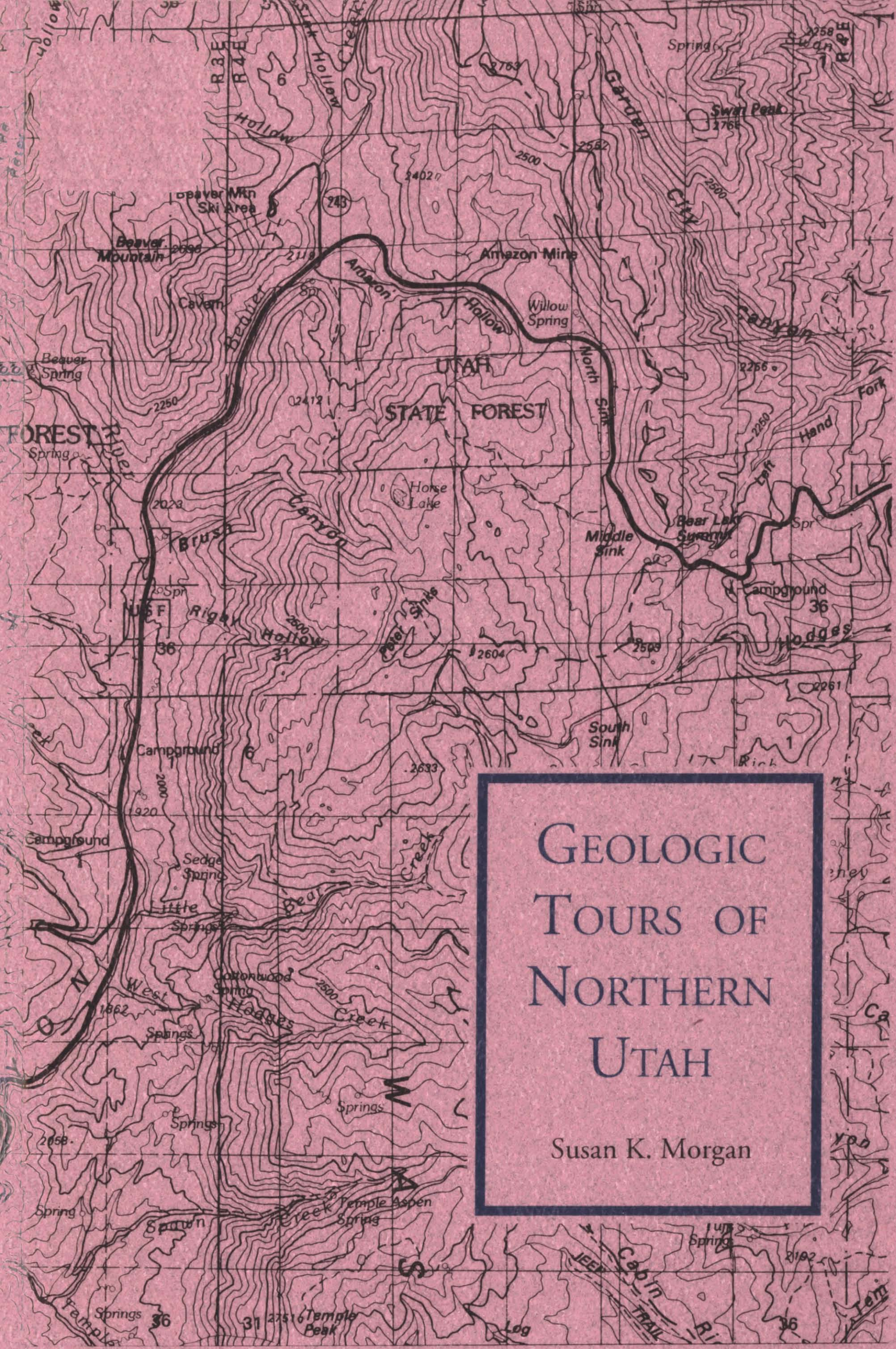

GEOLOGIC TOURS OF NORTHERN UTAH

Susan K. Morgan

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UTAH GEOLOGICAL SURVEY
a division of
UTAH DEPARTMENT OF NATURAL RESOURCES **1992**

Geologic Tours of Northern Utah

You go out and get a certain piece of rock.
It's not just a rock.
It's got energy forces in it,
it's a living thing, too.

Hopi Woman

Geologic Tours of Northern Utah

Susan K. Morgan

Utah Geological Survey

1992

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Book Design: R.P. Bissland

Cover from U.S. Geological Survey Logan 30 x 60-minute quadrangle, 1984

Table of Contents

This we know.
The earth does not belong to us;
we belong to the earth.
This we know.
All things are connected
like the blood which unites one family.
All things are connected.

Whatever befalls the earth
befalls the sons and daughters of the earth.
We did not weave the web of life;
We are merely a strand in it.
Whatever we do to the web,
we do to ourselves . . .

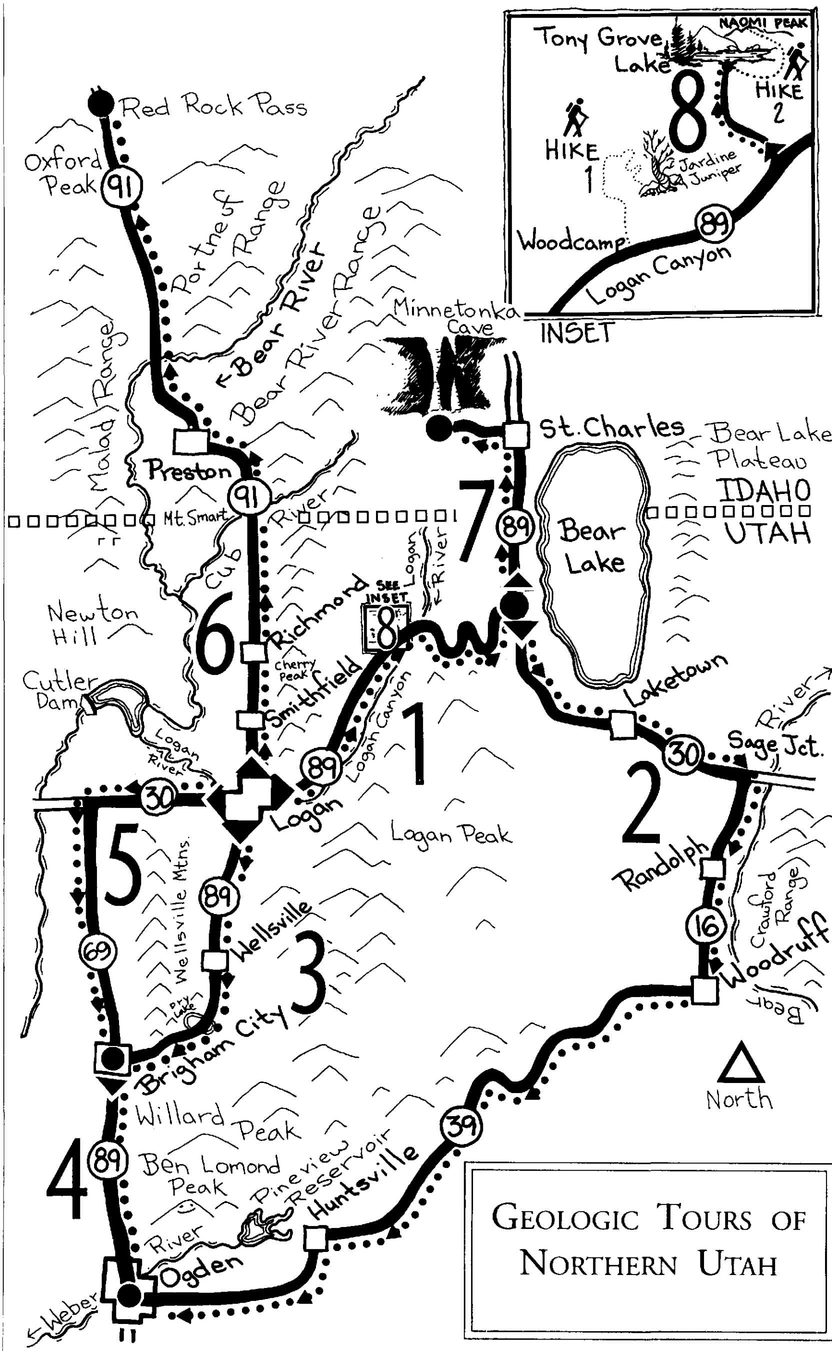
Chief Seattle

Acknowledgments

This book was made possible by a grant from the Utah Geological Survey.

I wish to thank the faculty of the Geology Department at Utah State University for answering questions and providing the latest interpretations of northern Utah geology. I especially wish to thank Drs. Peter Kolesar and James Evans for their generous help and critical review of this book.

Thanks also to Kayo Robertson and Bob Bissland who both prepared the illustrations.



Geologic Tours of Northern Utah
Red Rock Pass
Oxford Peak
91
Portneuf Range
Bear River
Bear River Range
Malad Range
Preston
Mt. Smart
Cub River
IDAHO
UTAH
Newton Hill
Cutler Dam
Logan River
6
Richmond
Cherry Peak
Smithfield
SEE INSET
8
Logan River
Logan Canyon
89
Logan
30
1
Logan Peak
Minnetonka Cave
St. Charles
Bear Lake Plateau
7
Bear Lake
Laketown
Sage Jct.
River
2
Randolph
16
Crawford Range
Woodruff
Bear
5
Wellsville Mtns.
Wellsville
3
69
Dry Lake
Brigham City
Willard Peak
4
Ben Lomond Peak
Pineview Reservoir
Huntsville
39
River
Ogden
Weber
North
Tony Grove Lake
NAOMI PEAK
HIKE 2
HIKE 1
Jardine Juniper
Woodcamp
Logan Canyon
INSET

Introduction

THE UNIQUE AND SPECTACULAR SCENERY of northern Utah is fashioned by dynamic processes that occur on and within the Earth's crust. Imagine that for over 200 million years the mountains and valleys we see today in northern Utah were previously the site of a shallow tropical sea.

The underlying component to all scenery is the rock. The three groups of rocks - igneous, sedimentary, and metamorphic - can be continuously recycled (Fig. 1). This process creates the mountains, valleys, and plains of the continents and myriad geologic features on the sea floor. Recycling rocks, and building and eroding mountains, requires one important ingredient - time. Earth, with 4.5 billion years since its formation, can be considered the original recycler. Geologic time of the Earth is subdivided into a time scale (Fig. 2) that names the specific time periods and provides the age of each.

A basic premise of geology is the concept that what happens today also happened in the past. Present events provide a key to the past. The geologic phenomena occurring today may be sudden, such as a volcanic eruption or a debris flow. Most processes are very slow, however, such as erosion of a river valley, requiring thousands and millions of years to produce change on the Earth's surface.

The rocks, mountains, valleys, and sediment you see from your car window, or from the geologic stops described in this guide, tell a story of the past history of Earth and the dramatic changes that have occurred through time. This book is for anyone who wonders about the rocks and scenery traversed by northern Utah highways. Perhaps it will increase your understanding and awareness of the landscape's story and the processes that shape our surroundings.

How to use this book

This book includes eight highway tours and two hikes. Logan is the starting point for four of the highway tours. Mileage, in distance from the starting point, and a brief description of what to look for are in boldface type. This is generally followed by an explanation of the geologic features. Several of the highway tours can be linked together into a loop trip. Touring a loop will inevitably result in driving one of the tours in the opposite direction. Therefore, you will encounter the geologic features described in the guide in reversed order for a portion of the loop.

To help alleviate possible confusion resulting from different vehicle odometer readings, most bridges, railroad tracks, cattle guards, and highway junctions are included as reference points. The tour of Logan Canyon, a scenic highlight of northern Utah, includes several stops, that provide good examples of specific geologic features.

Mileage is not included for the hikes since there are no mile posts along the trails. Instead a description of the trail route is augmented with numbered points of interest. These points of interest are located on the topographic map preceding Hike 1 and Hike 2.

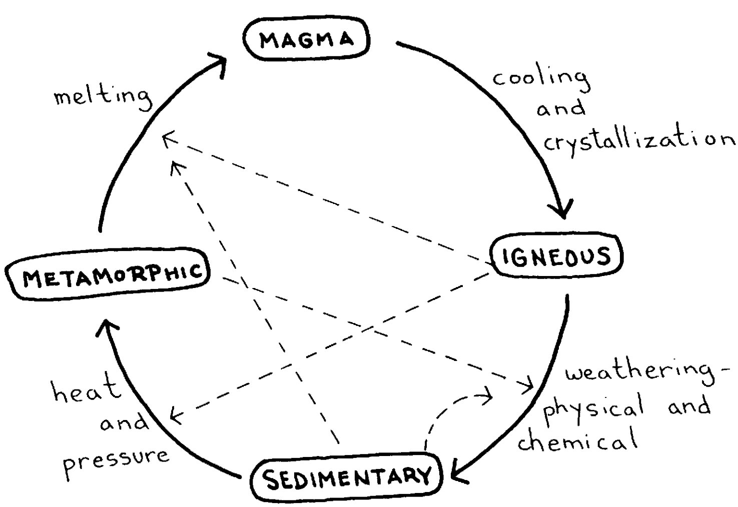
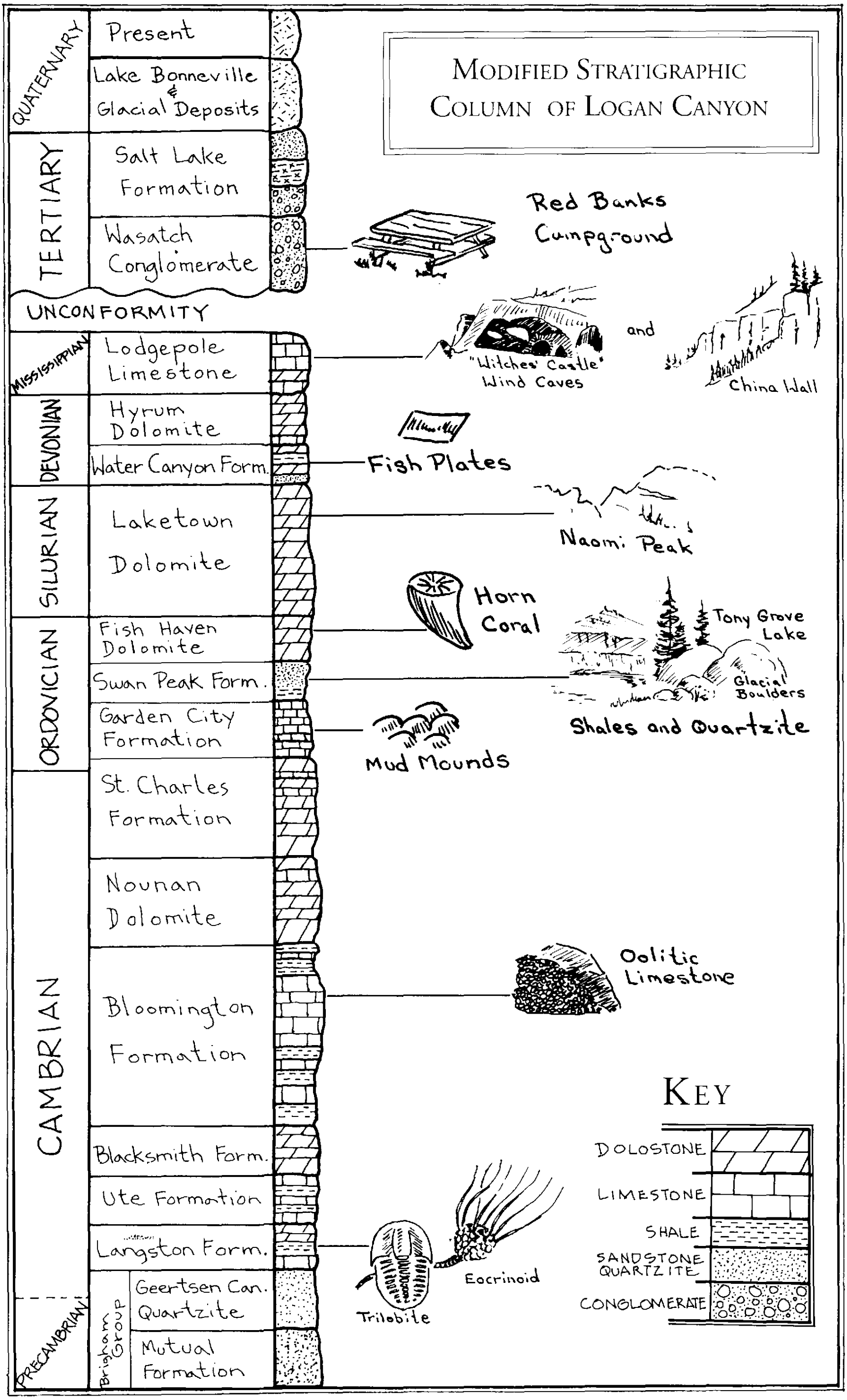


Fig. 1

Geologic Time Scale

Era	Period	Epoch	Age in millions of years
Cenozoic Cz Age of Mammals	Quaternary Q	Holocene	(10,000 yrs) .01
		Pleistocene	1.6
	Tertiary T	Pliocene	5
		Miocene	23
		Oligocene	37
		Eocene	58
		Paleocene	66
Mesozoic Mz Age of Dinosaurs	Cretaceous K		144
	Jurassic J		208
	Triassic TR		245
Paleozoic Pz Age of Early Life	Permian P		286
	Pennsylvanian IP		320
	Mississippian M		360
	Devonian D		400
	Silurian S		438
	Ordovician O		505
	Cambrian Є		570
Precambrian PЄ	Proterozoic		2,500
	Archeozoic		3,800
	Origin of the Earth		4,600

Fig. 2



Modified Stratigraphic Column of Logan Canyon
QUATERNARY
Present
Lake Bonneville & Glacial Deposits
TERTIARY
Salt Lake Formation
Wasatch Conglomerate
Red Banks Campground
UNCONFORMITY
MISSISSIPPIAN
Lodgepole Limestone
"Witches' Castle" Wind Caves
and
China Wall
DEVONIAN
Hyrum Dolomite
Water Canyon Form.
Fish Plates
SILURIAN
Laketown Dolomite
Naomi Peak
ORDOVICIAN
Fish Haven Dolomite
Horn Coral
Swan Peak Form.
Tony Grove Lake
Glacial Boulders
Shales and Quartzite
Garden City Formation
Mud Mounds
CAMBRIAN
St. Charles Formation
Nounan Dolomite
Bloomington Formation
Oolitic Limestone
Blacksmith Form.
Ute Formation
Langston Form.
Trilobite
Eocrinoid
PRECAMBRIAN
Brigham Group
Geertsen Can. Quartzite
Mutual Formation
Key
Dolostone
Limestone
Shale
Sandstone Quartzite
Conglomerate

Tour 1

Logan Canyon

Lady Bird Park, Logan to Garden City via Highway 89

Mile 0.0 Stop 1

Lady Bird Park There are several geologic phenomena that can be observed from this stop, including Lake Bonneville features, glacial features, and evidence of faults and mass wasting.

The LAKE BONNEVILLE features are probably the most striking to the casual observer. Looking south across the Logan River and east to the mouth of Logan Canyon, you can see several distinct level areas or benches. These are actually shoreline features formed by the ancient lake. The highest bench, at the base of the mountains, is the Bonneville level (5,120 feet), which indicates the highest level the lake reached approximately 16,000 years ago. After remaining at this level for about 1,500 years, the lake rapidly lowered by approximately 350 feet as it emptied through Red Rock Pass (see Tour 6) at the north end of Cache Valley, into the Snake River drainage, and eventually into the Pacific Ocean. The second bench, the one that you are now on at Lady Bird Park and the level Utah State University is built on, is the Provo level (4,790 feet), which formed approximately 14,000 years ago. This is the level the lake reached after catastrophically lowering through Red Rock Pass. If you look to the west you'll notice that the Provo level bench extends into the valley. This feature is actually a delta that formed at the mouth of Logan Canyon where the Logan River emptied into the quiet waters of Lake Bonneville and subsequently deposited the sediment it carried (Fig. 3). The lake was at this level for approximately 1,000 to 2,000 years and created a fairly large delta. The third and lowest level that you can see from here formed as a result of stream terracing in combination with local response to changing lake levels in Cache Valley.

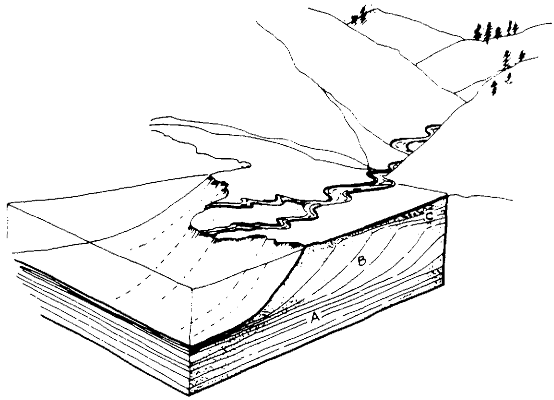


Fig. 3-Mile 0.0. Generalized drawing of a delta developed in Lake Bonneville. Deltas exhibit three characteristic parts: **A)** The lower part is deposited in front of the delta and is composed of fine-grained, flat-layered material. **B)** The middle part consists of coarse-grained material deposited along the steeply sloping, advancing delta front, forming cross-beds. **C)** The top part, overlying the cross-beds, is composed of coarse to fine-grained, flat-layered, stream deposited material.

Lake Bonneville was a temporary control of base level (the lowest level to which a stream can erode) of the Logan River. Since the lake started drying up in Cache Valley about 12,000 years ago, the Logan River has cut down through the earlier lake-deposited unconsolidated sediment. The material eroded by the Logan River was most likely deposited farther out in the valley. Thus erosion by the Logan River created the "Island" area, the lowland (flood plain) adjacent to the Logan River.

MASS WASTING processes have also helped the Logan River to create the Island. The steep walls on either side of the river valley are made of unconsolidated sand, clay, and gravel. This material slumps into the valley when saturated with water during wet climatic cycles or spring rains. Several slump scars and irregular looking areas can be seen on both the north and south valley walls.

The Wellsville Mountains across Cache Valley to the west have some classic GLACIAL FEATURES. During the Ice Age, which ended about 12,000 years ago, glaciers occupied valleys in most of the high peaks in Utah, including the Wellsvilles and the Bear River Range. Glaciers scour out and remove large amounts of rock to create amphitheatre-shaped cirques at the heads of many mountain valleys. Several cirques can be seen nestled below the highest peaks of the Wellsvilles, Box Elder Peak and Wellsville Cone (Fig. 4).

