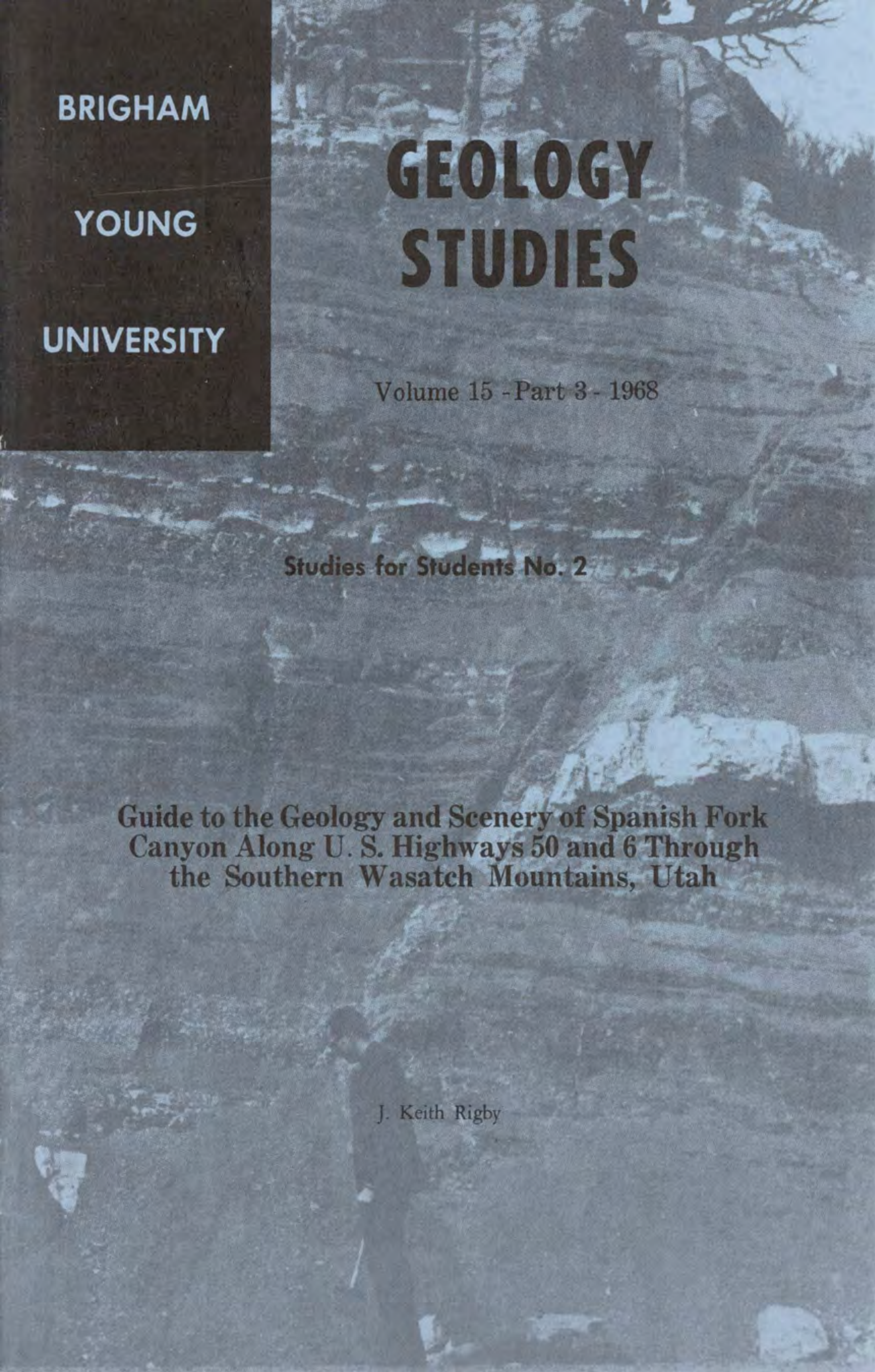

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Studies for Students No. 2

Guide to the Geology and Scenery of Spanish Fork Canyon Along U. S. Highways 50 and 6 Through the Southern Wasatch Mountains, Utah

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INTRODUCTION

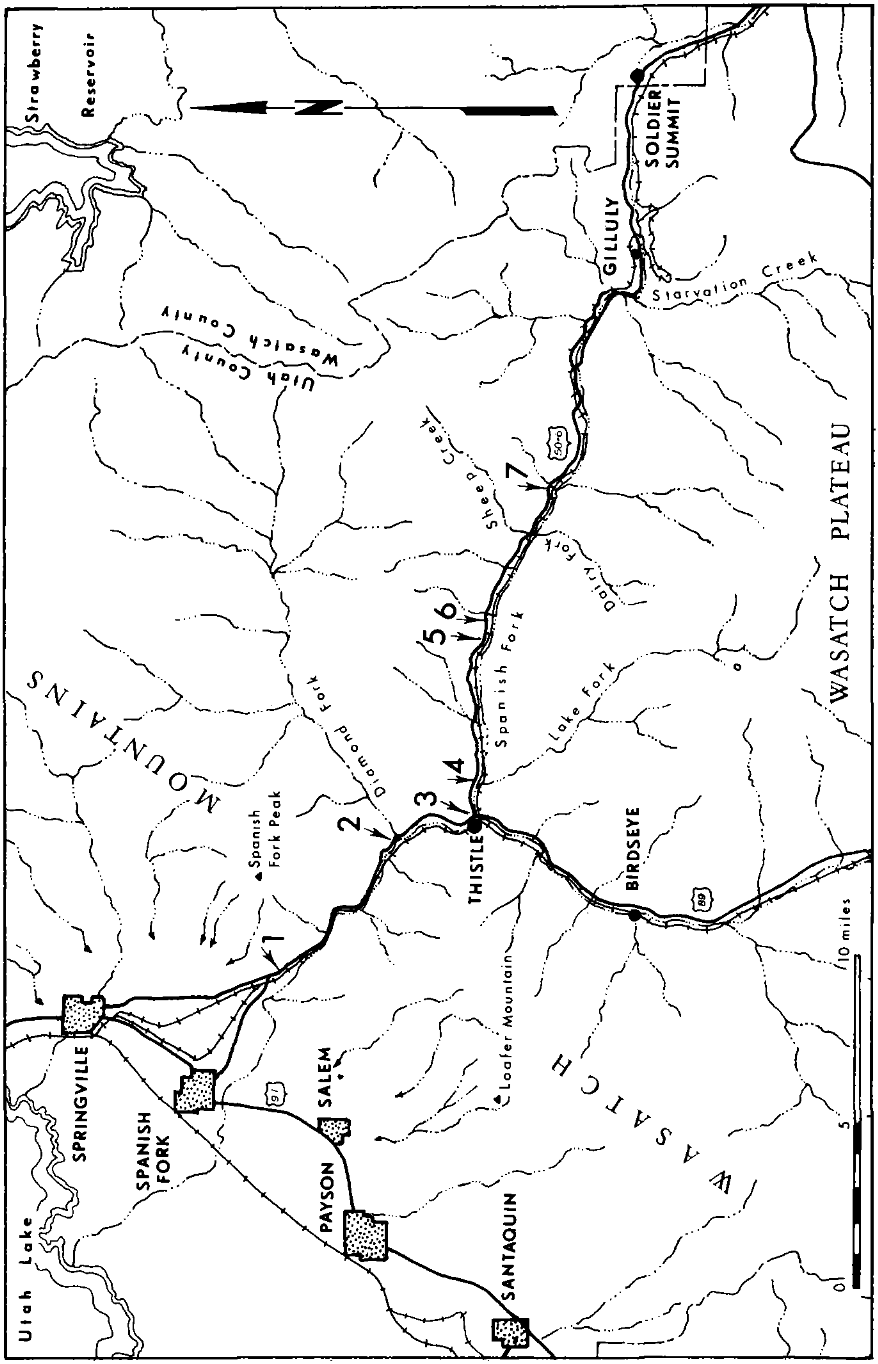
Spanish Fork Canyon cuts across approximately 25,000 feet of sedimentary rocks in its course from Soldier Summit to its mouth near the community of Spanish Fork (Text-fig. 1). Along the course of the canyon rocks of Pennsylvanian, Permian, Triassic, Jurassic, Cretaceous, and Tertiary ages are exposed in the walls (Text-fig. 5). This canyon offers an excellent opportunity to study this part of geologic history, and an opportunity to collect fossils and rocks typical of each of these geologic periods.

In addition to the broad aspects of historical geology, the outcrops in Spanish Fork Canyon also document part of the history of the great Laramide Orogeny, that phase of mountain building when the Rocky Mountains were folded. Not only are the crumpled rocks of the Wasatch Mountains visible, but so are the younger sedimentary rocks of the Late Cretaceous and Tertiary periods that were eroded from the rising mountains and deposited in great fans at the foot of the mountains and in lakes, the sea, marginal marine marshes, and river channels to the east. Some of these coarse gravel deposits now form the massive conglomerate cliffs of Red Narrows.

Various topographic features can also be seen along the field trip route. Landslide masses, tilted slump blocks, stream and lake terraces, alluvial fans and talus fans, fault features, and various types of valleys can be studied and are part of the late history of the canyon and the Wasatch Mountains and Wasatch Plateau in general.

