GLACIATION IN THE LOGAN QUADRANGLE, UTAH

by

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A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Arts and Sciences

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INTRODUCTION

That the higher valleys of the Wasatch Mountains were occupied by Pleistocene glaciers has long been known. King, Hague, and Emmons, geologists of the Fortieth Parallel Survey, the first to undertake a systematic study of any part of the Wasatch Mountains, recognized this fact and their report includes a map which shows in a rough way the extent of the glaciated areas in the Central Wasatch (1). In 1909 Atwood (1) made a detailed study of the glacial features of the Central Wasatch in connection with his study of glaciation in the Uinta Mountains. He mapped the deposits of 2 distinct glacial ages, but did not consider any part of the range north of Salt Lake County. Recently Bradley (2) has discovered the deposits of a third and older glacial age in the Uinta Mountains, thus indicating the possibility of a similar discovery in the Wasatch Mountains. Blackwelder (5) had previously recognized 3 glacial ages in the Wind River Mountains in western Wyoming and had made preliminary observations on glaciation in the Stansbury and Oquirrh ranges, Utah (7). While these studied have been completed for the central part of the Wasatch Range and for surrounding regions, no description of the glacial geology of the Northern Wasatch has ever appeared.

William Peterson, associate of Atwood in the study of the Uinta Mountains, has studied glaciation in the Bear River Range as a whole, but as yet has not published his results.

Reed W. Bailey (4) began the mapping of the Logan quadrangle some 10 years ago, and though recognizing the glacial features of parts of the area, made no attempt to delineate them on his map.
With the complete mapping of the Logan quadrangle (an active project of the Department of Geology at Utah State Agricultural College, to be completed, if possible, within two years) and in the absence of any published report on glaciation in the Wasatch Range north of the Cottonwood area, it seemed to the writer particularly desirable to undertake a study of glaciation in the Logan quadrangle. Two glacial ages have been recognized and all glaciated areas in the quadrangle have been carefully examined and the extent of the drift mapped. (See figure 1.)

FIELD WORK

Seven weeks of the 1938 field season were spent in working out the problem. The area was thoroughly covered by traverses that generally followed the ridges, from which a bird's-eye-view of the topographic features of adjacent areas could be had. Traverses were also made in the bottoms of all of the canyons in order that no details would be overlooked. Travel was done on foot for the reason that the rugged topography and the dense growth of trees and shrubs made the use of a horse unsatisfactory.

The base map used consisted of a copy of the Logan quadrangle map, enlarged in the offices of the Cache National Forest, United States Forest Service, to the scale of 2 inches to the mile. This scale was sufficiently large to make possible the location of positions by compass bearings from conspicuous topographic features. With such indefinite boundaries as existed in the glaciated area, much of which is densely wooded and clothed with brush, the method used is sufficiently accurate.

The base map was carried in the field and all conspicuous features
MAP SHOWING
GLACIATION IN THE LOGAN,
QUADRANGLE

LEGEND

ICE LIMIT

LATER DRIFT

DIVIDE

SCALE

BASED ON U. S. FOREST SERVICE MAP
GLACIAL GEOLOGY BY J. L. YOUNG

Figure 1.
were recorded at the time of observation. Lithologic samples of the outcropping bedrock were taken when laboratory verification of field identification of formations seemed desirable.

LOCATION AND EXTENT OF THE AREA

The Logan quadrangle is a 30-minute map located in the extreme north end of Utah near the eastern boundary line. The bold escarpment of the Front Ridge of the Bear River Range forms the western boundary of the Middle Rocky Mountain province. Cache Valley, at the base of the Front Ridge on the west, lies within the Basin and Range province. The west face of the Front Ridge divides the quadrangle into 2 nearly equal parts.

The greater part of the quadrangle is within the boundaries of Cache County. The Idaho State Line forms its northern boundary. Approximately 35 miles, or the southern half of the Bear River Range, is included within the quadrangle. That portion of the area examined for evidence of glaciation included all the mountainous region from Blacksmith Fork north to the Utah-Idaho State Line. The greater part of the glaciation occurred in the west tributaries of the Logan River within 10 miles of the northern boundary.