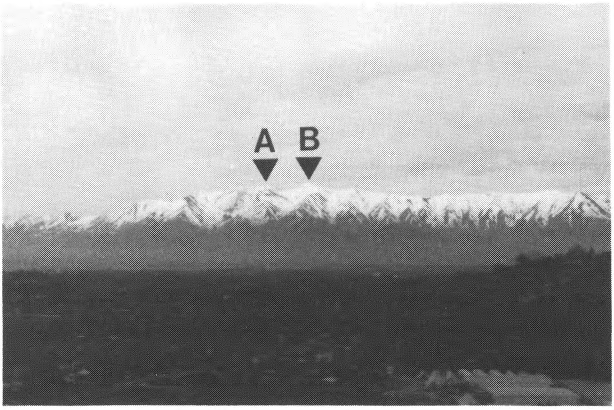


Fig. 4-Mile 0.0. Glacial formed cirques are nestled below Box Elder Peak (**A**) and Wellsville Cone (**B**), the highest peaks of the Wellsville Mountains.

The Bear River Range is bounded on the west by the East Cache fault zone, which is divided into three segments of NORMAL FAULTS (Fig. 5). Motion along this series of fault segments elevated the mountains while downdropping the valley. Fault scarps, steep slopes formed on Earth's surface by motion along a fault, are not always easy to distinguish from the pervasive Bonneville shorelines of this area. In fact, there are few actual fault scarps along the mountain fronts in Cache Valley. What evidence is there of faulting? Faceted spurs are obvious along the range front (Fig. 6). Spurs or ridges extend from the mountains to the valley. The ends of the spurs often form an inverted-V face. These are the facets and are produced by faulting. Because of faulting, the slope-forming erosional processes cannot keep pace with uplift; therefore, a flat facet is created. The faceted spurs can be seen on the mountains along the eastern margin of Cache Valley and on the Wellsville Mountains to the west. Man-made trenching also provides evidence of faulting. Trenches are dug across an area where faults are suspected to exist. Once the trench walls are stabilized, one can observe and document how the once-continuous layers of horizontal sediments have been offset or displaced.

0.3 **Golf Course and Road Cut to the Left (North).** Notice the bench in the golf course to the left of the road. This is actually a fault scarp. When the road cut was made in the early 1930s, offset of approximately 9 feet was obvious in the horizontal sediments (Fig. 7). Since then, the layers of sediment in the road cut have been covered over by material washing down the slope and by vegetation, both of which have caused them to lose their distinct appearance.

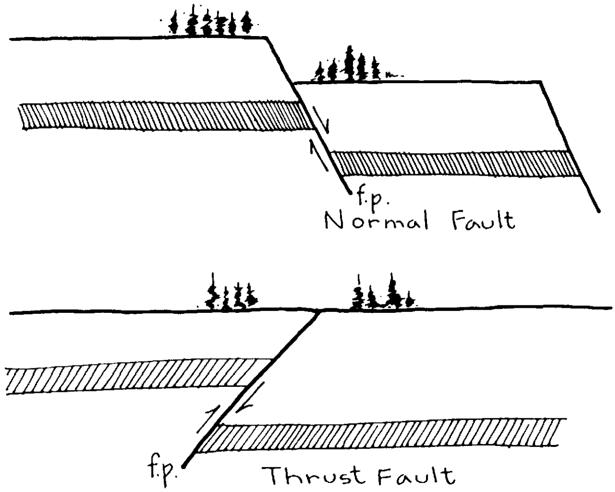


Fig. 5-Mile 0.0. This drawing illustrates the displacement of strata by a normal fault and a thrust fault. In a normal fault the rocks above the fault plane (f.p.) move down relative to the rocks below. In a thrust fault the rocks above the fault move up.

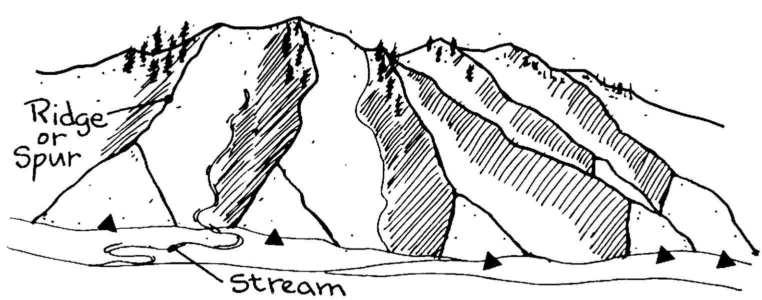


Fig. 6-Mile 0.0. Arrows indicate faceted spurs, produced by faulting, along the Bear River Range.

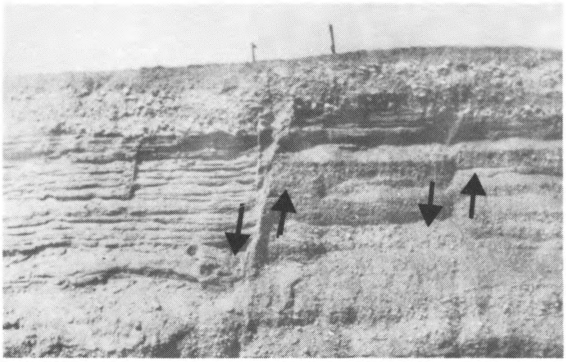


Fig. 7-Mile 0.3. A 1936 photo of the then fresh road cut which shows 9 feet of fault offset in the horizontal sediments below the golf course.

0.4 **First Dam to the Right (South).** Constructed in 1914, the dam is actually built on a projected segment of the East Cache fault. A drilling project in 1989 was instituted to determine the precise fault location relative to the dam.

0.5 **Hydro Park to the Left (North) - Bridge over Logan River.** The first rocks exposed along the mountain front as you enter Logan Canyon are the Upper Cambrian St. Charles Formation. This formation is a mix of limestone and dolostone. Although the rocks to the left (north) are very fractured or jointed, you can see a fold in the rock layers (Fig. 8). This is a small overturned syncline, probably a result of drag along an old inactive thrust fault located beside the mountain front. The rocks above the fault plane and the fault plane itself (the

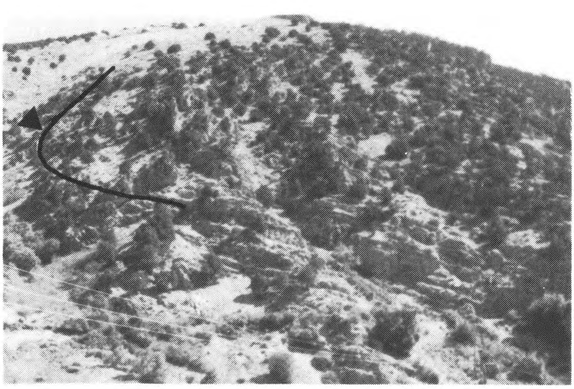


Fig. 8-Mile 0.5. As you enter Logan Canyon, a small overturned syncline (outlined) is exposed to the left, in the extensively jointed Upper Cambrian St. Charles Formation.

zone along which motion has occurred) have been removed by erosion. All that remains visible are the small drag folds which commonly result from faulting.

0.6 **Power Plant to the Left (North).** The rocks exposed in the canyon walls are steeply dipping (60°)to the east. This represents a limb of the Logan Peak syncline, the overall geologic structure of the Bear River Range (Fig. 9). The rocks cropping out to the north and south of the road are the Lower Ordovician Garden City Limestone. Look closely at the rocks to the right (south) of the road (under the pipe is a good place) and you may notice mound-like features in the layered lime-

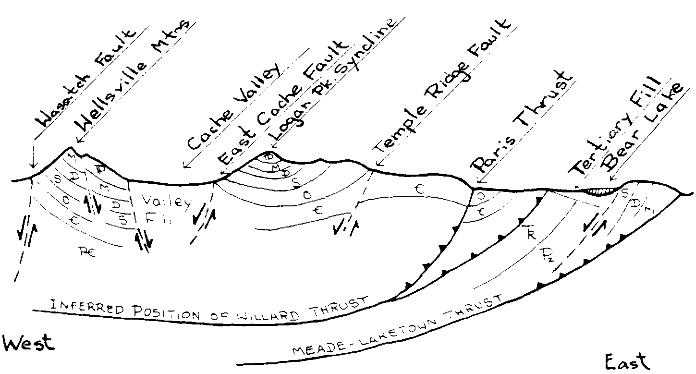


Fig. 9-Mile 0.6. Simplified cross-section of the geologic structure, including folds and faults, of the Bear River Range, Logan Canyon. The letters refer to the age of the rock layers. By convention, the Pennsylvanian is indicated by a IP and the Triassic by a TR. All other time periods are indicated by their first letter. Refer to the geologic time scale (Fig. 2) for period names.

stone (Fig. 10). These are ancient (approximately 500 million years old) mud mounds, a resistant mound-shaped accumulation of sediment formed by algal and sponge activity in a shallow tropical sea.

0.8 Stop 2

Pullout on the Left (North) Side of the Road. This is a good place to park if you'd like to go back and take a slower look at those mud mounds. You may also want time to reflect on the steeply dipping beds at the canyon entrance. From this location, one can also observe more evidence of Lake Bonneville. Look across the road to the south and notice sediment plastered high (100 feet or so) on the canyon wall. Some of this sediment is a result of Lake Bonneville. When the lake was at its highest level, it flooded the lower reaches of Logan

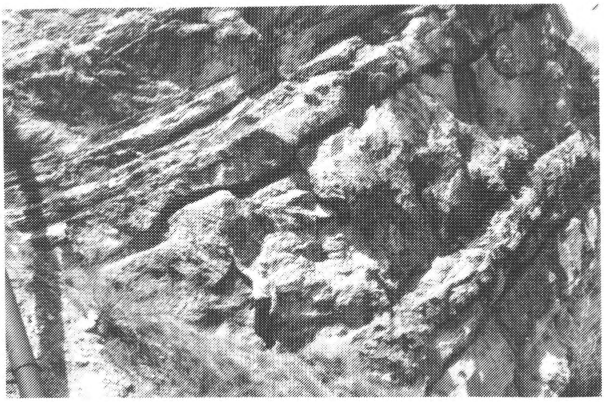


Fig. 10-Mile 0.6. The person is pointing to a large mud mound in the Lower Ordovician Garden City Limestone.

Canyon and caused the Logan River to deposit sediment along the canyon walls. If you went back in time, say 16,000 years, you would be under at least that much water and sediment. Most of the stream sediments that were deposited into the lower reaches of the canyon have since been removed through erosion by the Logan River.

1.1 **Bridge over Logan River.** As you proceed up the highway, rocks from Cambrian to Mississippian age are exposed in the canyon walls. You will probably notice that the Logan River has many curves in its course. The curves are a result of tributary streams coming out of the narrow side canyons, building up alluvial fans, and "pushing" the river from side to side. This also makes for a very winding road. The fans are more recent features than the Lake Bonneville deposits. From approximately 8,000 to 5,000 years ago, the climate in this area was hotter and drier than even today, thus less vegetation grew on the steep mountain slopes. When rain did fall, the probability of flash floods and mudflows/debris flows increased because of the lack of soil-stabilizing vegetation on the slopes. The alluvial fans were built by these mass wasting events. This process is going on today but at a slower rate due to the increased amount of vegetation growing on the hillsides.

1.6 **Dipping Rocks.** You are now driving down-dip, that is, in the direction the rocks are dipping, in this case to the east. Therefore, you are also driving up-section through progressively younger geologic rock units. The dip of the rocks remains eastward for several miles, although the angle of dip changes from steep (60°)to shallow (10° or less). At this location in the canyon you have gone through the Middle Ordovician Swan Peak Formation (there are no obvious outcrops easily seen from the road) and moved upward into the dark

Upper Ordovician Fish Haven Dolostone. Above the Fish Haven lies the Silurian Laketown Dolostone. The Laketown is usually lighter colored, but generally this distinction is difficult to perceive. Both units were deposited as sediment accumulated on a shallow, tropical sea floor. Corals and shells are some of the most easily seen fossils in these rocks because they are usually white against the dark dolostone.

2.4 **Second Dam to the Right (South).** As you continue to drive up-section, Devonian rocks crop out along the road. The two Devonian units that can be seen along the road are the older Water Canyon Formation and the younger Jefferson Formation. The Water Canyon Formation consists of thin-bedded, fine-grained, sandy dolostone. Scattered, fragmented fish fossils can be found in this formation. The Jefferson Formation contains two distinct rock types: a dolostone/limestone mix and red sandstone. These formations represent very shallow-water marine environments.

3.0 **Zanavoo Lodge.**

3.2 **Bridger Campground.**

3.4 **Cliff Straight Ahead (North of the Highway).** Here you find the first good view of the Mississippian Lodgepole Limestone which forms a prominent cliff band in this section of Logan Canyon. Often called the China Wall, the cliff is up to 150 feet high in many areas (Fig. 11). The Lodgepole is sometimes referred to as the Madison Formation. During Mississippian time when the Lodgepole was deposited, this area of Utah was a shallow, tropical sea. Life on the sea floor must have been plentiful, for the Lodgepole Formation is so rich with fossils that even beginning fossil collectors will always find something. Some of the more common fossils to see are crinoids, brachiopods, and corals (Fig. 12). The Lodgepole lies on top of the Devonian Leatham Formation (a limestone that does not crop out along the highway) which is above the yellow weathering slopes of the Devonian Jefferson Formation (you may want to refer to the stratigraphic column of Logan Canyon at the beginning of this guide).

3.8 Stop 3

Pullout at the Lake Bonneville Sign on the Left (North) Side of the Highway. Third Dam is to the right (south). This is the approximate extent of Lake Bonneville during its highest level, the Bonneville level. Mill Hollow, which starts high to the south of the road, had a small glacier at its head during the last Ice Age. Glacial meltwater moved

Fig.11-Mile 3.4. The Mississippian Lodgepole Limestone forms a prominent cliff in the lower part of Logan Canyon and is often referred to as the China Wall.

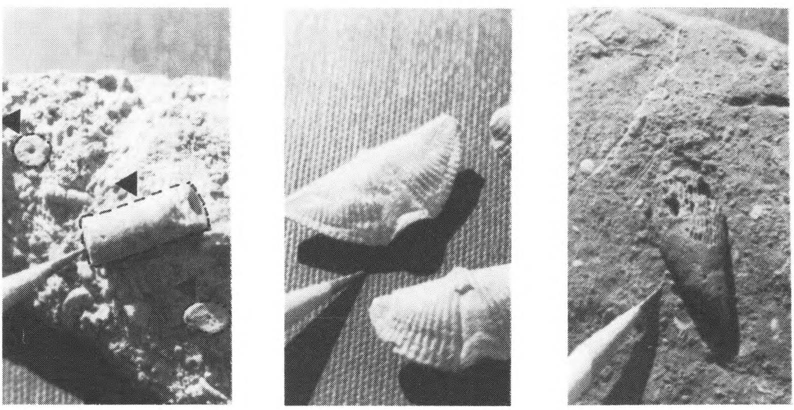


Fig.12-Mile 3.4. Common fossils found in the Mississippian Lodgepole Formation: **A)** crinoid stem; **B)** brachiopods; **C)** horn coral (pencil for scale).

down the hollow, deposited its sediment load in Lake Bonneville, and created the bench-like feature to the south (across the road), a fan-delta deposit. The upper reaches of the fan-delta have steep slopes and are probably alluvial fan deposits. The lower slopes, directly across the highway, are made of stratified material deposited in the lake as a delta (Fig. 13). Notice a small slide that has occurred in the unconsolidated deltaic deposits across the highway.

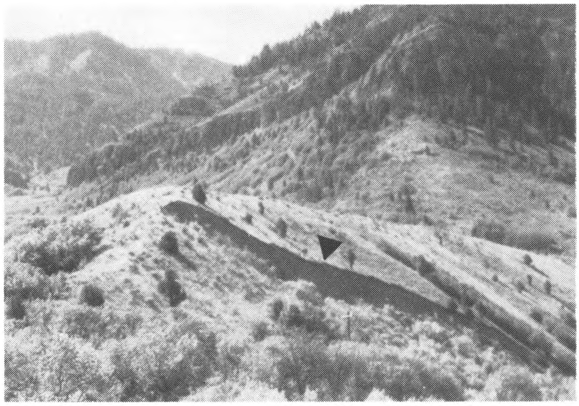


Fig.13-Mile 3.8. A fan-delta deposited into Lake Bonneville by Mill Hollow stream. A small slide (arrow) has occurred in the unconsolidated sediment.

4.1 STOP 4

Spring Hollow Picnic Ground - Pullout to the Right (South). The Devonian Jefferson Formation is exposed in the road cut across the highway to the left (north). At this location, the formation consists of layers of sandstone, dolostone, and shale. The different rock types indicate changing environments as the rise and fall of the Devonian sea level changed the shoreline position. The sands were deposited along a beach while the shales and dolostones were deposited in deeper water offshore as the sea level rose. Some mass wasting has occurred at this location; notice the suspended telephone pole at the top of the cliff (Fig. 14). If you look closely at the layers in the rock below the pole, you will see some small folds in the shale layers. Shale is incompetent and folds easily under compression while the more competent sandstone and dolostone do not fold readily.

Fig.14-Mile 4.1. The Devonian Jefferson Formation is exposed just below the suspended telephone pole.

Spring Hollow is the location of the axis, or low point, of the Logan Peak syncline (see Fig. 9). The rock layers have been dipping eastward; however, at Spring Hollow they are nearly horizontal, an expression of the axis. From here onward the rock layers will dip westward to form the structural feature called a syncline. As you are driving up-dip and therefore down-section, the rocks become increasingly older. Since the road actually parallels the strike of the syncline for several miles, you will be in and out of several of the same nearly horizontal units.

The Crimson Dawn trailhead is located at Spring Hollow. This trail provides easy access to the fossil-rich Lodgepole Limestone.

4.7 **Wind Caves Trailhead.** If you crane your neck and look up to the left as you approach the trailhead sign you may be able to glimpse the Wind Caves high up on the slope to the north. These features are sometimes referred to as the Witch's Castle and consist of a natural arch and a small cave. The Wind Caves have been formed in the Lodgepole Limestone. Contrary to what the name implies, the caves were not formed by wind erosion but by solution of the limestone by chemical weathering processes. If you hike up to the caves you will see evidence of their formation by water. In several places along the walls, water seeps from the rocks. Tufa, a type of limestone formed by springs, is common along the dry walls of the caves, indicating past spring activity. The tufa is deposited, forming little "terracettes", as the water slowly runs down the cave walls.

5.1 **Guinavah-Malibu Campground.**

5.9 **Dipping Rocks.** Since you crossed the axis of the syncline the rocks dip westward. You have also moved back down-section into older rocks. For the next mile or so, road cuts expose the west-dipping Devonian Water Canyon Formation.

7.0 **Card Guard Station on the Left (North).**

7.1 **Oxidized Road Cut.** The road cut in this area is very oxidized or rust colored. This is probably due to oxidizing fluids that moved along many small faults and joints in the rock. The vertical joint pattern is very pronounced and makes the west-dipping nature of the rock layers hard to see.

7.9 **Preston Valley Campground.** The beautiful spires and cliffs along the road are dolostone of the Fish Haven and Laketown Formations.

8.2 **Road Cut.** The road cut you are passing is in the Fish Haven Dolostone. The Fish Haven has a mottled, dark and light appearance. This mottled look is interpreted to be a result of burrowing by organisms living at the bottom of a shallow sea. Today many organisms, such as shrimp, worms, and clams that live in shallow marine environments, burrow and churn up sediment. As fluids move through burrowed sediment a chemical reaction occurs with any remaining organic material and causes the color differences.

8.6 Stop 5

Fucoidal Quartzite Sign - Pullout to the Left (North). This sign explains a surface phenomenon found on a nearby large chunk of Middle Ordovician Swan Peak Formation (Fig. 15). The chunk itself is out of place, that is, the rock that crops out above the sign is still the

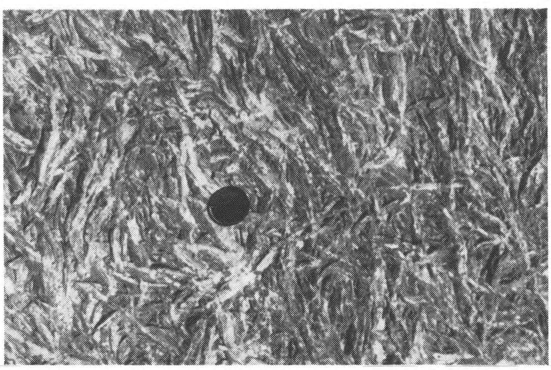


Fig.15-Mile 8.6. Fucoidal quartzite of the Middle Ordovician Swan Peak Formation (lens cap for scale).

Fish Haven Dolostone. The occurence of the Swan Peak chunk in this location is a mystery. The actual contact of the Swan Peak and the overlying Fish Haven is exposed nicely just 0.2 miles up the road. The Swan Peak is the only rock in the Bear River Range that has this fucoidal feature. Most geologists believe these are worm burrows. The worms were not fossilized, probably because they had no hard parts which were readily preservable, so only their burrows remain.

Ripple marks, occasional mud cracks, and a restricted fauna indicate that the Swan Peak represents an environment very near the shore, and thus suggests a regression or shallowing of the sea that covered this area of Utah. During the Ordovician Period, the geologic time when the sediment that formed this rock was deposited, the shoreline

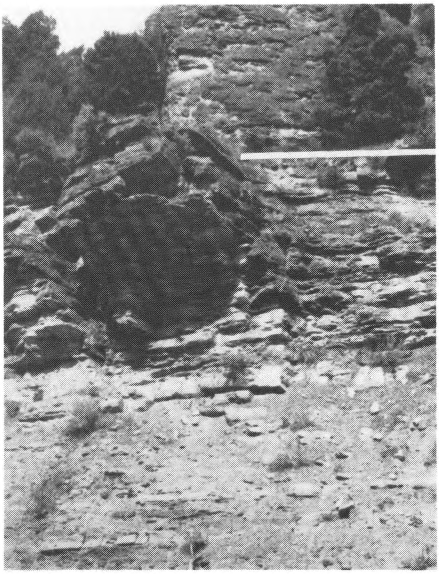


Fig.16-Mile 8.8. The line marks the abrupt contact of the overlying massive Fish Haven Dolostone and the underlying interbedded quartzite and shale of the Swan Peak Formation.

was located here in northern Utah. To the east there was exposed land; to the west there was an ocean.

The Swan Peak is a white to buff and purple quartzite unit with some interbedded dark shales. Even though it is called a quartzite, a term that normally refers to a metamorphic rock, it is a sedimentary rock. Since the particles that make up the rock are made of quartz and are cemented with quartz, technically it is called an orthoquartzite. Generally the "ortho" is left off when one is referring to the unit. Quartz particles cemented with quartz make a very hard rock. The Swan Peak was used as a building stone for some of the early structures in Logan, including the Logan Temple, the Logan Tabernacle, and the foundations of some of the older buildings on the Utah State University campus. The stone was quarried at Temple Quarry in Green Canyon, about 1.5 miles north of Logan Canyon.

