyon syncline. Photo by Ari Menon.

Mill Creek Canyon

8.7 miles
(mileage begins at the Fee Station)

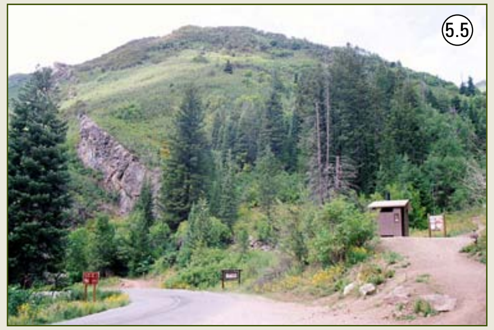


Map modified from *Geology of the Mount Aire quadrangle, Salt Lake County* and *Geology of the Sugar House quadrangle, Salt Lake County* (Crittenden, M.D., 1965: USGS Map GQ-379 and GQ-380, 1:24,000); and *Geology of the Park City West quadrangle, Salt Lake County* (Crittenden, M.D., and others, 1966: Map GQ-535, 1:24,000).

Mouth of Mill Creek Canyon, a typical "V" shaped stream valley.

Pennsylvanian-age Weber Quartzite. View up canyon.

Permian-age Park City Formation limestone. View down canyon.



Massive limestone ridge of the Triassic-age Thaynes Formation. View down canyon.

Triassic-age Woodside Shale on the south side of the road.

Quaternary-age glacial moraine, deposited by a glacier from Alexander Basin, on the south side of the road.

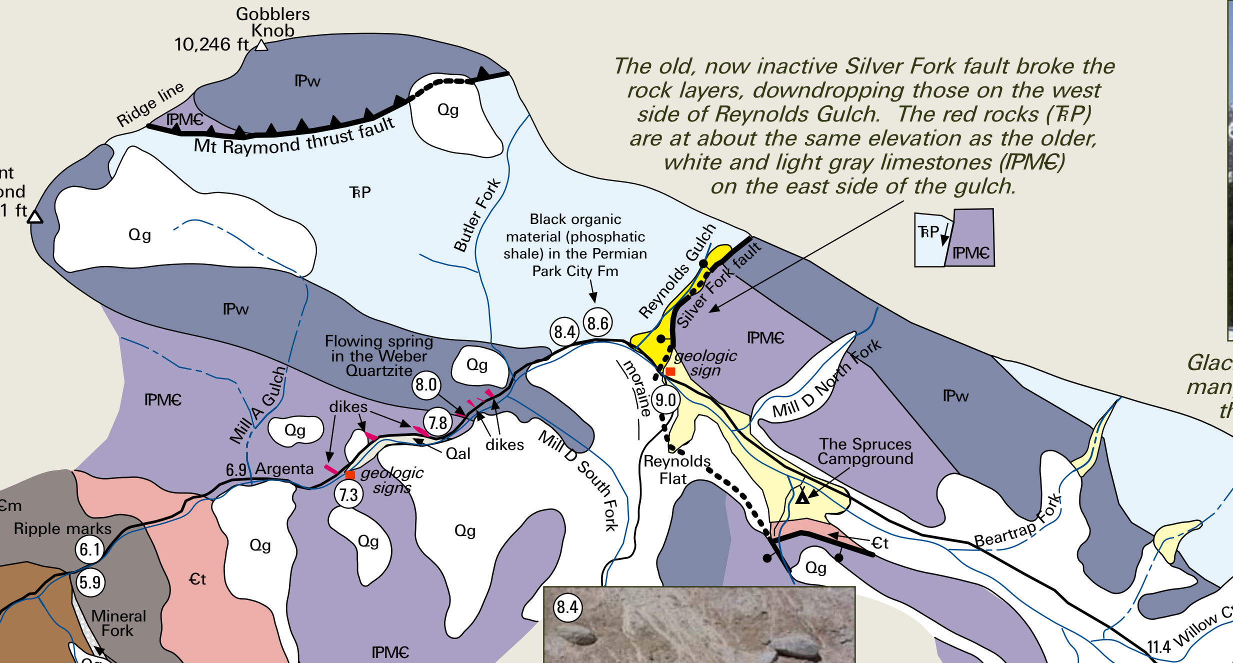
Big Cottonwood Canyon

15 miles
(mileage begins at road junction with Wasatch Blvd)

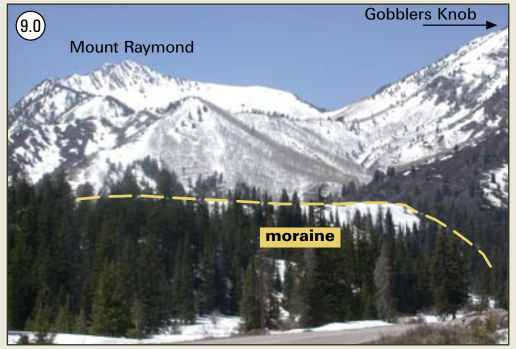
Tilted layers of reddish-brown quartzite and black to purple to green shale (p€bc), remnants of tidal environments, dominate the first 6 miles. Originally deposited as flat-lying sediments, these now steeply tilted rock layers provide good views of ripple marks and mud cracks.