The lower part of Spanish Fork Canyon is in the Wasatch Mountains and exposes the oldest rocks visible along the field trip route. Pennsylvanian and Permian rocks of the Oquirrh Formation (Text-fig. 4) represent sediments swept in from the east by streams draining ancient landmasses in eastern Utah and western Colorado. These silt and sand beds accumulated in a delta along the margin of an inland sea that stretched across western Utah into Nevada. In later Permian time this sea spread over the central Utah area and in it were deposited the Kirkman, Diamond Creek, and Park City formations.

Triassic and Jurassic rocks of Spanish Fork Canyon record several periods of invasion by the sea, sometimes from the west and sometimes from the north, separated by periods of nonmarine deposition by rivers or by desert winds. The Navajo Sandstone, the light tan sandstone that forms the cliffs at Thistle, was deposited as sequences of great sand dunes accumulated a sand blanket over the region as much as 1,000 feet thick. The Morrison Formation, of Late Jurassic age, is exposed in road cuts east of Thistle and is the same formation from which most of the dinosaurs known from western North America were collected.



TEXT-FIGURE 1.—Index map of the field trip route. The road log begins at the junction of U. S. Highways 50 and 6 with U. S. Highway 89 at the mouth of Spanish Fork Canyon and is a guide from there to Soldier Summit, at the head of the canyon.

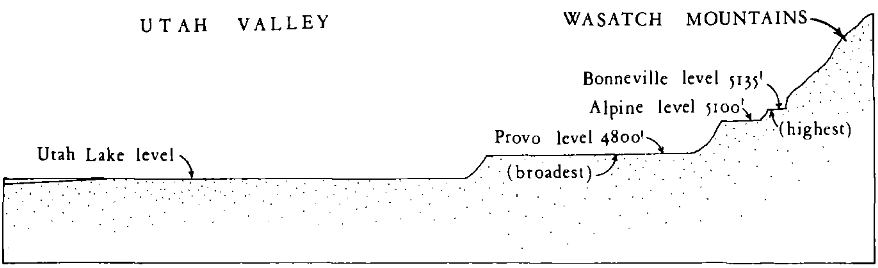
All of the rocks older than Late Cretaceous were buckled and broken during the period of intense folding and faulting that produced the Rocky Mountains. These rocks now dip at steep angles within the canyon. Younger rocks are not as folded and now rest over the upturned and eroded edges of the older rocks (Text-fig. 12). By their coarse texture they record a period of maximum uplift of the mountains to the west in Late Cretaceous and Early Tertiary time.

Abundantly fossiliferous sediments deposited in Early Tertiary Lake Green River and Lake Flagstaff are exposed in the upper reaches of the canyon. These lakes were apparently at low elevations, but now the sediments that accumulated within them have been uplifted to form some of the highest country of the Wasatch and West Tavaputs Plateaus. This uplift was probably concurrent with Mid- and Late Tertiary faulting along the western face of the Wasatch Mountains and the development of the Basin and Range province to the west. During this late stage of earth history, Spanish Fork Canyon began cutting through the Wasatch Mountains to ultimately develop the canyon that we seee today.

ROAD LOG

Mileage		
Interval	Cumulative	
0.0	0.0	INTERSECTION OF U. S. HIGHWAY 50 AND 6 WITH U. S. HIGHWAY 89, NEAR THE MOUTH OF SPANISH FORK CANYON. The highway is at the Provo level of an Ice Age lake known as Lake Bonneville (Text-fig. 2). To the east and southwest higher levels of the lake can be seen. The most prominent terrace, both east and southwest, is formed at the Alpine level of the lake, at an elevation of 5,200 feet. A slightly higher terrace, the Bonneville level, can be seen etched into the mountain front at an elevation of approximately 5,300 feet. This is the highest level of the lake and marks the elevation of the spillover point in southern Idaho.

The characteristic gravelly nature of shore-line sediments deposited in Lake Bonneville can be seen easily in



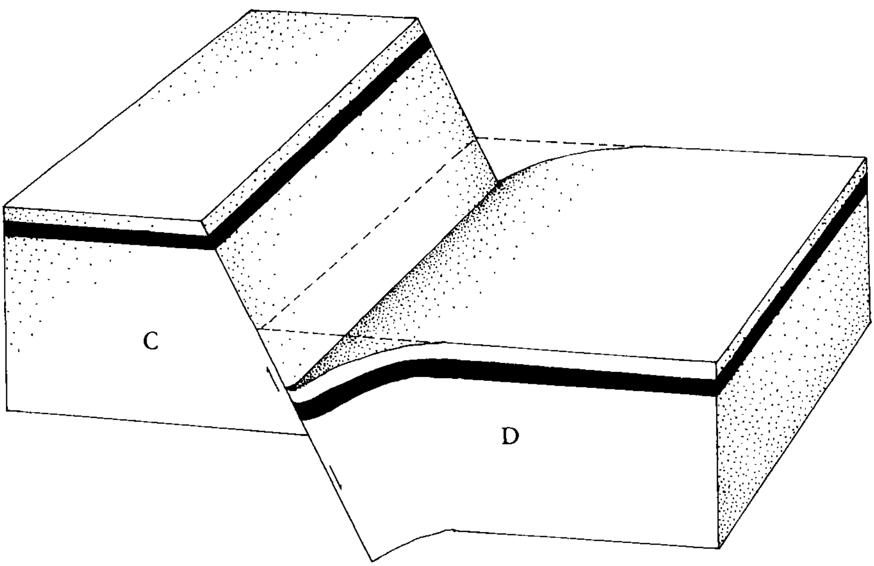
TEXT-FIGURE 2.—Generalized cross section from Utah Lake to the Wasatch Mountains showing relationships and elevations of the various lake levels evident in Utah Valley. Provo, Alpine, and Bonneville levels are terraces and deltas associated with Lake Bonneville, an ancient Ice Age lake.

road cuts and in canal excavations north of the intersection. These are moderately sorted, well-rounded pebbles and cobbles characteristic of stream deposits. These pebbles and cobbles are part of a delta formed by Spanish Fork Creek which comes out from the canyon directly ahead. The surface of the terrace is broken by a small normal fault which displaces the Provo level just north of the intersection, dropping the surface 20 to 30 feet down on the north. In the vicinity of the fault, where it crosses both U. S. Highway 89, a sag pond was developed against the scarp when the downdropped block sagged (Text-fig. 3).

0.1 0.1 Entrance to the dynamite plant of Trojan Powder Company.

0.5 0.6 OVERPASS OVER SPUR RAILROAD.

0.1 0.7 GEOLOGIC STOP 1 PULL OFF ROAD TO RIGHT BEYOND GUARD RAIL. The gorge of Spanish Fork Creek can be seen to the west, with several terraces developed along the stream channel (Text-fig. 4). Such terracing is the result of meandering of Spanish Fork Creek, gradually eroding and widening the channel as it dropped in response to the lowering of Lake Bonneville. The broad arcuate reentrant on the terrace level, to the northwest, is a result of a broad meander in the Spanish Fork Creek.



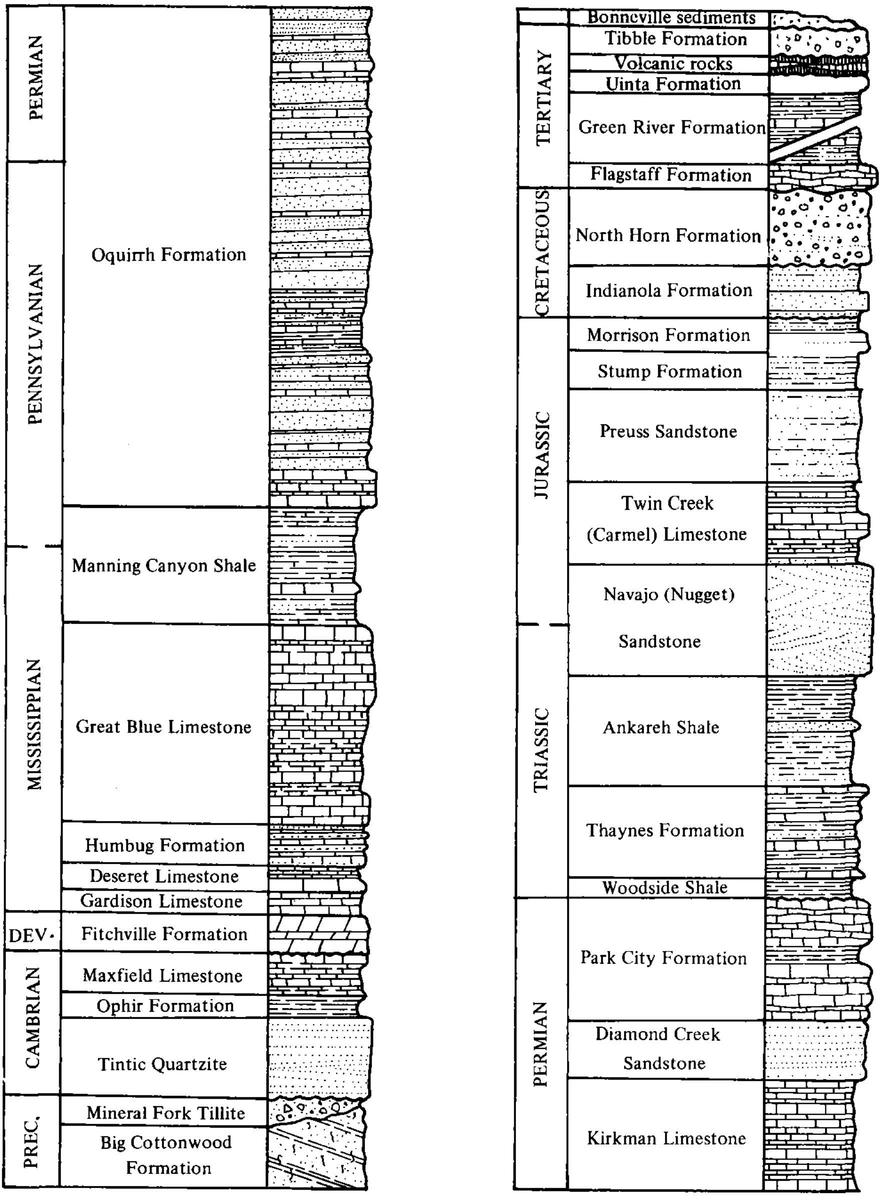
TEXT-FIGURE 3.—Block diagram of a sag pond developed near a normal fault. When the valley block (D) dropped down, the part of the block next to the fault sagged down farther adjacent to the fault surface to develop a small depression termed a sag pond.