8.8 **Road Cut to the Left (North) - Swan Peak Formation.** The interbedded fine-grained sandstone and shale of the Swan Peak Formation are well exposed in this road cut. The contact with the overlying Fish Haven Dolostone is abrupt and easily observed (Fig. 16). The Fish Haven represents a deeper marine environment indicating that once again the seas had invaded Utah as a transgression took place. An erosional surface, called a disconformity, exisits between

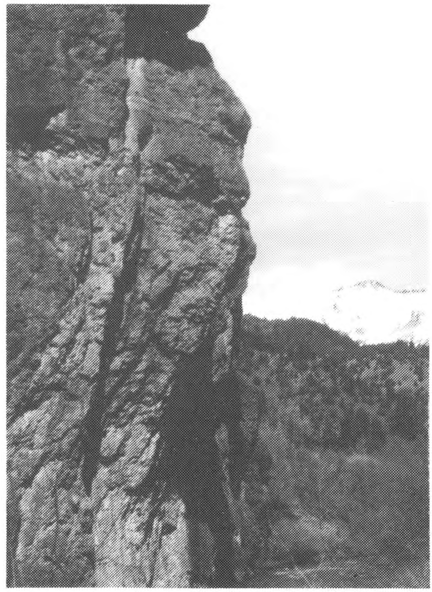


Fig.17-Mile 9.0. The Fish Haven Dolostone forms a cliff next to the Logan River. The river is slowly undercutting this cliff.

these two units. That means that some of the sediments that were deposited had subsequently been exposed and eroded before deposition of the Fish Haven occurred. Thus, the gap in the rock record represents missing time. Disconformities are not obvious and are usually identified by fossil evidence.

8.9 **Bridge over Logan River - Sign for Right Hand Fork Road.**

9.0 **Cliff along the Logan River to the Left (West).** The Fish Haven Dolostone forms a cliff (Fig. 17) on the opposite side of the river where occasionally you will see climbers practicing their skills. At the base of the cliff an overhang forms a small alcove that early wagon trains used as a camping spot.

9.6 **China Row Picnic Area.**

9.9 **Wood Camp Road/Campground.** Wood Camp road ends in approximately 300 yards at the trailhead to the Jardine Juniper Trail. See Hike 1 for a geologic guide of this delightful trail. The moss-covered rocks across the Logan River from the campground indicate the location of a spring discharging through the talus at the base of the small slope.

10.7 **Contact.** On the left (north) side of the road you can again see the well-defined contact between the Fish Haven and Swan Peak. The road weaves through the Swan Peak, Fish Haven, and Garden City Formations for several miles.

10.8 **Bridge across the Logan River.**

11.3 **Outcrops of the Garden City Limestone.** The outcrops along the road are in the upper section of the Ordovician Garden City Limestone, which contains significant amounts of black chert. Chert is a type of microcrystalline quartz, which is very resistant to chemical weathering. Chert is usually associated with marine rocks such as limestone and dolostone and seems to be concentrated in burrows. It forms from dissolution of silica and then subsequent deposition of a siliceous ooze. One common source of silica is tests or shells of small microscopic organisms called radiolarians. Another source of silica is sponge spicules. Some sponges have spicules, small rod-like parts composed of silica that join together to form a framework for the soft sponge tissue. These spicules can be dissolved and then redeposited as chert. The nodules and blebs of chert usually extend out in relief on the face of an outcrop because they are more resistant to weathering than the surrounding limestone.

Fig.18-Mile 11.5. Logan Cave developed along a joint and fault system in the Ordovician Garden City Limestone.

11.5 STOP 6

Logan Cave. Since the pullout at this location is narrow, use caution if you choose to stop here. Logan Cave is to your left (north) (Fig. 18). Spring water in varying amounts always issues from below the cave mouth. The cave was described and mapped in 1943 by V. Church. The cave extends along a joint and fault system for about 2,000 feet. It is best to explore the cave at low water levels in early spring, since one must walk through cold water in the beginning. The rock in which the cave formed is the Garden City Formation. It is a limestone unit that dissolves readily when exposed to even slightly acidic water. Where does the acid water come from? When carbon dioxide is dissolved in water it makes a weak acid called carbonic acid. Carbon dioxide may be dissolved in rain as it falls through the atmosphere to earth's surface. Additional carbon dioxide may be added to the rain water as it percolates through the soil, since organic decay resulting from bacteria in soil emits carbon dioxide. Even though the acid that forms is weak, with enough time it will dissolve limestone.

Although the Logan Cave has some interesting features, there are no spectacular cavestone formations, such as those present in some of the well-known caves across the nation. Very little water drips from the ceiling of Logan Cave to form stalagmites, stalactites, etc. Most of the water that enters the cave flows along jointed and faulted rock instead of slowly dripping in. Furthermore, many of the cave formations that were present have been vandalized by some of the people who enter the cave.

The cave developed in several stages. An early stage created pockets and cavities as dissolution occurred along joint patterns. This early dissolution occurred below the water table. As the Logan River downcut and lowered the local water table, a stream started to flow through the passageways and connect the earlier-formed pockets. The water in the cave continues to erode (by solution) downward, therefore slowly lowering the cave floor.

Because only the mineral calcite dissolves, any silt, sand, or clay in the limestone is left behind. This makes for a muddy experience, but the cave is still a fun place to explore.

The rocks that form cliffs along the road for the next mile or so are also the Garden City Formation.

12.9 **Narrow Road Cut - Bridge over the Logan River.** You are passing through a narrow road cut in the Garden City Formation, the same limestone unit in which Logan Cave was formed. As you pass through the road cut and cross over the Logan River, a beautiful view unfolds before you, where the Logan River forms a short, but scenic, deep canyon below. This is an area of an unusual geologic phenomenon called entrenched meanders, where the river eroded downward while keeping an original meander pattern. Rivers far from base level, as is the Logan River, typically erode downward and therefore create relatively straight, narrow, steep-walled valleys. Only when rivers approach their base level do they start eroding laterally to create wide valleys and a meandering river channel. So why is there a meandering river channel in a narrow canyon? The resistant Swan Peak Formation that the road crossed lower down the canyon formed a temporary base level on this section of the Logan River. It took some time for the river to cut through this hard quartzite unit, enough time for a short section of the river upstream to develop a meander pattern. When the river finally cut through the hard rock of the Swan Peak, it started to erode downward, keeping the original meander pattern, and the meanders became "entrenched".

The road continues to wind through the Garden City Formation, evidenced by the nearly horizontal layers of rock in this area.

13.7 **Bridge over the Logan River.**

14.3 **Temple Fork Road.**

14.9 Stop 7

Rick's Spring. This spring occurs in the layered rock of the Garden City Formation. A small normal fault in the vicinity of the cavern created the folds seen in the rocks directly above the cavern. The spring's discharge varies from zero cubic feet per second(cfs) in winter to about 150 cfs in June. There is a direct relationship between the spring's increased discharge and snowmelt in the spring; therefore, the source of the water is most likely local spring runoff which probably seeps into the ground in the Tony Grove Basin area to the northwest. It is possible that some of the spring's water may also come from the Logan River, since a fault intersects the river upstream from the spring and trends directly toward the spring.

16.0 **Cliffs to the Right (East).** The rocks that form cliffs to the right (east) and to the left farther up the road are the Fish Haven Dolostone.

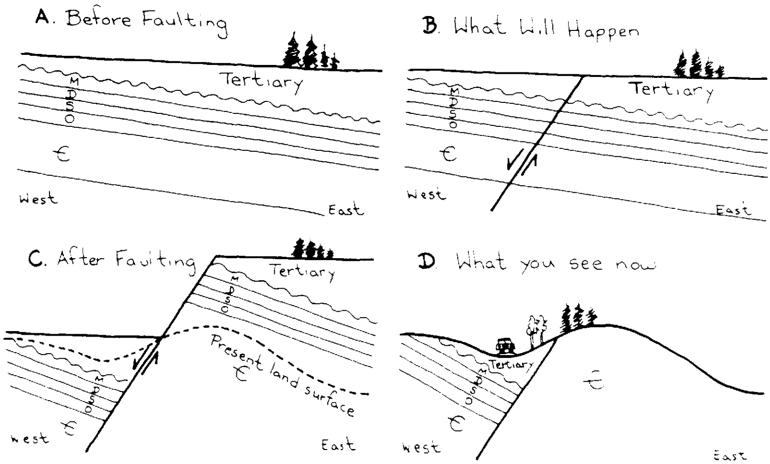


Fig.19 -Mile 16.5. Idealized diagram of the development of the Temple Ridge fault. The wavy line represents an unconformity. The letters indicate the geologic period during which the different layers of rock were deposited. Refer to the geologic time scale (Fig. 2) for period names.

16.5 **Cattle Guard.** The valley widens and straightens above this point, trending north-south for several miles. This north-south trend is a result of structural control by the Temple Ridge fault, a normal fault just east of the highway. Motion along this north-south trending fault downdropped rocks to create the linear valley. To the left (west) of the road, Ordovician to Mississippian rocks crop out while to the right (east) are Cambrian age rocks. The younger rocks were faulted down relative to the older rocks (Fig. 19).

In 1962, a magnitude 5.7 earthquake in Cache Valley caused destruction in the town of Richmond. This quake's focus, the point underground where motion along a fault occurs and thus generates seismic waves, may have been located on the Temple Ridge fault. The fault plane dips about 45° to the west, locating the epicenter, the point on Earth's surface directly above the focus, in Cache Valley.

18.0 **Utah State University Forestry Field Station.** Aspen trees, which require a certain amount of moisture to grow, are very common on the valley floor and surrounding rolling hills. Fine-grained soils developed on the Tertiary age Wasatch Formation, a red sandstone and conglomerate, and Quaternary age sediments, retain more moisture than soils developed on the associated limestone and dolostone. The aspen favor the more moist Tertiary and Quaternary deposits, thus their distribution can be used to indicate rock type. You can actually locate the surface expression of the Temple Ridge fault to the right (east) of the road by the aspen trees. Aspens extend only to an altitude that marks the extent of the Wasatch Formation, which was downdropped, as a result of the fault, against Paleozoic limestone and dolostone (see Fig. 19).

18.6 **Tony Grove Lake Road.** For a scenic side trip up Tony Grove road refer to Tour 8. During the Pleistocene Epoch glaciers formed on many of the high peaks to the left (west) and extended down the valleys nearly to the highway. The last glacial episode in this area is called the Pinedale Glacial and occurred approximately 12,000 to 30,000 years ago. As the glaciers melted, they deposited the mixture of rock material they carried. This unsorted mix of large boulders to fine-grained particles is called "till". When till is deposited by a receding glacier it is usually referred to as a moraine. You will see moraine material as you continue up the highway.

19.4 **Bridge over Logan River.**

19.5 **Red Banks Picnic Area.** Aptly named for the obvious steep red bank across the Logan River, this is a good place to get a close look at the red Wasatch Formation, an Early Tertiary sandstone and conglomerate that was deposited by streams eroding mountains east of the Bear River Range. The Bear River Range was not uplifted in Early Tertiary time, instead the area was probably a broad basin where deposition of the conglomerate occurred. As the Bear River Range started to be uplifted, approximately 10 to 15 million years ago, the Wasatch conglomerate was removed by erosion from most of the range and remains only as occasional isolated remnants.

The Wasatch Formation is nearly horizontal and overlies older dipping Paleozoic strata. All of the rock of the geologic time between the Paleozoic Era and the Tertiary Period are gone. Therefore, the Mesozoic Era is not represented by rocks in this part of the Bear River Range. Such a break in the rock record is called an unconformity and results either from deposition of the rock material and then later erosion, or simply by nondeposition. When the underlying rocks are at an angle or dipping, as the Paleozoic rocks are here, and are then covered with flat-lying sediments (the Wasatch Formation) the type of unconformity formed is called an angular unconformity (see Fig. 19). The unconformity is exposed at Tony Grove Lake, although the dipping nature of the underlying rocks is not obvious.

20.0 **Cross Cattle Guard.** The road cut to the right (east) consists of Wasatch Formation capped with glacial till (moraine deposit) composed of glacially reworked Wasatch Formation. So what you see is red rock on red rock, not a clear distinction. However, this is one area where the road actually goes through a glacial moraine. Most of the glacial deposits are to the left (west) of the road.

The conical peak seen to the northwest (to your left at about 11 o'clock) is Steam Mill Peak. The top section of the peak is composed of the Swan Peak Formation.

21.7 **Franklin Basin Road - Glacial Moraine to the Left (West).** This is a rough gravel road that connects with the Cub River Road in Idaho and eventually to Highway 91. The Logan River has its source in springs located up the Franklin Basin area. The creek along Highway 89 is no longer the Logan River; it is now Beaver Creek.

The road cut to the left, just past the Franklin Basin Road, is through a glacial moraine composed of till, fine-grained to coarse-grained unsorted, unconsolidated material that commonly slumps. There are several small slumps in the road cuts in this area.

22.2 **Bridge over Beaver Creek.**

22.3 **Rock Outcrops.** The rock adjacent to the road is the Middle Cambrian Bloomington Formation. Several outcrops can be seen along the old road across Beaver Creek to your left (north). The Bloomington is composed of shale and limestone layers, some of which are massive and quite thick.

24.3 **Beaver Mountain Winter Sports Area Road.** Just past the ski road the highway passes through an old glacial moraine deposit. This deposit is somewhat of an enigma to the area. If it is a glacial moraine, what is the origin of the glacier that deposited the material? There is little evidence in the surrounding hills to suggest where the glacier might have existed. It is generally agreed, however, that this feature is old; that is, it is not from the most recent glacial pulse. We know it is old because most of the boulders and rocks making up the moraine are quartzites of the Swan Peak Formation. There are very few limestone or dolostone boulders in the moraine. This is probably a result of solution (chemical weathering) destroying the more easily dissolvable carbonates, leaving the very resistant quartzite. Such a process would take time, thus, an older age is speculated for the moraine. Geologists think this moraine was deposited during the Bull Lake Glacial event which occurred at least 60,000 years ago.

Beaver Creek has its source up the drainage to the north.

24.8 Stop 8

Pullout to the Right (there is a wide spot adjacent to the road as you travel through the open valley). Some interesting periglacial features, features that form in proximity to glaciers, can be viewed from here. Patterned ground can be seen on the shallow slopes of this valley. Patterned ground is a set of distinctive morphological characteristics (polygons, circles, stripes) that form at the surface due to frost action. These features form in very cold climates where the repeated freeze and thaw cycle of frost action sorts coarse and fine-grained material to create the patterns. Its relict occurrence is a useful indicator of past climate. During the time when glaciers existed in the area, any land not covered by ice would most certainly have been subjected to some serious frost action. Vegetation differences make the pattern of circles more obvious, with sagebrush and grasses covering the circular mounds and mule's ear growing in the area between the mounds. This creates light and dark areas which make the circular patterns. The patterns do become more noticeable as you increase your vantage point when the road curves south and gains elevation.

The Amazon Mine is located just east of here. Discoveries of metallic mineral deposits near Salt Lake City in 1863-64 led people to prospect for ore in the Bear River Range. Not much was discovered until the1890s. In 1892, the Amazon Mine shipped 5 tons of ore worth $5,000 to Salt Lake City. The principal ore mined was silver, with lesser amounts of copper, lead, and gold recovered. Metallic mineral deposits usually result from hot fluids (hydrothermal solutions) that deposit minerals in veins along cracks or fissures in the rock. The fluids are generally associated with igneous activity. However, there is little geologic evidence of igneous activity in the Bear River Range, and hydrothermal activity and associated mineralization are rare.

25.3 **Road Cut to the Left (North).** This road cut and the next several road cuts are through the Cambrian Blacksmith Dolostone.

26.0 **Contact.** The contact with the overlying Bloomington Formation is in this area. Notice that the beds are now east-dipping approximately 24°. You are now driving through a small anticlinal structure called the Temple Ridge anticline.

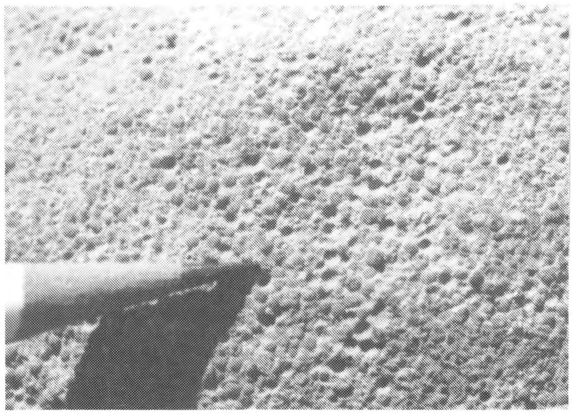


Fig. 20-Mile 26.6. Ooids, small, circular particles that form in agitated shallow marine environments, occur in the Bloomington Formation (pencil for scale).

26.6 Stop 9

Steep-walled Road Cut. There is a pullout just before a steep-walled road cut. This is a great road cut through the Cambrian Bloomington Formation. However, if you decide to get out and look at the rocks be careful of the traffic. The Bloomington consists of interbedded green shale and gray limestone. The shale is very fissile, that is, it breaks up into small thin pieces. Some of the limestone is made up of ooids (Fig. 20). These are small, dark, circular particles that have a very specific mode of formation. Generally, ooids form in agitated shallow marine conditions. Calcium carbonate is precipitated in concentric layers as the spherical particles are moved about by wave action. It is difficult to imagine, but if you went back in time to when the Bloomington was being deposited, this area would have been a shallow body of water, or shoal, in a warm tropical sea, perhaps similar to shoals found today off the Bahamas. The sedimentary layers have also been offset by several faults.

To your right (southwest) is Amazon Hollow and some old mine tailings. Tailings refer to material that was mined but contained very little or no ore.

26.8 **Utah Department of Transportation State Maintenance Station.** The cliffs above the road just past the maintenance station are Upper Cambrian St. Charles Formation and Ordovician Garden City Formation. A normal fault extends along the base of the cliffs.

The large depression to the right (south) of the highway is called a sink and is a feature of karst topography. Karst refers to a set of characteristic surface features that form by solution of limestone and/or dolostone rocks underlying the ground surface. The sink was formed in the limestone of the Cambrian Bloomington Formation. There are a number of sinks in the Bear River Range. Perhaps the most famous is Peter's Sink, where several winters ago the lowest temperature recorded was -66°F. The road cuts from here to the summit are through shale and limestone of the Bloomington Formation.

28.3 STOP 10

Pullout - Restroom to the Right. As you look north, there is a good view back to the sink area. You can take a look at outcrops of the Bloomington Formation in the area just west of the parking lot. The surfaces are very rough, a direct result of solution chemical weathering of the limestone. The buff colored quartzite boulders lying around were brought here to be used as fill material to build up the pullout; they are not native to this area.

29.1 **Bear Lake Summit - Elevation 7,800 feet.**

29.2 **Limber Pine Trailhead and Rest Area**. The road cuts are still through the Bloomington Formation; however, a small amount of the Cambrian Nounan Limestone is exposed along the road to the left (north) just past the summit.

29.8 **Sunrise Campground.**

29.9 STOP 11

Bear Lake Overlook. Bear Lake occupies the southern portion of Bear Lake Valley. Drill-hole data show that Bear Lake existed in this area for at least 28,000 years. During most of that time the lake was fed by runoff from adjacent streams. The Bear River did not flow into the lake. The lake had a natural outlet to the north, which drained into the Bear River. The lake was developed into a reservoir when a channel was constructed in 1918 to divert the water of the Bear River into the lake.

Evidence of past shorelines along the western margin of the lake indicate that the lake had higher water stages. The three most recent higher-water shorelines developed during an overall gradual fall of the lake level and are collectively referred to as the Lifton Episode. The highest lake level of the Lifton Episode is called the Willis Ranch shoreline and was about 25 feet higher than the lake's present level. The Garden City shoreline is an intermediate stage of the Lifton Episode when the level was only 15 feet higher than present. The last level of the Lifton Episode, the Lifton shoreline, formed when the lake was 9 feet higher than today.

Why these fluctuations in Bear Lake's water level? Since Bear Lake always had an outlet, increased precipitation is not an adequate answer for the higher-water levels, for if there were an increase in run-off into the lake, the excess water would have flowed into the outlet. Instead, geologic evidence suggests that a significant factor in the formation and water level fluctuations of Bear Lake is faulting. Movement along the Bear Lake fault, which flanks the eastern shore of the lake, tilted the valley floor south and east, creating increased accommodation space for the lake water. Assuming the amount of water in the lake stayed relatively stable, as accommodation space increased due to faulting along the eastern margin of the lake, the western shoreline would have been lowered as the lake water readjusted to fill the newly created area. Bear Lake is not a remnant of Lake Bonneville, as is the Great Salt Lake, nor do the Bear Lake levels correspond to the Bonneville levels. The differences result from the different mechanisms for the formation of the two lakes.

The abrupt steep slopes and faceted spurs seen on the mountains east of the lake mark the location of the Bear Lake fault. The highland east of the Bear Lake fault is called the Bear Lake Plateau. Mesozoic rocks crop out along the eastern edge of the lake; however, the plateau is capped with the red Tertiary Wasatch Formation. On a clear day you can see the Uinta Mountains to the southeast.

30.3 **Road Cuts.** As you drop down to Bear Lake, road cuts reveal the Wasatch Formation red conglomerate and sandstone and Cambrian gray limestone.

30.7 **Tertiary Volcanic Tuff.** The white rock exposed along the road is a Tertiary volcanic tuff. A tuff is volcanic ash, like the ash from Mt. St. Helens, that has been turned to rock. This tuff is part of a unit called the Salt Lake Group and indicates that during at least part of the Tertiary, when this material was deposited, there were violent volcanic eruptions in western North America.

31.5 **Cache National Forest Sign.**

Fig. 21-MIle 32.0. Garden City Canyon (arrow) is the location of the epicenter of the November 1988 earthquake felt by many people in Cache Valley.

32.0 Stop 12

Pullout on the Left (North). This pullout is on a turn, so be careful. The rock that crops out in the road cut to the right is west-dipping Cambrian Geertsen Canyon Quartzite, a quartz sandstone cemented with quartz. Although this is the same type of "quartzite" as the Swan Peak Formation, these two rock units are not the same age. The Geertsen Canyon Quartzite is a shallow-water, high-energy deposit.

Garden City Canyon, to the left (north) (Fig. 21), is the location of the epicenter of the November 1988 earthquake of magnitude 4.8. Magnitude 4.6 aftershocks were felt by many people in Cache Valley. The quake knocked groceries off shelves in the small towns along Bear Lake. The depth of the focus was 11 km (6.6 miles).

