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Geomorphic Features and History of the Lower Part of Logan Canyon, Utah

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GEOMORPHIC FEATURES AND HISTORY OF THE LOWER PART OF LOGAN CANYON, UTAH

by

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INTRODUCTION

General Statement

Logan Canyon is located east of Logan, Utah, in the Bear River Range. The lower part of Logan Canyon is considered that section of the canyon from its mouth upstream to Tony Grove Canyon, a distance of 22 miles[1], Figure 1. Some tributary canyons of the lower part of Logan Canyon have been included in this investigation because of their relationship to Logan Canyon. Grassy Flat Canyon, a south tributary of Logan Canyon 4.4 miles from Logan, exhibits several geomorphic features related to the geology of Logan Canyon. Because of its extensive use and close association with Logan Canyon, Tony Grove Canyon is also included. Tony Grove Canyon extends from Logan Canyon northwestward to the crest of the Bear River Range, a distance of about six miles.

More than 20,000 feet of Paleozoic rocks ranging in age from Cambrian to Pennsylvanian are exposed in Logan Canyon. Cenozoic deposits are widespread in and near the canyon. The crest of the Bear River Range near Naomi Peak and Tony Grove Canyon was the center of

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[1]All distances in Logan Canyon are measured from Fourth North and Main Street in Logan, Utah, east toward Bear Lake. Small mileage signs have been erected every mile along the south side of the highway which show the mileage from the same point in Logan.

glacial activity during the Pleistocene. During the glaciations of Tony Grove Canyon, Lake Bonneville extended into Logan Canyon and influenced the geomorphic development near the mouth of the canyon.

Logan Canyon is vital to the economy of Cache Valley. The canyon is a large part of the Logan River watershed. Logan River passes through three hydroelectric plants in Logan Canyon and supplies culinary and irrigation water for the valley below. Animals and plants of a wide variety are abundant, providing fishing, hunting, and a harvest of forest products.

U. S. highway 89 traverses the canyon and carries a large volume of traffic to points within the canyon, as well as to other areas. Logan Canyon is entirely within the Cache National Forest. Improved campsites and recreational facilities, which were used by almost 1.5 million visitors during 1963; according to the U. S. Forest Service, are located throughout the Canyon. Increased recreational and travel use of the canyon has resulted in a demand for more geologic work in this area.

Field Work

Field work for this report was conducted during the fall of 1962, spring of 1963, and intermittently during the summer of 1963. A plane table and alidade were used to obtain elevations and slope angles of the alluvial terraces in the lower part of Logan Canyon. A Paulin altimeter was used to obtain some elevations where the area being studied was not close to a bench mark. Aerial photos were used in all field work and were the base on which glacial features, alluvial terraces and other features were plotted in the field. The maps of Tony Grove Canyon and sections of Logan Canyon, Figures 5, 7, and 13, are tracings taken from aerial photos. No corrections were made on these maps for distortion, so contact positions must be considered approximate. The Index map, Figure 1, is taken from Utah-Idaho Logan Quadrangle map made by the U. S. Geological Survey.

Previous Investigations

Early studies of the geology of the Logan Canyon area began in the late 1800's. The Fortieth Parallel Survey (Hague and Emmons, 1877) and the Hayden Survey party (Peale, 1879) made brief studies of the area during the 1870's. G. K. Gilbert visited Cache Valley and Logan Canyon in the course of his investigations of Lake Bonneville (Gilbert, 1890). The U. S. Geological Survey published a stream profile of Logan River in 1916 (Herron, 1916, p. 10). Several later studies of the Logan Canyon area were made by Williams (1948, 1956, and 1958). Studies conducted by graduate students of Utah State University have included parts of Logan Canyon (Peterson, 1936; Young, 1939; and Taylor, 1963).

STRATIGRAPHIC AND STRUCTURAL SETTING

General Statement

Logan Canyon is situated in a region which has been affected by the major events of the Paleozoic, Mesozoic, and Cenozoic Eras. Rocks older than Paleozoic are not exposed in Logan Canyon, although they probably underlie the entire area. Precambrian rocks of the Big Cottonwood series are found beneath Cambrian rocks in the James Peak area, about 24 miles south of Logan (Williams, 1958, p. 17).

In the early Paleozoic, the Cordilleran sea inundated the region from the southwest, and remained throughout most of Paleozoic times. The Logan Canyon area, because of its position near the eastern edge of the Cordilleran geosyncline, was exposed, at times, to erosion caused by lateral shifting of the shoreline. When the area was on the west side of the shoreline, it was an area of deposition and conversely, it was being eroded when on the east side of the shoreline. Major hiatuses are present in the local section representing times when the area was subject to erosion or nondeposition.

Rocks of Mesozoic age are not found in Logan Canyon, but are found northeast in Idaho and southward in central Utah. Prior to their removal, Mesozoic sediments probably covered the area to an estimated depth of 5,000 feet (Williams, 1948, p. 1158). During the late Mesozoic, uplift of western North America marked the advent of the Laramide orogeny. Erosion followed uplift, removing all of the previously deposited Mesozoic sediments and cutting deeply into the Palezoic section.

Two major periods of orogeny affected the rocks in Logan Canyon. The first of the two, the Laramide orogeny, took place during the late Mesozoic. The second major period of orogeny occurred during the Cenozoic Era.

Paleozoic Rocks

The Paleozoic rocks of the Logan Canyon area have been studied by Williams (1948 and 1958). A brief summary of exposures in Logan Canyon is given here.

The oldest Paleozoic rocks in Logan Canyon were deposited during the Cambrian Period, Table 1. The Early Cambrian Brigham quartzite forms the basal unit. Limestone, shales, and dolomites of the Langston, Ute, Blacksmith, Bloomington, Nounan, and St. Charles formations were deposited throughout the remainder of the Cambrian. Cambrian Rocks are best exposed on Temple Ridge which forms the east side of Logan Canyon about 23 miles from Logan, although an outcrop of the St. Charles formation is seen north of the highway at the mouth of Logan Canyon (Williams, 1948 pl. 1; and Williams, 1958, p. 19).

The Garden City limestone was deposited during the Ordovician Period followed by deposition of the Swan Peak formation and the Fish Haven dolomite. The Swan Peak formation is composed of beds of shale

Table 1. Paleozoic formations in the Logan Canyon area. Modified after Williams (1948, p. 1130)

Formation	Description	Location and thickness of measured section
Tertiary Wasatch fm.		
Unconformity		
Pennsylvanian		
Oquirrh fm.	Calcareous sandstone and gray limestone	Wellsville Mountain 6,000'+
Unconformity		
Mississippian		
Great Blue ls.	Gray limestone	Dry Lake 1,500'-3,700'
Humbug ss.	Calcareous sandstone	
Disconformity		
Lodgepole ls.	Thin-bedded fossiliferous limestone, and some black shale near base	Logan Canyon 845'
Unconformity		
Devonian		
Jefferson fm.	Thin-bedded sandstone and siltstone, with dark-gray dolomites and limestones	Green Canyon 1,840'
Disconformity		
Water Canyon fm.	Thin-bedded sandy and silty dolomite, sandy shale and sandstone	Logan Canyon 540'
Disconformity		
Silurian		
Laketown dol.	Light and dark-gray dolomite generally massive	Green Canyon 1,510'
Disconformity		
Ordovician		
Fish Haven dol.	Dark-gray, massive dolomite	Green Canyon 140'
Unconformity		
Swan Peak fm.	Gray and brown fucoidal quartzite, and black shale	Green Canyon 340'
Garden City ls.	Dark-gray, thin-bedded limestone and shaly limestone weathering olive-buff	Green Canyon 1,400'

Table 1. Continued.

Formation	Description	Location and thickness of measured section
Disconformity(?)		
Cambrian		
St. Charles fm.	Massive gray dolomites and thin-bedded limestones, with drab quartzite member at base	High Creek 1,015'
Disconformtiy(?)		
Nounan fm.	Gray dolomites with some gray limestones in upper part	High Creek 1,125'
Bloomington fm.	Gray limestone and tawny-olive shale	High Creek 1,500'
Disconformity(?)		
Cambrian		
Blacksmith dol.	Neutral-gray dolomite and dolomite limestone, generally massive	Left Fork of Blacksmith Fork Canyon 325'
Ute fm.	Dark gray limestone and shale	Left Fork of Blacksmith Fork Canyon 665'
Langston fm.	Gray dolomites, tan weathering. Black, green and gray shales. Some limestone	Left Fork of Blacksmith Fork Canyon 380'
Brigham qtz.	Gray and light-brown quartzites	Wellsville Mountain 1,800'
PreCambrian		
Big Cottonwood series	Quartzites and phyllites	James Peak, Thickness unknown

while the upper part is composed of beds of quartzite. Fucoidal markings are found in the quartzite. Thickness of the quartzite beds varies locally due to a time of erosion following its deposition (Williams, 1958, p. 23). The Ordovician formations are seen in several parts of Logan Canyon. Outcrops occur at the mouth of Logan Canyon upstream for a distance of about two miles. Rocks of Ordovician age form the bottom of Logan Canyon at the junction of Right Fork. A slab of fucoidal quartzite from a nearby outcrop of Swan Peak formation is displayed north of the highway a fourth of a mile downstream from the junction of the Right Fork road. The Swan Peak formation outcrops at a point 13.3 miles from Logan and is seen as a brown quartzite unit below a massive dolomite ledge on the north side of the highway. A short distance upstream the Garden City is exposed and forms the canyon bottom for a distance of about five miles. In the vicinity of the intrenched meanders, the Garden City forms the impressive ledges along the Logan River. In the upper part of Tony Grove Canyon the Swan Peak formation is exposed and has been eroded by glaciation. It forms part of the ledge on the west side of Tony Grove Lake and extends northward into White Pine Canyon.

The Silurian system in Logan Canyon is represented by the Laketown dolomite. It is exposed about one mile from the mouth of Logan Canyon forming impressive ledges on each side of the Canyon. The Laketown dolomite is also exposed a half mile downstream from the Card Guard Station and extends upstream for a distance of about four miles. It forms impressive ledges on each side of Logan Canyon upstream from the junction of Right Fork. The Laketown dolomite forms the crest of the Bear River Range in the vicinity of Naomi Peak and upper Tony Grove Canyon.