TEXT-FIGURE 4.—Meander terraces and channel of Spanish Fork Creek to the west of Geologic Stop 1. The highway here is at the Provo level of Lake Bonneville. Higher terraces across the canyon to the west are the Alpine, the most prominent, and the Bonneville, the highest, levels of the lake. Meander terraces were formed as the winding river cut down through the lake sediments and delta of the Provo level.

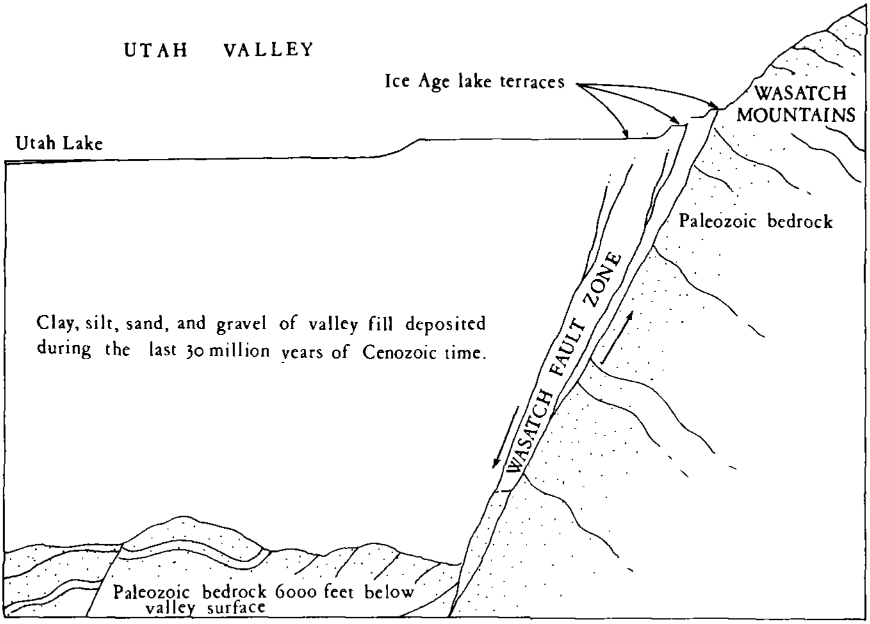
The Alpine level terrace can be seen about 200 feet above the level of the highway to the west. This is the remainder of a delta built by Spanish Fork Creek when Lake Bonneville stood at that level, a delta which has been largely removed by subsequent erosion of Spanish Fork Creek.

Amount of past movement along the Wasatch Fault, which crosses Spanish Fork Canyon at about this stop, can be determined by measuring the relative position of some formations visible in the small canyon to the west, to the right. A small, light-colored hill of Permian age Diamond Creek Sandstone (Text-fig. 5) can be seen in the mouth of this small canyon. It has been faulted down considerably out of its normal position, which is some distance above the peaks to the south. Here there is a relative displacement of about 10,000 feet. To the north the valley has been filled by from six to eight thousand feet of sediments, suggesting displacement of 10 to 16 thousand feet on the Wasatch Fault Zone (Text-fig. 6).

The first outcrop or exposure of rocks in the road cuts at the mouth of the canyon (Text-fig. 7), approximately 300 yards to the south, is the Oquirrh Formation (Text-



TEXT-FIGURE 5.—Generalized stratigraphic section of the Southern Wasatch Mountains showing formations exposed in the various canyons and along the field trip route.



TEXT-FIGURE 6.—A generalized section from Utah Valley into the Wasatch Mountains through the Wasatch Fault zone. The valley is partially filled with sediments swept off the surrounding highlands and is low because of relative movement along the Wasatch Fault which dropped the valley down.

fig. 5). These rocks represent dirty siltstones and sandstones in the upper part of the formation and are part of an ancient delta complex built by streams flowing from mountains rising in eastern Utah and western Colorado during the Pennsylvania Period. The sea was to the west in central Utah and the delta mass and dry land was to the southeast.

At least one branch of the Wasatch fault is close against the mountain front here, where the sediments exposed on the downdropped valley block are placed against outcrops of the Oquirrh Formation.

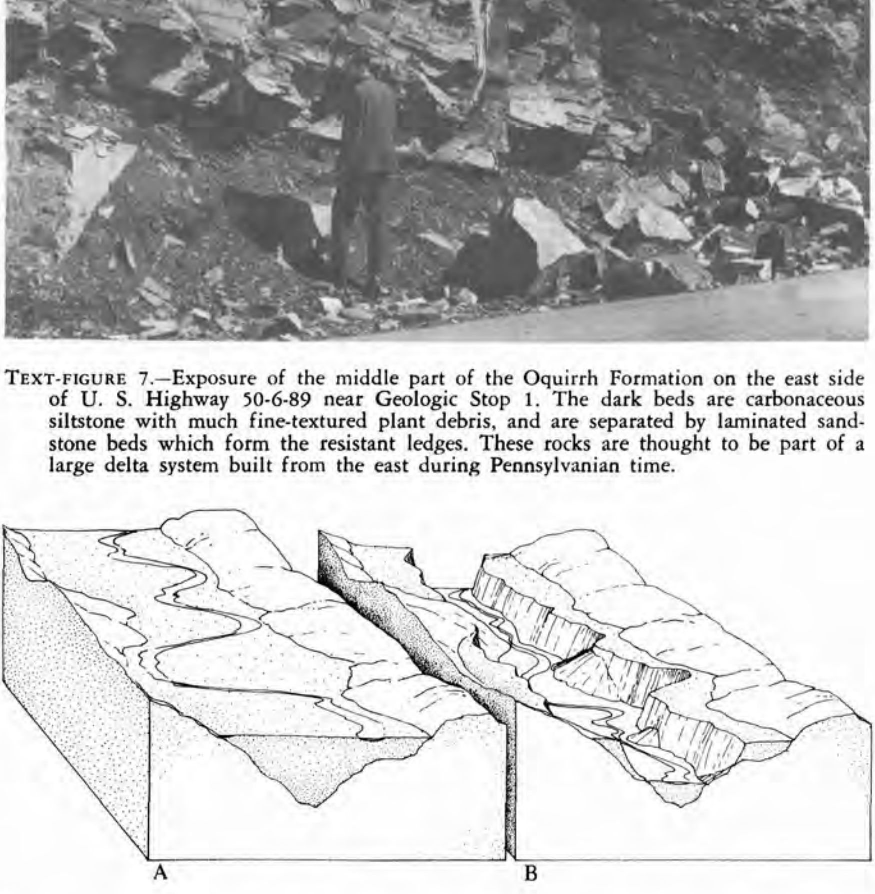
CONTINUE SOUTHEAST ON U. S. HIGHWAYS 50, 6 AND 89.

0.1 0.8 Road Cut in Oquirrh Formation.

0.1 0.9 Angular blocks of debris, largely broken by frost action, has accumulated in talus fans. Such talus fans are quite characteristic of the Oquirrh Formation. Notice how the angular fragments of talus differ from the rounded pebbles and boulders in the stream channel and in the delta deposits visible in stream cuts across the railroad track to the right.

The lower part of Spanish Fork Canyon is a rejuvenated or resurrected feature (Text-fig. 8). The valley was filled

TEXT-FIGURE 7.—Exposure of the middle part of the Oquirrh Formation on the east side of U. S. Highway 50-6-89 near Geologic Stop 1. The dark beds are carbonaceous siltstone with much fine-textured plant debris, and are separated by laminated sandstone beds which form the resistant ledges. These rocks are thought to be part of a large delta system built from the east during Pennsylvanian time.



TEXT-FIGURE 8.—Two steps in development of a rejuvenated valley: *A,* An ancient valley has been filled with debris. *B,* Much of the debris filling the original valley has now been removed, with a new valley forming along the channel of the older one when the soft debris was removed. Remnants of the original fill form terraces along the flanks of the new valley.

with sediments during high still stands in Lake Bonneville history, but now the sediments deposited in the canyon have been largely removed by the downcutting stream.