This is also the approximate location of the Paris thrust fault, an inactive fault at least 90 million years old (see Fig. 9). The rocks of the Bear River Range originated as sediment approximately 50 km (30 miles) to the west and were thrust eastward in Cretaceous-Tertiary time. This thrusting took place at some depth underground and happened slowly. It took a long time for the rocks to be moved so many miles. During Late Cretaceous to Early Tertiary time, subduction of tectonic plates occurred off the west coast of North America creating a great deal of compressive stress. When translated to the rocks, this stress caused folding and thrust faulting.

33.7 **Road Cuts.** The road winds back into bright red Tertiary Wasatch conglomerate and sandstone, white volcanic tuff, and dark gray Cambrian to Ordovician limestone.

35.7 **Garden City, Utah.** Garden City was established in 1864 and was the first Utah settlement along Bear Lake. Junction with Highway 30 and end of Tour 1.

TOUR 2
GARDEN CITY TO OGDEN

GARDEN CITY SOUTH ON HIGHWAY 30 THROUGH LAKETOWN CANYON TO SAGE JUNCTION, SOUTH VIA HIGHWAY 16 TO WOODRUFF, THEN EAST VIA HIGHWAY 39 TO OGDEN

0.0 STARTING POINT

Garden City. Turn right on Highway 30 and head south along Bear Lake.

2.5 **Pickleville to the Right.**

3.1 **Sweetwater Resort to the Left.**

3.6 **Road Cut.** The road passes through layered, or stratified, conglomerate and sandstone of the red Tertiary Wasatch Formation. The strata have been offset or displaced along several normal faults. One fault, near the end of the cut, juxtaposes red rock against white rock. This produces a small-scale example of the faulting which created Cache Valley and Bear Lake Valley.

6.6 **Bear Lake Rest Stop.** There have been many modern fluctuations of the lake level. Wet years provide enough moisture to raise the level close to the road. During dry years the level is significantly lower, allowing shells of freshwater snails that live in the lake to wash up on the beaches.

The Lower Cambrian Geertsen Canyon Quartzite crops out to the right (west).

7.6 **Rendezvous Beach.**

9.1 **Entering Laketown.** The community of Laketown is located at the southern end of Bear Lake. In the summers of 1827 and 1828, fur

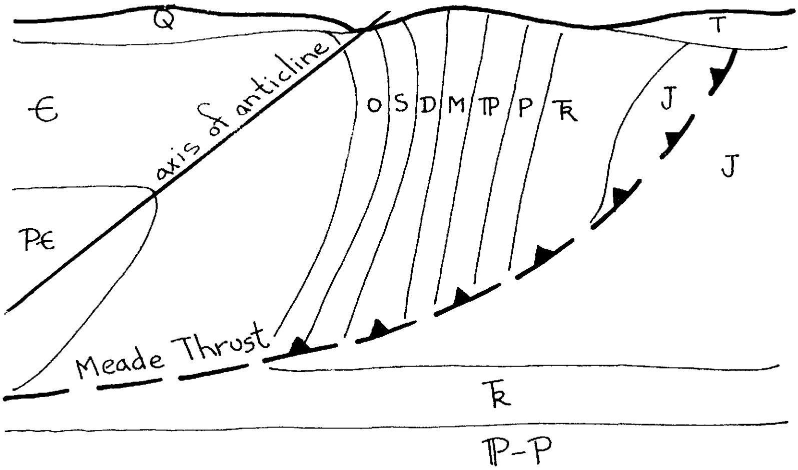


Fig. 22-Mile 10.0. A cross-section view through Laketown Canyon illustrates the axis of the Laketown anticline. The east-dipping rock layers become the overturned rocks that make up the eastern limb of the structure. (Illustration modified from G. L. Valenti.)

trappers gathered in the vicinity of Laketown to sell their winter's catch to buyers from St. Louis. Approximately 7,400 pounds of fur, mostly beaver pelts, valued at just over $27,000 were traded in 1827.

To your left, along the steep mountain front to the northeast, red Mesozoic rocks crop out. These are collectively called red beds because of their distinctive color.

9.8 **Old Laketown Canyon.** The road enters Old Laketown Canyon and winds its way up onto the Bear Lake Plateau. The rocks in the canyon are steeply dipping; therefore, many formations are exposed in a short distance.

10.0 **Steeply Dipping Rocks.** You now start driving through a vertical to steeply east to west-dipping Paleozoic and Mesozoic rocks that form the eastern limb of the tightly folded Laketown anticline (Fig. 22). The first rock exposed in the canyon is Ordovician Garden City Formation. You quickly drive up-section through Silurian to Permian limestone, dolostone, sandstone, siltstone, and phosphatic shale. Some minor folds occur in the overall anticlinal structure.

10.5 **Change in Dip.** The rock layers change their inclination or dip from east to west and are now overturned; that is, at road level, they dip in the same direction as the axis of the anticline (see Fig. 22).

11.3 **Mesozoic Rocks.** You are now driving through sandstone, limestone, and shale of the Triassic Thaynes and Ankareh Formations. The Thaynes Formation was deposited in a shallow sea and is predominantly limestone. It locally contains abundant fossil gastropods (snails) and ammonoids, a coiled type of cephalopod similar to the present day *Nautilus*. The Ankareh Formation is predominantly red shale, siltstone, and multicolored sandstone. These rocks are still part of the eastern limb of the Laketown anticline and are overturned.

12.3 **Tertiary Rocks.** Red conglomerate and sandstone of the Tertiary Wasatch Formation are exposed to your left (north).

12.7 **Road Cut.** This road cut traverses the Wasatch Formation.

Fig. 23-Mile 13.5. The Crawford Mountains east of the Bear Lake Plateau.

13.5 **Top of the Plateau.** Since the top of the Bear Lake Plateau is blanketed by the Wasatch Formation, you will see numerous exposures of red sandstone and conglomerate.

Several oil discovery wells were drilled in this area in the late 1970s. Some natural gas was found, but all the wells are now nonproducing and are capped. This small natural gas field is atypical for the region.

From here you can see the Crawford Mountains to the east (Fig. 23) and the high mountains of the Uinta Range to the southeast.

16.4 **Gravel Pits.** The gravel pits to the left (north) were developed in the Wasatch Formation. Although the gravel that makes up this conglomerate is cemented together, it is easy to break apart, and therefore serves as a good source of roadbed material.

17.4 **Mudstone.** Purple mudstone, still part of the Wasatch Formation, crops out to the left (north).

20.5 **Sage Junction - Turn Right on Highway 16 and Proceed South.** The Crawford Mountains, on your left (east), abruptly rising from the valley floor, are composed of folded and thrust-faulted Paleozoic, Mesozoic, and Cenozoic east-dipping rocks. The rocks in the northern section of the range dip steeply, however, the dip shallows to the south. Mississippian, Pennsylvanian, and Permian age rocks form the prominent outcrops.

The mountains are bounded on the west (the side you are looking at) by the Leefe normal fault, which creates the steep mountain front, and on the east by the Crawford thrust fault. In Early Tertiary time, the thrust fault moved the rocks approximately 18 miles from west to east.

The Bear River flows from its source to the southwest high in the Uintas through this broad valley into Bear Lake Valley. From there it flows north to Soda Springs, Idaho, where it became blocked by lava flows 35,000 years ago. The river now swings south through Gem Valley, passes through Oneida Narrows into Cache Valley, through the Bear River Narrows west of Logan, into northern Salt Lake Valley and finally empties into the Great Salt Lake.

26.0 **Road Cut.** This road cut is through Early Tertiary conglomerate, sandstone, and volcanic tuff.

27.0 **Crawford Mountains.** A disrupted area near the top of the Crawford Mountains on your left (east) is part of an open-pit phosphate mine developed in the Permian Phosphoria Formation, a rock unit rich in phosphate minerals. The Phosphoria Formation is the focus of the major mining activity in the Crawfords and northward to the area near Soda Springs, Idaho. Most mining is underground, but several relatively small open-pit mines are developed in outcrops near the crest of the range.

28.3 **Entering Randolph.** This small town was settled by early pioneers in 1870. Southeast of Randolph, in 1976, an exploratory gas/oil well was drilled to a depth of 15,400 feet, but only water was recovered from the well.

The road continues on Holocene gravel.

29.8 **Historical Marker on the Right (West).** This marker is made of red sandstone.

32.0 **Southern Portion of the Crawford Range.** The rocks exposed in the southern portion of the range are shallowly east-dipping, Mississippian age limestone.

37.9 **Entering Woodruff.**

38.2 **Junction with Highway 39 - Turn Right and Proceed West.** Highway 39 passes through some very scenic country as it winds its way to Huntsville and Ogden.

39.8 **Road Cut.** The road cut and hills to your right (north) are composed of red sedimentary rock of the Wasatch Formation.

The hay meadows to the left (south) are on the flood plain of Gene's Creek. Flood plains are flat areas that form adjacent to streams by deposition of material that was transported during flood stage. Fertile soils generally develop on flood plains, creating productive agricultural areas.

Fig. 24-Mile 43.5. Outcrops of Tertiary Wasatch Formation.

43.5 **Cattle Guard - Cliffs to the Right (North).** As you enter this area you may think that you have been transported to southern Utah where the scenery is dominated by red rocks. The outcrops that form the cliffs (Fig. 24) are the red Tertiary Wasatch Formation.

44.8 **Nearly Vertical Rock Outcrops to the Right (North) - Folded Rocks to the Left (South).** You have just moved from relatively flat-lying Tertiary red rocks into nearly vertical Mesozoic rocks. The two rock units are separated by a fault. The vertical rock layers or beds are interbedded limestone and shale of the Jurassic Twin Creek Formation.

Fig. 25-Mile 44.8. Tightly folded anticline (**A**) and hogback (**B**) in the limestone of the Jurassic Twin Creek Formation.

Across the road, to your left, the lower limestone layers of the Twin Creek form a steeply dipping hogback, while the upper limestone layers are compressed into a tightly folded anticline (Fig. 25). The limestone is more resistant to weathering processes and forms cliffs and hogbacks while the shale weathers easily and forms slopes. A hogback is a geologic term for a narrow outcrop of steeply dipping resistant rock formed by differential erosion of adjacent softer rock.

Fig. 26-Mile 46.4. Cliff-forming, west-dipping limestone of the Twin Creek Formation.

45.5 **Birch Creek Reservoir Road to the Right (North).**

46.4 **Rock Outcrops.** Shale of the Twin Creek Formation crops out, forming slopes for the next mile until you approach a massive cliff of west-dipping limestone of the Twin Creek (Fig. 26).

47.0 **Alluvial Fan.** The road crosses an alluvial fan composed of redeposited Tertiary Wasatch Formation. The red gravel and sand were eroded and transported down-valley from the upper hills by a small intermittent stream and deposited in this fan-shaped feature.

47.4 **Rock Outcrops.** The road moves back into sandstone and shale of the Jurassic Twin Creek Formation.

49.0 **Rock Outcrops.** These outcrops are steeply west-dipping limestone of the Triassic Thaynes Formation.

49.4 **Cliffs.** The nearly flat-layered Tertiary Wasatch red conglomerate and sandstone form cliffs south of the road.

50.0 **Precambrian Outcrop.** The Precambrian Mutual Formation, a sedimentary quartzite, has been thrust over the much younger Triassic and Jurassic rocks. This thrust faulting occurred during the same time interval as the Paris thrust, which moved rocks from west to east in the Bear River Range of Logan Canyon. Precambrian quartzite of the Mutual Formation is exposed for the next mile, after which the Cambrian Geertsen Canyon Quartzite is exposed for approximately 2 miles. The road continues to move up-section through the older Precambrian rocks and into younger Cambrian dolostone and limestone.

53.3 **Painted Cattleguard.** The road traverses open rolling hills composed of the Wasatch Formation.

54.6 **Rock Outcrops.** The road now passes by west-dipping Cambrian Langston Dolostone.

54.9 **Cattle Guard.**

55.7 **View to the Left (Southeast).** On a clear day the peaks of the Uintas are easily seen to the southeast. The highland, which the road traverses from here west, is underlain by Paleozoic rocks, which in turn are overlain by the red Tertiary Wasatch Formation.

56.2 **Curtis Creek Road on the Right (North).**

57.3 **Monte Cristo Campground and Guard Station.**

59.4 **Dairy Ridge Road on the Left (South).**

60.3 **View to the North.** The road has climbed to a vantage point where a spectacular view unfolds to your right (north). The Wellsville Mountains, which border the southern portion of Cache Valley and Mantua Valley, are visible from here. East of the Wellsvilles, the mountains of the Bear River Range flank Blacksmith Fork Canyon, a major canyon south of Logan Canyon.

From here you drive through Ordovician and Silurian limestone and dolostone interspersed with red rock of the Tertiary Wasatch Formation.

61.5 **Pullout on the Left.** A major pullout on the left side of the highway is a good place to park if you want to take a look at the outcrops of the thin-bedded Mississippian Lodgepole Limestone on the right side of the road. When the sediment that makes up this rock was deposited this area of Utah was a shallow tropical sea teeming with life. Today we see a very fossiliferous rock - good for fossil collecting. Some common things you might find are crinoids, corals, and brachiopods (see Fig. 12).

You also get a panoramic view of the "backside" of the Wasatch Range to the west and Cache Valley and the Bear River Range to the north. Road cuts expose the red Wasatch Formation for approximately the next 8 miles.

63.5 **Dry Bread Hollow Road.**

68.2 **Hardware Ranch Road Junction.** This dirt road leads north to Blacksmith Fork Canyon. It is probably a good idea to travel the road in a high clearance vehicle during dry conditions. The gently rolling hills are covered with Tertiary Wasatch Formation through which Paleozoic rocks crop out.

69.8 **Spring.** A spring occurs on the left (east) side of the road. The rocks in this area are east-dipping Mississippian limestone of the Humbug Formation.

Fig. 27-Mile 72.5. The east-dipping Pennsylvanian Wells Formation exposed to the left (east).

71.7 **Cross Beaver Creek.** The road passes through cuts that expose very large rounded boulders and cobbles in fine-grained material, part of a Quaternary fanglomerate. Fanglomerate refers to sedimentary material of mixed grain sizes that was deposited in an alluvial fan. The boulders and cobbles are quartzite eroded from the Wasatch Formation and redeposited by an ancient stream.

72.5 **Road Cut.** A half-mile long road cut exposes the Pennsylvanian Wells Formation, a gray limestone containing numerous black chert nodules. The rock is stained red from the overlying Wasatch Formation (Fig. 27).

These east-dipping rocks are part of the western limb of the Beaver Creek syncline, the geologic structure in this area. The axis of the syncline, occurring just to the left (east), and most of the folded rocks of the syncline are covered by the Tertiary Wasatch Formation.

76.1 **Causey Dam Road - Continue on Highway 39.** From here there is a good view of cliffs of the Tertiary Wasatch Formation to the left. The formation is not as red in this location.

The road now follows the South Fork of the Ogden River. Here Beaver Creek joins the South Fork.

76.9 - 77.3 **Campgrounds.** Three campgrounds occur along this short stretch of road: Willows, Meadows, and Perception Park. Once past Perception Park, the road crosses the unconformable contact of the Tertiary Wasatch Formation and the underlying Paleozoic rocks. Since the Paleozoic rocks are east-dipping, you will be driving down-section through increasingly older rocks.

77.9 **Rock Outcrop.** The road passes through an outcrop of Middle Cambrian Blacksmith Limestone.

78.1 **South Fork Campground.** The rocks to your left (south) are east-dipping limestone and dolostone of the Middle Cambrian Ute and Blacksmith Formations.

78.5 **Botts Campground.**

79.1 **Hobble Campground.** Since the rocks dip eastward, and you are driving west or up-dip, you continue to move down-section into the older Middle Cambrian Langston Dolostone. The contact (the surface between two different rock units) of the Langston and the Lower Cambrian Geertsen Canyon Formation, part of the Brigham Group, occur in this vicinity.

81.1 **Magpie Campground.** The Lower Cambrian Geertsen Canyon Quartzite crops out on both sides of the road and dips eastward approximately 45°.

Fig. 28-Mile 81.6. Rocks of the Precambrian Proterozoic Brigham Group crop out to the south of the canyon of the South Fork of the Ogden River.

81.6 **Precambrian Rocks.** The rocks exposed on both sides of the road are part of the Precambrian Proterozoic to Cambrian Brigham Group. Most of the rocks that make up the Brigham Group are sedimentary quartzites, that is, they are quartz sandstone cemented with quartz. This thick sequence of quartzite suggests that in Precambrian time, a shoreline existed for an extended length of time in this area of Utah (Fig. 28).

Fig. 29-Mile 83.9. Glaciated peaks of the Wasatch Range.

82.8 **Bonneville Features.** As you exit the canyon into Ogden Valley, to the right (north) is a small hill, a shoreline feature of Lake Bonneville. During the maximum elevation of Lake Bonneville, the lake extended through Ogden Canyon and created a large bay in this valley.

83.9 **Junction of Highway 39 and Highway 166 - Stay on Highway 39.** From here there is a good view to the southwest of the glaciated peaks of the Wasatch Range (Fig. 29).

85.1 **Junction Highway 39 and Highway 167 - Stay on Highway 39 and Proceed West.**

Fig. 30-Mile 88.0. Alluvial fan (outlined) developed at the mouth of Geertsen Canyon north of Pineview Reservoir.

86.3 **Anderson Cove Campground - Pineview Reservoir.**

86.7 **Snow Basin Road.** From here the road travels over fine-grained material deposited during the high level of Lake Bonneville.

88.0 **Alluvial Fan to the Right (North).** There is a good view of a large alluvial fan that developed at the mouth of Geertsen Canyon north of Pineview Reservoir (Fig. 30). This fan postdates Lake Bonneville deposits in Ogden Valley.

88.3 **Precambrian Outcrops.** The outcrops on the left are Precambrian siltstone of the Perry Canyon Formation that have been thrust over younger Mississippian rocks. The road crosses the plane of the Willard thrust in this vicinity.

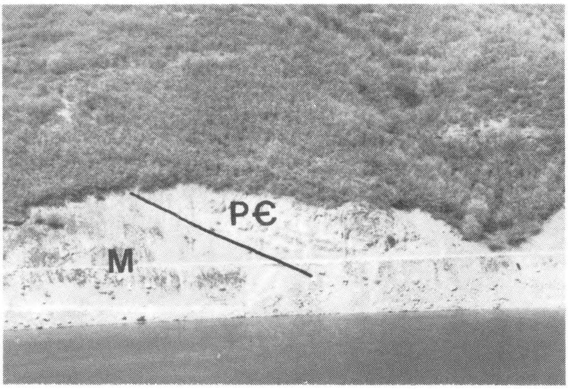


Fig. 31-Mile 89.0. View of the Willard thrust exposed across Pineview Reservoir. The thrust places older Precambrian rocks (**P€**) over younger Mississippian rocks (**M**).

89.0 **Pullout to the Right (North) along Pineview Reservoir.** From here you can see the plane of the Willard thrust exposed in a road cut just to the right of Shanghai Creek Canyon, across Pineview Reservoir (Fig. 31). The trace of the thrust fault extends up the canyon for approximately three-quarters of a mile and then cuts to the west. The thrust moved rocks from west to east and placed older Precambrian rocks on top of younger Mississippian rocks. To the left (west) of Shanghai Creek Canyon, the east-dipping Mississippian Humbug Formation is exposed while to the right (east) much older Precambrian rocks crop out.

The road cut adjacent to this pullout is limestone of the Mississippian Humbug Formation.

89.3 **Pineview Dam - Junction of Highway 39 and Highway 162 - Stay on Highway 39 and Enter Ogden Canyon.** From here you will be driving down-section, that is, the rocks will get older as you continue along the road. The first outcrops along the road are Mississippian limestone, followed by Devonian sandstone and dolostone, Ordovician limestone, and Cambrian dolostone and limestone. Several normal faults cut out part of the rock record exposed along the road.

There is some very interesting geology in Ogden Canyon. However, the road is very narrow and there is usually heavy traffic; please use caution when driving through the canyon.

89.7 **Water Treatment Plant on the Right (North).** Although difficult to see from a vehicle, there is a spectacular Z-shaped fold in the rocks directly above the plant. The folded rocks are limestone of the Mississippian Humbug Formation that lie below the Willard thrust and were deformed due to movement along the fault. The movement occurred slowly and at some depth below the Earth's surface, so the rocks acted as a plastic material, folding in response to stress. These features are exposed on the Earth's surface due to subsequent uplift and erosion.

90.4 **The Oaks.** You continue to drive down-section through increasingly older rock units. The older Middle Cambrian Ophir Formation shale and sandstone are at road level, while the cliffs above are composed of the younger Cambrian Maxfield Limestone.

90.9 **Rockfall.** A relatively fresh rockfall occurred high up the slope to the left (south). Large "fresh looking" or unweathered boulders of Maxfield Limestone lie on the weathered rubble of talus.

91.7 **Ogden Thrust.** The Ogden thrust appears just east of Johnson Draw to your right (north). This thrust fault places older Lower Cambrian Tintic Quartzite over younger Middle Cambrian Maxfield Limestone and Ophir Formation.

92.4 **Rock Outcrops.** The Cambrian Tintic Quartzite is exposed along the road as a result of thrust faulting. The Tintic Quartzite is repeated, as a result of thrust faulting, as you drive down the canyon.

92.9 **Taylor Thrust Fault to the Right (North) - Opposite Smoky the Bear Sign.** Another thrust fault, the Taylor thrust, is exposed high on the north canyon walls to the right. The relationship of older on

Fig. 32-Mile 92.9. The Taylor thrust is exposed high on the north canyon walls. The older pink Tintic Quartzite lies above the fault while the gray Maxfield Limestone lies below the fault.

younger rocks is again displayed with the repeated sequence of older pink Lower Cambrian Tintic Quartzite thrust over the younger Middle Cambrian gray Maxfield Limestone. Although the fault plane dips eastward (Fig. 32), the rocks were moved from west to east like all the other thrust faults you have seen.

The Maxfield Limestone and Ophir Formation crop out along the road.

93.0 **Contact.** The contact of the Ophir Formation shale and limestone with the underlying Lower Cambrian Tintic Quartzite occurs along the road in this location. The quartzites dip steeply eastward or are vertical.

93.5 **Gravel.** The well-cemented gravel plastered up against the Tintic Quartzite is a remnant of material that was most likely deposited by the Odgen River as it flowed into Lake Bonneville when the lake occupied Ogden Valley to the west. At the lake's higher levels this portion of Ogden Canyon was flooded. When the Ogden River entered the quiet water of the lake, it deposited the material it was transporting. Renewed erosion of the Ogden River, as a result of lowering its temporary base level, Lake Bonneville, has removed most of this earlier-deposited material.