TOPOGRAPHIC SKETCH OF THE AREA

The most conspicuous features included in the Logan quadrangle are the Wellsville Mountains, Cache Valley, and the Bear River Range. The important streams entering Cache Valley, all coming from the Bear River Range, are Logan River, Blacksmith Fork River, Bear River, East Fork, Little Bear River, High Creek, and Smithfield Creek. A part of
the water supplied to the valley drains into the Bear River and is thus carried into Great Salt Lake.

The southeast portion of the Wellsville Mountains is included in the Logan quadrangle. They are located in the southwest corner. The narrow mountains form a continuation of the Wasatch Front Range and they vary in elevation from 8,000 to 9,500 feet above sea level. The west front of the range is rugged and steep. Normal faults are numerous throughout the range, thus complicating the structure. Paleozoic rocks, which range in age from Brigham quartzite of the Cambrian to upper Pennsylvanian formations, make up the mountains.

Cache Valley is one of the most fertile valleys in the state of Utah. Its relatively flat-bottomed floor is about 4,450 feet in elevation and is marked by a wide meander belt of the Bear River. Numerous oxbow lakes are observed along the course of the river. The length of the valley is about 50 miles, 30 of which are in Utah and 20 in southern Idaho. The average width is about 10 miles. The east side of Cache Valley is bounded by the abrupt face of the Bear River Range. The southwestern section of the valley is bordered by the Wellsville Mountains. North of the Wellsville Mountains are the isolated Clarkston Mountains. Most of the major streams entering Cache Valley do so in deep V-shaped canyons. Bear River, which is the largest stream in this area, commences on the northern slope of the Uinta Mountains. It enters Bear Lake Valley, east of the Logan quadrangle, and flows on northwest around the terminal end of the Bear River Range near Soda Springs, Idaho. The stream enters Cache Valley through a narrow, steep-sided gorge and then meanders south over the aggraded floor of the valley for a distance of nearly 15 miles. There it swings to the northwest, leaving Cache
Valley through a narrow gorge between the Wellsville and Clarkston Mountains.

During Pleistocene time Lake Bonneville occupied Cache Valley. Its high Bonneville level was cut nearly 900 feet above the present surface of Great Salt Lake. Conspicuous terraces around the valley reveal the various stages of the ancient lake. It was over a low pass at the northern end of Cache Valley that the Bonneville Lake overflowed and cut its way to the Portneuf, Snake, and Columbia Rivers and finally reached the Pacific Ocean.

From the west face of the Bear River Range, east of the city of Logan, commences a series of deltas which descend to the valley floor in a step-like profile. These deltas are the result of the discharge of the Logan River in Lake Bonneville. It is upon the most pronounced delta, known as the Provo level, that the Utah State Agricultural College is located. Logan City, the county seat of Cache Valley, is situated on the different delta levels. Most of the cities in the Logan quadrangle are located on the old deltas formed in the Pleistocene Lake.

Logan River, one of the major streams of the area, rises on the east slope of the Bear River Range and on the west slope of the Temple Ridge, approximately 3 miles north of the Utah-Idaho boundary line. The river flows through a broad valley in the northeastern part of the Logan quadrangle between the above mentioned ranges. Near the mouth of the Logan Canyon the stream has cut a narrow, steep-walled gorge nearly 1 mile deep. There it is cutting through and across the dipping Paleozoic strata. For a distance of over 10 miles back in the canyon, from the front of the Bear River Range, pronounced stream terraces and deltas, formed in the old Lake Bonneville, are observed. Most of the larger canyons in Cache
Valley are characterized by deltas and stream terraces formed in the lake.