0.7 1.6 To the right, a steep, broad, post-Lake Bonneville alluvial fan has been formed at the mouth of one of the small tributary canyons. Sediments within this arcuate structure have very poor sorting which suggests that much of the sediment was transported by mudflows.

0.1 1.7 Outcrops of the Oquirrh Formation can be seen on the east (left) side of the road. These rocks are badly fractured quartzite, similar to the rocks seen at Geologic Stop 1. Shiny polished and grooved surfaces called slickensides result from movement between blocks during faulting and folding.

0.3 2.0 A cut through the toe of an alluvial fan is exposed across the canyon to the southwest (right). Notice how the sediments in the lower part are horizontally stratified but those in the upper part of the fan are only crudely stratified, probably the result of deposition by a series of mudflows.

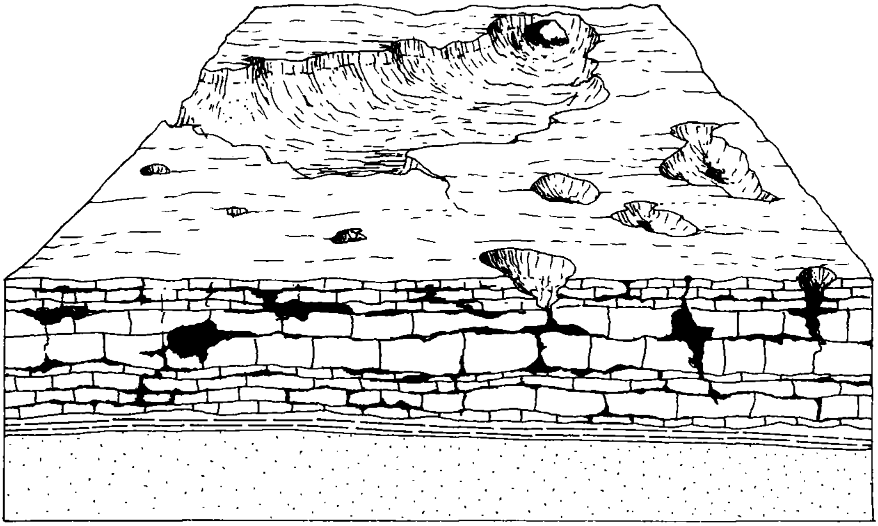
0.2 2.2 DIVERSION DAM FOR IRRIGATION CANAL ON SPANISH FORK CREEK TO THE RIGHT.

0.2 2.4 Extensive exposures of the Oquirrh Formation occur in outcrops to the north (left). A thin coal seam and organic-rich shale can be seen in the middle of the road cut. Some inarticulate brachiopods, fossils which appear similar to false fingernails, can be collected from shale near the coal. Excellent examples of trace fossils—tracks or organic smears left on the bedding planes by burrowing worm-like organisms—show on nearly every block.

0.5 2.9 Jointed rocks of the Oquirrh Formation. Cubic blocks are formed by the intersection of joints and bedding.

0.3 3.2 COLD SPRING POND. This spring supplies some culinary water to the community of Spanish Fork. The spring is probably related to porosity and percolation of water up from underlying carbonate rocks that are partially dissolved. The water issues here through the fragmented Oquirrh Formation.

0.6 3.8 FARMHOUSE IN THE MOUTH OF THE MAJOR CANYON TO THE SOUTH (RIGHT). The canyon is carved in the Permian-age Kirkman Limestone (Text-fig. 5), a laminated, thin-bedded limestone which dissolves away much more readily than the underlying Oquirrh Formation or the overlying Diamond Creek Sandstone. Numerous sinkholes (Text-fig. 9) are developed in the Kirkman Limestone in areas on the terraces to the south and southwest of the farmhouse. When these depressions were first found they were thought to be meteorite scars but after extensive



TEXT-FIGURE 9.—Block diagram showing development of karst topography, a landscape dominated by features formed by solution of bedrock by water. Sinkholes are circular depressions formed as caves collapsed or when the surface dissolved. Natural bridges and long steep-walled valleys with no obvious surface drainage are also characteristic of karst areas.

mapping they proved to be collapse features dissolved in limestone. GET PERMISSION FROM THE FARMER BEFORE HIKING TO EXAMINE THE SINK-HOLES.

Rounded boulders and cobbles in the terrace area to the north (left) were deposited in the ancient channel of Spanish Fork Creek during a high stand of Lake Bonneville. These gravels are at about the same elevation as the high Bonneville terrace below the Diamond Creek Sandstone at the mouth of the canyon. Spanish Fork Canyon was probably filled to at least that depth. An idea of the volume of sediments transported by a small stream can be gained here by noting the amount of material removed by Spanish Fork Creek to lower the valley floodplain from the elevation of the high terrace down to its present position south of the highway, in the small creek to the right. Remnants of this higher terrace will still be evident in the canyon ahead. Depth of alluvium remaining beneath the present stream is unknown, but judging from the shape of the canyon walls it could be considerable, with much work by Spanish Fork Creek still left to be done before bedrock is exposed.

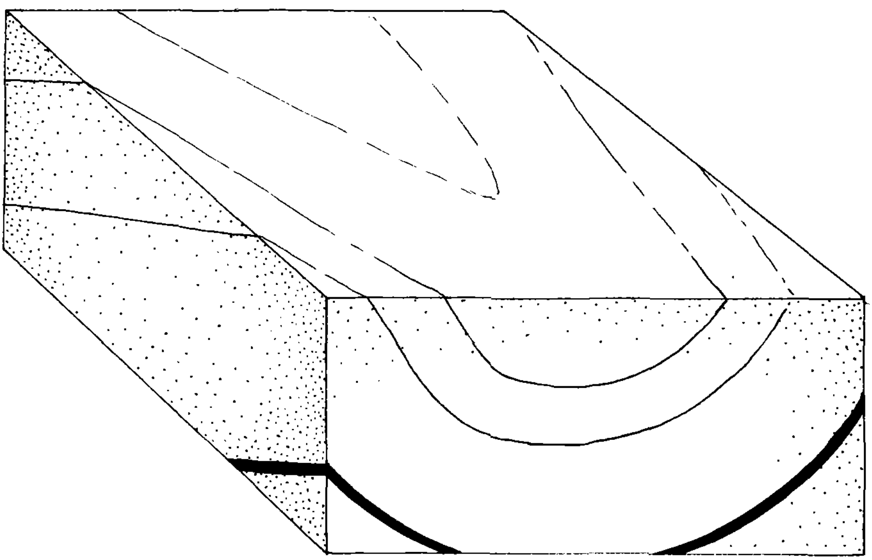
0.5 4.3 The high-level terrace shows well to the north (left).

0.4 4.7 Quarry in yellow-gray Permian-age Diamond Creek Sandstone (Text-fig. 5) to the north (left). This unit probably represents a marine sandstone, although fossils are quite rare here. The rocks are dipping down canyon here, but at Geologic Stop 1 they are dipping up canyon, to form a broad syncline or downfold in the rocks (Text-figs. 10, 12). To the east, a short distance up canyon from the quarry, a small concrete springhouse is present on the north side of the canyon. A sulfurous spring rises here at the crest of a narrow upfold or anticline (Text-figs. 11, 12). This fold is probably the controlling factor in the spring's position. The water is sufficiently warm that the springhouse streams during the winter and is used by some of the local mineral-water enthusiasts as a warm mineral-water bath. You, too, may participate..

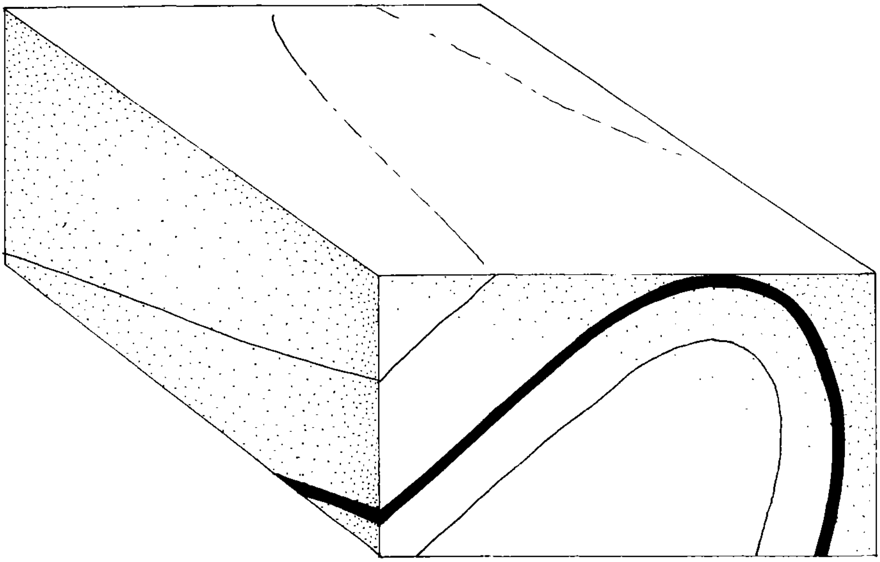
0.5 5.2 Roadside outcrops of overturned to vertically dipping Diamond Creek Sandstone can be seen. The sandstone is brittle and fractures easily so that joint surfaces obscure the generally vertical attitude of the bedding on the overturned eastern limb of the anticlinal fold (Text-figs. 11, 12). The large boulders and blocks on the slope east of the roadside outcrop are gradually moving down the slope by rock creep.