93.8 **Farmington Complex Rocks.** The dark-colored metamorphic rocks of the Precambrian Proterozoic Farmington Complex of the form cliffs adjacent to the road.

The road crosses under a suspended irrigation pipe.

94.1 **Exit Ogden Canyon.** Lake Bonneville terraces exist on both sides of the road as you leave Ogden Canyon. Two levels are obvious: the highest is the Bonneville level; the large flat terrace that extends into the Ogden Valley is actually a Provo-level delta formed when the South Fork Odgen River deposited its sediment load upon entering the quiet waters of Lake Bonneville.

95.1 **Junction with Highway 203 (Harrison Boulevard) - Stay on Highway 39 Heading West.**

96.4 **Turn Right on Washington Street (Highway 89) - Follow Highway 89 back to Logan.** End of Tour 2. See Tour 4 for the Brigham City to Ogden section (reverse direction).

The finest workers in stone are not copper or steel tools,
but the gentle touches of air and water working at their leisure
with a liberal allowance of time.

Henry David Thoreau

Tour 3

Sardine Summit

Logan to Brigham City through Wellsville Canyon via Highway 89/91

0.0 Starting Point

Cache County Courthouse, Main and 200 North. Proceed south on Main Street through Logan. Main Street is Highway 89.

1.1 **Approach "Y" in the Road - Stay to the Right on Highway 89/91.**

2.2 **Cross Railroad Tracks.**

3.0 **Wellsville Mountains.** As you leave Logan, the road heads southwest toward the Wellsville Mountains, the northern most extension of the Wasatch Range. From here you have a good view of the Wellsvilles to the west and the Lake Bonneville shorelines that formed along their base.

6.1 **Jensen Historical Farm on the Right (West).**

7.2 **Cross Railroad Tracks.**

7.5 **Cross the Little Bear River.**

Fig. 33-Mile 8.4. Gravel pit (arrow) developed in a spit that projected out into Lake Bonneville.

8.4 **Lake Bonneville Spit.** The gravel pit to the right (west) in the distance, was developed in a spit that projected out into Lake Bonneville (Fig. 33). Spits are elongate ridges of sand and gravel formed by long shore currents.

8.6 **Junction Highway 23 on the Right (West).**

8.8 **Lake Bonneville Deposit.** A small gravel pit is on the right (west) as the road starts uphill through Wellsville Canyon (Fig. 34). Several thousand years ago this was a gravel beach created by wave action along the shoreline of Lake Bonneville. The gravel has been cemented together by calcite, forming the sedimentary rock called conglomerate.

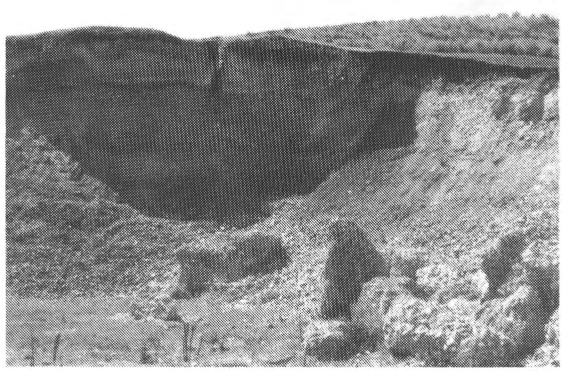


Fig. 34-Mile 8.8. Small gravel pit at the mouth of Wellsville Canyon was originally a beach formed by wave action along the shore of Lake Bonneville.

10.9 **Cache National Forest Sign - Enter the Canyon.**

11.4 **Rock Outcrops.** The rock outcrops along this section of the road are steeply dipping limestone, calcareous sandstone, and minor amounts of shale of the Pennsylvanian to Permian Oquirrh Formation. This is one of the few areas where these youngest rocks of the Paleozoic Era occur at road level.

Directly ahead is an outstanding view of the east-dipping limestone and dolostone that form the ridge of the Wellsvilles.

12.0 **Rattlesnake Canyon Trailhead.** A parking area for Rattlesnake Canyon trailhead, which accesses the Wellsville Crest Trail, is to the right.

13.4 **Sherwood Hills Resort Road.**

13.7 **Old Landslide.** The road begins to traverse a small rise that is alluvial fan and landslide material from the small canyon to the right. The landslide blocked the natural drainage of Dry Lake Valley, into which the road now descends. Seismic evidence indicates the bedrock underlying the unconsolidated sediment of the valley is lowest in the vicinity of the landslide. This pinpoints the location of the previous drainage of the valley.

14.2 **View of Dry Lake.** In the spring, run-off from snowmelt on the adjacent hills collects in this closed basin. By mid-summer, however, the water is usually gone, as it slowly percolates through the soil and fractured bedrock and evaporates in the hot, dry summer weather. In wet climate cycles, such as 1983-1985, this basin contained a year-round lake since percolation and evaporation could not keep pace with the increased amount of precipitation. During the wet cycle, the water rose high enough to threaten the road, so the roadbed was raised several feet.

15.3 **Road Cut.** The steep-sided road cut you are about to enter exposes the Upper Mississippian Great Blue Formation. During the geologic age when the sediment now forming this rock was deposited, the area was a shallow sea rich with life. Many fossils can be seen on the rock exposed to your right (west) where the bedding or layers dip toward the road. These fossils tell the story of past life in the Mississippian and include several different types of corals, brachiopods, and bryozoans.

15.9 **Sardine Summit - Highway Maintenance Road Camp - Small-scale Syncline.** A great exposure of Silurian Laketown Formation occurs directly behind the maintenance buildings to the east. The layered limestone and dolostone are folded into a syncline, a small-scale version of the major structural feature of the Bear River Range in Logan Canyon.

Notice that the rock's surface is irregular, a result of solution pits that formed on the limestone surface when the rock was exposed to weathering processes on the Earth's surface. Although the rock is now covered with a layer of dirt, there is very little dirt on the top of the hill and much more along the sides of the hill. This is unusual, because dirt formed by soil-making processes on the underlying bedrock, would have a more uniform thickness. The dirt is actually loess, silt-sized particles that were transported by wind. The source of the particles was most likely fine-grained material that collected in gravel bars and flood plains of glacial meltwater streams. The grinding action of glaciers on bedrock produces a very fine-grained material called rock flour. Rock flour is transported by glacial meltwater and deposited in bars along glacial streams where wind can pick it up and move it great distances. What you are looking at is more evidence of the Ice Age, when glaciers occupied many of the high mountain valleys in this area of Utah.

16.8 **Midway Antique Shop.**

16.9 **Rock Outcrops.** On the left (east) moderately east-dipping Paleozoic limestone and dolostone crop out. Similar rocks occur along both sides of the road for the next mile. Numerous normal faults juxtaposing the rock layers add complexity to the bedrock geology in this area.

There are many small earthflows on the west side of the road in the reddish-colored loess.

18.2 **Kiln on the Left (East).** The road enters Mantua Valley which is partially filled by Mantua Reservoir. The reservoir was formed in the 1950s when the outlet of the valley was dammed. The Bonneville level, the highest level Lake Bonneville reached before emptying through Red Rock Pass, extended to Mantua from the west.

18.6 **Road to Mantua on the Left (South).**

19.7 **Rock Outcrop.** An extensive road cut to the right (west-north) exposes faulted and altered quartzite of the Precambrian to Cambrian Brigham Group. Although these rocks dip to the east, they have such a prominent joint or fracture pattern that their east-dipping nature is not obvious.

19.9 **Mantua Fish Hatchery Road.**

20.0 **Box Elder Campground Road to the Left (South).** The road now follows Box Elder Creek.

20.8 **Cache National Forest Sign.**

20.9 **Precambrian Outcrops.** The dark brown, iron-stained outcrops on both sides of the road are composed of Precambrian Upper Proterozoic to Cambrian Brigham Group sedimentary rocks including siltstone, sandstone, and argillite, a highly compacted mudstone.

Fig. 35-Mile 21.8. Road cut through the Provo-level delta that formed when Box Elder Creek entered Lake Bonneville.

21.8 **Provo Delta.** The road passes through unconsolidated gravel and sand of a Provo-level delta formed when Box Elder Creek entered the quiet waters of Lake Bonneville, lost velocity, and deposited the coarser material it was transporting (Fig. 35).

23.2 **Wellsvilles.** To the right (north) is a good view of the abrupt west-facing side of the Wellsvilles which are composed of east-dipping Paleozoic rocks. This mountain range is bounded by normal faults on the west and east. The west-facing side is bounded by the Collinston segment of the Wasatch fault, while the east-facing side is bounded by the West Cache fault. It is estimated that 30,000 feet of displacement occurred along the Wasatch fault. While motion along a fault uplifts mountains, erosional processes are at work wearing them down so you never see all of the relief of this displacement at one time.

The Bonneville shorelines extend along the base of the mountains to the north but become less distinct in rocky areas.

23.5 **Stoplight and Intersection with Main Street.** End of Tour 3. See Tour 4 for Brigham City to Ogden and Tour 5 for Brigham City to Logan via Cache Butte Divide.

Tour 4

Brigham City to Ogden

Brigham City South along Highway 89 to Ogden

0.0 Starting Point
Stoplight at the intersection of Highway 89 and Main Street just south of Brigham City, turn left and head south.

0.5 **Lake Bonneville - Wasatch Fault.** This section is sometimes locally referred to as "fruit way" because of all the orchards and fruit stands lining the highway. The pervasive Lake Bonneville shorelines form prominent benches along the base of the Wasatch Mountains to your left (east).

The Wasatch fault bounds the western front of the Wasatch Range. Studies indicate that the fault is divided into a series of segments that probably behave somewhat independently. The segments are separated by boundaries, either another fault or a salient, a geologic term for a major bedrock spur that extends out into a basin or valley. From here, south to Rocky Point, the mountains are bounded by the Brigham City segment of the Wasatch fault.

2.6 **Great Salt Lake to the Right (West).** Willard Bay, the northern end of the Great Salt Lake, appears on your right. The Salt Lake is a remnant of the once larger, ancient Lake Bonneville. A change to a warmer and drier climate at the end of the last Ice Age, approximately 12,000 years ago, led to the shrinkage of the lake waters as evaporation increased over precipitation. The level of the Great Salt Lake still responds to climate variations. In the 1983-1985 wet climate cycle, the lake level rose several feet and flooded adjacent land, including most of the Bear River Wildlife Refuge. The refuge encompasses most of the wetlands formed where the Bear River enters the Great Salt Lake, just west of Brigham City. The Bear River delivers most of the fresh water that enters the lake.

Precambrian rocks are exposed on the hillsides to the left (east) and are part of the rock sequence of the upper plate of the Willard thrust. Once you approach Willard Canyon the road crosses the trace of the thrust, and the rocks forming the magnificent cliffs from Willard south are part of the Precambrian to Cambrian rock sequence of the lower plate (underneath) of the Willard thrust.

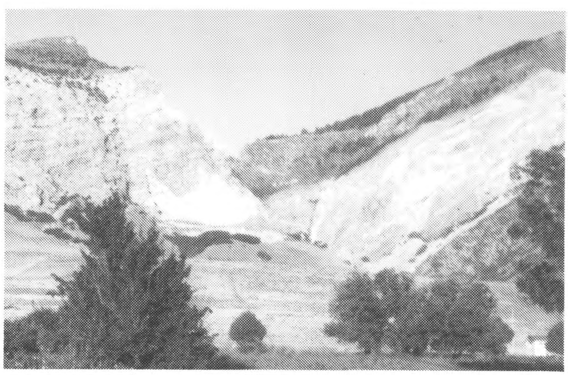


Fig. 36-Mile 4.3. The light-colored, east-dipping, Lower-Middle Cambrian Tintic Quartzite overlies the dark, 1.8-billion-year-old Farmington Complex at Willard Canyon. The boundary between the two rock units is a nonconformity and represents over 1 billion years of missing time.

4.3 Willard Canyon to the Left (East). You can just start to see Willard Canyon, a large canyon carved into the western slopes of the mountains (Fig. 36). The first outcrops of pink, steeply dipping, Lower-Middle Cambrian Tintic Quartzite are to the left (north) side of Willard Canyon. The light-colored Tintic remains visible along the mountain front as you drive south to Ogden. This quartzite is also a "sedimentary quartzite" like the quartzites that occur in the Bear River Range. It consists of sand-sized quartz particles and scattered rounded pebbles and exhibits small-scale cross-bedding, a sedimentary structure that tells a story about how the original sand grains were deposited. Small-scale cross-beds are a slice through ripple marks, which occur in streams and along beaches today, and are formed by moving water. By looking at modern features and making comparisons to the ancient rock record, geologists unravel the mysteries hidden within the rocks. Since the Tintic Quartzite is composed of ripple-marked, well-rounded sand grains and pebbles, geologists can postulate it was probably deposited in a near-shore or beach environment. In Cambrian time, the sands most likely were eroded from exposed continental rock to the east, transported by rivers to the ocean, and finally formed beaches rippled by shoreline currents.

From here south, the spectacular rugged outcrops expose some of the oldest rock in Utah. The dark, lower rocks are part of the Precambrian Lower Proterozoic Farmington Complex, metamorphic schist and gneiss that have been radiometric age-dated to be at least 1.8 billion years old and possibly as old as 2.5 billion years. The Farmington Complex is directly overlain by the much younger Cambrian Tintic Quartzite, 550 million years old. Color differences make the boundary between these two rock types apparent. You may recognize that there is a big chunk of time missing, or not represented by the rock record, between these two rock units. This is an unconformity and results from deposition of the "missing" material and subsequent erosion removing the material. An unconformity may also result from nondeposition of the material during that time interval. When sedimentary rock unconformably overlies metamorphic or igneous rock, the contact between the two rock units is called a nonconformity.

Metamorphism refers to changes that occur to the rocks, a result of changes in the rocks' environment such as increased heat and/or pressure. Geologists studying the Farmington Complex have determined that most of the gneiss was originally a granitic intrusion, while some of the lenses of gneiss and schist were originally sedimentary rock. Most of these rocks are tightly folded, a common characteristic of metamorphism.

The Willard thrust is located just above the pink cliffs of the Tintic Quartzite and places older Precambrian rock on top of younger Cambrian rock.

5.1 **Debris Flow Basin.** On your left, you will soon be passing a rock wall that is really a spillway for a debris flow basin constructed in the early 1920s. In 1910 the uppermost slopes of the drainage basin of Willard Canyon were heavily overgrazed. The removal of soil-stabilizing vegetation by overgrazing resulted in two debris flows which moved through the canyon and deposited material. These debris flows damaged structures in the town of Willard. A debris flow is a combination of mud, sand, gravel, and boulders saturated with water that becomes unstable and moves down slope. After this disaster two things were done to mitigate the situation. First, grazing was limited on the upper slopes and these slopes were terraced and planted with trees. Second, a debris basin was constructed to channel and contain any future debris flows. A debris basin is just what it sounds like, a large basin constructed directly below the hazard area that will hopefully contain any debris flow coming off the mountain slopes. The rock spillway you see from the highway allows water, collected in the basin behind it, to run off. Since its construction, the debris basin has been nearly filled by debris flows. Debris basins are still being constructed in many areas of the United States where mass wasting hazards are present.

5.6 **Alluvial Fans.** A small canyon, to the south of Willard Canyon, with a very nice alluvial fan developed at its mouth, is coming into view. Alluvial fans form when a steep mountain stream with a high gradient empties onto a plain of lower gradient. The abrupt gradient change causes a decrease in the stream's velocity and thus the stream's carrying capacity; therefore, the stream deposits the material it transported down from the mountain slopes. This depositional process gradually builds a ramp-like feature called an alluvial fan. All of the small canyons along the mountain front have alluvial fans at their mouths. If you look closely you will notice that large boulders comprise part of the fan material. Streams probably didn't move such big rocks; more likely these are old debris flow deposits. Because no shoreline features are developed on them, the alluvial fan deposits postdate Lake Bonneville.

6.5 **Toe of an Alluvial Fan.** The road traverses the toe of an alluvial fan. Notice the boulders that dot the alluvial fan. These boulders were most likely moved by mass wasting events.

8.9 **Junction Highway 89 and Interstate 80.** Stay to the right on Highway 89 to reach Ogden Canyon and downtown Ogden.

9.8 **Rocky Point.** The road curves around Rocky Point, part of the Pleasant View salient. Complex faulting extends this bedrock point, or salient, some distance from the mountain front. Even though the point is composed of Cambrian Tintic Quartzite, only a few outcrops of quartzite can be seen above the Lake Bonneville sediments that blanket the underlying rocks.

Once you are past Rocky Point, the east-facing Wasatch Mountains are bounded by the Weber segment of the Wasatch fault, an active normal fault that continues to uplift the Wasatch Range. Fault scarps of the Wasatch fault, steep slopes created by movement along the fault, are not easy to distinguish from Bonneville shoreline features.

10.3 **Road Cut through the Tintic Quartzite.**

10.4 **Peter Skene Ogden Historical Marker on the Left (East).**

13.2 **View of the Wasatch Mountain Front to the Left (East).** The Wasatch is an imposing mountain range formed by complex thrust and normal faulting during the geologic past. The dark, lower rocks, the Farmington Complex metamorphics, are overlain by the lighter pink Cambrian Tintic Quartzite. All of these rocks have been moved from west to east by thrust faulting. Here one captures a glimpse of Earth's complexity, since several thrust sheets are stacked one on top of another. Two thrusts that occur below the Willard thrust, the Ogden and Taylor thrust faults, are exposed in the Wasatch Range east of Ogden and cause repetition of the rock sequence.

At this point, the road tour to Ogden is essentially complete. The guide will continue to the starting point of Tour 2, Garden City to Ogden, for those who are interested in connecting with that route.

15.2 **Junction Highway 204 (Wall Street) - Stay on Highway 89.**

16.1 **Junction Highway 235 - Stay on Highway 89.**

17.0 **Junction Highway 39 - Turn Left (East) on Highway 39.**

18.3 **Junction Highway 203.** End of Tour 4. Stay on Highway 39 if you would like to continue through Odgen Canyon. Proceed to Tour 2 (reverse direction).

To see the greatness of a mountain, one must keep one's distance;
To understand its form, one must move around it;
To experience its moods, one must see it at sunrise and sunset,
At noon and at midnight, in sun and in rain,
In snow and in storm, in summer and in winter
And in all the other seasons
He who can see the mountain like this comes near to the life of
the mountain.

Mountains grow and decay, they breathe and pulsate with life.
They attract and collect invisible energies from their surroundings
The forces of the air, of the water, of electricity and magnetism;
They create winds, clouds, thunderstorms, rains, waterfalls
and rivers. They fill their surroundings with active life and give
shelter and food to innumerable beings. Such is the greatness
of mighty mountains.

Lama Govinda

TOUR 5

LOGAN TO BRIGHAM CITY

VIA CACHE BUTTE DIVIDE

LOGAN WEST VIA HIGHWAY 30 THEN SOUTH ON HIGHWAY 69 TO BRIGHAM CITY

0.0 STARTING POINT

Cache County Courthouse, Main and 200 North. Proceed west on 200 North, which turns into Highway 30.

0.7 **Cross Railroad Tracks.**

3.8 **Road to Benson to the Right (North).**

5.0 **Logan Marsh Bridges.** There are four bridges, in a short distance, that span the waters of the Logan Marsh. The Little Bear River enters the marsh from the left (south) and eventually flows into the Bear River to the north. The marsh provides habitat for many different creatures, including a variety of waterfowl such as pelicans, sandhill cranes, ducks, and geese.

From here you have a good view of the Wellsville Mountains. These mountains trend north-south and are bounded by normal faults on both the east-facing (the side you are looking at) and west-facing sides. This range is often referred to as the steepest mountain range in the world, that is, they are very high in relation to the width of their base. It is such a narrow range, that if you stood on the ridge top, you would look almost directly down into the northernmost Salt Lake Valley. A patch of bare, rocky ground on the northern end of the range is a result of a recent landslide.

The two most prominent Lake Bonneville levels, the highest Bonneville level and the lower Provo level, are easy to observe along the mountains on the west side of Cache Valley. In addition to these two levels, you can see many minor shorelines.

6.5 **Petersborough Sign.** From here the road starts up a gentle incline, passes over old lake shorelines, and continues over Cache Butte Divide into the Salt Lake Valley. When the lake was at its highest level, this pass was covered with water. The lowest point along the ridge, where the water of Lake Bonneville initially entered Cache Valley, is just north of the road, at Bear River Narrows, the site of Cutler Dam. Bear River Narrows was also the connection between the western portion of the lake and Red Rock Pass, in northern Cache Valley, when the lake began to empty (see Tour 6).

7.1 **Cross Railroad Tracks.**

7.3 **Junction with Highway 23 - Stay on Highway 30 Heading West.**

9.3 **Road Cut.** A volcanic tuff, an ash-fall deposit of the Tertiary Salt Lake Group, is exposed to your right (north). Since the highest level of Lake Bonneville covered this area, it is likely that the tuff was reworked by wave action and currents.

10.3 **Crest of Hill - Cache Butte Divide.** As you crest the hill, you will see your first view of the northernmost Salt Lake Valley.

The Malad Range to the right (north) and the Wellsville Mountains to the left (south) are separated by Cache Butte Divide.

10.6 **Provo-level Shoreline.** At this point, the road crosses the somewhat obscure Provo-level shoreline.

10.8 **Cutler Dam Road to the Right (North).**

11.0 **Gullies.** The road crosses a small gully eroded by Willow Creek, an intermittent creek, into the soft Lake Bonneville sediment. Several narrow but deep gullies formed in these easily erodible sediments and are skirted by the road.

13.4 **Bear River.** From here you have a good view of the Bear River and its flood plain, both of which are incised into old lake-bottom sediment. This portion of the Bear River is considered to be a mature stream; that is, it is close to its temporary base level, the lowest level a stream can erode - in this case the Great Salt Lake. Most of the erosional work of the river is extended laterally instead of downward to form elegantly curved meanders.

The notch, or lowest point, in the ridge to the right (north) that separates Cache Valley and Salt Lake Valley is the Bear River Narrows. The Bear River eroded the notch through Silurian and Ordovician limestone and dolostone. Cutler Dam was built in the gap.

Many intermediate Bonneville shorelines are developed on the mountains on the west side of the Salt Lake Valley.

14.1 **Junction with Highway 69 (30) and Highway 120.** Stay on Highway 69 (30), which turns south toward Brigham City.

15.0 **Enter Collinston.** The rock outcrops to the left (east) are the Collinston Conglomerate, a member of the Tertiary Salt Lake Group. This conglomerate consists of rounded to somewhat angular gravel fragments eroded from the rocks on the surrounding hillsides. In places, it contains numerous gastropod (snail) shells.

Two gravel pits south of this small town offer nice cross-section views of layered Lake Bonneville shoreline deposits. Some of the gravel and sand layers are horizontal, some are on an angle, and some are contorted into swirls.