Ripple marks

Mud cracks
5-7 inches in diameter

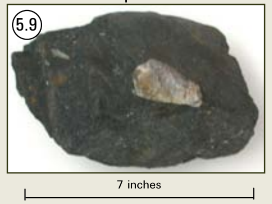


The old, now inactive Silver Fork fault broke the rock layers, downdropping those on the west side of Reynolds Gulch. The red rocks (ҍP) are at about the same elevation as the older, white and light gray limestones (IPM€) on the east side of the gulch.



Glaciers, 500 to 800 feet thick, occupied the canyon and many of its tributaries, mostly above Reynolds Flat. Here the canyon straightens and widens due to glacial erosion. The immense volume of material that glaciers carried is evident as moraines (seen as hills or ridges) and the scattered white granitic boulders transported from the canyon's upper portions. Moraines are visible at Reynolds Flat (the largest one is in this photo and marked on map), and as a one-mile-long 280-foot-high aspen-covered ridge along the northeast side of the road below Brighton (marked on map).

Large angular boulders make up part of the talus at Stairs Gulch.



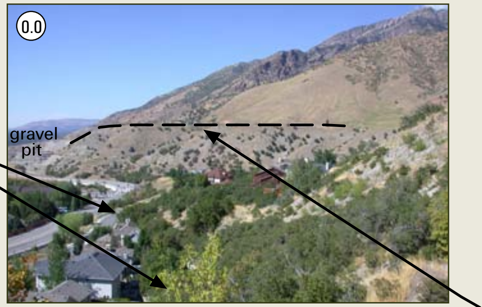
800-million-year-old glacial till (Mineral Fork Tillite). Seen as black debris on slope above creek.

← ancient glacial till
younger glacial till →

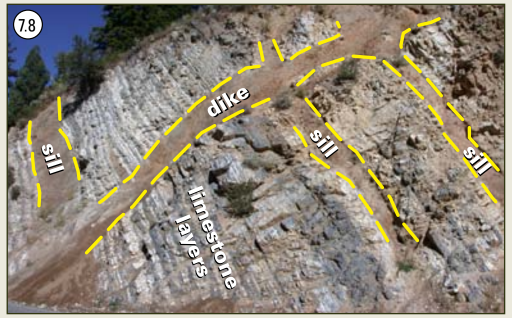
Boulders (1 to 3 foot diameter) in a silty matrix (glacial till). Transported by a glacier about 13,000 years ago.

Silver Springs and Argenta (mile 7) were two mining towns in the 1870s, complete with stores and hotels.

The Wasatch fault forms the steep 60-foot break in slope above Wasatch Boulevard.



Glacial outwash was carried by the creek into Lake Bonneville - forming a delta-like feature (escarpment marked on map). Delta on south side of creek is a very gently sloping terrace.



Red- to dark-colored dikes and sills contrast with the light-colored limestone and marble along the road between miles 7.3 and 8.3.

View up Mill D South Fork shows glacial arête on the ridge line.

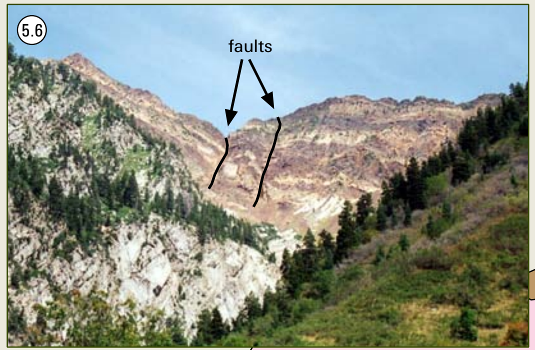
Map modified from *Geology of Big Cottonwood mining district* (Crittenden, M.D., and others, 1978: UGMS Bulletin 114, plate 1, 1:24,000).

Little Cottonwood Canyon

9.9 miles
(mileage begins at geologic view park)

Contact between Precambrian Big Cottonwood Formation (left) and light-colored quartz monzonite (granite) of the Little Cottonwood stock.