0.4 5.6 The road crosses the Permian-Triassic age boundary. Poor outcrops of the red Triassic Woodside Shale (Text-fig. 5) can be seen to the north (left) in the bottom of a small gully near the telephone line.

0.2 5.8 Poor exposures of the Triassic-age Thaynes Limestone (Text-fig. 5). This formation is an interbedded red and green



TEXT-FIGURE 10.—A syncline in folded rocks. Synclines form when segments of the earth's crust fold downward and beds dip toward the trough of the fold.

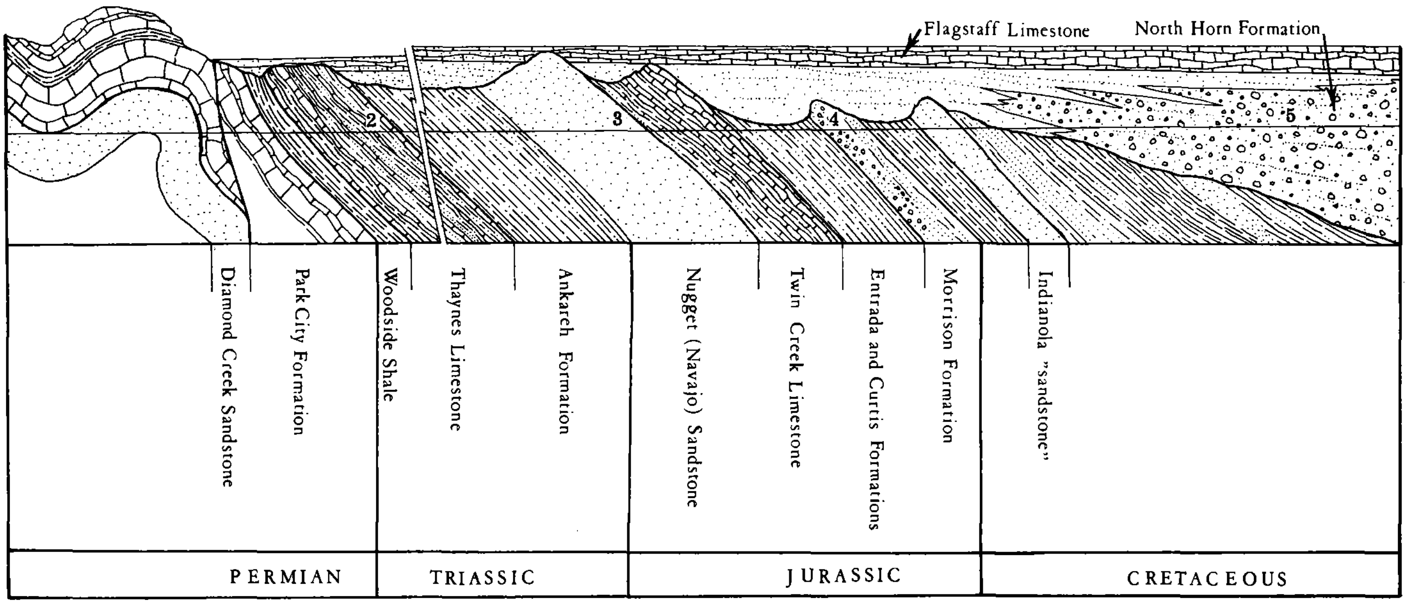


TEXT-FIGURE 11.—An anticline is an uparching of the earth's crust so that beds dip away from the crest of the fold. In this particular fold the right limb of the fold is steeper than that on the left, and near the base of the block the beds are overturned from their normal position. This fold is an overturned anticline.

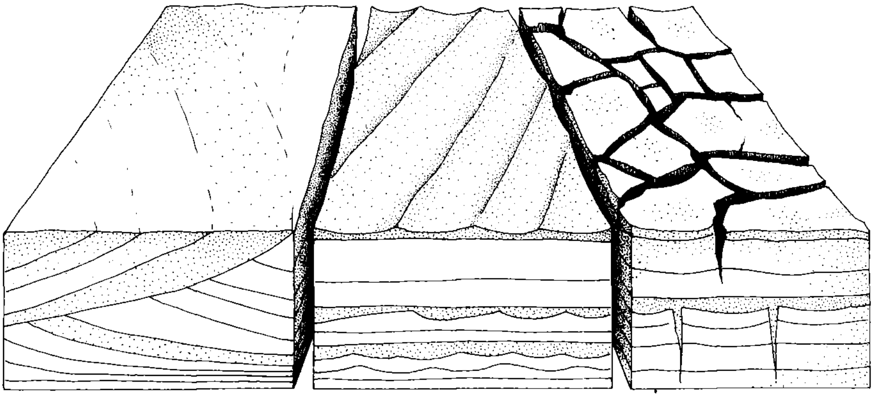
mottled shale, siltstone, and limestone sequence. Fossiliferous limestone beds form the angular fragments, and shale forms the rubbly red and green slopes. Marine pelecypods, pecten-like and oyster-looking forms, can be collected from the limestone blocks and from some sandstones in the slope area north of the road.

0.3 6.1 GEOLOGIC STOP 2. PULL OFF THE SOUTH SIDE (RIGHT) OF THE ROAD, JUST SHORT OF THE JUNCTION OF DIAMOND FORK WITH SPANISH FORK CANYON. The road cut on the north side is in the upper part of the Thaynes Limestone. The abrupt rough ledges are siliceous limestone. Fossil sponges, clams, scallops, algae, crinoids, and brittle stars have been collected from limestones of the formation. Other fossils have been reported in the greenish shale and siltstone of the underlying sequence. Here the reddish rocks are considered nonmarine and were deposited by streams or running water, but the limestone and greenish rocks represent marine material deposited in the sea. The green rocks are thought to represent old tidal flats because ripple-marked sandstone, mud cracks, and other diagnostic structures are common (Text-fig. 13).

The channel of Spanish Fork Creek is obviously choked here by sediments which are mostly debris transported in by



TEXT-FIGURE 12.—Generalized geologic cross section along the route of the field trip. Approximate positions of Geologic Stops 2 to 5 are shown by numbers along the road level, the tilted line at midsection.



TEXT-FIGURE 13.—Sedimentary structures seen in formation on the field trip. *A,* Cross-bedding is the result of shift in direction of transport or in velocity of the transporting medium. Here the lower beds were deposited by a current moving from left to right, but upper beds were deposited by a current moving in the opposite direction. *B,* Ripple marks are features produced by gentle currents moving across a bed of sand or silt, or by a current moving back and forth across loose sediments. *C,* Mud cracks are the result of drying of water-soaked sediments that have enough clay to bind polygons together as the water is removed and volume is reduced.

Diamond Fork. The channel and meander pattern of Diamond Fork were established for a small stream, but now a considerable volume of water is being emptied into Utah Valley via this small canyon through a tunnel which was drilled from the head of Diamond Fork to the Strawberry Reservoir. This increase in water volume in the creek has resulted in upsetting the established pattern of the stream so that now the whole canyon bottom of Diamond Fork is actively undergoing erosion. At the present rate of erosion much of the flatland in Diamond Fork will be destroyed or modified as a result of the enlargement of the meander pattern and shifts in the channel of the creek. Diamond Fork is the site for one of the storage dams for the Central Utah Project. CONTINUE AHEAD ON U. S. HIGHWAY 89, 50, and 6.

0.3 6.4 CROSS DIAMOND CREEK. Notice the transported pebbles, logs, and debris being swept downstream as the meander patterns of Diamond Fork enlarge in the area upstream(to the left).

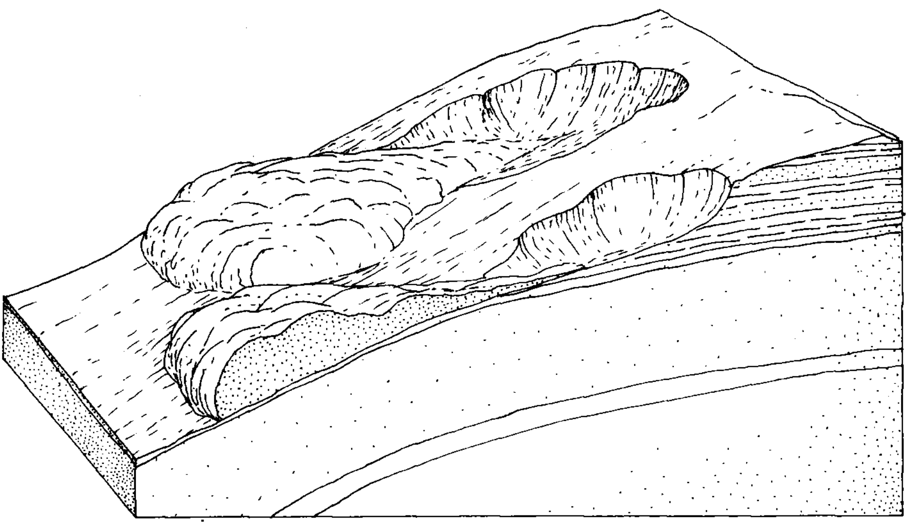
The bright red and brick-red outcrops immediately east (left) of the road are siltstone and sandstone basal beds of the Ankareh Formation (Text-fig. 5). Ankareh is an Ute word meaning red ridge. This formation seems aptly named. Most of the silty or sandy beds of the Ankareh Formation are ripple marked; some show raindrop impressions and mud cracks. Some of the apparently silty beds are in reality clay-ball conglomerates in which pellets of clay have acted like pebbles.