The Devonian system is represented by the Water Canyon formation (Taylor, 1963), and the Jefferson formation. The Water Canyon formation outcrops at the mouth of Grassy Flat Canyon 4.4 miles from Logan, and a half mile downstream from the Card Guard Station. The Jefferson formation forms the bottom of Logan Canyon between the two exposures of the Water Canyon formation, a distance of about four miles.

Rocks of Mississippian age in Logan Canyon are the Leatham formation, Lodgepole limestone, Humbug sandstone, and Great Blue limestone. The Leatham formation was studied by Holland (1952) in Leatham Hollow, a tributary to the Left Fork of Blacksmith Fork south of Logan. It is the basal Mississippian unit, and is seen in Logan Canyon as the slope below a high ledge about seven miles from Logan. The high ledge, the lower third of the Lodgepole limestone, is sometimes called the "Chinese Wall." It forms an impressive ledge on each side of Logan Canyon. Above the ledges, near the summits of Logan and Beirdneau Peaks, is exposed the Humbug formation and the Great Blue limestone (Sadlick, 1955, p. 51) which was previously called the Brazer formation by Williams (1948, p. 1142).

The youngest Paleozoic rocks in Logan Canyon are the Oquirrh formation which comprises the summit of Logan Peak. It was thought for some time that rocks younger than Pennsylvanian were not exposed in the Logan Canyon area. Bissell (1962) has recently discovered Permian fusulinids in the upper part of the Oquirrh formation in the Wellsville Mountains, 10 miles west of Logan, Utah. Permian rocks probably do not exist at Logan Peak because only a thin section of the Oquirrh is exposed there. A large upper part of the section has been removed by erosion since uplift of the Bear River Range.

Cenozoic Rocks

Exposures of the Eocene Wasatch formation are widespread in Logan Canyon east of the crest of the Bear River Range. Isolated patches of Wasatch occupy the passes between deep canyons near the summit of the high mountains on the crest of the range. Evidence thus indicates that the Wasatch formation covered the entire area before development of the Bear River Range and Cache Valley.

The Wasatch formation in this area is made up of two members, a lower Cowley Canyon limestone and an upper "Wasatch" conglomerate (Williams, 1948, p. 1145). The Cowley Canyon member is a stromatolitic limestone that was deposited in a fresh water lake. The stromatolites are light-brown, calcareous algal deposits cemented by a compact cream-colored limestone. The lake in which the deposits accumulated may have covered a wide area in northern Utah, southeastern Idaho and western Wyoming (Williams, 1948, pp. 1144-1145).

Exposures of the Cowley Canyon member of the Wasatch formation in the Logan Canyon area are found in Cowley Canyon, a tributary to the Right Fork of Logan Canyon. In Cowley Canyon 0.9 miles above the junction of the Cowley Canyon and Right Fork roads is the type locality of the Cowley Canyon member (Williams, 1948, pp. 1144-1145). Other exposures are found west of the summit of the Cowley Canyon-Herd Hollow road in the vicinity of White Bedground.

The Cowley Canyon member is overlain by what Williams (1948) called "Wasatch" conglomerate. "Wasatch" conglomerate is a pebble and cobble conglomerate cemented with a matrix of sand and iron oxide. The deposit is typically red because of its high content of ferric iron, indicating that deposition took place on land. The "Wasatch" conglomerate is thought to have been a piedmont accumulation deposited between an uplifted area to the west, and Green River Lake located to the east in Wyoming (Williams, 1958, p. 69). The "Wasatch" conglomerate covers a large area, and is widespread in the upper part of Logan Canyon. One of the most colorful outcrops in Logan Canyon occurs 23 miles from Logan near the Red Banks camping area.

Isolated patches of Paleozoic rocks protrude through the cover of the Wasatch formation (Williams, 1948, pl. 1). In the upper part of Logan Canyon, the Wasatch formation partially covers the canyon bottom and sides, but has been removed by erosion from the hills on the west exposing the underlying Paleozoic rocks.

The Salt Lake group was deposited in Cache Valley after the valley was developed by faulting. The Salt Lake group is made of up to approximately 7,000 feet of tuff, tuffaceous sandstone, limestone and conglomerate (Adamson, 1955). No exposures of the Salt Lake group are found in Logan Canyon, but it is useful in dating the development of Cache Valley and the Bear River Range. The Wasatch formation was deposited with the streams draining eastward, and the Salt Lake Group was deposited after initiation of the Basin and Range faulting at which time the streams started flowing westward into Cache Valley. Apparently deposition of the Salt Lake group took place over a long period of time extending from late Eocene to Pliocene (Brown, 1949; and Adamson, 1955). Logan Canyon probably started to develop when the streams began to flow westward into Cache Valley, and deposition of the Salt Lake group began.

Structural Features

The Laramide orogeny, which marked the end of the Mesozoic Era, extended well into Cenozoic times. During the Laramide orogeny, western North America was uplifted, faulted, and folded, forming the Rocky Mountains. The Laramide orogeny was associated with compressional forces that resulted in low angle trust faults, folding, and uplift of the rocks. The Paleozoic rocks of the Logan Canyon area were deformed, faulted, and elevated during this time. Although the major faulting that formed the Bear River Range occurred during a later orogeny, some

Laramide uplift and canyon development took place (Armstrong and Cressman, 1963, p. 14).

The most prominent structure produced in Logan Canyon by the Laramide orogeny is the Logan Peak syncline, Figure 2. The folded rock structure has been dissected by the Logan River. The rock structure has been dissected by the Logan River. The axis of the Logan Peak syncline trends in a north-northeast direction and crosses Logan Canyon in the vicinity of Spring Hollow 6.6 miles from Logan. The axis passes through Logan Peak, Beirdneau Peak, and about a mile east of Naomi Peak, following for the most part the crest of the Bear River Range.

Near the end of the Eocene, the Laramide orogeny died out. Shortly thereafter, normal faulting was initiated. The faulted and folded sediments deformed by the Laramide orogeny were block faulted, forming the horsts and grabens characteristic of the Basin and Range Province. The Bear River Range is near the eastern limit of Basin and Range faulting, and was formed by the normal faulting initiated at the end of the Eocene (Williams, 1948, p. 1125). The range is a block bounded on the west by the East Cache fault zone (Williams, 1948, p. 1154), and on the east by the Bannock fault zone (Armstrong and Cressman, 1963, pl. 4). Numerous other Basin and Range faults have been identified in the Logan Canyon area, among which the most prominent is the Temple Ridge fault on the west side of Temple Ridge near the Tony Grove Guard Station (Williams, 1948, p. 1153).

Figure 2. Logan Peak syncline as seen on the north side of Logan Canyon. Beirdneau Peak can be seen at right center. Cache valley is in background. View is toward northwest.

Initiation of the Basin and Range faulting is thought to be between deposition of the Eocene Wasatch formation, and the Eocene-Pliocene Salt Lake group. Although activity of most Basin and Range faults has continued to the present time, displacement is thought to have started during the late Eocene or early Oligocene Epoch.

GEOMORPHIC FEATURES

Logan Canyon

General statement

The mountains in the Logan Canyon area are near 10,000 feet elevation. The high points of the Bear River Range in the vicinity of Logan Canyon are Logan Peak, elevation 9,713 feet; Beirdneau Peak, elevation 8,912 feet; and Naomi Peak elevation 9,980 feet. At a point seven miles east of Logan, the canyon is 5.6 miles wide from Logan Peak on the south, to Beirdneau Peak on the north, and more than 4,000 feet deep. The elevation at the canyon mouth is 4,685 feet. At the junction of Tony Grove and Logan Canyons, the elevation is about 6,250 feet.

Logan Canyon has several tributaries of which the largest are Right Fork, Blind Hollow, Temple Fork, and Tony Grove Canyon. These tributary canyons are part of the Logan River watershed, and add a considerable volume of water to Logan River.

East of Logan, Logan Canyon trends in a northeasterly direction for a distance of 11.7 miles. At that point, the canyon turns toward the northwest for a distance of 1.1 miles. It then continues in a northeasterly direction to Ricks Spring. Upstream from Ricks Spring, the canyon continues in a north and northwesterly direction into Idaho.

Channel profile

The stream gradient of the Logan River from Ricks Spring downstream to Logan is about 72 feet per mile. The profile of the Logan River is mainly concave but has some irregularities, Figure 3. One irregularity occurs near the mouth of Logan Canyon where the stream profile is convex for about five miles. Renewed movement on the East Cache fault zone is reflected in this irregularity of the stream profile. It represents waterfall recession and canyon cutting upstream after formation of fault scarps at or near the mouth of the canyon. When the upper concave section of the stream profile is projected downstream from a point five miles from the mouth of the canyon as a continuation of the normal upstream profile, the minimum movement on the East Cache fault zone since the normal upstream stream profile developed can be estimated. On this basis, movement on the East Cache fault zone has been about 325 feet since that time, Figure 3.