The mountainous area occupying the eastern half of the Logan quadrangle consists of 2 roughly parallel ranges. These are designated on the map as the Bear River Range and the Wasatch Range. However, in the following report the writer will refer to these as the Bear River Front Ridge (4) and the Temple Ridge. The 2 ridges terminate at Alexander, Idaho, and at the south they merge into the Wasatch Range proper.

The Front Ridge is approximately 75 miles long and varies in width from 10 to 25 miles. The southern end, about 35 miles in length, is shown on the Logan sheet. The crest of the Front Ridge attains a maximum elevation in the Logan quadrangle of 9,980 feet, rising over 5,500 feet above the floor of Cache Valley. The former elevation marks the top of Mt. Naomi, which is located in the northeastern section of the quadrangle and at the head of some of the most severely glaciated canyons discussed in this paper. Other conspicuous peaks in the near vicinity of Mt. Naomi include Mt. Magog and Mt. Gog with elevations of 9,756 and 9,700 feet respectively, and Steam Mill Peak, which rises 9,300 feet above sea level. A number of unnamed peaks in the same section are above the 9,500 elevation.

Logan Peak forms one of the most pronounced points of the range near the central portion of the quadrangle. It attains an altitude of 9,713 feet and stands approximately 4,935 feet above Provo level of the ancient Lake Bonneville, upon which the Utah State Agricultural College is situated.

The west front of the Front Ridge forms one of the most striking features in the central part of the Logan quadrangle. There the mountain spurs, instead of sloping imperceptibly on the plain, are systematically
cut off into triangular facets.

STRATIGRAPHY AND GEOLOGICAL STRUCTURE
IN THE LOGAN QUADRANGLE

The walls of Logan and Blacksmith Canyons, as well as the west face of the Front Ridge of the Bear River Range, reveal one of the most complete Paleozoic sections known in the Cordilleran region. Their rugged slopes are made up of strata ranging in age from Cambrian to Pennsylvanian. The west face of the range exposes a great thickness of Cambrian rocks, at the base of which is the Brigham quartzite. The predominant colors of this massive, fine to coarse-grained quartzite are dull-green, buff-tan, and lavender. The Brigham formation, lower and middle Cambrian, is apparently conformably overlain by massive and thin-bedded, fine to medium-grained limestones and shales. The formations composing this group are the Langston dolomite, the Ute limestone at the base of which is the Spence shale member, Blacksmith limestone with the Hodges shale member at its base, and the Noman dolomite, respectively. Directly overlying the Noman dolomite is the Worm Creek quartzite member which forms the base of the massive and thin-bedded St. Charles limestone and dolomite.

The Ordovician system is well-developed in this area. This system of rocks is especially well-exposed near the mouth of Logan Canyon where its lower rocks form high cliffs. The strata are separated into the following formations: the Garden City limestone, characterized by abundant intraformational conglomerate, the Swan Peak quartzite conspicuous for its fucoidal markings, and the Fish Haven dolomite.

The Laketown formation of Silurian age is made up of dolomites.
The formation is conformable with the underlying Ordovician strata.

Apparently conformably overlying the Laketown dolomite is the Jefferson dolomite of lower and middle Devonian age. Thin-bedded limestones, shales, and lenses of sandstone are associated with the dolomite. Directly above the Laketown dolomite is the Threefords formation, which in this locality consists of thin-bedded, gray-to buff-colored sandstones and siltstones.

Lower Carboniferous rocks, represented by the massive to thin-bedded Madison and Brazer limestones, are conspicuously exposed in Logan Canyon. Due to the characteristic wall-like exposure of the lower Madison limestone, it is locally known as the Chinese Wall. The Madison formation conformably overlies the Threefords limestone.

Merging almost imperceptibly into the Brazer limestone is the Wells formation, consisting of quartzite, sandstone, and calcareous sandstone. The quartzite is a gray to light yellowish-gray color, while the sandstones are predominantly light to blue-gray. Permian beds are wanting in the Logan quadrangle. (Table 1 summarizes Paleozoic rocks in the Logan quadrangle.)