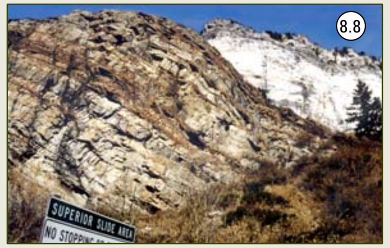
Faults in the Big Cottonwood Formation. Quartz monzonite (granite) of the Little Cottonwood stock is in the foreground.



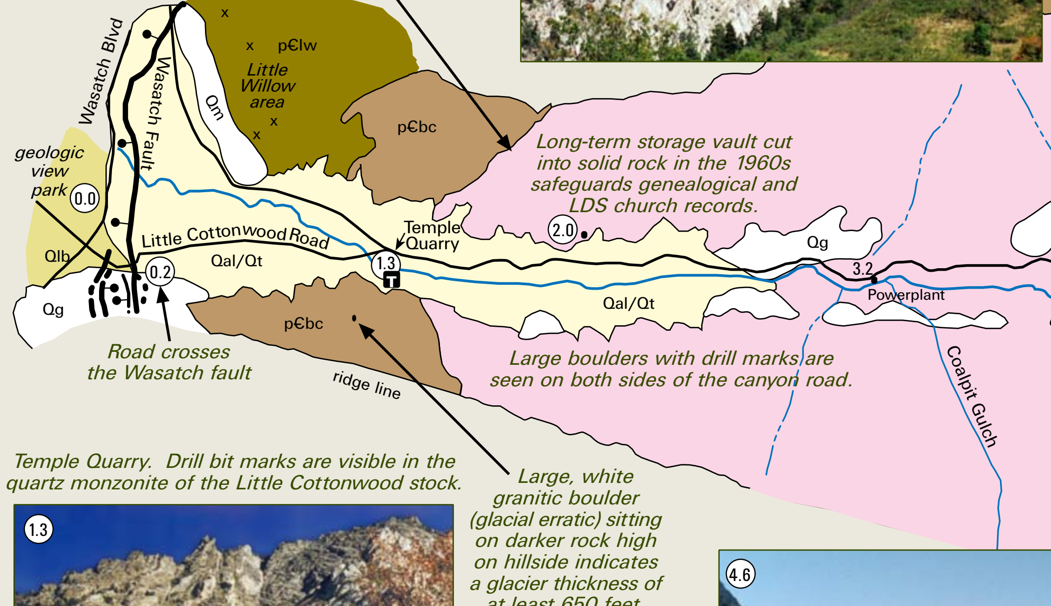
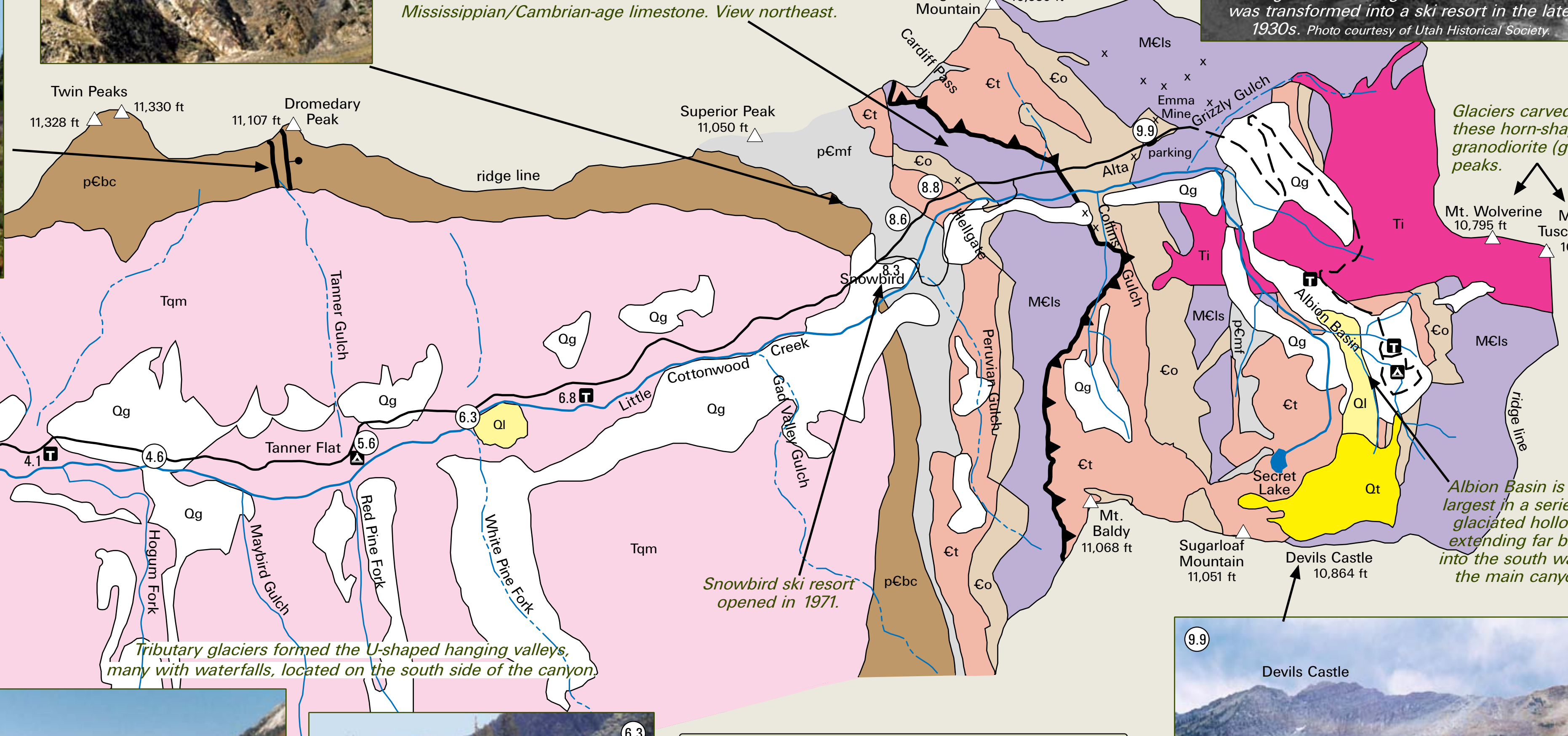
Contact between Precambrian Big Cottonwood Formation (lighter rocks on left) and Mineral Fork Tillite. View northwest.