Intrenched meanders

At a point 15.5 miles from Logan, Logan Canyon has looplike bends resembling those of a meandering stream, Figure 4. The canyon bottom is narrow with steep sides. Five hundred feet above the canyon bottom, the sides open up into a broad valley measuring almost one mile across which can be traced upstream about three miles, Figure 5. The steep meandering canyon is clearly intrenched in the old valley bottom. Outcrops of the Ordovician Swan Peak formation are located at the downstream outlet

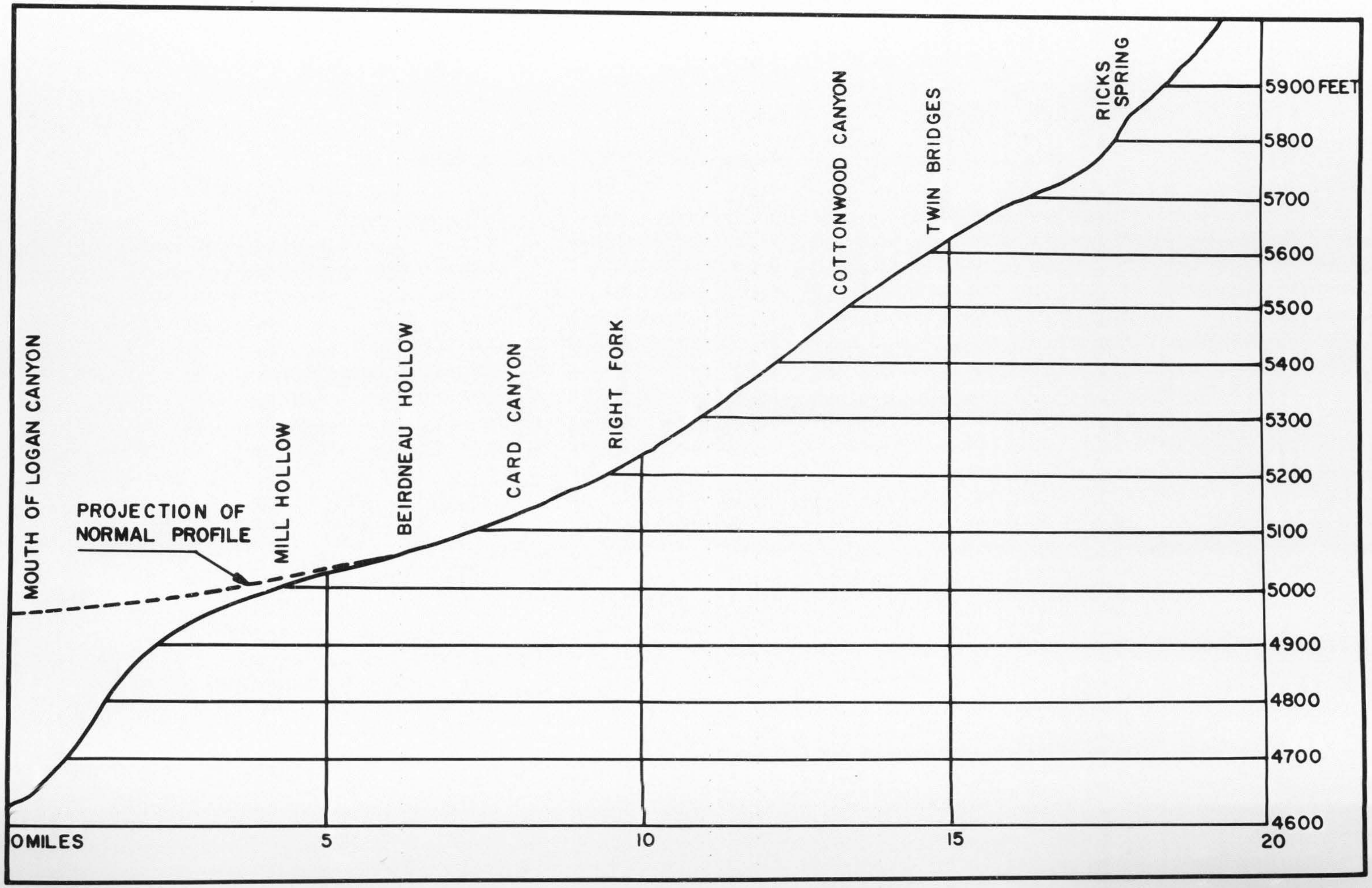

Figure 3. Profile of Logan River showing waterfall recession after faulting in Cache Valley. Modified after Herron (1916, pl. 10).

Figure 4. Intrenched meanders in Logan Canyon. Upper Twin Bridge can be seen at lower right. Oblique view with top toward the northwest.

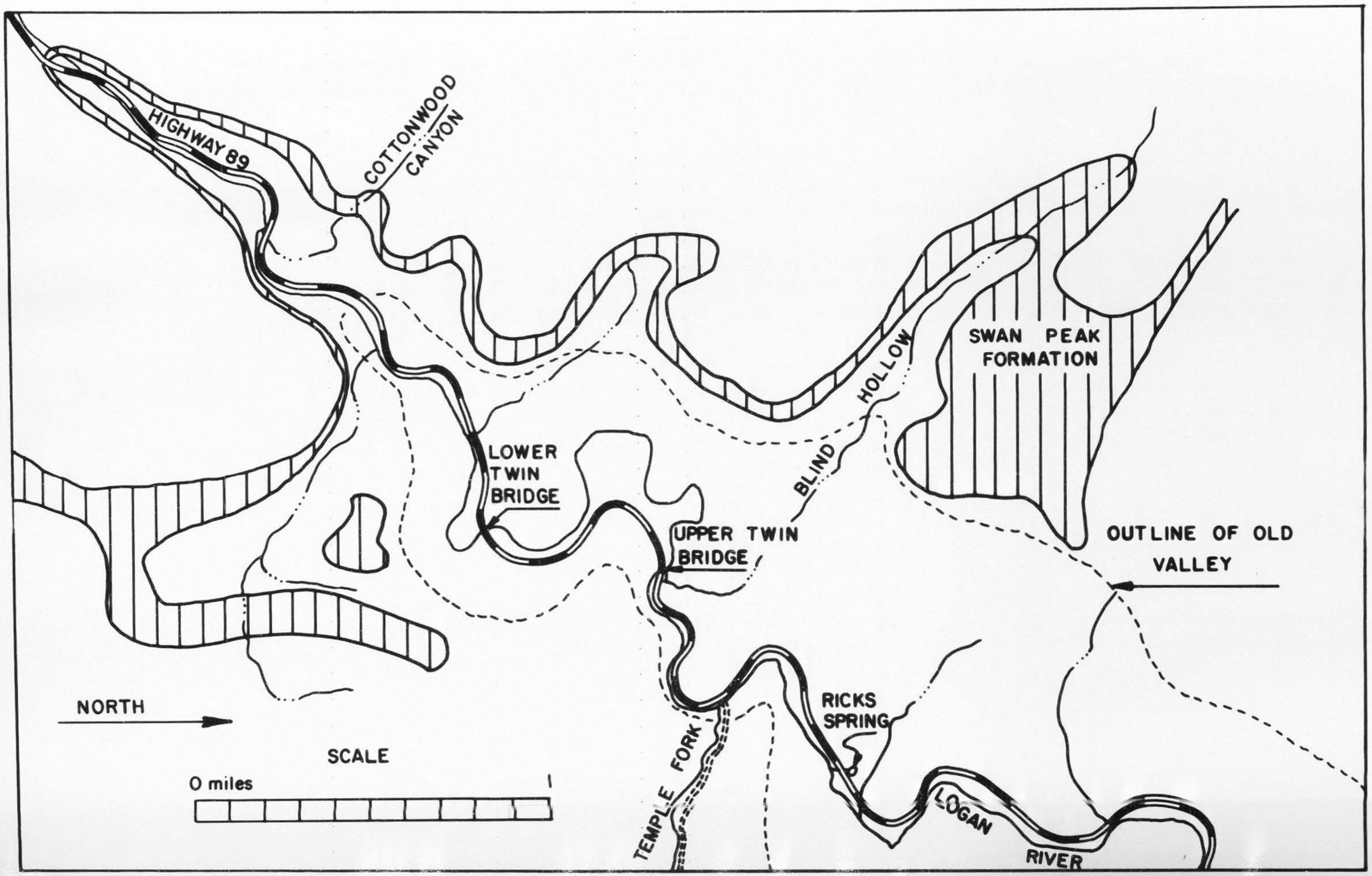

Figure 5. Map of Twin Bridges area.

of the old valley on each side of the canyon. The Swan Peak formation appears to have acted as a retaining wall through which the river did not erode rapidly. The Swan Peak formation dips westward about 10 degrees and made a continuous barrier through which the river had to cut. Sufficient time was provided while the rock unit was being eroded that the old valley was widened by lateral planation of the bedrock by shifting river channels. The old valley is wider upstream than it is near the valley outlet indicating that widening of the valley continued in the upper part as erosion of the quartzite beds lengthened the valley downstream. As canyon cutting advanced upstream from Cache Valley to the old valley outlet, it facilitated a more rapid erosion and removal of the quartzite barrier. As the quartzite barrier was removed, downcutting in the stream channel intrenched the meanders. As downcutting took place, the stream channel may have been controlled to a large extent by the joint structure in the Garden City limestone. Logan Cave, downstream about two miles, which also formed in the Garden City limestone, was controlled by a similar joint system. Church (1943, p. 122) indicates that Logan Cave developed along the following major joints: N. 15°, W., N., 28° E., N. 42° W., and N. 80° E. Segments of the intrenched meanders trend in the same direction as the joint systems in Logan Cave indicating that some localization of the meanders along joints may have taken place.

Lake Bonneville features

At the mouth of Logan Canyon, several features left by Lake Bonneville can be seen, Figure 6. The highest strand line is at an elevation of 5,142 feet, the level of the Bonneville stage.[1] No delta was built at the mouth of Logan Canyon during the Bonneville stage. During the Provo stage of Lake Bonneville a massive delta was built at the mouth of Logan Canyon at an elevation of 4,777 feet. This is seen as the second highest terrace in Figure 6. The lower-most terrace was built while the lake was at a lower level. The Alpine cycle of Lake Bonneville did not leave any conspicious features, although an excavation above the Provo level near the north side of the mouth of the canyon exposes a succession of beds representing at least two advances of the lake level to that point. They are thought to correlate with the Alpine and Bonneville cycles of the lake (Williams, 1961).

During the Bonneville cycle, water extended into the canyon about eight miles to the vicinity of the junction of Card Canyon and Logan Canyon. In as much as no delta was built at the mouth of Logan Canyon during the Bonneville cycle, gravel and other deltaic material was deposited within the canyon. A deposit of well-bedded sand is found north

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[1] Although an elevation 5,135 feet above sea level is accepted for the Bonneville level, Crittenden (1963) assigns a 5,142 foot elevation to the Bonneville strand line at the mouth of Logan Canyon. According to Crittenden isostatic rebound due to unloading by evaporation has altered the elevation of the strand lines in most localities.