Tertiary formations are found around the margins of Cache Valley. Near the southern end of the valley red Wasatch rocks are exposed as patchy deposits on either side. A conspicuous outcrop occurs near the eastern base of the Wellsville Mountains. Gray conglomerate, covering the lower slopes of the west face of the Front Ridge, is considered of Miocene age. This calcareous conglomerate is especially well-shown east of the city of Hyde Park, forming the walls of Hyde Park Canyon near its mouth.

Bonneville beds occupy the lowlands of Cache Valley, constituting
<table>
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<th>Age</th>
<th>Formation</th>
<th>Thickness in feet</th>
<th>General character</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pennsylvanian</td>
<td>Wells formation</td>
<td>1,000</td>
<td>Massive to thin-bedded quartzite, sandstone and calcareous sandstone.</td>
</tr>
<tr>
<td></td>
<td>Brazer limestone</td>
<td>1,900</td>
<td>Largely massive gray limestone with thin-bedded siliceous limestone, sandstone and black shale.</td>
</tr>
<tr>
<td>Mississippian</td>
<td>Madison limestone</td>
<td>1,000</td>
<td>Thin-bedded gray limestone and dolomite.</td>
</tr>
<tr>
<td></td>
<td>Threeforks limestone</td>
<td>1,300</td>
<td>Gray to buff, thin-bedded sandstone and siltstone.</td>
</tr>
<tr>
<td></td>
<td>Jefferson dolomite</td>
<td>1,300</td>
<td>Massive, light-and dark-gray dolomites. Intraformational breccia abundant.</td>
</tr>
<tr>
<td>Devonian</td>
<td>Laketown dolomite</td>
<td>1,200</td>
<td>Massive, light-gray dolomite.</td>
</tr>
<tr>
<td></td>
<td>Fish Haven dolomite</td>
<td>200</td>
<td>Massive dark-gray dolomite.</td>
</tr>
<tr>
<td></td>
<td>Swan Peak quartzite</td>
<td>300</td>
<td>Fine-grained, white to light-purple quartzite; green and brown shale.</td>
</tr>
<tr>
<td></td>
<td>Garden City limestone</td>
<td>1,300</td>
<td>Thin-bedded to massive, light-to dark-gray limestone. Intraformational conglomerate common.</td>
</tr>
<tr>
<td></td>
<td>St. Charles forma-</td>
<td>100</td>
<td>Massive to thin-bedded, fine to medium-grained blue gray limestone and dolomite.</td>
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<td>Cambrian</td>
<td>tion</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Nounan dolomite</td>
<td>1,000</td>
<td>Massive to medium-bedded, gray limestone and dolomite.</td>
</tr>
<tr>
<td></td>
<td>Bloomington</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>limestone</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hodges shale</td>
<td>1,275</td>
<td>Medium crystalline, thin-bedded, light-gray to dark-blue-gray limestone, dolomite and shale.</td>
</tr>
<tr>
<td></td>
<td></td>
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<tr>
<td>--------------------------------</td>
<td>--------</td>
<td>-----------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td><strong>Blacksmith dolomite</strong></td>
<td>450</td>
<td>Light- to steel-gray, medium-grained, thick and thin-bedded dolomite.</td>
<td></td>
</tr>
<tr>
<td><strong>Ute limestone</strong></td>
<td></td>
<td>Thin limestone interbedded with shale, gray to dark-blue-gray, and fine-grained.</td>
<td></td>
</tr>
<tr>
<td><strong>Spence shale member</strong></td>
<td>685</td>
<td>Massive blue-gray to gray crystalline limestone, dolomite and sandstone.</td>
<td></td>
</tr>
<tr>
<td><strong>Langsten limestone</strong></td>
<td>575</td>
<td>Massive, fine to coarse-grained, dull-green, buff-tan and lavender quartzite.</td>
<td></td>
</tr>
<tr>
<td><strong>Brigham quartzite</strong></td>
<td>1,000</td>
<td></td>
<td></td>
</tr>
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nearly the entire surface. At the base of the Front Ridge the beds are gently inclined towards the valley. Around the margin of this valley, outcrops of Paleozoic and Tertiary rocks are observed overlain by Bonneville deposits.