To the right, across Spanish Fork Canyon, can be seen a hummocky surface which is the result of creep and landslide of soft sedimentary rocks which overlie the tilted rocks of the canyon bottom (Text-fig. 14). The formations in the bottom dip upstream 15 to 20 degrees but the overlying formation is essentially horizontal. Additional evidence of this pronounced angular relationship, termed an angular unconformity, can be seen up-canyon east of Thistle.

0.5 6.9 Thick-bedded, red sandstone in the upper part of the Ankareh Formation. Joints have controlled the angular blocky pattern of erosion at the south edge of the outcrop. The hummocky landslide surface and some stream terraces of intermediate elevation show very well to the west (right).

1.1 8.0 Bend in the road. A magnificent landslide mass of soft sediments can be seen coursing down through a narrow V-shaped notch through the Navajo Sandstone ahead and to the right across the canyon.

0.2 8.2 Cliffs of Navajo Sandstone (Text-fig. 5) are exposed on the east (left) of the road. Remnants of the old highway, which used to be on the west side of the canyon, can be seen both north and south of the landslide mass. Maintenance was such a problem that the road was finally moved



TEXT-FIGURE 14.—Landslide masses result from water-soaked or otherwise unstable sediment or rocks moving down slope. This tends to produce a hummocky or rolling uneven surface that is quite distinctive.

to the east, after the right-of-way had been blasted in the Navajo Sandstone.

0.4 8.6 ENTERING THE SMALL COMMUNITY OF THISTLE. SEPARATION OF U. S. HIGHWAYS 50 AND 6 FROM U. S. HIGHWAY 89. GEOLOGIC STOP 3. PULL INTO THE WIDENED AREA TO THE WEST OF THE JUNCTION ON THE SOUTH (RIGHT) SIDE OF THE ROAD. Geologic Stop 3 gives a good view of the Navajo Sandstone, but an even better view can be seen by walking east a short distance up the canyon on the left-hand side of the road beyond the cliff-side exposures. Magnificent cross-bedding in the upper part of the Navajo Sandstone shows from here as marked lineations or irregular beds (Text-fig. 15). The Navajo Sandstone represents an ancient belt of sand dunes, or desert deposits, and is part of the same layer of sediments which forms the prominent cliffs in Zion National Park in southern Utah. The soft slope zone in the little narrow canyon to the east is in the overlying marine Twin Creek (Carmel) Limestone (Text-figs. 5, 12, 15). A reddish zone separating the two formations is a transitional zone from an arid desert environment to one of an invading sea. The first small ledges on top of the red zone are composed of oolitic limestone, with fragments of fossils being rather common. Dipping beds of the upper part of the Twin Creek (Carmel) Formation form the narrows along Spanish Fork Creek east of the highway bridge at Thistle. RETURN TO THE CARS AND CONTINUE EAST ON U. S. HIGHWAYS 50 AND 6 TOWARD PRICE

0.5 9.1 Excellent exposures of fine-grained limestone of the Twin Creek (Carmel) Limestone in road cuts on the north (left).

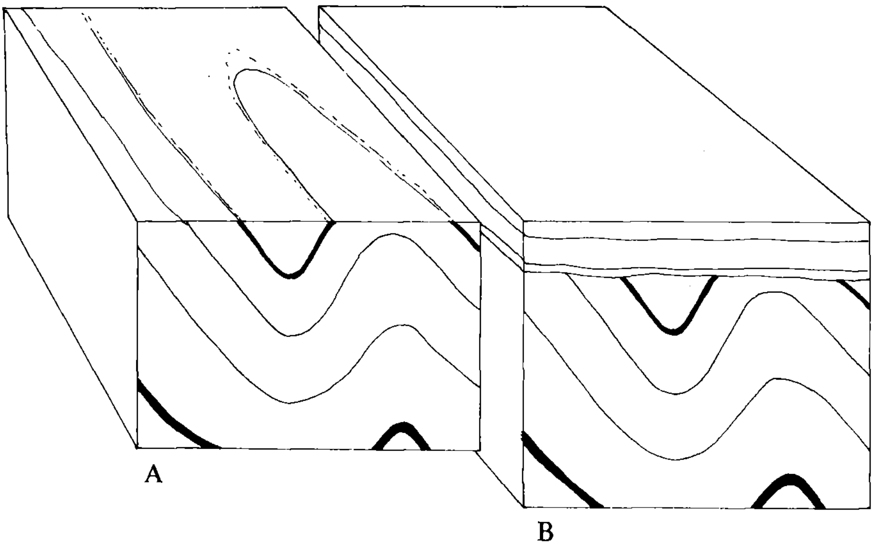
0.2 9.3 High-level stream terraces can be seen up to two hundred feet above the highway on both the north and the south side of the canyon. These terraces were probably related to a high level of Spanish Fork Creek when it was adjusted to a Lake Bonneville level. To the north (left) slumped, light gray Flagstaff Limestone on top of red North Horn Formation is visible.

0.8 10.1 GEOLOGIC STOP 4. PULL OFF ON GRADED SHOULDER TO NORTH AT ROAD CUTS ON THE NORTH (LEFT) SIDE OF THE ROAD AT THE BEND OPPOSITE A SMALL ROUND HILL ON THE SOUTH SIDE OF THE VALLEY. Sandstone and conglomerates exposed in the cuts are in the Upper Jurassic Morrison Formation (Text-figs. 5, 12). This is the same formation which has produced the dinosaurs at Dinosaur National Monument and most of the Jurassic dinosaurs known in North America from Wyoming, Colorado and Utah. Rocks

TEXT-FIGURE 15.—Photograph of the top beds of the Navajo Sandstone and bottom beds of the Twin Creek (Carmel) Limestone as exposed on the north side of the highway at Thistle Junction near Geologic Stop 3. Cross-bedded Navajo Sandstone is the light-colored cliff-forming unit. Marine shale and limestone form the more easily eroded lower part of the overlying Twin Creek Limestone exposed in the small gully to the right.

in the road cut are dipping to the east. If we should climb up the hill to the north, to near the skyline, we would see the overlying rocks with a nearly horizontal dip or attitude. These are the overlying Tertiary rocks, which are unconformable on the folded Jurassic rocks in the road cut (Text-figs. 12, 16).

Spanish Fork Creek is entrenched below the general level of the flat floodplain of the valley to the south. This is possibly related to adjustments of the stream course to its downcutting farther down toward the mouth of the canyon. CONTINUE UP CANYON WITH CAUTION.



TEXT-FIGURE 16.—Development of an angular unconformity. *A,* Beds which were originally deposited horizontally were folded to produce anticlines and synclines and then eroded to form a nearly smooth surface. *B,* The block settled and sediments were deposited to bury the relatively smooth erosional surface. Thus there is an angular relationship between the overlying and underlying beds. This buried erosional surface is an angular unconformity.

0.5	10.6	Steeply dipping beds are exposed low in the road cuts. This is the upper part of the Morrison Formation below the unconformity.
0.2	10.8	Prominent white Indianola sandstone hogback (Text-fig. 12) is exposed above the road on the north (right). This rock exposure is probably part of a barrier island or a beach sequence. Oyster-shell fragments occur but are rare in the lower part of the sandstones on the west edge of the outcrop. Numerous casts and molds of small clam-like pelecypods occur in thin beds on the east end of the outcrop. Flat-lying Tertiary rocks can be seen above the unconformity on the skyline to the north (Text-figs. 5, 12). Redbeds of the North Horn Formation, between the white, massively bedded, Cretaceous sand and the overlying lacustrine limestones that form the skyline, represent clastic material whose thickness varies with the position of the unconformity.
1.1	11.9	Excellent exposures of the light-colored Tertiary Flagstaff Limestone (Text-fig. 4) can be seen up the small canyon to the north, overlying the reddish, very coarse clastic, North Horn rocks.