Figure 6. Mouth of Logan Canyon. At least three levels of Lake Bonneville can be seen.

of the highway about one-fourth mile downstream from the Card Guard Station. This deposit is near the 5,142 foot level and probably represents a deposit of the Bonneville cycle. The bedded sand was deposited on the inside of a curve in Logan Canyon and is protected by a spur of Ordovician Laketown dolomite extending into the canyon from the north.

Lower in the canyon small notches are found on each side of the mouth of Spring Hollow near the 5,142 foot mark. It is thought that they were formed during the Bonneville cycle of Lake Bonneville.

Alluvial terraces

Alluvial terraces are seen in several localities in the lower part of Logan Canyon. They are most conspicious in an area from Mill Hollow upstream 1.8 miles to Beirdneau Hollow, although they exist in other parts of Logan Canyon. Logan Canyon is sufficiently wide in the Mill Hollow-Beirdneau Hollow vicinity that those terraces in the canyon have not been destroyed by erosion. The terraces extend into Logan Canyon from major tributary canyons and drainage areas in this vicinity, Figure 7. It is thought that the terraces were constructed during three distinct times and were built during the last three major pluvial cycles of the Pleistocene. Williams (1956, p. 19) observed similar alluvial slopes and terraces in Green Canyon north of Logan Canyon, and in Dry Canyon south of Logan Canyon. The terraces and slopes were graded to the Provo level of Lake Bonneville.

The surface gradients of the terraces in a longitudinal direction range from two degrees to six degrees at their upper parts. The terraces

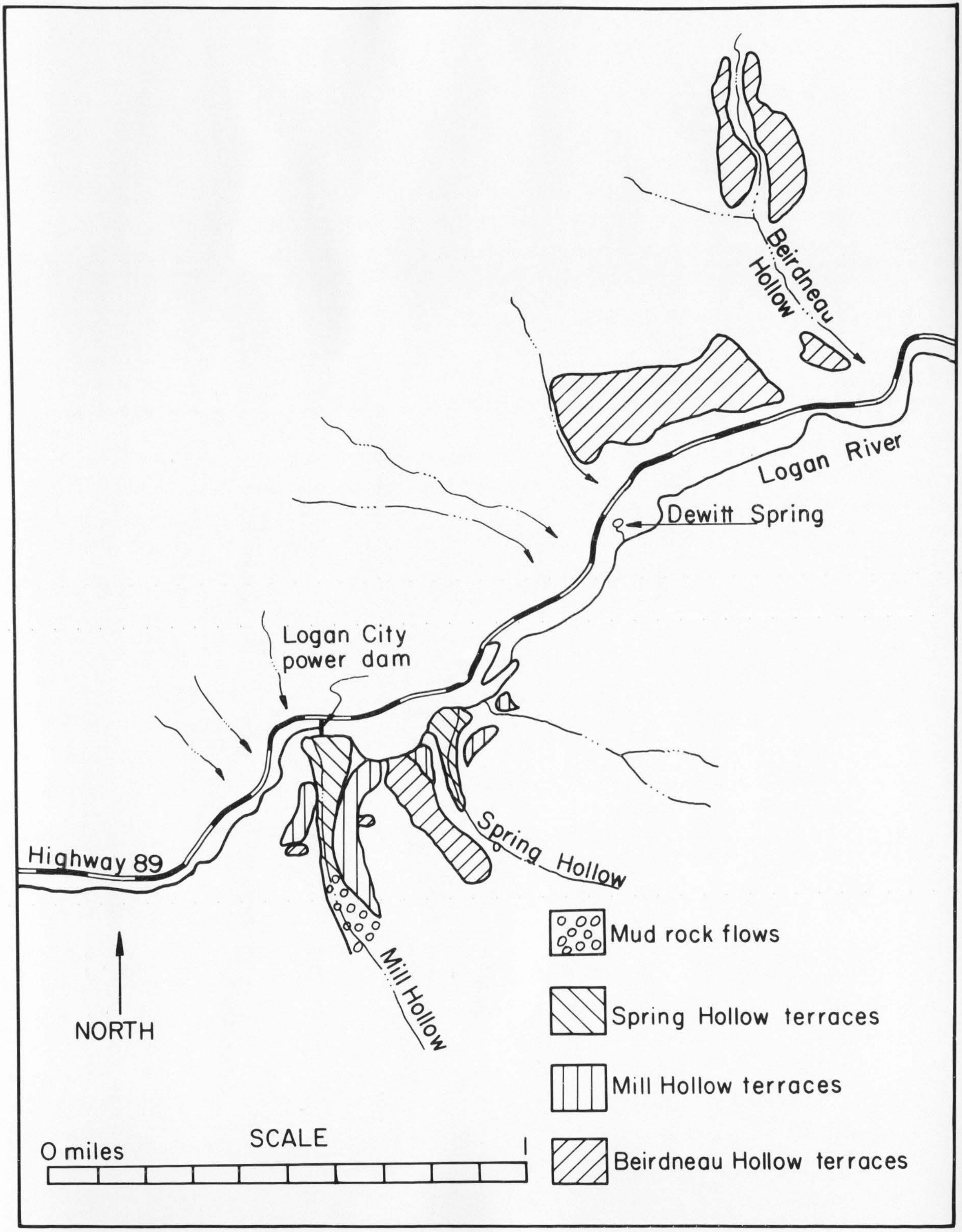

Figure 7. Map of Spring Hollow area showing alluvial terraces.

are made up of unsorted sub-rounded rock fragments derived from weathering of bedrock upstream in the tributary canyons. Most of the rock fragments are less than one foot in diameter but boulders with a diameter of two feet are sometimes found. The terraces are distinguished from alluvial fans by their relative large size and low longitudinal gradient, indicating a larger quantity of water is involved in construction of the terraces. Alluvial fans are actually fan-shaped with the apex of the fan at or very near the mouth of the tributary canyons. The alluvial terraces extend into the tributary canyons. In some cases, as with the last formed terraces, they become the floor of the tributary canyons. The alluvial fans found in lower Logan Canyon are though to have been built under arid conditions when surface runoff was at a minimum.

Beirdneau Hollow terrace. The earliest formed terraces occupy the highest position on the canyon walls of both Logan Canyon and the tributary canyons. The highest group of terraces are here called the Beirdneau Hollow terraces because of their extensive occurrence in Beirdneau Hollow. A terrace extends into Logan Canyon from Beirdneau Hollow as a large mass of alluvial material about 150 feet above the canyon bottom. Upstream in Beirdneau Hollow, terraces are seen on each side of the stream channel, and extend up canyon for about a half mile. A terrace is found below a large drainage surface west of Beirdneau Hollow. It is high on the canyon wall and probably corresponds with the terraces in Beirdneau Hollow. Terraces corresponding in position to those in Beirdneau Hollow are also found on the west side of Spring Hollow, extending upstream in Spring Hollow about a fourth mile. Small Beirdneau Hollow terraces less than 200 feet across are located near the mountain face on each side of the mouth of Mill Hollow in Logan Canyon. The surfaces of all Beirdneau Hollow terraces are at least 150 feet above the bottom of Logan Canyon. All have been truncated at their lower ends by the Logan River.

Mill Hollow terraces. The Mill Hollow terraces are so named because of their extensive occurrence at Mill Hollow, Figure 8. The Mill Hollow terraces have been truncated at their lower ends by the Logan River. If the upper surface of the terraces was projected northward across the river to near the north side of the canyon, it would be near the 5,142 foot level of Lake Bonneville.

Terraces corresponding to those in Mill Hollow are located on each side of the mouth of Spring Hollow in Logan Canyon and extend up Spring Hollow a short distance. They have notches carved into their lower ends at 5,142 feet elevation, the same as the Bonneville cycle of Lake Bonneville. The terraces seem to be graded to a level a few feet above the notch. Notches found in the terraces upstream a fourth mile in Logan Canyon are at the same level indicating that the terraces probably were built into standing water. When the terraces were being built, that part of Lake Bonneville in Logan Canyon was crowded to the north side of the canyon by encroachment of the terraces. Terraces correlating to those in Mill Hollow are also found in American Legion Hollow 3.4 miles from Logan. Wood Camp Hollow and Tab Hollow, east of

Figure 8. Mill Hollow terrace near the mouth of Mill Hollow. A Spring Hollow terrace surface can be seen in the foreground. A Beirdneau Hollow terrace can be seen above the Mill Hollow terrace at right side of picture. View is to the east up Logan Canyon.

Beirdneau Peak, also have wide graded bottoms. They are thought to correspond with the Mill Hollow terraces.

Spring Hollow terraces. Spring Hollow terraces are so named because of their occurrence on the bottom of Spring Hollow and extending from there into Logan Canyon. They are also seen in the bottom of Mill Hollow extending into Logan Canyon near the Logan City power dam. They are graded to a level about 20 feet above the present canyon bottom, and were constructed by entrenchment of the Mill Hollow terraces. In Mill Hollow, the terrace is obscured by mud rock flows with angular boulders up to six feet in diameter. The Spring Hollow terraces have been entrenched to a depth of about six feet by the stream channel, but actually forms the floor of the tributary canyons.

Age of alluvial terraces. An attempt has been made to date the alluvial terraces in lower Logan Canyon. The Beirdneau Hollow terraces are higher on the canyon walls, and are dissected by the Mill Hollow terraces. Eardley and Gvosdetsky (1960, p. 1323) showed that Lake Bonneville had at least two pre-Alpine pluvial cycles. It is thought that the Beirdneau Hollow terraces were constructed during the latter of the two. Erosion during the pre-Alpine interglaciation of the Mill Hollow terraces was started during the Alpine cycle of Lake Bonneville.

The Mill Hollow terraces are massive, and by far the most extensive of the terraces in the canyon. Early Wisconsin times seemed to be the period of the most extensive glaciation in the Tony Grove Canyon. Climatic conditions that produced the pluvial climate could provide the large quantity of water required for construction of the Mill Hollow terraces. The Mill Hollow terraces also seem to be graded to the 5,142 foot Bonneville level. Occurrence of notches carved into their lower ends at that level at Spring Hollow indicate that they were built before and or during the Bonneville cycle of Lake Bonneville. All available evidence indicates that the terraces were built during Early Wisconsin time.