In the glaciated section (see figure 2), in the northeastern part of the Logan quadrangle, Cambrian rocks are conspicuously exposed between Bunchgrass and Hell's Kitchen Canyons. In some canyons Cambrian limestones form narrow gorges through and over which the ice flowed. On the east side of Logan River, Cambrian rocks are exposed above the patchy deposits of Tertiary and Quaternary age. The Garden City limestone forms the floor of most of the cirques and is overlain by the Swan Peak quartzite. In nearly all of the glacial basins the Swan Peak formation forms precipitous walls, and most of the glacial erosion was done in it. This quartzite is conspicuously shown in the drift of the area, many of the larger fragments exposing the typical fucoidal markings. The upper parts of the basins, above the Swan Peak formation, are sculptured out of Ordovician and Silurian dolomites.

At the head of Providence Canyon, which marks the southern extent of glaciation in the Logan quadrangle, younger formations are exposed in the catchment area of the single glacier. Here the cirque is sculptured out of upper Paleozoic rocks in the southeast face of Logan and Providence Peaks. The floor of the cirque is cut in the Brazer limestone of Mississippian age. The Wells formation, marking the top of the known Paleozoic rocks in the Logan quadrangle, makes up the walls of the catchment basin.

Between Cottonwood and White Pine Canyons several large exposures of the Tertiary Wasatch formation occur. A small patch of Wasatch
FIGURE 2. GEOLOGIC MAP OF THE NORTHEAST SECTION OF THE LOGAN QUADRANGLE, UTAH
conglomerate is exposed just south of Tony Grove Lake at the mouth of the cirque. Red Banks, west of the highway and 1 mile north of Tony Grove Ranger Station, is typical of the Tertiary material in this area. There the Wasatch formation consists of a conglomerate with a conspicuous red color. The roundstones making up the conglomerate are predominantly of quartzite, ranging in size from one-quarter of an inch to 2 and 3 feet in diameter. They are cemented by calcium carbonate.

All of the formations considered above have contributed, though in different amounts, to the glacial drift in the area. The glaciers that reached the Wasatch formation gathered large quantities of the conglomerate. It is very probable that a number of the more rounded boulders, found in the drift near the lower end of the canyons, came from the Wasatch conglomerate.

THE INFLUENCE OF STRUCTURE ON GLACIATION

The great difference between the generation of ice on the east and the west slope of the Front Ridge of the Bear River Range seems to be due to the general structure of the range. The fact that the catchment areas of the glaciated canyons on the east slope are located in the central portion of the broad synclinal structure of the range is of primary importance. In these basins the dip of the Paleozoic strata is much more gentle than the dip in the basins on the west slope of the range. The average stream gradient on the east slope is approximately 530 feet per mile, while the streams on the west face have a gradient of nearly 775 feet per mile. The average elevation at the mouth of the severely glaciated canyons on the east slope is nearly 1500 feet higher than the elevation at the mouth of corresponding canyons on the west
slope, the length of the canyons being approximately the same. The
streams on the west slope descend more abruptly, draining directly
into the Bear River; whereas the streams on the east slope of the Front
Ridge are accordant with the Logan River which flows through Logan Canyon,
joining Bear River near the west side of Cache Valley.

Consequently, the basins on the east slope of the Front Ridge are
located at higher elevations than the basins on the west face; also,
these basins occupying the central part of the syncline, with the dip
of the beds almost horizontal, covered a greater area at the higher
elevation. These factors, as well as the fact that the prevailing
winds from the southwest must have carried great amounts of snow over
into the eastern basins, seem sufficient to account for the more wide-
spread glaciation on the east slope of the Front Ridge.