Mississippian/Cambrian-age limestone. View northeast.

Cambrian Tintic Quartzite near road, black and white limestone in background.



Alta began as a mining town in the 1870s and was transformed into a ski resort in the late 1930s. Photo courtesy of Utah Historical Society.

Long-term storage vault cut into solid rock in the 1960s safeguards genealogical and LDS church records.

Road crosses the Wasatch fault

Large boulders with drill marks are seen on both sides of the canyon road.

Large, white granitic boulder (glacial erratic) sitting on darker rock high on hillside indicates a glacier thickness of at least 650 feet.

Tributary glaciers formed the U-shaped hanging valleys, many with waterfalls, located on the south side of the canyon.

Snowbird ski resort opened in 1971.

Glaciers carved these horn-shaped, granodiorite (granite) peaks.

Albion Basin is the largest in a series of glaciated hollows extending far back into the south wall of the main canyon.

Temple Quarry. Drill bit marks are visible in the quartz monzonite of the Little Cottonwood stock.

Glaciers plowed along the entire length of Little Cottonwood Canyon, carving out its distinctive U-shape. View down canyon.

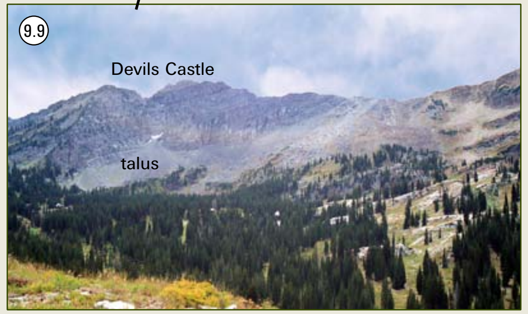
A mound of angular rocks deposited by a prehistoric rock slide.

- Normal fault; dotted where concealed, ball on downthrown side
- Thrust fault; sawteeth on upper plate
- Stream, dashed where intermittent
- Road, dashed where dirt
- 3.2 Road mileage
- (0.0) Road mileage at points of interest
- Peak
- Campground
- Trailhead
- x Mine dump
- Water

N

0.5 mile

See p. 23 for description of map units.



Talus (rock debris) lies at the base of Devils Castle, which is composed of Mississippian-age limestone.

Map modified from *Geologic map of the Brighton quadrangle* (Baker, A.A., 1966: USGS Map GQ-534), *Geology of the Draper quadrangle* (Crittenden, M. D., 1965: USGS Map GQ-377), and *Geology of the Dromedary Peak quadrangle* (Crittenden, M.D., 1965: USGS Map GQ-378), 1:24,000.