On the western remnant of the Mill Hollow terrace in Mill Hollow, two small pits have been dug to a depth of about eight feet. Both show a soil profile, Figure 9. Dr. Raymond W. Miller, Department of Agronomy, Utah State University, examined the soil profiles. He estimated that a soil profile of this type could be developed within 1,000 years under present climatic conditions. Miller also stated that a soil could become stable and may not change appreciably through a considerable length of time. He pointed out that climatic conditions drier than at present could slow down the soil formation processes. Such a dry period during Post-Wisconsin times in northern Utah has been described by Williams (1956). Thus the Mill Hollow terraces formed at least 1,000 years ago and probably earlier than that.

After the Mill Hollow terraces were built, Lake Bonneville withdrew from the canyon. During the Provo pluvial cycle of Lake Bonneville, the Spring Hollow terraces were built by dissection of the Mill Hollow terraces.

Figure 9. Soil profile on Mill Hollow terrace.

Alluvial fans

Alluvial fans extend into Logan Canyon from most of the small tributary canyons. The size of each fan usually depends on the gradient and size of the tributary canyon. The alluvial fans described here are distinguished from the alluvial terraces described earlier by their fan shape and relative small size. Some alluvial fans are almost 50 feet thick and several hundred feet wide. The toes of some of the alluvial fans have been truncated by the Logan River. When the surface of these fans is projected across the river, they appear to have at one time filled the canyon bottom. If the river was continually flowing at the time the fans were being constructed, they would probably be graded to the level of the river. Williams (1956, p. 20) observed the fans and pointed out that they were constructed during the Hypsithermal, a dry period lasting from 7,000 to 4,500 years before the present. The fans grew across the canyon with little interference from the stream. Since the end of the Hypsithermal, the climate has become wetter, stream flow has increased, and the river has truncated the lower parts of the fans thus re-establishing its bedrock channel.

Rockslide

A rockslide involving rocks of the Devonian Jefferson formation has occurred north of the highway 4.9 miles from Logan. The mass of loose rock material measuring about 1,000 feet by 650 feet and almost 100 feet high has slipped down-dip in a southeasterly direction on the steeply inclined beds of the Jefferson formation. The source area of the rockslide is clearly outlined because vegetation has not completely re-established itself. The rockslide rests on an alluvial fan projecting from a nearby tributary canyon, and is above the level of the river. The slide movement probably took place rather recently but pre-dates early settlement of the area.

Caves

Logan Cave is located near the north side of the highway 14.4 miles from Logan. The cave developed along a fault and joint system by solution of the Garden City limestone (Church, 1943). The cave extends about 4,000 feet into the mountain and has at least three interconnecting levels. The lower level extends almost 2,000 feet in a north westward direction. It is from five to twenty feet wide and in some places more than 70 feet high (Church, 1943, p. 113).

The lower level is barren of significant calcium carbonate cave deposits but contains other deposits such as rockfalls, clay, and stream deposited sand and gravels. The first 200 feet of this level is actually split with a slightly higher level above the main part of the cave. In this report the higher level near the mouth of the cave is considered part of the lower level.

The lower level contains a stream that flows toward the mouth of the cave. The stream flows from a pool of water at the back of the cave. Well-rounded chert and quartzite pebbles in the end pool, and around an opening extending downward on the right side of the pool indicate a possible continuation of that level. The stream flow toward the mouth of the cave disappears below the cave floor about 400 feet from the opening. It is seen again as it issues from a spring near the mouth of the cave. When the water in the cave is muddied, the spring soon becomes muddy.

The second level is 50 feet higher in elevation than the lower level and is an estimated 1,000 feet long. It is connected with the first level by a narrow passageway in the ceiling of the lower level a few hundred feet from the pool at the back of the lower level. The second level is generally smaller than the lower level. In some places the cave is less than five feet wide and only 10 feet high. In the second level stalactites, stalagmites, gypsum flowers, and small aragonite crystals have formed. No stream flows in this level, although the cave is wet where the travertine and aragonite deposits are actively growing.

A newly discovered room in the ceiling of the second level is located about midway to the end of that level. The room measures about 20 feet across and 10 feet high. On the walls, floor and ceiling stalactites, stalagmites, and aragonite crystals have formed. Some aragonite crystals are almost one foot long, Figure 10.

A third level continues an estimated 600 feet further into the mountain from the end of the second level. This level in some places is only one foot wide and five feet high. In several places it displays

Figure 10. Aragonite crystals in Logan Cave.

dripstone stalactites and stalagmites. At the end of the third level, sand and well rounded pebbles are found around a small opening indicating a probable continuation of that level.

The lower level of Logan Cave was largely developed by circulation of water below the water table along a fault and a joint system (Church, 1943, p. 115). Solution along joints and faults in limestone is a common mode of cave formation (Bretz, 1953). Church studied only the lower level, but the upper two levels were probably formed under the same conditions. Phreatic solution features that Church reported in the lower level, such as, floor, wall, and ceiling pockets, also exist in the upper two levels. The room in the ceiling of the second level is probably a ceiling pocket developed under phreatic conditions.

Continued downcutting of Logan Canyon by the Logan River has lowered the water table, and exposed the cave. The lower level is now being further eroded and deepened by the stream flowing along it. The two upper levels are not being enlarged at the present time.

Witches Castle. The Witches Castle, a group of natural arches and caverns, is located high on the north side of Logan Canyon 7.0 miles from Logan and can be seen from the highway. The features have been formed in the Mississippian Lodgepole limestone. The Witches Castle was probably a part of a cave system formed in a manner similar to that of Logan Cave. Widening of Logan Canyon has cut into the limestone exposing the caverns. Where the caverns have been cut into from two sides, a natural arch has been formed, Figure 11.

Figure 11. Witches Castle.

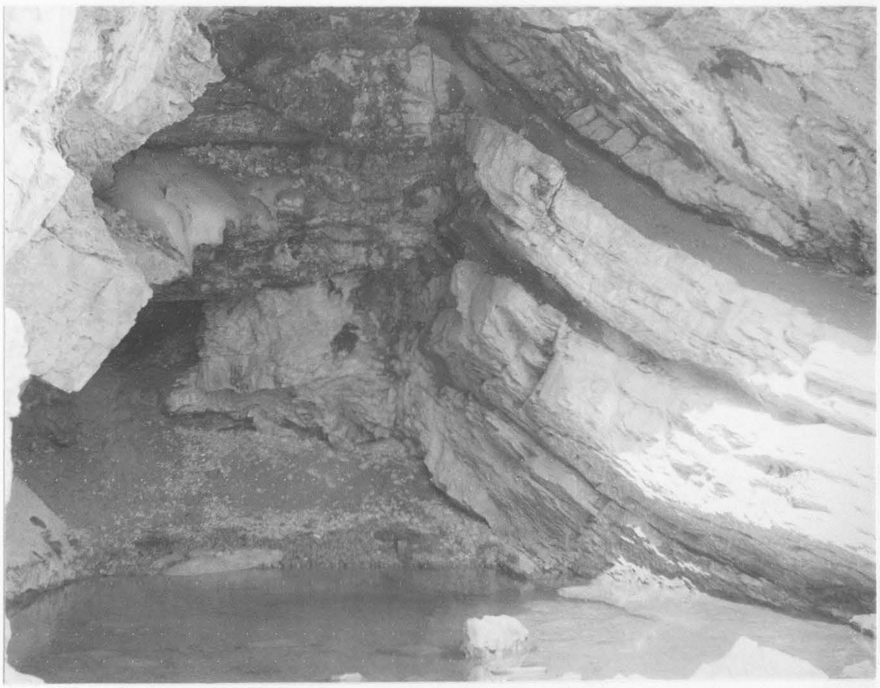

Figure 12. Ricks Spring fault. Note drag folds on each side of fault.

Ricks Spring. Ricks Spring is located on the north side of the highway 18.1 miles from Logan. The underground channel of Ricks Spring has developed along a normal fault in the Garden City limestone which is seen as a vertical fracture in the back of the shallow cave that forms the opening of the spring, Figure 12. The spring flows throughout the spring and summer season but does not flow during the winter months. Recharge water is probably retained above the surface as snow during the winter months.

A cave system is probably associated with Ricks Spring. Logan Cave has developed in the same limestone formation from which Ricks Spring issues, and it is possible that the water flowing from Ricks Spring has formed a cave in this locality. Shallow caves at and near the mouth of the spring supports this supposition. If the cave system is still below the regional water table, it is still in a process of development.

Tony Grove Canyon

General statement

Tony Grove Canyon is a tributary of Logan Canyon on the east flank of the Bear River Range about 22 miles from Logan. Tony Grove Canyon extends northwestward from Logan Canyon to the crest of the Bear River Range, a distance of about six miles. It is an area that was extensively glaciated during the Pleistocene. The description of moraines and glacial erosion given here will be restricted to those in Tony Grove Canyon, Figure 13. Previous studies of this area describe two periods of glaciation, an earlier and a later (Young, 1939).

Blackwelder (1915) named three glaciations in the Wind River and Teton Mountains in Wyoming. The Buffalo glaciation was the earlier and more extensive. The Buffalo glaciation was followed by a long interglaciation. The Bull Lake glaciation then took place. The Bull Lake glaciation was followed by another interglaciation, and in turn was followed by the Pinedale glaciation. Holmes and Moss (1955) further subdivided the Bull Lake and Pinedale and show at least two post-Pinedale glaciations. The BullLakeI glaciation advanced downstream, retreated, then advanced a second time as Bull Lake II. Pinedale glaciation is divided into the Main Pinedale and the Late Pinedale. The Pinedale ice advanced and withdrew a number of times during both the early and Late Pinedale glaciations. Bull Lake II and Main Pinedale terminal moraines were deposited in the same general area; however, in some regions Pinedale ice over-rode Bull Lake II terminal moraines.