Proportional to the larger catchment basins on the east of the
Front Ridge, the glaciers on that slope were much greater in depth and
length. In general, the movement of the ice was with the dip of the
underlying bedrock and towards Logan River, although at the head of
Tony Grove and White Pine Canyons there was a considerable spreading
out of the ice into adjacent canyons and gullies.

GLACIAL PHENOMENA OF THE CANYONS ON THE EAST SLOPE
OF THE FRONT RIDGE

Cottonwood Canyon. Cottonwood Canyon (fig. 1, no. 1) is a tribu-
tary to Logan River Canyon, on the east slope of the Front Ridge. It
is located 3 miles north of Right Fork, approximately midway between
the latter and Temple Fork. The canyon is about 6 miles long, trending
almost north-south. The upper forks of Cottonwood Canyon swing slightly
west and perpendicularly into the crest of the range.

Conclusive evidence of glaci ation in this canyon is lacking; however, there is some indication of ice movement in a small southwest fork located on the west side, 2 miles down canyon from the head. This fork heads into a small amphitheater-like basin about one-half mile wide. The floor of the basin is approximately 1,000 feet below the summit of the range and is covered with a number of irregular ridges ranging in height from 10 to 20 feet. The sides of the small canyon from the head to the point where it joins the main canyon is bounded by bedrock ridges, with no definite indications of glacial movement.

It is considered possible that ice was generated in this basin, but does not seem likely that it was great enough to reach the main canyon. However, there is the possibility that the irregular and hummocky ridges in the basin are the result of a large landslide and subsequent drainage.

**Blind Hollow (fig. 1, no. 2)**. The catchment basin of Blind Hollow is located between the head of Cottonwood Canyon and the southeast rim of Tony Grove basin. It is approximately one-half mile wide and is slightly greater in length. The floor of the basin is not more than 400 feet below the surrounding peaks. About 75 feet above the floor of the basin is a low swale connecting Tony Grove and Blind Hollow basins. Material covering the slope between the 2 basins suggests glacial drift. It consists of dolomite and quartzite fragments, subangular in shape interbedded in silt and clay.

What appears to be a lateral moraine is located near the lower end of the small basin and on the southwest side. This deposit is approximately
15 feet high and 200 feet long. The lower end of the ridge is at approximately the 8,600 foot elevation. The material covering the ridge is essentially dolomite and quartzite, ranging in size from fine sand and silt to boulders $2\frac{1}{2}$ feet in diameter. Surrounding the ridge is material of the same nature.

Apparently, a small tongue of ice extended into the head of Blind Hollow from the Tony Grove cirque during the earlier epoch. There is no well-developed cirque at the head of Blind Hollow in which ice could have accumulated to account for the deposits. The fact that the ice in Tony Grove cirque was nearly 300 feet higher than the base of the low gap between the 2 basins makes it seem very possible that a small tongue of the Tony Grove glacier flowed through and at least one-half mile down canyon.

Within the relatively diminutive basin of Blind Hollow are 2 large sink holes. One of the sinks measures about 50 feet deep and 100 feet wide, while the other is approximately 25 by 200 feet. The sinks are surrounded by bedrock dolomite of Ordovician or Silurian age, and the floors are covered with clay and silt, except for a few large fragments. These sinks are post-glacial, indicating no evidence of glacial erosion.

**Bear Creek (fig. 1, no. 3).** Bear Creek enters the Logan River about $1\frac{1}{2}$ miles north of Blind Hollow. Near the lower end of the stream a smooth curve to the north is made as a result of a projecting bedrock ridge. Near the head the small canyon forks into a north and south fork. The south fork heads into Tony Grove basin at an elevation of about 8,200 feet.

Evidence of glaciation in Bear Creek is very meager; however, it is
quite definite. Near the head of the south fork, subangular quartzite boulders are observed, ranging in size from a few inches to as large as 13 by 8 by 3.5 feet. These larger fragments do not resemble any of the larger material included in the Wasatch formation, exposed on top of the southwest shoulder of the canyon. No well-defined moraines are present, although several hummocky, heterogeneous deposits are observed which are considered glacial drift.