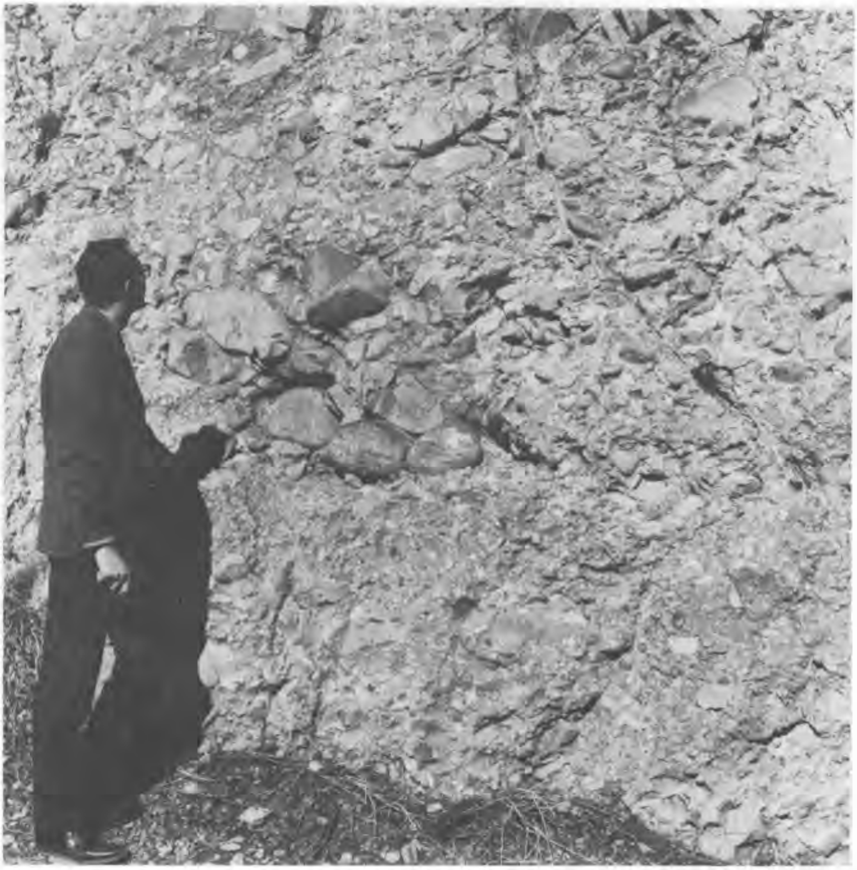
0.2	12.1	Road cuts through Recent or Pleistocene gravel which is plastered against North Horn Conglomerate of Early Tertiary or Late Cretaceous age. The North Horn Formation forms the ledges in the bedrock in the same general vicinity.
0.8	12.9	Massive conglomerate beds are visible on the north and south sides of the canyon. These form the rugged, irregular ledges, columns, and pillars along the canyon wall. The conglomeratic gravels are composed of fragments of the Oquirrh Formation and older more resistant units exposed in regions to the west. The area in the vicinity of Provo and to the west is considered to be the probable source of the gravel. It was deposited here by streams flowing eastward into the sea which occupied much of eastern Utah and Colorado.
0.8	13.7	Alluvial fan of small stream draining in from the north (left). Jointed conglomerate shows well, forming peculiar resistant units both north and south of the highway.
0.4	14.1	Very shallow cave and a reentrant into the conglomerate ledges east of the road (Text-fig. 17, 18). For approximately the next two miles conglomerate is well exposed in cuts immediately adjacent to the road. Notice the characteristic rounding of the fragments in the conglomerate, even though some of the blocks are exceedingly large (Text-fig.

TEXT-FIGURE 17.—View of the western part of the Red Narrows of Spanish Fork Canyon from the west. Cliffs are carved in thick beds of conglomerate of the North Horn Formation. The small cave or reentrant in the cliff to the left of the highway is at Mile 14.1 in the road log.

TEXT-FIGURE 18.—Cliff of coarse conglomerate of the North Horn Formation at approximately Mile 14.3 in the Red Narrows. Fragments in the conglomerate were brought in from the west by ancient streams draining eastward into Colorado and eastern Utah. These gravels represent a period of folding in mountainous areas to the west and give us clues to times of Laramide mountain-building activity.

19). Thin-bedded sandstone forms reddish units. Most of the gravels in these cliffs and in the outcrop to the right are composed of eroded Paleozoic formations. The road continues eastward past road cuts in the North Horn Conglomerate (Text-figs. 18, 20).

0.8 14.9 A massive conglomerate fills channels cut into more evenly bedded siltstone and sandstone in the road cut on the north (left) at road level (Text-fig. 20). Base of the channel has cut down across the evenly bedded sandstone and siltstone. This channel marked the position of one of the streams which transported this debris from the mountains to the west. A smaller channel is exposed in the center part of the road cut a hundred feet to the east. The road continues to the east through conglomerate of the North Horn Formation (Text-fig. 12).



TEXT-FIGURE 19.—Blocks and boulders in North Horn Conglomerate exposed in the Red Narrows. The large block is near the base of the picture in Text-figure 18.

0.9 15.8 SPRING WITH FOUNTAIN AT ROAD LEVEL. GEOLOGIC STOP 5. PULL OFF ON NORTH (LEFT) SIDE OF HIGHWAY. A broad cone of tufa can be seen to the north above the fountain (Text-fig. 21). A similar tufa cone is visible up the canyon to the east with an overhanging ledge. The tufa is made of calcium carbonate deposited by springs. Leaves of the redbark birch are occasionally preserved in the tufa, where they were gradually covered over by spring deposits. The springs are located along fractures where faults have broken the bedrock to form channels where spring water can well up. Several conglomerate and sandy beds cut by the faults can be seen across the canyon to the south of the fountain.

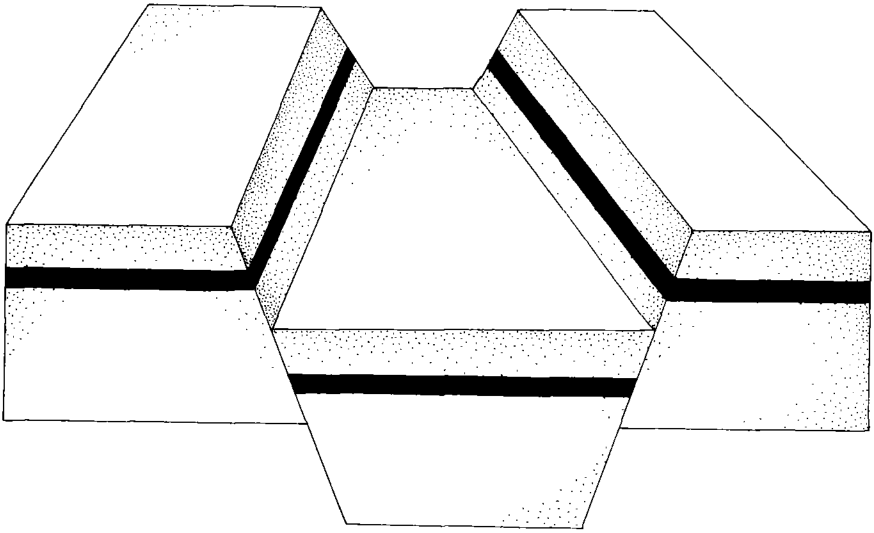
0.2 16.0 Red siltstones and sandstones of the upper part of the North Horn Formation are exposed here.

TEXT-FIGURE 20.—Conglomerate-filled channel exposed on the north side of the highway at Mile 14.9 in the road log. The channel cuts into underlying sandstone and represents an ancient stream channel that was cut, abandoned, and filled during deposition of the North Horn conglomeratic sequence.

0.3	16.3	Drag along a major fault has tilted the beds steeply here. This fault bounds the western side of a graben structure, a narrow downfaulted block (Text-fig. 22). The tan and light yellow-gray rocks to the east are in the Tertiary Flagstaff Limestone (Text-fig. 5).
0.2	16.5	GEOLOGIC STOP 6. PULL TO THE NORTH SIDE OF THE ROAD IN THE BROAD OPEN FLAT AT THE BEND. Walk to the north and examine ledges in the Flagstaff Limestone (Text-fig. 5). One of the units near the middle of the ledges is composed of algal balls. These structures were made by algae which gradually developed onion-like, or concentric masses, of limestone as the balls rolled back and forth along the shore or beach of Lake Flagstaff. The onion-like structures grew around snail and clam shells or around twigs. RETURN TO CARS AND CONTINUE EAST ON U. S. HIGHWAYS 50 AND 6:

TEXT-FIGURE 21.—Tufa cone of a spring at the eastern end of the Red Narrows at Geologic Stop 5. Water from the spring is heavily charged with calcium carbonate which is precipitated to form porous, punky tufa at the mouth of the spring.

0.2	16.7	Carbonaceous shale and siltstone of the upper part of the Flagstaff Limestone are exposed in cuts to the north. A crocodile, several turtles, many snails and clams, and much broken plant debris have been collected from this locality. These sedimentary rocks represent sediments in a marginal marshy area in the upper part of Lake Flagstaff history.
0.1	16.8	Small canyon enters from the north. This marks the approximate base of the Green River Formation (Text-fig. 5) and upper beds of the coarse deltaic beds equivalent to the Colton Formation. The road is built for the next several miles through rocks of the Green River Formation.
0.2	17.0	Greenish shale and white limestone of the Green River Formation show in the outcrop to the north (left).
0.2	17.2	Baer's Bluff. This is an area worked in detail by a graduate student from Brigham Young University and shows the transition from marshy delta sediments in the western part of the outcrop into open lake sediments in the upper or eastern part of the outcrop.



TEXT-FIGURE 22.—Generalized block diagram of a graben structure. The graben is a narrow, down-dropped fault block.

0.6 17.8 JUNCTION OF SHEEP CREEK ROAD TO STRAWBERRY RESERVOIR TO THE NORTH. Continue ahead on U. S. Highway 50 and 6.