The two prominent shorelines in this area are still the upper Bonneville level and the lower Provo level. To your right (west) is a good view of what was once the flat-floored lake bottom. The Bear River has eroded into the lake bottom sediment after the lake dried up about 10,000 years ago.

18.0 **Gravel Pit.** This is a great place to look at different ways sediment can be deposited. The varying grain sizes can be related to different energy levels of water that transported and deposited the sediment. In areas along the gravel pit walls, you may see cross-bedded gravel overlying horizontally bedded silt. While high energy is needed to move the coarse material, silt, which is generally carried in suspension, requires quiet water to settle out. What kind of story does this change in sediment type tell?

19.0 **Rock Outcrops.** South of the gravel pit, outcrops of Paleozoic rock form cliffs that jut out of the steep hillsides. The rocks are inclined, or gently dipping, to the northeast and are Pennsylvanian to Permian

Fig. 37-Mile 19.0. Talus (outlined) forms slopes beneath cliffs of the Pennsylvanian to Permian Oquirrh Formation.

limestone of the Oquirrh Formation. Abundant talus forms slopes under the cliffs (Fig. 37). Talus forms mainly as a result of frost action, the repeated freeze and thaw of water, which eventually breaks rock apart.

19.2 **Junction with Highway 69 (30) and Highway 102.** Continue driving south on Highway 69 (30) toward Brigham City.

19.4 **Enter Deweyville.**

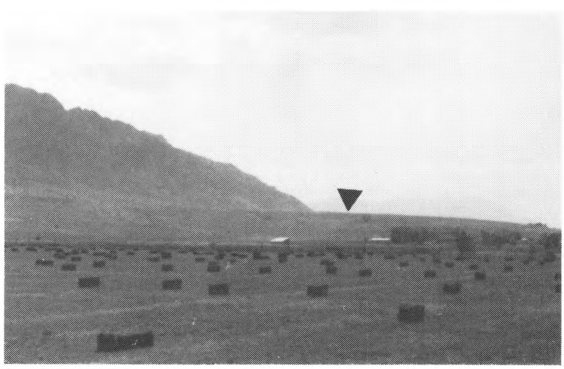


Fig. 38-Mile 21.2. An alluvial fan (arrow) south of Deweyville.

21.2 **Alluvial Fans.** As you travel south of Deweyville there is a good view of what appears to be a ramp jutting out into the valley (Fig. 38). This is an alluvial fan made of stream deposits and mudflow and debris-flow material. Alluvial fans occur at the mouth of every canyon along the Wellsvilles.

22.3 **Enter Honeyville.** In 1939, a mammoth's tusk was found near the small community of Bear River City, southwest of Honeyville, a reminder of the different creatures that roamed this area in the past.

23.0 **Crystal Hot Springs.** The hot spring to your right (west) is located in proximity to the fault-bounded Wellsville Mountain front. Fault zones are areas where rock is fractured and broken by the grinding movement of rock. Fluids can flow easily through these fractured zones. The water that reaches the surface at Crystal Springs is most likely heated deep below the Earth's surface. It then moves to the surface via the path of least resistance - a fractured and consequently permeable fault zone.

23.0 **Wellsville Homocline.** From here there is a good view of the thick pile of Paleozoic limestone and dolostone, including a thick sequence of quartzite, that comprise the Wellsville Mountains. The layers, or strata, all dip steeply to the northeast and are cut by numerous small-scale normal faults. You may notice fault offset of some of the more obvious rock layers.

When the strata all dip in one direction, as they do in this portion of the Wellsville Mountains, they form a structural feature called a homocline.

24.7 **Junction to I-15 on the Right (West) - Stay on Highway 69 South.** As you continue to drive south along the base of the Wellsvilles, you move down-section, that is, the rocks are becoming older (since the rocks dip northeast). Several small normal faults have also helped to rearrange the rocks so they are older as you drive south.

24.2 **Alluvial Fan.** The road crosses an alluvial fan emanating from the mouth of Cottonwood Canyon.

26.2 **Gravel Pit.** A large gravel pit, to your left (east), is against the base of the mountains just north of Call's Fort Canyon. By now you probably realize that the gravel and sand, a valuable resource, are a result of Lake Bonneville shoreline deposits.

26.3 **Call's Fort Canyon on the Left (East) - Call's Fort Historical Marker on the Right (West).** The historical marker tells the history of Call's Fort, which was built in 1855. The local history is fascinating, but so are the rocks that make up the historical marker. The distinctly color-banded boulders are gneiss from the Farmington Complex (see Tour 4) that crops out south of Brigham City. The more common

Fig. 39-Mile 26.3. Paleozoic limestone and dolostone form the spectacular cliffs in Call's Fort Canyon. An alluvial fan was formed at the mouth of the canyon.

rounded pink quartzite boulders are from the lower Cambrian Brigham Group that crops out just south of Call's Fort Canyon. Why are so many of the quartzite boulders rounded? Stream action will round the boulders; however, these stones were taken from an early flour mill where the grinding action produced rounded boulders. What better stone could be used to grind flour than a hard, quartz-rich rock such as this?

Besides all of the wonderful rocks making up the historical marker, there is a beautiful view of the spectacular cliffs of Paleozoic limestone and dolostone in Call's Fort Canyon to your left (east) (Fig. 39). A characteristic alluvial fan is also formed at the mouth of the canyon. Just south of this canyon are the first outcrops of the Precambrian to Cambrian Brigham Group Quartzite. These are the dark brown to rusty colored rocks at the base of the mountains.

28.2 **Shorelines.** From here is a good view directly south along the range front to Brigham City and the well-developed Bonneville and Provo-level shorelines.

29.3 **Alluvial Fan, Mines, and Fossils.** You are now traveling over the toe of an alluvial fan which includes mudflow and debris-flow material from Cascade Canyon to the left (east). The numerous large boulders indicate such mass wasting events.

The Cambrian Spence Shale, a member of the Langston Formation, crops out in the lower part of Cascade Canyon. The Spence Shale is a fossiliferous unit, with trilobites and brachiopods among its more common fossils. Brigham City resident Lloyd Gunther has collected extensively in the Spence Shale over many years. He has uncovered a variety of world-class fossils, some of which are new species. If you care to hunt fossils in the Spence Shale, note that the property adjacent to the mountains is private land and that you must have the land owner's permission before crossing private property.

At this point, an old road scar begins to cross the mountain front and leads to an old antimony mine in Antimony Canyon, the next large canyon to the south. The road starts from private land and is now nearly impassable due to rockfalls. During World War II, antimony was highly valued as an alloy in metals for airplanes. Antimony is relatively rare in the United States, so the small amount found by prospectors was enough to expend a large amount of money for developing the mine. Mine buildings, including a mill and living quarters for mine workers, were constructed in Antimony Canyon and in several of the smaller canyons to the north. However, very little ore was actually shipped out for the war effort.

Due to faulting, the Spence Shale crops out high up the steep slopes of Antimony Canyon. This is the location of one site where Mr. Gunther and others have collected numerous fossil specimens.

30.3 **Brigham Group Quartzite.** From here south, the outcrops making up the mountain front are Cambrian Brigham Group Quartzite.

31.9 **Enter Brigham City.** Continue through town to the junction with Highway 89.

35.1 **Junction with Highway 89.** End of Tour 5. See Tour 3 for Logan to Brigham City and Tour 4 for Brigham City to Ogden.

And the rocks, the rocks have songs.
Like this rock I wear around my neck, it has a song.
All the stones that are around here, each one has a language of its own.
Even the Earth has a song.
We call it Mother Earth.
We call her Grandmother,
and she has a song.

Black Elk

Tour 6
Red Rock Pass

Logan to Red Rock Pass, Idaho via Highway 91

0.0 Starting Point

This tour starts at the intersection of Main Street and 400 North. Proceed north on Main Street, which becomes Highway 91, through Logan.

1.2 **Intersection with 1400 North.**

1.5 **View of the Bear River Range.** As you drive north there are many good views of the west-facing "front" of the Bear River Range. This mountain range trends north-south and is made up of mostly Paleozoic sedimentary rock, limestone, dolostone, and minor amounts of shale and sandstone. The eastward dip or inclination of the rocks is apparent in Green Canyon, the first major canyon north of Logan Canyon directly to the right (east). A small quarry, Temple Quarry, is located just a few miles up Green Canyon. The quarry was developed in the Swan Peak Quartzite, a buff to purple quartz sandstone cemented with quartz, that was used by early pioneers as a building stone.

2.0 **Cache Valley and Lake Bonneville.** Cache Valley is a narrow elongate basin that crosses the Utah-Idaho state line. It is approximately 50 miles long and from 7-13 miles wide. Both sides of the valley are bounded by normal faults; therefore, it is a structural basin called a graben. This structural "style" of normal faults is characteristic of the Basin and Range Province, of which Cache Valley is part (see Hike 2 for an additional explanation of the Basin and Range). The valley is filled with up to 7,000 feet of sediment, which was eroded and transported from the surrounding mountains, and which overlies a floor of Paleozoic bedrock. During the Late Pleistocene, the valley was occupied by a portion of Lake Bonneville called Cache Valley Bay In the late 1800s, geologist G. K. Gilbert recognized evidence that led him to believe a large lake once occupied much of western Utah. Among the most obvious old lake features are the numerous shorelines that formed along the mountains. These are often referred to as benches.

3.9 **Hyde Park Road to the Right.**

4.0 **Alluvial Fan.** As you look straight ahead you may notice a slight rise in the highway. The road moves onto a post-Bonneville alluvial fan composed of gravel and sand deposited by Summit Creek. The town of Smithfield is built on this alluvial fan.

5.0 **Smithfield City Limits Sign.** Several small hills are separated from the mountain front to the right (east). Long Hill has the large "SV" letters for Sky View High School. These hills are composed of Tertiary Salt Lake Group conglomerate. The conglomerate represents material eroded and moved downslope from the mountain front as it was starting to be uplifted during Late Tertiary time. The East Cache fault runs between these small hills and the mountain front.

6.6 **Stoplight - Smithfield.**

7.1 **Gravel Pit.** As you leave Smithfield, a large gravel pit comes into view on the right (northeast). The coarse-grained, west-dipping layers of sediment in the gravel pit walls indicate that this deposit was a delta formed by Summit Creek as it emptied into Lake Bonneville. The gravel pit has two levels: the upper is developed in the Bonneville-level shoreline, while the lower is in the Provo-level shoreline.

8.0 **Crow Mountain on the Right (East).** Crow Mountain, the hill next to the road, is composed of Precambrian to Cambrian Brigham Group Quartzite and Cambrian and Ordovician dolostone and limestone. The rocks of Crow Mountain were downdropped to their present position along a small normal fault. A view of the flat valley floor, the old Bonneville lakebed, is to your left (west). Newton Hill juts up from the valley floor. Prominent shorelines are developed completely around it, indicating that it was an island at the time of Lake Bonneville.

The Malad Range rises behind Newton Hill. The town of Clarkston is located in the foothills of the range. In 1939, a fragment from a mammoth's tusk was discovered near Clarkston, a reminder not only that the scenery was different during the Pleistocene when Lake Bonneville filled Cache Valley, but that the animals roaming the hillsides in the past were also different.

9.0 **Outcrops.** The blocks of rock on both sides of the road are Cambrian Brigham Quartzite.

11.1 **Richmond City Limits Sign.** The town of Richmond is built on a post-Bonneville alluvial fan formed by City Creek, a small drainage to the east. In the early 1900s, the discovery of mineralization along intersecting faults in City Creek Canyon led to the development of several small-scale lead mines.

12.2 **Flashing Overhead Light - Richmond.** From here the road drops down off the City Creek alluvial fan and onto the Bonneville lake bottom.

Fig. 40-Mile 12.7. Cherry Peak (arrow), at the head of Cherry Creek Canyon.

12.7 **Cherry Peak.** To your right (east) is a wonderful view of Cherry Peak, directly up Cherry Creek Canyon (Fig. 40). The rocks underlying the foothills are Brigham Group Quartzite, while Cherry Peak itself consists of Ordovician limestone of the Garden City Formation.

Fig. 41-Mile 14.8. Ancient Lake Bonneville shorelines developed on Mt. Smart.

14.8 **Gravel Pits and Shorelines.** A number of small gravel pits have been developed in the Provo-level lake terraces to the right (east). Straight ahead and just to the left (northwest), Mt. Smart rises 600 feet from the valley floor (Fig. 41). The town of Franklin, Idaho, the oldest community in Idaho, is nestled against Mt. Smart's eastern slope. Bonneville-level shoreline processes formed the flat bench near the top of the mountain, indicating that, at the lake's highest level, Mt. Smart was no more than a small island. The lower Provo-level bench is approximately 200 feet above the valley floor.

15.8 **Road to Lewiston.**

17.4 **Idaho-Utah State Line and Historical Route Marker Sign.**

18.2 **Entering Franklin, Idaho.** John Weber's group of trappers wintered near here in 1824. Jim Bridger, a member of Weber's group, explored the Bear River, following it to the Great Salt Lake. Ephriam Logan, also a member of Weber's party, trapped along the Logan River.

18.7 **Flood Plain of the Cub River.** As you leave Franklin the road drops down onto the flood plain of the Cub River. As the water of Lake Bonneville began to recede, the Cub River eroded downward through the lake sediments and formed a flood plain, the flat land adjacent to the river.

19.1 **Old Lakebed.** The road crosses the Cub River and travels up out of the flood plain onto old lake sediment and continues over lake sediment for several miles.

23.3 **Sewage Treatment Plant on the Right (North).** Approximately one-half mile after passing the plant, the highway ascends a gentle rise onto a very large Provo-level delta. The town of Preston is built on this delta formed as the Bear River deposited its sediment load as it entered Lake Bonneville.

24.5 **Entering Preston.** Proceed through town staying on Highway 91.

26.2 **Intersection with Highway 34/36 - Stay on Highway 91.** The road curves to the left and heads west for a few miles, providing a good view of the Malad Range.

28.5 **Delta and Lake Deposits.** The road descends through delta and lake deposits to the flood plain of the Bear River. The Bear River has its headwaters in the Uinta Mountains and travels a circuitous path until it empties into the Great Salt Lake near Brigham City. After Lake Bonneville dried up in Cache Valley, the Bear River's base level lowered, causing the river to erode downward through unconsolidated lake and delta sediment.

Since the river is close to the Great Salt Lake, which is its base level, it erodes laterally and develops a very sinuous or meandering channel. The meanders are not static features; rather, they move downstream and from side-to-side with time. This movement results because the river's erosional force is strongest on the outside of the meander bend and erodes material there. Sediment deposition occurs on the inside of the bend. With time this process leads to channel migration.

29.4 **Cross the Bear River.**

30.0 **Historical Marker - Pullout to the Right (East).** You may want to stop at this pullout since it provides good views of the numerous landslides along the valley sides. During wet times, such as in the spring or during big storms, the unconsolidated sediments of the valley walls are saturated with water, become unstable, and are pulled downward under the influence of gravity. Mass wasting is an important process of widening stream valleys.

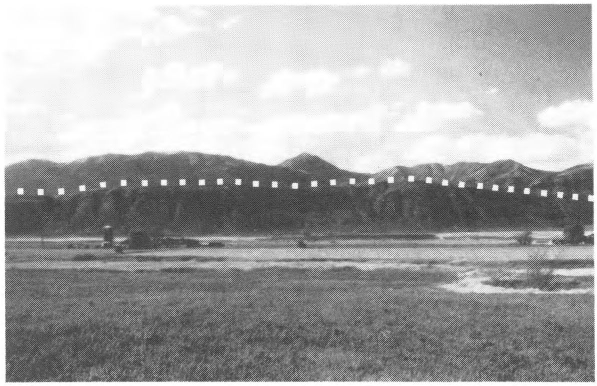


Fig. 42-Mile 32.0. Long Ridge (outlined) is composed of the oldest rocks in Cache Valley.

In addition, you may also enjoy looking at the unique historical marker. It is constructed of a wide variety of rocks, minerals, fossils, and even artifacts. A large, rounded, fossil coral head and a mano and matate, ancient grinding stones, are just some of the fascinating items incorporated into this marker.

30.8 **Rough Road.** This section of the road is uneven and cracked resulting from motion of the underlying ground. The hummocky appearance of the ground surface to the right is a good indication that it is part of a landslide. You also have a good view of the Bear River Valley and the slope failure along the valley walls.

32.0 Long Ridge to the Left (West). Long Ridge, separated from the mountains, is composed of the oldest rocks in Cache Valley (Fig. 42). These Precambrian rocks record ancient volcanic eruptions and glaciation.

34.3 Oxford Peak to the Northwest. Oxford Peak, the highest peak in the Malad Range, is composed of northeastward-dipping Proterozoic to Paleozoic rocks (Fig. 43). Similar to the Bear River Range and the Wellsvilles, the rocks of the Malad Range have been moved by thrust faulting from west to east during mountain building events. From here the northern part of Cache Valley narrows and the valley floor gains elevation. Lake Bonneville shorelines become less distinct as the road begins to traverse rolling hills.

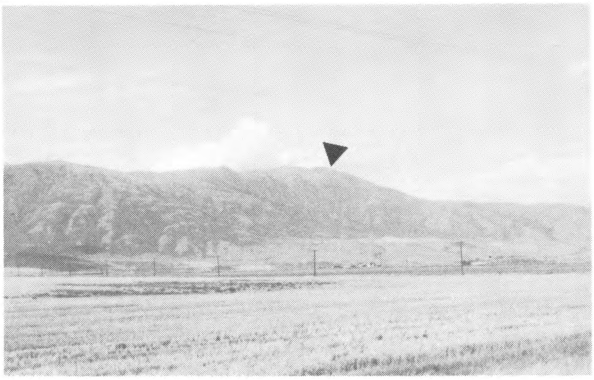


Fig. 43-Mile 34.3. Oxford Peak (arrow) is composed of northeastward-dipping Paleozoic rocks.

41.1 **Swan Lake to the Left (West).** The white rock exposed in the road cuts from here north is Tertiary volcanic tuff of the Salt Lake Group. This volcanic tuff is discussed in more detail in Tour 1.

42.2 **Entering the Community of Swan Lake.**

44.8 **Outcrops.** The rock along the road and the surrounding hills is Cambrian dolostone and limestone of the Bloomington and Blacksmith Formations. The first road cut exposes the Bloomington Formation, whereas the very next one exposes a jumble of chaotic blocks of rock. The blocks and their chaotic nature indicate that this may be an old landslide deposit. The Blacksmith Formation forms the outcrops past the old slide material.

46.3 **Red Rock Pass - Geologic Sign and Pullout to the Right (East).** Red Rock Pass marks the northern extent of Cache Valley and was the only outlet of Lake Bonneville, a large, fresh-water, pluvial lake (pluvial refers to a lake formed during a wet climatic cycle). Lake Bonneville formed and the area was glaciated during the same time, a time of cooler weather and increased precipitation. The lake occupied a large intermountain basin until an outlet to the ocean was breached.

Red Rock Pass served as a natural physical barrier to the waters of the lake. However, once the lake waters rose high enough to top this barrier, the water discharged catastrophically. The water first flowed into Marsh Creek, from there into Portneuf Creek, to the Snake River, into the Columbia River, and finally into the Pacific Ocean. If you walk up the steps to the pioneer historical marker on the knoll, you will have

Fig. 44-Mile 46.3. View north of Red Rock Pass. The outcrops forming the cliffs are the Upper Cambrian St. Charles Formation.

a good view of the pass (Fig. 44). Before the flood, the pass did not look as it does today. The valley you see now was filled with unconsolidated gravel, sand, and silt that had eroded from the surrounding hills. Once the lake waters topped the barrier, however, the current began to excavate a channel through this material. As the channel size increased, the amount of water discharged increased, and the increase in discharge in turn increased erosion of the sediment. Eventually, a huge river catastrophically flowed through the pass, flooding everything in its path. The discharge rate has been calculated to be five times the flow of the Amazon River. Once the water had eroded to bedrock, that is, once all the loose sediment was removed, the channel excavation slowed and the flooding most likely ceased. Many geologists believe that the lake lowered approximately 330 feet very quickly, possibly in days to only a few weeks time, from the Bonneville level to the Provo level.

The rocks of the knoll and surrounding hills are the Upper Cambrian St. Charles Formation. In this northern part of the Bear River Range, the St. Charles has a buff colored quartz sandstone member, the Worm Creek Sandstone, which is exposed along the stairs leading up the knoll. The pioneer monument on top of the knoll is made of granite similar in appearance to the granite cropping out in Little Cottonwood Canyon near Salt Lake City.

End of Tour 6.

TOUR 7
MINNETONKA CAVE

GARDEN CITY, UTAH NORTH VIA HIGHWAY 89 TO ST. CHARLES, IDAHO, THEN WEST ON MINNETONKA CAVE ROAD TO MINNETONKA CAVE

0.0 STARTING POINT

Garden City, Utah - Proceed North on Highway 89. The road heads north following the western shoreline of Bear Lake.

1.2 **Bear Lake State Recreation Area.**

2.0 **Historical Marker on the Left (West).** This marker provides information regarding the Oregon Trail and pioneer activity in the Bear Lake area.

3.0 **Rock Outcrop.** Cambrian Brigham Group Quartzite crops out to your left. The rocks are steeply dipping and form a prominent cliff.

3.8 **Utah-Idaho State Line.**

4.7 **Scenic Route Information - Bear Lake Historical Marker on the Right (East).**

4.8 **Enter the Town of Fish Haven.** Fish Haven Canyon is the major canyon to your left (west). The Late Ordovician Fish Haven Dolostone that crops out in Logan Canyon was first described in Fish Haven Canyon. A sequence of rock that was originally described and given a formation name by geologists is called a type section. The formation is commonly named after a geographic feature in its type locality (such as a mountain, canyon, etc.). Type sections serve as standards for defining the formation in other areas. Initial geologic investigations of the Bear River Range, including defining and describing formations, were done in the early 1900s. Many of the type sections of formations were measured and described in the canyons along the eastern side of the range.

10.5 **Enter the Town of St. Charles.** Continue to drive through town.

11.1 **St. Charles Canyon Road - Minnetonka Cave - Turn Left (West).** The U.S. Forest Service provides guided tours of Minnetonka Cave every half hour, from 9:30 A.M. until 5 P.M. daily, from mid-June through Labor Day. There is a small fee for the tour. But even if you don't want to walk through the cave, the drive up St. Charles Canyon is very beautiful. The road parallels spring-fed St. Charles Creek for most of the way, plus there are several geologic points of interest.

The type section of the Upper Cambrian St. Charles Formation is located up St. Charles Canyon.