The upper mile of the south fork of Bear Creek is U-shaped. Only a small notch, not more than 3 feet deep, is cut in the floor by the creek. Intermittent springs issue from the loose material along the sides of the canyon. The floor of the upper section of Bear Creek canyon is boggy in several places.

Bear Creek apparently received a small amount of ice from the Tony Grove glacier during the earlier epoch. The ice appears to have extended through the low swale, which is not more than 300 feet above the floor of Tony Grove cirque, and to have continued down canyon for approximately 1 1/2 miles, terminating near the 7,500 foot elevation. No evidence was found to indicate that the canyon contained ice during a later epoch.

**Twin Creek (fig. 1, no. 4).** Twin Creek Canyon enters the Logan River Canyon about 2 1/2 miles south of the Tony Grove Ranger Station. It is approximately 3 miles long and heads into the south ridge of Tony Grove canyon. The upper 2 miles of the canyon has a definite U-shaped profile, while the lower one mile is narrow and V-shaped. The relatively small creek has incised itself but a few feet into the canyon floor, through the U-shaped section.

Twin Creek shows more abundant evidence of glaciation than does
Bear Creek or Blind Hollow, to the south, although the 3 canyons were apparently supplied with ice from the Tony Grove glacier at the same time. Twin Creek has no individual catchment basin in which ice could have been generated, but the drift located within the canyon suggests that ice moved from the Tony Grove basin over the low south shoulder into this canyon.

The top of the rounded ridge between Twin Creek and Tony Grove basin is covered with irregular deposits of morainic material. Several small kettle holes are formed within the drift. On the north side of the canyon, commencing at about the 8,000 foot elevation, a lateral moraine extends down canyon for about one mile. Near the terminal end the moraine swings slightly into the head of a small canyon on the north. This deposit is the only well-defined drift located at the head of Twin Creek. It is approximately 20 feet high and 100 or more feet wide at the base. The larger fragments covering the surface are predominantly quartzite with a minor amount of dolomite and some limestone. The fragments are subangular in shape, some showing smooth faces, but none were observed showing glacial markings. The quartzite boulders indicate hardly any weathering, while the dolomite fragments contained cherty nodules as much as one-half inch in relief.

One and three-quarters miles up stream from the mouth of Twin Creek 2 small moraines flank either side of the canyon slope. The deposits are convex downstream, standing about 10 to 15 feet high and 150 feet long. It appears that this material represents the terminal end of the glacier; however, it is possible that deposits are recessional moraines. Upstream from these moraines, several irregular hillocks and mounds are scattered over the floor of the canyon and slightly up on the shoulders. This
material represents ground moraine. The coarser material of the drift consists of quartzite, dolomite, and some limestone. The soil profile is quite well-developed over the morainic deposits. Several small springs issue from near the base of the drift.

During the earlier ice age the glacier apparently extended about 2 miles down Twin Creek. The glacier was relatively small but still sufficiently vigorous to modify the pre-glacial, V-shaped stream channel to a typical U-shaped glaciated canyon. It is possible that ice extended the entire length of Twin Creek Canyon but conclusive evidence was not found to support this idea.

Tributary (fig. 1, no. 5). Between Twin Creek and Tony Grove is an unnamed canyon shown on the Logan quadrangle. This canyon will be referred to as a tributary of the Logan River Canyon and is listed as number 5 on figure 1. The canyon is approximately 2 miles long and a little less than one-quarter of a mile wide. It heads into the south ridge of Tony Grove basin, immediately northeast of the head of Twin Creek. The elevation, where the two join, is approximately 7,700 feet. The entire length of the tributary is beautifully U-shaped and suggests that the glacier possibly extended its entire length.