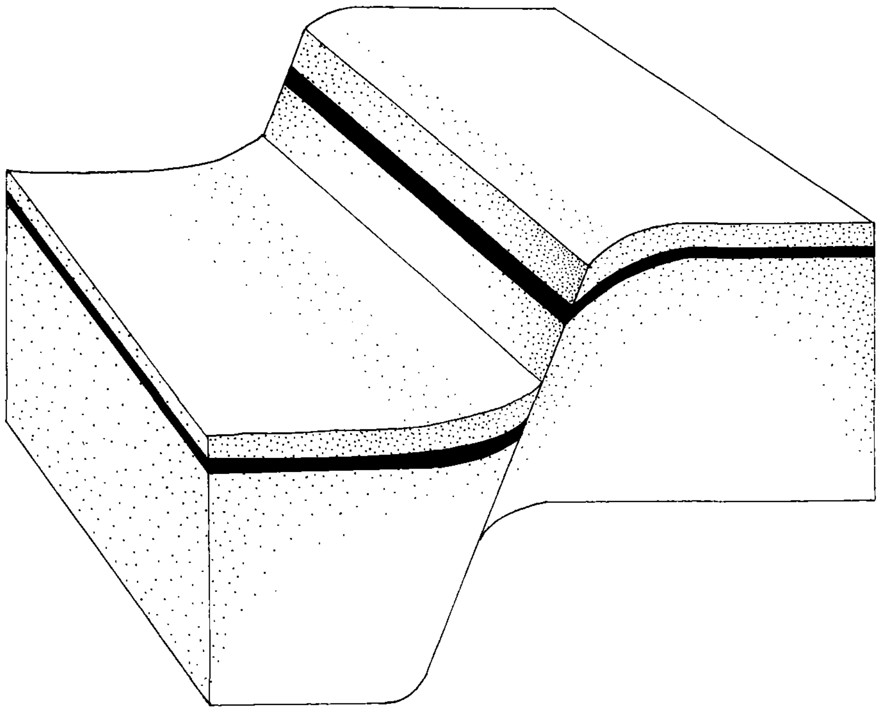
0.2 18.0 JUNCTION OF DAIRY FORK ROAD TO THE SOUTH. Continue ahead on U. S. Highway 50 and 6.

1.1 19.1 Roadside outcrop of the Green River Formation. Terraces are visible to the south of the road. These terraces are probably part of the same sequence that has been above the general level of Spanish Fork Creek since we left Thistle.

0.3 19.4 GEOLOGIC STOP 7. PULL OFF ROAD TO THE NORTH JUST BEYOND BRIDGE AND WALK BACK THE SHORT DISTANCE TO THE ROAD CUT. Small faults can be seen here in the Green River Formation. The white limestone beds have been offset and displacement on the fault can be easily calculated. Notice the fault drag (Text-figs. 23, 24) on the upthrown eastern block. A major fault zone is developed a short distance to the west of the prominent small fault where the rocks have been badly broken and smeared.

The prominent greenish-gray ledge above the road cut is a sandstone which probably represents deltaic deposits of an old river emptying into Lake Green River from the west. RETURN TO CARS AND CONTINUE EAST (UP CANYON) ON U. S. HIGHWAYS 50 AND 6.

0.3 19.7 Green River Formation is exposed in road cuts to the north



TEXT-FIGURE 23.—Drag of beds along a fault plane, caused as a result of high friction between the two moving blocks. The block on the left moved down with respect to the block on the right, as indicated by their relative position and by the drag at the fault surface.

(left). The rounded sandstone ledges possibly represent old distributary channels of a delta built out into Lake Green River, part of the same delta complex mentioned earlier.

0.5 20.2 Fossiliferous Green River beds are exposed in road cuts on the north, broken by small faults that show drag folds. Northward-dipping older rocks of formations below the Green River Formation can be seen ahead on the skyline and to the south forming cuestas on the skyline. From here to the east for some distance the road is in a subsequent valley whose position has been adjusted by erosion to the soft shaly lower beds of the Green River Formation.

2.0 22.2 Marsh area just beyond major road cut. This is an abandoned channel of the creek which was displaced to the south by construction of the highway. This is a typically-appearing abandoned channel.

The next series of road cuts are all in about the same fossiliferous Lower Green River Formation. Not all units

TEXT-FIGURE 24.—Small normal fault in the Green River Formation, exposed on the north side of the highway at Geologic Stop 7 at Mile 19.4 in the road log. The eastern block is upthrown relative to the one on the west. The light gray beds are relatively unfossiliferous limestone in more easily eroded green shale and siltstone. Thick-bedded, coarse-grained sandstone is exposed at the top of the cut and probably represents filling of a river channel built into Lake Green River.

are fossiliferous but gastropods, pelecypods, ostracods, fish fragments, turtles, and bird tracks occur at this level.

1.6 23.8 RAILROAD OVERPASS. Excellent exposures of the Green River Formation occur in cuts near the highway.

1.3 25.1 SERVICE STATION AND MOTEL. Green River Formation is well exposed in railroad cuts on the north (left) side of the valley. Notice the lenticularity on some of the white limestone beds in the cut on the hill northwest of the service station.

0.6 25.7 Small faults are visible in Green River beds in cuts along the railroad on the north (left) side of the canyon .

0.5 26.2 Lenticular wedging, massive sandstone of the lower Green River Formation is visible on the northeast (left) side of the highway, across the canyon between the creek and the railroad.

0.5 26.7 SKYLINE DRIVE FOREST ROAD JUNCTION TO THE SOUTHWEST (RIGHT). Continue ahead on U. S. Highway 50 and 6, through the lower part of the Green River Formation.

0.2 26.9 CROSS STARVATION CREEK. Excellent bird tracks have been collected in the basal beds of the Green River rocks both east and west of here. For the next several miles the canyon is carved in the Colton Formation (Text-fig. 5) which is a series of red siltstones and shales that are even softer than the Green River beds and have eroded to form the valley.

0.6 27.5 Excellent landslide and slump features (Text-fig. 14) are visible to the south (right). The hummocky rolling surface is the Colton Formation sliding down into the valley from the south. Notice how the stream occasionally has trenched through hummocks on the slide masses. Careful observation will show twisted trunks on some of the trees that have adjusted to down-slope movement of their substrate.

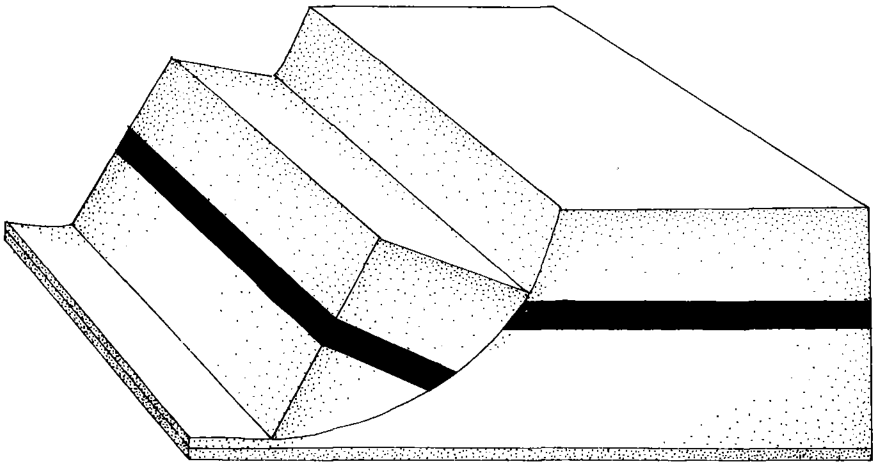
0.7 28.2 A landslide mass has deflected the channel around the toe of the landslide. There is sufficient creep over the entire surface here that the railroad must be constantly maintained. Landslides here have rocks of approximately the same age as rocks in the landslides developed in Spanish Fork Canyon between Diamond Fork and Thistle.

0.6 28.8 RAILROAD SIDING OF GILLULY. Green River beds form the bluffs to the north; the valley is cut in the Colton Formation (Text-fig. 5); and bluffs to the south expose the algal-ball Flagstaff Limestone, a resistant unit which holds up the ridge.

0.3 29.1 RAILROAD OVERPASS. Reddish Colton rocks are visible in outcrops up the canyon ahead.

0.4 29.5 Toreva blocks (Text-fig. 25), large rotated masses of Colton and Green River beds, are exposed on the north. These blocks form the irregular topography immediately north of the highway.

0.2 29.7 Red beds of the Colton Formation, a stream floodplain accumulation, are exposed in road cuts on the bend. Both the north and south walls of the canyon are slumping toward the small creek in this vicinity. Toes of the landslide masses are being gradually removed by erosion. This sequence is particularly susceptible to slumping because the shale beds concentrate water and lubricate movement of overlying beds.



TEXT-FIGURE 25.—Toreva block development results from slipping and rotation of a single block on a curved slide surface. This does not develop a rolling topography like landslides, but large tilted blocks.

Numerous small springs issue in the same general vicinity where the slump masses have formed.

1.3 31.0 The canyon narrows here, largely as a result of slump masses moving into the canyon from the south. The hummocky topography between here and the railroad is characteristic of slumping. The small stream obviously has been displaced here as the landslide mass moved out into the canyon, forcing the stream toward the north near the road.

1.1 32.1 A spring area on the south side of the canyon is a result of groundwater coming to the surface in the canyon bottom.

0.4 32.5 Excellent exposures of the stream-deposited Colton Formation occur in the road cuts.

1.0 33.5 ENTERING COMMUNITY OF SOLDIER SUMMIT. High point and divide are in Soldier Summit.

0.3 33.8 WASATCH COUNTY-UTAH COUNTY. Turn around and return to Provo.

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