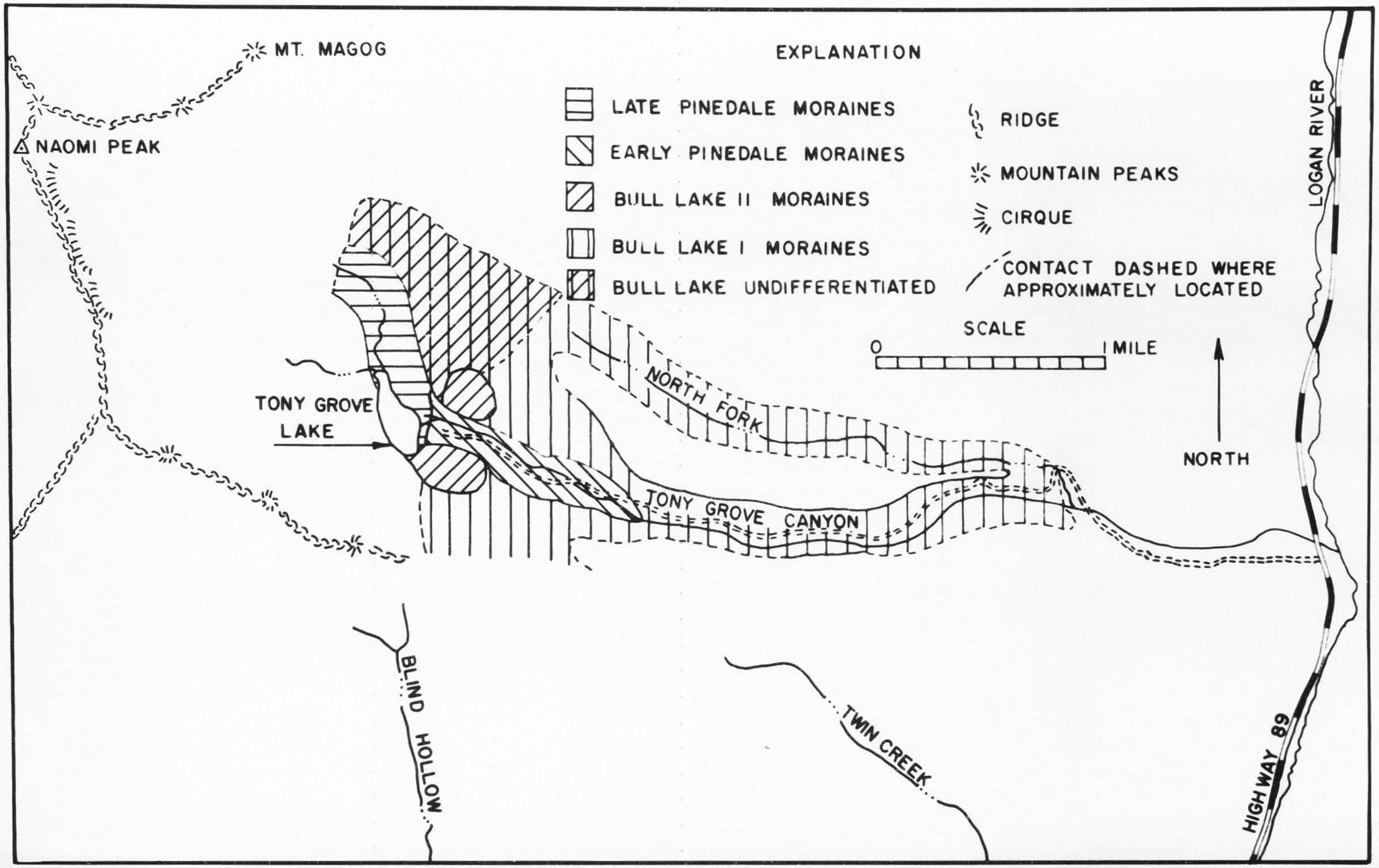

Figure 13. Map showing moraines in Tony Grove Canyon.

Holmes and Moss (1955) also believe that the Bull Lake I and II glaciations took place during Early Wisconsin times, and that Early and Late Pinedale glaciations occurred during Late Wisonsin times.

Glaciations in Tony Grove Canyon are here correlated with those studied by Holmes and Moss (1955) in the Wind River Mountains. In this report, the Wind River terminology will be used to designate the correlative equivalents in Tony Grove Canyon.

Moraines

The head of Tony Grove Canyon is near the crest of the Bear River Range in a large semicircular east-facing basin. Mt. Magog, elevation 9,756 feet is on the north side of the basin. Naomi Peak, elevation 9,980 feet, forms the west side. A high ridge extends south and then east from Naomi Peak and forms the southern limit. The basin contains several cirques. The elevation of the floor of the cirques is about 9,000 feet. During Bull Lake times, the ice flowed eastward out of the basin. The Bull Lake ice was split and one tongue flowed southeastward down the North Fork of Tony Grove Canyon and the other flowed southward to the Tony Grove Lake area, then southeastward down Tony Grove Canyon. The Tony Grove Lake tongue was split again and part of the ice flowed over the ridge southeast of Tony Grove Lake and down Bear Creek and Twin Creek (Young, 1939, p. 23). During Pinedale times, the ice was confined to Tony Grove Canyon.

Bull Lake and Pinedale moraines in Tony Grove Canyon are distinguished by the degree of weathering of the deposits and relative position of the moraines to each other. Bull Lake moraines show only a few boulders on the surface. A large portion of these are quartzite. Where carbonate boulders are found, they are highly weathered. Chert nodules in the limestone stand out in high relief of three to four inches. A strong soil has developed on Bull Lake moraines, Figure 14.

Pinedale deposits show a marked increase in occurrence of boulders on the surface. Carbonate boulders make up the largest number. Relief of chert nodules is rarely more than one inch. A weak soil has developed on Pinedale moraines.

In Tony Grove Canyon the glacial advances were similar to those in the Wind River Mountains in Wyoming. Bull Lake I and Bull Lake II can be distinguished. A Main Pinedale and at least one Late Pinedale glaciation are recognized. Bull Lake I ice advanced down Tony Grove Canyon to an elevation of about 6,500 feet. The terminal moraines were deposited in Tony Grove Canyon about 3/4 mile from its mouth. Bull Lake II terminal moraines were deposited upstream 3.1 miles at an elevation of about 8,000 feet. The Main Pinedale ice extended downstream beyond Bull Lake II terminal moraines about one mile to an elevation of 7,800 feet.

Buffalo. In the Wind River Mountains Buffalo glaciation covered a larger area and extended to lower elevations than Bull Lake glaciation (Holmes and Moss, 1955, pl. 1). It is probable that Buffalo glaciation occurred in Tony Grove Canyon but no evidence has been found. In Logan Canyon downstream from the mouth of Tony Grove Canyon are

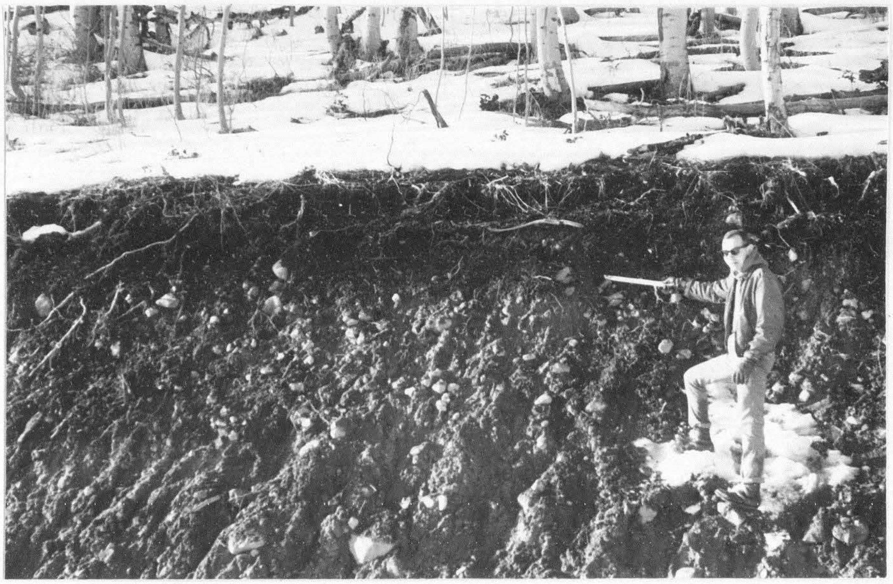

Figure 14. Soil profile on Bull Lake moraine. Pointer is at the bottom of the A horizon.

several features that may indicate Buffalo glaciation in that area. Logan Canyon is wide with a U-shaped cross section. It is possible that this shape of the canyon could have been in part produced by glaciers. Erosion has not been great since the valley was formed when compared with the erosion that has taken place near the mouth of Logan Canyon. Deposits within Logan Canyon resemble moraines, and are made up of rounded quartzite boulders and clay. Since the area is widely covered with the Tertiary Wasatch formation, the rounded boulders may have been derived from glaciation of that rock unit. A large angular quartzite block measuring 20 feet long, 10 feet wide and 10 feet high is located in Logan Canyon 20 feet north of the Twin Creek road. It may have been deposited there by glaciers. No striations have been found on the quartzite boulders, but if the deposits correspond to Buffalo glaciation, weathering probably removed all traces that may have existed.

Bull Lake glaciation. Bull Lake I and Bull Lake II ice extended 5.4 miles and 2.3 miles respectively from the cirque. The Bull Lake I terminal moraine was deposited within Tony Grove Canyon, and has since been almost entirely removed by Tony Grove Creek. Ice probably did not extend more than a few hundred yards downstream from the junction of the North Fork of Tony Grove Creek and Tony Grove Creek. Bull Lake lateral moraines are not traceable downstream from that point. A combination medial and terminal moraine was deposited where the North Fork tongue joined the main ice flow in Tony Grove Canyon. The mouth of the North

Fork was completely blocked by the moraine and the stream has made a narrow cut through the east end of the combination moraine. The new road to Tony Grove Lake has cut through the combination moraine exposing a strong soil profile, Figure 14. Unweathered striated boulders have also been exposed in the road cut. Upstream from the junction of the North Fork and Tony Grove streams, the main Tony Grove Canyon has a broad U-shaped cross section. Tony Grove Creek has carved a narrow V-shaped gully in the valley bottom. The gully continues about one mile upstream. Bull Lake I lateral moraines are found on the sides of Tony Grove Canyon. The ice depth may be estimated from their position on the valley walls. Bull Lake I ice, based on this evidence, was about 600 feet thick in the vicinity of Tony Grove Lake. The canyon wall over which Bull Lake I ice flowed into Twin Creek is about 300 feet above the canyon bottom. After deposition of the Bull Lake I terminal moraine, the ice retreated upstream, then advanced to the vicinity of Tony Grove Lake. The Bull Lake II terminal moraine blocked Tony Grove Canyon. Quite possibly a lake formed behind the moraine following melting of the ice. Later erosion removed most of the moraine. A large remnant is left immediately southeast of Tony Grove Lake. A camping area has been constructed on the remnant by the U. S. Forest Service. A remnant of the moraine is found also on the north side of the stream. The latter remnant can be recognized on aerial photos, but is not readily seen in the field.