12.9 **Minnetonka Cave Information Sign.**

13.2-13.4 **Rock Outcrops.** Ordovician limestone and dolostone form a small syncline exposed in the road cut to your right. At first, you pass west-dipping rocks, then the dip shallows so that the rocks are almost flat-lying (this is the axis of the syncline). Finally, the rocks dip eastward.

13.9 **Paris Thrust Fault.** The Paris thrust fault, an inactive fault, is a major structural feature in this area and is exposed on the hillside to the south. Figure 45 illustrates the location of the fault and the age relationships of the rocks both above and below the fault. Thrust faults result from compressional stresses that move older rock onto younger rock along a zone of weakness (the fault plane). In this case, older Cambrian rock has been thrust over younger Ordovician rock. Tectonic forces, present off the west coast of North America in the Cretaceous Period, moved the rocks on the thrust sheet above the fault approximately 30-40 miles from west to east.

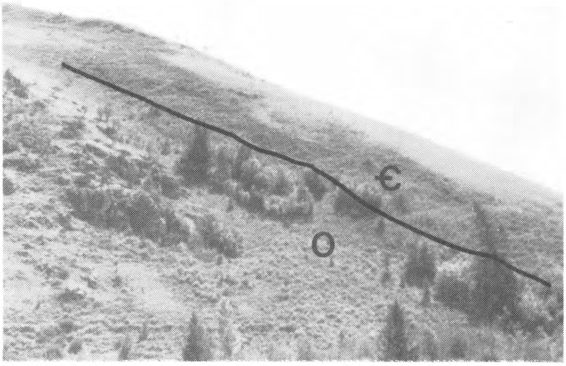


Fig. 45-Mile 13.9. The line follows the trace of the Paris thrust fault on the hillside south of the road. Cambrian (€) rocks have been thrust over younger Ordovician (O) rock.

For the next mile you will see west-dipping Cambrian Brigham Group purple conglomerate and buff quartzite.

15.1 **Cattle Guard - Enter Cache National Forest.**

15.3 **St. Charles Campground.**

15.5 **Blackstone Mine.** Old mine tailings and timbers to your left (south), just past the campground, are part of the Blackstone Mine, an extensive underground lead mine. The mine was developed and operated during the 1890s and was one of the largest in the Bear River Range. Mineralization occurred along faults and joints in the Cambrian Blacksmith Dolostone.

Since the rock layers dip west, as you drive up canyon you will be moving up-section, through increasingly younger Paleozoic rocks.

16.8 **Avalanche Chute.** A narrow, barren slot through the forest to your left (south) is an avalanche chute, an area cleared of trees by the power of snow moving rapidly downslope. The outcrops on the hillsides are dolostone and limestone of the Cambrian and Ordovician St. Charles and Garden City Formations.

17.7 **Cattle Guard.**

17.9 **Blue Pond Spring Sign and Pullout.** A short trail takes you to this beautiful crystal clear pond fed by spring water welling out of fractured limestone.

18.7 **Rock Outcrops.** The rocks along the road are purple Middle Ordovician Swan Peak Quartzite and dark grey Upper Ordovician Fish Haven Dolostone.

19.2 **Cattle Guard.**

19.3 **Porcupine Creek Campground.**

19.5 **Cross St. Charles Creek.**

19.9 **Cloverleaf Campground.** After passing this campground the road switches back and gains elevation.

21.3 **Scenic Pullout.** From here you are looking north at the head of St. Charles Canyon. Bloomington Canyon is located across the divide at the top of the canyon. The rocks cropping out on the east side of the upper canyon are Devonian limestone, sandstone, and shale.

21.8 **Minnetonka Cave.** The cave developed along a fault by the dissolution of limestone in the Mississippian Lodgepole Formation. This very fossil-rich rock was deposited on a shallow, warm sea-bottom over 300 million years ago. Look closely and you may find evidence of past life on the Mississippian sea floor.

The cave is approximately 1,800 feet long and has several up and down sections with a total of 448 stairs. Running and dripping water has created some fascinating cavestone formations, narrow passageways, and large rooms. It is a great place to cool off on a hot summer day since the air in the cave maintains a constant temperature of 40°F .

End of Tour 7.

Tour 8

Tony Grove Lake Road

Tony Grove Road Turnoff, Logan Canyon to Tony Grove Lake

0.0 Starting Point
Turn off Highway 89 onto the Tony Grove Lake Road.

0.5 **Cattle Guard.**

1.7 **Overlook - Pullout to the Right.** From this vantage point you have a good view of the valley that the Logan River occupies. The Temple Ridge fault (discussed in Tour 1, mile 16.5) is located across the valley to the east. This section of the Logan River valley is called a strike valley because it parallels the direction, or strike, of the fault.

The road cut just before this pullout exposes the Wasatch Formation, a Tertiary (55 million years old) red conglomerate (see Tour 1, mile 19.5, for an explanation of this unit).

3.2 **Tony Grove Creek.**

5.5 **Cattle Guard.** Once you cross the cattle guard, numerous large, mostly buff-colored, quartzite boulders of the Swan Peak Formation litter the ground to your left and extend up the hillside to your right (Fig. 46). The boulders are part of a glacial moraine deposit. This depositional feature consists of a mix of coarse to fine material directly deposited by a glacier. Glaciers erode and transport a significant

Fig. 46-Mile 5.5. Boulders of the Swan Peak Formation, part of a glacial moraine deposit, litter the ground once you pass the cattle guard.

amount of material. When the ice melts, the transported material is left behind. During the last Ice Age, the high peaks straight ahead (to the west) accumulated more snow in the winter than melted in the summer. After some time the snow was transformed into ice and began to flow down-valley under the influence of gravity. Thus, a glacier was born.

The moraine was deposited by glaciers that existed between 30,000 to 12,000 years ago and is referred to as the Pinedale moraine. You can tell how deep the ice was during the Pinedale Glacial Episode by looking at the level of the glacial moraine on the surrounding hillsides. Where did all those boulders dotting the hillsides come from? As the glacier receded, the boulders and other transported material were deposited, to leave a record of the extent and thickness of the Pinedale glacier.

6.4 **Campground Road to the Left.** Proceed straight ahead to the end of the road at Tony Grove Lake.

6.6 **Tony Grove Lake.** There are several interesting geologic phenomena that can be observed from Tony Grove Lake. The lake is nestled in a small cirque, an amphitheater-like feature hollowed out by glacial erosion. The lake was dammed on its east side by a small glacial moraine. In the 1930s, the moraine was enhanced by people to increase the lake's size and depth. The large boulders, a mix of gray dolostone and limestone and buff to pink quartzites, are also part of glacial moraine material. If you look hard enough you may see glacial

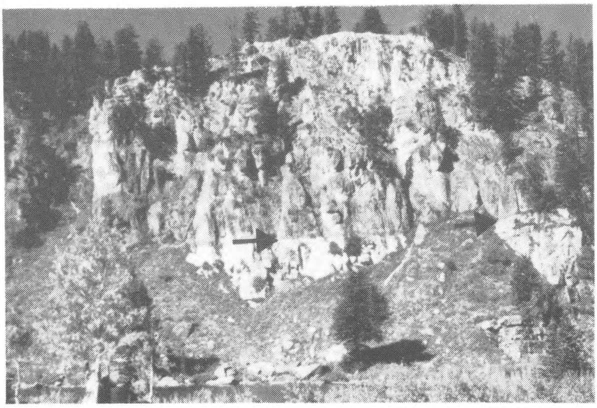


Fig. 47-Mile 6.6. The abrupt contact (arrow) of the lower white Swan Peak Formation and the upper gray Fish Haven Dolostone is apparent west of Tony Grove Lake.

grooves, or striations, on some of the quartzite boulders. These small-scale abrasional features form when rocks frozen in the bottom of glacial ice scratch their way across other rocks as the ice moves.

Tony Grove Lake formed within the lowermost shale unit of the Ordovician age Swan Peak Formation. The shale layers are impermeable and act as a barrier for water seepage, thus creating the lake. The white rock just above the lake (to the west) is also part of the Swan Peak Formation and is the upper white quartzite layer. The contact of the white Swan Peak Quartzite and the overlying gray Fish Haven Dolostone is abrupt and well-exposed in the cliffs surrounding the lake (Fig. 47).

Fig. 48-Mile 6.6. The Tertiary Wasatch Formation (T) overlies the Ordovician Fish Haven Dolostone (O) south of Tony Grove Lake.

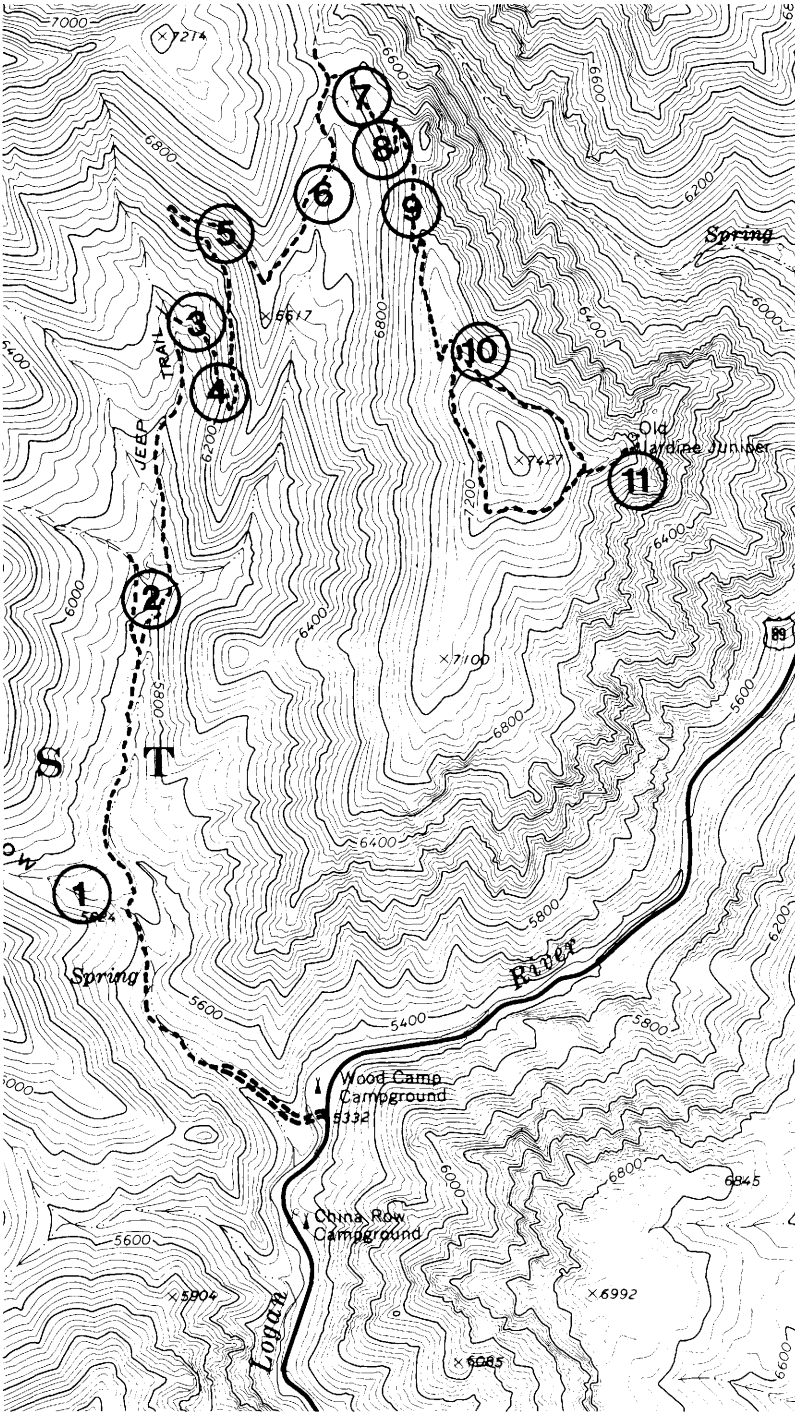
An excellent example of an unconformity, or break in the rock record, is located south of the lake. The tan cliff, high on the hillside, exposes Tertiary Wasatch Formation, a conglomerate, which lies directly on Ordovician Fish Haven Dolostone (Fig. 48). The relationship of the Tertiary and Ordovician rock means all the rock material that was deposited after the Ordovician Fish Haven was exposed and eroded away before the much younger conglomerate of the Wasatch Formation was deposited. The gap in the rock record expressed by this unconformity extends from the Late Ordovician to the Early Tertiary, approximately 314 million years. The boundary between the two rock units is an angular unconformity, with flat-layered conglomerates of the Wasatch Formation lying directly on dipping Paleozoic rocks. However, the dip of the underlying rocks is not visible.

Numerous small caves occur in the dolostone ridges to the southwest of Tony Grove Lake. As in Logan Cave, these were also formed by the dissolution of rock by slightly acidic water. Only one cave's formation has been directly related to underground stream flow. Most caves developed as a result of water slowly percolating down preexisting vertical joints in the rock, enlarging only the joints. Any connecting horizontal sections were created by collapse and not by dissolution. Most of the caves are small and have very few cavestone deposits.

Two trails into the Naomi Peak Wilderness begin from the lake parking lot. See Hike 2 for a geologic trail guide of the Naomi Peak trail. Naomi Peak is the highest peak in Utah's Bear River Range. The White Pine Lake trail splits off the Naomi Peak trail and is a delightful walk to one of the most beautiful cirque lakes in these mountains.

Ice mountain melted
ages ago
          and made this ridge,
this place of changes.

Chinook Psalter



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JEEP TRAIL
Spring
Old Jardine Juniper
Wood Camp Campground
China Row Campground
Logan River
89
S T

HIKE 1

JARDINE JUNIPER

WOOD CAMP TO JARDINE JUNIPER, 5 MILES ONE WAY, 1,900-FT ELEVATION GAIN

Topographic Map: Mt. Elmer

The trailhead for this hike starts at the end of Wood Camp road. The trail is not difficult and the views are fantastic. It can be a hot, dry walk in the summer, so take plenty of water.

1 - Wood Camp Hollow
Shortly after you start walking, a fairly wide valley opens on your left. Notice all the broken trees. In February 1985, after a heavy snow-storm, a very large, wet avalanche moved down this canyon, snapping trees and gouging the ground.

The fossil-rich Mississippian Lodgepole Formation is exposed in the lowest cliffs you see up Wood Camp Hollow. A side excursion to these cliffs to look for fossil crinoids, corals, and brachiopods could be fun.

2 - Continue up the Trail
Cross the usually dry creek bed that empties out of Wood Camp Hollow and continue along the Jardine Juniper trail. You will probably notice more broken trees and other debris at the mouth of the next canyon on your left. This is also avalanche debris from the same winter

storm. A large outcrop of Paleozoic dolostone is in the middle of an alluvial fan that extends into the main canyon from this side canyon. Alluvial fans are stream depositional features that form when a stream encounters a change in velocity and can no longer transport its sediment load. One common cause of a change in stream velocity is a change in the gradient, or steepness, of the stream course. When mountain streams flow into valleys an abrupt gradient change causes material being moved by the stream to be deposited.

3 - After First Switchback

It is not until after the first switchback that you see any bedrock exposed along the side of the trail, a bleached-looking Paleozoic dolostone.

4 - Spring

After an uphill stretch, you will see a small spring at the side of the trail. Groundwater intersects the land surface at this point and drips out onto the ground. There are many springs in the mountains of the Bear River Range, which are composed of predominantly limestone and dolostone. These two rock types easily dissolve as a result of chemical weathering processes. Dissolution of these rock types can enlarge joint or fracture patterns and create cavities that water flows through. When these water-filled fractures or cavities intersect the ground, a free-flowing spring results. Notice the white to tan spongy material on the bedrock immediately around the spring. This is the mineral calcite. It was originally dissolved in the groundwater and now is being precipitated as a coating around the bedrock and vegetation. This type of limestone is called tufa.

5 - More Bedrock

Several more switchbacks above the spring lead you to more exposed dolostone, which at first you may find uninteresting, but if you look closely you'll find fossils in this rock. Most of the fossils are cross-section views of brachiopod shells. Remember, this is a cross-section view so the wispy concave or convex white lines are the shells.

6 - Open Meadow

Eventually, an open meadow comes into view. The trail follows the edge of the meadow to a shallow divide which separates the meadow from the much deeper and steeper Cottonwood Canyon to the north. There is a bench under a tree at the top of the meadow. You may be wondering if this is the Juniper. But if you look at the cones and needles, you'll discover that this large tree is a Douglas Fir. This is a nice rest stop, but you still have a fair distance to travel before you reach the

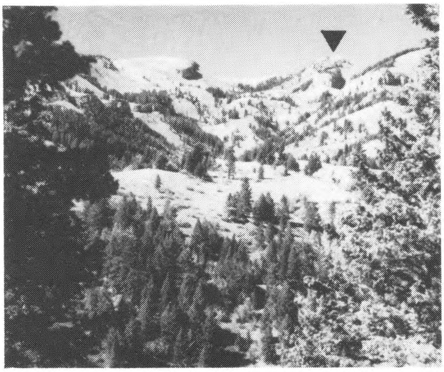


Fig. 49-8. Mt. Elmer (arrow) at the head of Cottonwood Canyon.

Jardine Juniper. The cliffs you see across Cottonwood Canyon to the north are Silurian Laketown Dolostone.

7 - Next Outcrop

The next outcrop, after you leave the bench, is limestone. By now you have probably observed that dolostone and limestone have a very similar appearance. This is true because most dolostone, which is calcium magnesium carbonate, forms by the replacement of original limestone, calcium carbonate. Magnesium is added to the system and a new mineral is formed - dolostone. The easiest way to tell the difference between these two rock types is to drop diluted hydrochloric acid (muriatic acid) on the rock. Limestone fizzes while dolostone will not readily fizz.

After the limestone you walk past more dolostone, sandstone, conglomerate (gravel that is now rock), and back into limestone. All of these rocks belong to the Devonian Period.

8 - Near the Top

As you approach the top of the switchbacks, you'll see some red sandstone, part of the Devonian Jefferson Formation. You will also find a wonderful view. Look back and up to the head of Cottonwood Canyon. The mountain peak at the head of this canyon is Mt. Elmer, 9,676 feet high, and is composed of the Mississippian Lodgepole Formation (Fig. 49). The talus slopes at the base of Mt. Elmer are full of interesting fossils, with horn corals being particularly plentiful. A trail to this beautiful peak starts at the head of Green Canyon.

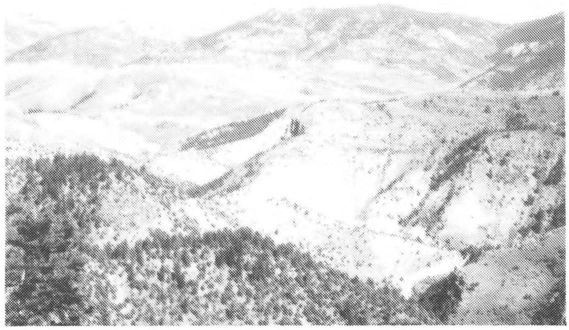


Fig. 50-9. Logan Canyon and the entrenched meanders of the Logan River.

9 - Scenic View Point

After traveling through the woods for a while, you approach an opening on a rocky ridge which affords a superior view of Logan Canyon below (Fig. 50). From this point you are looking down on the entrenched meanders of the Logan River (an explanation of this phenomenon is in Tour 1). The rocks below, along the road and river in this section, are the Ordovician Garden City Limestone. In the distance, behind the river and road, are cliffs of older Cambrian rocks. How can older rocks appear to be above younger rocks? There is a normal fault (the Temple Ridge fault) that runs between the older rocks of the cliffs and the younger rocks adjacent to the river and road. The old rocks have moved up while the younger rocks have moved down relative to each other.

While enjoying the view, you are most likely to be sitting on the Silurian Laketown Dolostone.

You will soon come to a route option. The shady route to the left is quite enjoyable. Both trails lead to the Jardine Juniper.

10 - Jardine Juniper Turnoff

As you walk along this descending trail, you pass cliffs of gray dolostone that contain small fragments of fossils and blebs of dark, more resistant chert. Trees grow directly out of many of these cliffs. As the tree roots continue to grow and get larger, they exert pressure on the rock in which they are growing. This helps break apart rock and is one of the physical weathering processes.

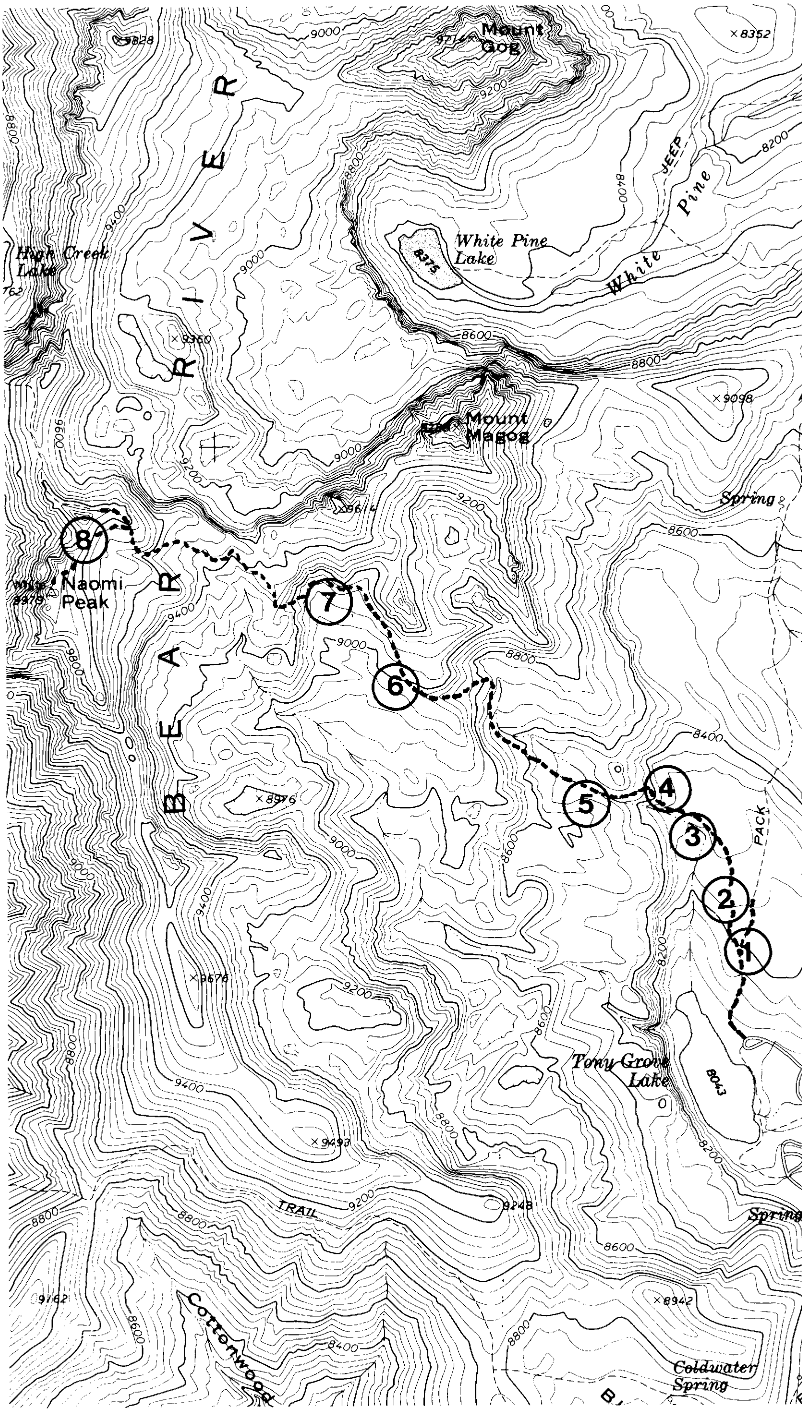
11 - Jardine Juniper

Incredibly, the Jardine Juniper is 3,200 years old, and although many of the limbs are dead it is alive and seems to be literally growing out of solid rock. The rock is a Silurian dolostone and is approximately 400 million years old.

As you sit at this spot perhaps you will ponder these time intervals and the geologic phenomena that have occurred since the time of deposition of the material that is now the rock you walk upon. A long, long time ago the dolostone your feet have trod was most likely deposited as a limestone in a shallow tropical sea. At that time North America was rotated so that the equator extended from what is now Texas to Maine. Utah was at approximately 17° north latitude. The lime material deposited in this sea was probably produced by organisms such as shelled creatures and algae. A great thickness of lime sediment accumulated through millions of years.

As the sediment became buried it was turned to rock through compaction and cementation. Eventually, the original limestone was altered to dolostone. The rocks remained below the Earth's surface through the Cretaceous mountain-building event called the Sevier Orogeny. At this time, about 80 million years ago, there was subduction of an oceanic plate under the North American plate off the west coast. As a result of this plate interaction to the west, these rocks were stressed and subsequently folded and thrust faulted. The thrust faulting moved these rocks from west to east, where they are today.

Still, the rocks remained below the surface and Logan Canyon did not exist. Then, about 15 million years ago, Nevada and western Utah began to be gently and slowly pulled apart by different plate tectonic forces. Block faulting occurred that actually created the Bear River Range. Finally, Logan Canyon began to form. Ice ages came and went and with these climatic changes from cool to warm, so the animal life and vegetation changed. The tundra-alpine flora that existed during the cooler glacial episodes eventually gave way to a very different flora of conifers about 5,000 years ago. One day, about 3,200 years ago, a seed sprouted and took hold on this rock outcrop. The juniper seedling grew into this magnificent tree, which we can still enjoy today.


Mount Gog
White Pine Lake
White Pine
JEEP
High Creek Lake
BEAR RIVER
Mount Magog
Spring
Naomi Peak
PACK
Tony Grove Lake
TRAIL
Spring
Cottonwood
Coldwater Spring
1
2
3
4
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8

HIKE 2

NAOMI PEAK

TONY GROVE LAKE TO NAOMI PEAK, 4 MILES ONE WAY, 1,940-FT ELEVATION GAIN

Topographic Map: Naomi Peak

The trailhead for this hike starts just north of the parking lot at Tony Grove Lake. The trail travels over terrain that was covered by glaciers as early as 12,000 years ago. You may be able to find evidence for the past glaciation by looking for glacial abrasion features such as scratches or grooves on the surfaces of rocks. These will not be easy to find, however, especially on the gray limestone or dolostone (collectively called carbonate rocks), since both are highly vulnerable to chemical weathering. It has been calculated that carbonate rocks exposed to weathering processes in the Tony Grove Basin would be subjected to a minimum solution rate of 1.8 inches per 1,000 years. Therefore, in 12,000 years, for example, approximately 21 inches of rock have been dissolved away. Unfortunately, any scratches or grooves eroded by glacial abrasion on the surfaces of the limestone and dolostone would most likely have been removed by weathering. However, the buff, pink, white, and brown rocks are quartzites, which resist chemical weathering. These rocks may still have some glacial scratches left to tell a story.

1 - Junction

Shortly after you leave the parking lot the trail turns right and starts up a small incline that leads to a trail junction. Take the left fork to Naomi Peak. The right fork goes to White Pine Lake, a beautiful cirque lake.

Fig. 51-3. Glacial plucking of the nearly flat-layered Swan Peak Formation helped form this unique outcrop of giant stair steps.

2 - Boulder-Strewn Field

The trail continues through a field strewn with boulders. The boulders include a variety of pink, tan, and white quartzite of the Middle Ordovician Swan Peak Formation. The boulder field is a glacial moraine deposit, that is, it is composed of material that was transported by a glacier and then deposited as the glacier receded. Since the quartzite is much more resistant to chemical weathering, it is the dominant rock type of the boulders, whereas most of the limestone and dolostone boulders have been dissolved away with time.

The individual boulders can be fun to look at closely. Some of the quartzites are layered, a result of deposition of different colored sediments and/or slightly different grain sizes. Others are burrowed. The burrows come in several varieties: some appear as "squiggles" on the rock's surface; others give the rock a pock-marked appearance; and still others impart a very mottled look to the rock. The burrows were made by unknown organisms, perhaps some type of worm.

3 - Giant's Stairway

The trail turns left and ascends a slight ridge. To your left, an outcrop of the Swan Peak Formation forms giant stair steps (Fig. 51). The nearly flat layering of the rock plus glacial plucking as the ice moved over the slope many years ago combined to form this unique outcrop. Once you are nearly across from the "top" of the stairway, there is a nice view to the south of Tony Grove Lake.

4 - First Steep Section
The trail now moves up the first steep section. The outcrop you are walking on is the upper part of the Swan Peak Formation. You can see many pock-marks (burrows) on the surface of this white quartzite. As you hike up the hill you cross a very oxidized (rust colored) zone of rock. This zone has been altered by hydrothermal fluids moving along fractures in the rock. Near the top of the incline the trail switches back to the left and makes a long traverse along the hillside. Just after the switchback you cross the contact between the Swan Peak Formation and the overlying Upper Ordovician Fish Haven Dolostone. That is, you cross from the white quartzite of the Swan Peak, which represents a beach environment, to the dark gray dolostone of the Fish Haven, which represents a deeper marine setting. The gray Fish Haven is generally burrowed, reflected by the rock's mottled appearance. Fossils such as crinoid stems and corals can be found in the rocks.

5 - Small Valley
Once you reach the top of the steep section, the trail goes around a corner, winds through some gray dolostone cliffs, and then follows a gully before finally opening up into the first small valley. The rocks surrounding you in this small valley are the Silurian Laketown Formation. The Laketown rocks are also dolostone but are generally a lighter color of gray than the underlying Fish Haven. The Laketown Formation was also deposited in a shallow tropical sea as were most of the Paleozoic rocks of the Bear River Range. Some of the more common fossils you may encounter in the rocks are brachiopod shells, crinoid pieces, and Halysites, a coral commonly called chain coral because of its characteristic chain-like appearance. The Laketown is also very mottled, indicating that the marine environment that existed at the time of deposition (440 million years ago) was very favorable for burrowing organisms.

The trail skirts the small valley to the left and continues uphill through more outcrops of the Laketown Dolostone. Occasional small blebs of white and black chert (microcrystalline quartz) can be seen weathering out in relief on the rock's surface. Remember that since quartz is much more resistant to dissolution by chemical weathering processes the dolostone dissolves but the quartz does not, thereby creating the relief. There is a great boulder part way up the hill and to the left of the trail that illustrates this surface weathering phenomenon. It has white chert blebs on its surface that have at least one to two inches of relief due to weathering. (Don't worry, if you miss this boulder there are plenty of other examples).

Figure 52 - 6. Naomi Peak (arrow) can be observed on the high ridge ahead.

6 - Second Valley

The trail continues uphill through the Laketown Dolostone, through more cliffs, along another narrow gully and opens into a second, higher valley. The trail then drops down into the valley and follows a small creek bed which is usually dry. Your destination, Naomi Peak, can be observed on the high ridge ahead (Fig. 52). The Laketown Dolostone extends to and comprises the peak. The Laketown is exposed over a broad area here because you are very close to the axis of the Logan syncline. At the axis, or lowest point, of the synclinal structure, the rocks are nearly horizontal and therefore a single formation is exposed over large areas.

There are some small sink holes, or dolines, in this valley. One is to the left as you enter the valley. Sink holes are a result of dissolution by rain or snowmelt of exposed areas of limestone and dolostone and are a characteristic feature of karst topography. Karst topography refers to a landscape in which the surface features or topography are shaped by the dissolution of rock.

7 - Continue to the Ridge Top

The trail continues uphill where you eventually reach a good view to the south of a small amphitheater-like depression, which is a moderately developed cirque. In the early summer, snowbanks can cover much of the ground from here to the top of the ridge. Some of the water from the melting snowbanks infiltrates into the ground while the rest moves as surface run-off and forms small streams. As the snow

Fig. 53-8. Composed of east-dipping Ordovician Garden City Limestone, Cherry Peak is one of the more impressive mountains in the Bear River Range.

melts and exposes the ground, an array of beautiful alpine flowers starts to bloom. By mid-summer much of the snow is gone. Now, water generally issues from the rock as seeps, rather than in surface streams. By late summer many of the flowers are finished blooming and the snow is all gone. Depending on the dryness of the year, all of the seeps usually dry up too. There are no year-round natural springs in the area.

8 - From the Top

The trail ends at a saddle on the ridge. There is a path, worn by the feet of many hikers, that follows the ridge to its highest point, Naomi Peak, which at an elevation of 9,979 feet, is the highest point in Utah's Bear River Range. Whether you go to the top of Naomi Peak or stay at the saddle (9,800+) you will enjoy a glorious view. As you look down and to the west, you will see the head of Smithfield Canyon. Cherry Peak, one of the more impressive mountains in the Bear River Range, is almost directly across from the saddle (Fig. 53). Rising to an elevation of 9,765 feet, it is composed of east-dipping Ordovician Garden City Limestone. From the saddle the trail descends to the right and connects with the High Creek Trail just above High Creek Lake, a small cirque lake nestled against steep rock walls.

The distinctive flat floor of Cache Valley becomes apparent when you look past the peaks into the valley. The flat valley floor is a result of Lake Bonneville, which occupied Cache Valley as early as 10,000 years ago. Through time sediment suspended in the lake water slowly settled out on the lake bottom, which filled in any topographic irregularities thereby creating a very flat floor.

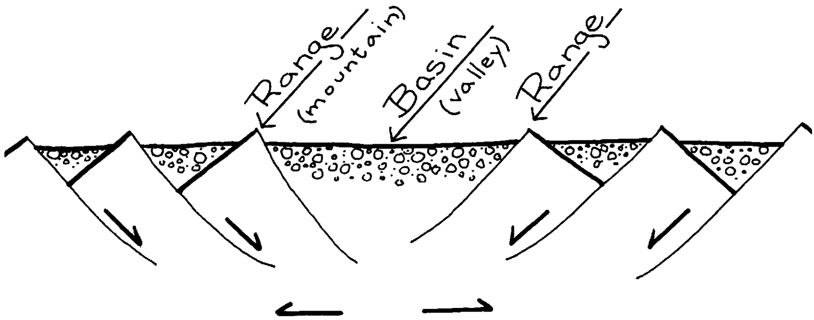


Fig. 54-8. Simplified schematic drawing illustrating Basin and Range geology. As Nevada is pulled apart by tectonic forces, normal faults develop, which form the characteristic mountains and valleys of the Basin and Range.

On a clear day you can see many ranges west of Cache Valley. The Bear River Range is near the eastern edge of the Basin and Range Province. Most of Nevada and western Utah are part of this geologic province. The Basin and Range Province refers to the geographic location of mountains (ranges) and valleys (basins) and implies a specific mode of geologic formation. In essence, Nevada is being "pulled apart" by plate tectonic forces. This pulling apart started approximately 15 million years ago and still continues which is why this area is seismically active, or, that is to say, prone to earthquakes. As Nevada pulls apart, normal faults develop, which uplift the mountains and downdrop the valleys (Fig. 54). The basins and ranges generally have a north-south trend since the Earth's crust is being stretched in an east-west direction. Besides being interesting geologically, the basins and ranges are also ecologically unique. Since the climate of the ranges is much different from the intervening basins, each host very different animal and plant communities. The mountains are separated by wide valleys that form a barrier to the migration of mountain animals and plants. Therefore, the ranges can be considered islands in a sea that effectively isolates animal and plant ecosystems.

To the east, the view includes the high plateau country of Wyoming; to the southeast, the Uintas are often observable; and to the northeast, with the aide of binoculars and an exceptionally clear day, you might get a glimpse of the Tetons.

Glossary

Alluvial Fan A fan-shaped mass of sand, silt, and gravel deposited by a stream where it leaves a mountain valley.

Angular Unconformity An unconformity marked by a difference in dip of younger overlying rocks and older underlying rocks.

Anticline An arch-shaped fold.

Argillite A very compact fine-grained rock.

Axis (fold) A line that divides the two limbs, or sides, of a fold.

Base Level The lowest level to which a stream can erode. The ultimate base level is sea level.

Chemical Weathering The decay of rock by chemical reactions which dissolve minerals and/or create new minerals that are stable at Earth's surface conditions.

Chert A hard sedimentary rock composed of microcrystalline quartz.

Cirque A steep-walled semicircular hollow high on a mountainside produced by frost action and glacial erosion.

Conglomerate A sedimentary rock composed of cemented rounded gravel set in a finer-grained matrix of sand and silt.

Contact A surface between two rock units of different age or composition.

Debris Flow A mass of unconsolidated material, of which greater than one-half is coarser than sand sized, that moved downslope under the influence of gravity.

Delta A mass of sediment deposited by a stream as it enters quiet water.

Dip The inclination, or angle, of rock layers.

Dolostone A sedimentary rock composed of calcium magnesium carbonate that generally reflects deposition in a marine environment.

Entrenched Meander A deepened meander eroded downward into the valley in which the original meander formed. It results from uplift of the land and/or lowering of base level.

Epicenter The point on Earth's surface directly above the focus, or rupture point, of an earthquake.

Faceted Spur A spur, or ridge, that has an inverted-V face formed by faulting.

Fan-delta A mass of gravel, sand, and silt formed when an alluvial fan builds out into quiet water.

Fanglomerate A sedimentary rock composed of rock fragments of all sizes deposited in an alluvial fan.

Fault A fracture along which displacement has occurred.

Fault Plane The surface along which displacement has occurred.

Fault Scarp A steep slope formed on Earth's surface by motion along a fault. This is the exposed surface of the fault.

Flood Plain The flat area of land adjacent to a stream which can be covered with water when the stream overflows its banks.

Formation A body of rock, with distinct characteristics, that is mappable on Earth's surface.

Fucoid An informal name for trail-like trace fossils.

Hogback A very sharp ridge of nearly vertical resistant rock formed by differential erosion.

Homocline Rock layers that all dip in the same direction.

Igneous Rock Rock formed by the crystallization of magma, molten rock material.

Karst Topography A landscape formed by the dissolution of underlying limestone or dolostone. Sinkholes, caves, and underground drainage are common features.

Limestone A sedimentary rock composed of calcium carbonate that commonly reflects marine deposition.

Loess Wind-deposited angular silt. The silt is derived from deserts and floodplains of glacial streams.

Mass Wasting Downslope transport of rock and unconsolidated material under the influence of gravity.

Metamorphic Rock Rock derived from preexisting rock changed, in a solid state, by heat, pressure, and chemical reactions.

Moraine A ridge of boulders, gravel, sand, and silt directly deposited by a glacier.

Mud Cracks Roughly polygonal-shaped cracks formed in wet mud as it begins to dry.

Mudflow A mass of fine-grained unconsolidated sediment saturated with enough water that it moves downslope as a viscous fluid.

Nonconformity A type of unconformity where sedimentary rocks overlie igneous or metamorphic rocks.

Normal Fault A fault in which the rocks above the fault plane moved down relative to the rocks below the fault plane.

Patterned Ground A set of surface features, such as circles, polygons, and stripes, that form as a result of intense frost action.

Pluvial Lake A lake formed during a wet climatic cycle.

Physical Weathering The decay of rock, by physical processes such as frost action, into smaller and smaller fragments of the same rock.

Salient A landform that projects outward from its surroundings.

Sandstone A sedimentary rock composed of sand-sized particles.

Sediment Unconsolidated solid particles derived from weathering and transported by water, wind, or ice.

Sedimentary Rock Rock formed by cementation and/or compaction of sediment.

Shale A sedimentary rock composed of silt and clay-sized particles.

Strata Layers of rock.

Stratigraphic Column A diagram which illustrates, in a single column, the rocks that occur in a given location.

Stratified The layered arrangement of sediment or rock.

Stream Terrace A level surface in a stream valley that represents remnants of an old flood plain.

Strike The trend or direction an outcrop or fault makes on Earth's surface.

Syncline A downwarped or trough-like fold.

Talus Fragments of rock lying on a slope or at the base of a cliff.

Temporary Base Level Local control, such as a lake or resistant rock unit, of the level to which a stream can erode the land.

Till An unstratified mixture of boulders, gravel, sand, and silt deposited by a glacier.

Trace Fossil The fossilized trace, such as a track or burrow, left by an organism. The actual organism is not preserved.

Tuff Fine-grained ash, produced by violent volcanic eruptions, that has become consolidated.

Type Section The originally described section of rock that has specific characteristics and is given a formation name. It is used to define the formation in other locations.

Unconformity A break or gap in the rock record that represents an absence of part of the rock record. It results from cessation of deposition or erosion of material that was deposited.

Weathering The chemical and physical breakdown of rock at or near the Earth's surface.

Suggested Reading

For those who would like more information on the geology of Utah:

Geologic History of Utah
by Lehi F. Hintze

Geology of Utah
by William Lee Stokes

Roadside Geology of Utah
by Halka Chronic

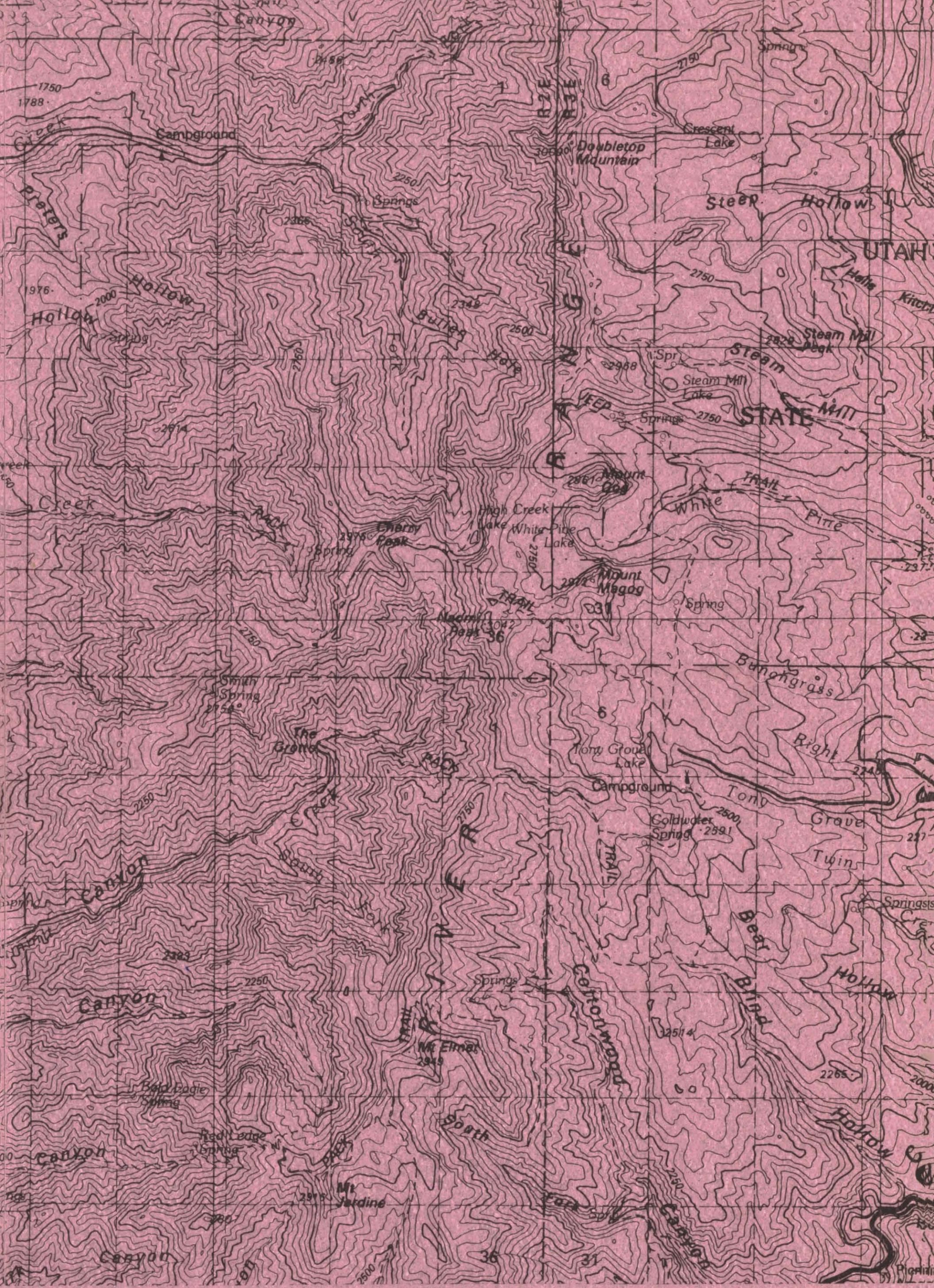
For those who would like information on general geologic concepts:

The Field Guide to Geology
by David Lambert and the Diagram Group

A Field Manual for the Amateur Geologist
by Alan M. Cvancara

Clouds are flowing in the river, waves are flying in the sky.
Life is laughing in a pebble. Does a pebble ever die?

Eveline Beumkes



Canyon
Campground
Doubletop Mountain
Crescent Lake
Steep Hollow
UTAH
Steam Mill Peak
Steam Mill Lake
Steam Mill
STATE
Springs
Mount Gog
High Creek Lake
White Pine Lake
White Pine
Cherry Peak
Mount Magog
Naomi Peak
Smith Spring
The Grotto
Tony Grove Lake
Campground
Coldwater Spring
Bunchgrass
Tony Grove
Cottonwood
Mt Elmer
Mt Jardine
Red Ledge Spring
Bald Eagle Spring
Hollow
Canyon
TRAIL
PACK
JEEP