Figure 15. A glaciated valley a fourth mile north of Tony Grove Lake. The low hill below center is a Pinedale lateral moraine. Bull Lake erratic boulders can be seen on the hill in the background. Bull Lake ice almost covered the hill on the right skyline. The view is to the northeast.

Figure 16. Polished and groved surface on quartzite of the Swan Peak formation.

Pinedale glaciation. The Pinedale glaciation followed an interglacial after the Bull Lake II glaciation. Main Pinedale ice extended 3.2 miles from its cirque, and flowed between the remnants of the Bull Lake II terminal moraine. No large moraines were deposited compared to those of the Bull Lake ice, but seem to be thin and scattered. Late Pinedale ice did not flow beyond the limit of Bull Lake II ice but deposited a moraine on the east edge of Tony Grove Lake, 2.1 miles from its cirque. A fourth of a mile north of Tony Grove Lake, the Late Pinedale glacier left two lateral moraines, Figure 15. Polished and groved surfaces on quartzite beds of the Swan Peak formation are found between the moraines, Figure 16. Abrasion surfaces on bedrock are not found elsewhere although Bull Lake ice covered the entire area.

Temple Lake glaciation. Moraines corresponding to the Temple Lake glaciation have not been distinguished in Tony Grove Canyon, although they may exist. Temple Lake Terminal moraines in the Wind River mountains are at an elevation of 10,700 feet in a valley leading from a north-facing cirque (Holmes and Moss, 1955, p. 642). In as much as the cirques face east in Tony Grove Canyon, and have an elevation of about 9,000 feet, Temple Lake glaciation was probably not extensive in this area.

Tony Grove Lake

Tony Grove Lake lies near the head of Tony Grove Canyon about 4.2 miles from Logan Canyon. The lake basin is in the lower shale unit of the Ordovician Swan Peak formation. The upper quartzite unit of the Swan Peak formation and the overlying Fish Haven dolomite form a cliff immediately west of the Lake, Figure 17. The Ordovician Garden City limestone is exposed in a road cut 1,000 feet east of the lake. All rock units dip gently toward the southwest. Storage capacity of the lake has been increased by a U. S. Forest Service dam.

The basin of Tony Grove Lake was formed by a combination of ice erosion and damming. It is located at a right angle bend in Tony Grove Canyon where the glaciers made a sharp turn from south to nearly east. Ice erosion was particularly effective in the lower shale unit of the Swan Peak formation. The outcrop of Garden City limestone 1,000 feet east of the lake is near the valley bottom and is level with the old pre-dam lake outlet. In as much as Tony Grove Lake had a depth of 27½ feet when it flowed through its natural outlet (Young, 1939, p. 23), the basin was obviously deepened by ice erosion in the non-resistant lower part of the Swan Peak formation.

A Late Pinedale moraine is located on the east side of Tony Grove Lake. The moraine is found on both sides of the pre-dam outlet suggesting a continuous morainal dam across Tony Grove Canyon.

<u>Karst topography</u>

Karst topography has developed at the head of Tony Grove Canyon upstream from Tony Grove Lake. Numerous sinks and caves have formed along a joint system in the Laketown dolomite. Some sinks have a

Figure 17. Tony Grove Lake. The cliff on the far side of the lake is made up of the quartzite member of the Swan Peak formation forming the lower half and the Fish Haven dolomite forming the upper half. The high mountain on the right skyline is Mt. Magog, elevation 9,756. View is to the north.

funnel-like shape being several hundred feet across at the top. Others are less than 10 feet across at the top and have a depth over 100 feet. One sink in this area measures about 20 feet across at the surface, and has a vertical drop of 220 feet (Dale Green, personal communication). All cirques at the upstream limit of Tony Grove Canyon have one or more sinks in them, and no surface streams flow from the cirques. Several sinks contain perpetual snow and ice banks. Melting of the ice along the walls of the sink permits access to the sink bottom. In several cases, the ice is over 100 feet thick. Ice thickness depends on the depth of the sink, circulation of air in the sink, and protection of the ice bank from the sun. A cave sometimes called Tony Grove Cave is located about 2,000 feet southwest of the south tip of Tony Grove Lake. The size and extent of the cave is not known.

Grassy Flat Canyon

General statement

Grassy Flat Canyon is a southern tributary to Logan Canyon 4.4 miles from Logan. It is a narrow V-shaped canyon in which an intermittent streams drains part of the north flank of Logan Peak. It is a distance of one mile, the bottom of Grassy Flat Canyon rises 2,000 feet in elevation.

Mud rock flows

A large mass of rock debris resembling deposits of a mud rock flow is located near the mouth of Grassy Flat Canyon at about 5,000 feet elevation. The mass of rock debris is over 100 feet thick, about 330 feet wide and over 650 feet long. It is made up of unsorted, angular rock fragments with some boulders more than three feet in diameter. The remaining upper surface shows evidence of at least three mud rock flows although more probably occurred. The mud rock flows on the upper surface are seen as a succession of terraces, each bordered by a ring of boulders. At one time the deposit probably filled the bottom of Grassy Flat Canyon and extended well into Logan Canyon, but a major part has been removed by erosion. In as much as Grassy Flat Canyon drains part of the northwest flank of Logan peak, rocks ranging from Devonian to Pennsylvanian in age are involved in the mud rock flows.

Striations and polished surfaces on bedrock are found at the junction of Grassy Flat Canyon and Logan Canyon and upstream as far as one mile in Grassy Flat Canyon, Figure 18. They are found as high as 100 feet above the bottom in the downstream part of the canyon. The narrow V-shape of Grassy Flat Canyon and the low elevation of the polished striated surfaces, near 5,000 feet, rule out the possibility of their being produced by ice. Glaciers did not extend below 6,000 feet elevation in the Bear River Range. Striations formed by ice are not found on limestone bedrock in Tony Grove Canyon. Weathering has had sufficient time to remove all traces on exposed surfaces since the Pinedale glaciation. Striations left by the Pinedale glaciation are found only on resistant quartzite beds of the Swan Peak formation. Striated surfaces formed by mud rock flows are found on limestone

Figure 18. Striated and polished surface on bedrock of the Jefferson formation.

bedrock of the Devonian Jefferson formation in the lower part and on bedrock of the Mississippian Lodgepole limestone upstream. Weathering of the polished and striated bedrock has been rapid, and in some cases they are not clearly defined. Since they still exist, it is probable that they were formed since the Late Pinedale glaciation.

Williams (1956) points out that the Hypsithermal, starting 7,000 years ago and lasting until 4,500 years ago, was a period of active mud rock flows throughout northern Utah. The extremely dry climate of the Hyspsithermal allowed only a minimum of protective vegetation to grow. During infrequent high-intensity rainstorms, when surface runoff was high, mud rock flows were formed. The mud rock flows in Grassy Flat Canyon probably occurred during this time, Figure 19. Mud rock flows covering the alluvial terraces in Mill Hollow probably occurred during the same period as those in Grassy Flat Canyon.

GEOMORPHIC HISTORY

General Statement

At the beginning of the Cenozoic Era, much of western North America was a highland. The drainage streams of northern Utah flowed from the highland into a basin located eastward in Wyoming. It was under these conditions that the Tertiary Wasatch formation was deposited in the Logan area. Later Basin and Range faulting that may have started as early as late Eocene began to form the Bear River Range and Cache Valley. The drainage systems then started to flow into the enclosed basins in the Basin and Range Province, and deposition of the Salt Lake group was initiated in Cache Valley. Logan River early established a permanent stream channel, and as uplift of the Bear River Range continued, Logan Canyon was widened and deepened by erosion and weathering of the Paleozoic rocks. Major times of canyon cutting seem to be related to movement on the East Cache fault zone. Movement on the fault zone would produce a fault scarp over which the Logan River would fall. Increased energy of the river at that point would cause the waterfall to move upstream starting a cycle of canyon cutting. Several cycles of canyon cutting have formed Logan Canyon.

The geomorphic history of Logan Canyon also reflects the climatic changes that have taken place and indicates the depositonal forces that operated in the canyon. This section on the geomorphic history of Logan Canyon includes a description of the relationship of the events that occurred. Detailed information of these events is discussed in separate sections of this report. Correlation of events important in the geomorphic history of Logan Canyon is shown in Figure 19.

Geomorphic History

Pre-Pleistocene

The Wasatch formation covered the entire Logan Canyon area before initiation of the Basin and Range faulting. Isolated patches of Paleozoic rocks protruding through the Wasatch formation cover and small remnants of the Wasatch formation on divides near the crest of the Bear River Range suggest that the Bear River Range had some topographic relief before being covered by the Wasatch formation. High points in the crest of the Bear River Range are located on each side of Logan Canyon. This suggests an almost continuous ridge that was covered by the Wasatch formation. The canyon started to develop on the Wasatch surface after Basin and Range faulting began, and the canyon was superposed across the crest of the Bear River Range.

There is an almost level plateau between Logan Canyon and the Right Fork south of Twin Bridges that is covered by the Wasatch formation. Logan Canyon has been cut into this plateau as a narrow V-shaped canyon.

Events in the Rocky Mountain Region					Events in Logan Canyon		
Age		Wind River Glaciations	Years Ago	Lake Bonneville (Salt Lake Valley)	Erosion & Deposition	Lake Bonneville	Glaciation
Recent		Modern Moraines Temple Lake	2,800$\pm$200 10,000$\pm$275		Alluvial fans Mud rock flows		Temple Lake (?)
Pleistocene	Late Wisconsin	Pinedale	27,000$\pm$800	4,410' 5,470' 4,770'		4,777$\pm$	
Pleistocene	Middle Wisconsin	Bull Lake II		4,800' (Provo) 5,135' (Bonneville)	Spring Hollow terraces Mill Hollow terraces	4,807$\pm$ 5,142'	Bull Lake II
Pleistocene	Early Wisconsin	Bull Lake I	70,000	5,100'		5,107$\pm$	Bull Lake I
Pleistocene		Buffalo			Beirdneau Hollow terraces		Buffalo (?)
Pre-Pleistocene					Canyon cutting		

Figure 19. Correlation of events in Logan Canyon.

A broad valley formed in Logan Canyon upstream from a barrier of resistant beds of quartzite in the Swan Peak formation. The downstream end of the valley is 15.5 miles from Logan. It is about one mile across, three miles long, and was formed by lateral planation of the bedrock by shifting meander channels. The quartzite beds of the Swan Peak formation dip about 10° toward the west and thin rapidly down dip. The quartzite barrier was removed more rapidly due to thinning of the quartzite unit as erosion progressed downstream. Receding waterfalls moved upstream to that point which also helped to erode the barrier. When the barrier was removed, downcutting in the stream channel intrenched the meanders. Canyon cutting has progressed upstream to the vicinity of Ricks Spring where an irregularity of the stream profile is seen in Figure 3.

Early Pleistocene

Erosion and canyon cutting continued through early Pleistocene times. Logan River had by that time developed a normal concave profile. Renewed movement on the East Cache fault zone started another cycle of waterfall retreat. This is seen as a section of the stream profile that is convex near the mouth of Logan Canyon, Figure 3.

Several intervals of glaciation took place in Tony Grove Canyon during the Pleistocene. Early Pleistocene Buffalo glacial cycles have been described in the Wind River Mountains by Moss and Holmes (1955), in the LaSal Mountains by Richmond (1962), and in the Teton Mountains by Blackwelder (1915). Buffalo glaciation probably took place in

Tony Grove Canyon, but no evidence has been found. In the Beirdneau Hollow-Mill Hollow area, terraces were built from the tributary canyons into Logan Canyon by the large amounts of water that accompanied the glacial climate. Due to their position on the canyon walls and their relationship to later terraces, it is thought that they were constructed during the Buffalo glaciation. Erosion following the Buffalo glaciation removed a large part of the terraces.

Early Wisconsin

The Wisconsin stage started about 70,000 years ago (Frye, and Willman, 1963, p. 504), and was a time of glaciations throughout the Rocky Mountain region. Several cycles of glaciation took place during this time and have been subdivided by Holmes and Moss (1955) in the Wind River Mountains, and Richmond (1962) in the LaSal Mountains. Glaciation in Tony Grove Canyon can be correlated with glaciation in other areas. Terminology used by Holmes and Moss (1955) in the Wind River Mountains will be used here to designate the correlative equivalents in Tony Grove Canyon.

The Bull Lake I glaciation of Early Wisconsin times greatly affected the geomorphology of Tony Grove Canyon. The ice was about 600 feet thick in the vicinity of Tony Grove Lake. The glaciers eroded Tony Grove Canyon and gave it a broad U-shaped cross profile during this time. Later glaciations were not as effective as the Bull Lake glaciation in changing the general shape of the canyon. They were confined to areas within the limits of Bull Lake I glaciation and deposited moraines within the Bull Lake I valley. Bull Lake I glaciation was followed by an interglacial which was followed by Bull Lake II glaciation.

Pluvial cycles of Lake Bonneville were contemporaneous with the glacial cycles in this area (Morrison, 1961, p. 126). Lake Bonneville filled to an elevation of about 5,100 feet during the Bull Lake I glaciation. At that time, construction of the Mill Hollow terraces was probably started. Construction of these terraces was continued during a later glacial cycle.

Late Wisconsin

The Late Wisconsin started about 27,000 years ago (Richmond, 1962, p. 128). Early Pinedale glaciation in Tony Grove Canyon extended down canyon about one mile further than the Bull Lake II ice but the positions of the lateral moraines show that the Pinedale ice was considerably thinner than that of the Bull Lake II glaciation. Late Pinedale glaciation deposited a terminal moraine on the east side of Tony Grove Lake near the Bull Lake II terminal moraine.

Lake Bonneville reflects at least three short pluvial cycles during which the level rose to 4,800 feet, 4,470 feet, and 4,410 feet respectively (Richmond, 1961, p. 126). Construction of the Spring Hollow terraces was probably continued during these pluvial cycles. Late Wisconsin cycles of Lake Bonneville which did not reach the 4,770 foot mark are evident as lower deltas built into the lake near the mouth of

Logan Canyon, Figure 6. Radiocarbon dating of driftwood found in the lake sediments in Ogden Valley 35 miles southwest of Logan shows that the last time that Lake Bonneville occupied that area was B. P. 10,300± 275 years (Williams, J. S., personal communication).

Recent

An arid interval called the Hypsithermal followed the Wisconsin. Only a minimum amount of protective vegetation grew. Infrequent high-intensity storms caused floods and mud rock flows. Mud rock flows are evident in some tributaries to Logan Canyon, namely Grassy Flat Canyon and Mill Hollow.

Alluvial fans were built into Logan Canyon from tributary canyons during this time. Logan River was but a small intermittent stream and did not interfere with the growth of the fans. Later, the toes of the fans were truncated by the river.

Another cycle of glaciation called the Temple Lake followed the hypsithermal. Temple Lake glaciation started about 2,800 years ago (Richmond, 1962, p. 91). Although Temple Lake moraines have not been identified in Tony Grove Canyon they may exist. Moraines found about 3,000 feet downcanyon from the cirques can be identified on aerial photos, but snow conditions prohibit examination of the moraines at the time of writing.

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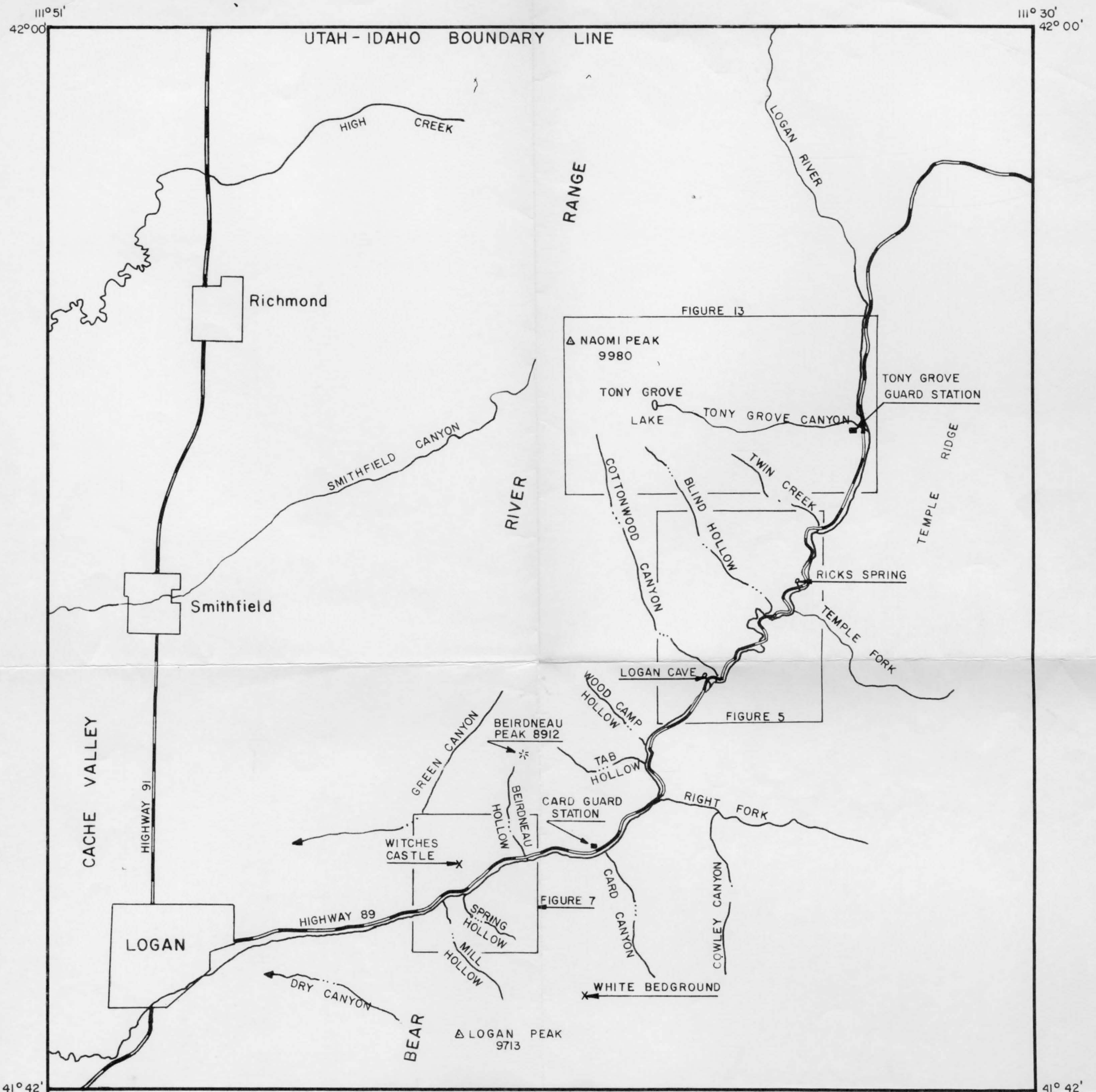

FIGURE I INDEX MAP OF LOGAN CANYON AREA

BY EDMUND J. WILLIAMS

BASE FROM U. S. GEOLOGICAL SURVEY
UTAH-IDAHO LOGAN QUADRANGLE 1914

SCALE

0 1 2 3 4 MILES