Drift covers the rounded ridge between the tributary and Tony Grove, forming hummocky deposits and enclosing several depressions. Ground moraine covers the floor of the canyon for more than 1 mile downstream. Slightly less than 1 mile from the head 4 small recessional moraines swing nearly across the canyon. The lower south moraine has been partly removed by post-glacial drainage. The deposits are all about equal in size, standing about 15 feet high and between 150 and 200 feet long.
The coarser material on the surface is largely quartzite with a minor amount of dolomite and limestone. Some re-worked Wasatch sandstone and limestone was observed. The dolomite fragments show the same cherty nodules, ranging from one-eighth to one-half inch in relief. Fragments of dolomite and quartzite range in size up to 4 feet in diameter.

At the mouth of the tributary is a large irregular ridge, the surface of which is covered with coarse quartzite and dolomite fragments. The ridge appears to have nearly blocked the mouth of the canyon, diverting the intermittent stream to the south. Many of the quartzite boulders on the surface are rounded and quite smooth but show no glacial markings. It is possible that these more rounded fragments were picked up by the ice from the Wasatch formation and from Logan River channel. The configuration of the ridge suggests a lateral moraine deposited by the Tony Grove glacier as it moved down Logan Canyon.

Apparently the ice made only one advance down this tributary, that being during the earlier ice age. No evidence could be found to suggest a second advance.

Tony Grove Creek (fig. 1, no. 6). Immediately to the north of Tony Grove Ranger Station a small stream enters the Logan River known as Tony Grove Creek. This creek flows a very small volume of water during the late summer and fall, but in the spring it furnishes the Logan River with a considerable amount of water. The stream heads into Tony Grove Lake 4½ miles back into the Front Ridge and drains the great catchment basin at its head. At the time of this field work a dam was being constructed across the outlet of the lake to conserve the heavy spring runoff of the area and to make possible a small irrigation project and a hydro-electric
plant near the mouth of the canyon. The entire project is under the direction of the United States Forest Service. The lake area may be reached by automobile.

The catchment basin at the head of Tony Grove Canyon is one of the largest in this area, being surpassed only by the White Pine basin to the north. The cirque is cut deep into the gently dipping Paleozoic rocks. The catchment area is very favorably situated, heading almost perpendicularly into the crest of the Front Ridge and into some of the loftiest peaks in this section. This location made it the collecting area of the snows carried by the prevailing southwest winds which were whipped up and over the crest of the range. The bounding, almost crescentic-shaped walls of the basin, added further protection to the accumulating snows. The walls of the cirque average about 9,800 feet. Mt. Magog at an elevation of 9,756 feet and Naomi Peak 9,980 feet, the latter being the highest point in the Logan quadrangle, tower above the cirque. The collecting area is more than 2½ miles wide, 1 mile long and descends from 9,980 feet to 8,000 feet in a step-like profile. Very small accumulations of talus toe the base of the cliffs. The cirque now presents a cleaned-out appearance, consisting of broad areas of bare rock surface, except for several small basins which apparently were cirque lakes and whose floors are not covered with silt and clay. Post-glacial drainage within the cirque has notched the bedrock to depths of 30 and 40 feet. The general appearance of the collecting area from the top of Naomi Peak is that of numerous small cirques within a cirque.

The upper 2 miles of Tony Grove Canyon is a beautifully symmetrical U-shaped valley. Below this point, for a distance of three-quarters of a mile, the canyon assumes a rather broad V-shaped form. The lower 1 mile
of the canyon again becomes flat-bottomed and cup-shaped. At the head of the canyon and located at the base of the Swan Peak quartzite is the only remaining glacial lake in this canyon. (See plate 1 A.) The lake has dwindled in size until it is now approximately 400 feet long and 200 feet wide. The maximum depth of the lake is $27\frac{1}{2}$ feet. It is supplied by several small springs, as well as the runoff from the area surrounding it. The depth of the ice, in the area of the lake, was probably not less than 600 feet.

During the earlier age of glaciation the ice of Tony Grove Canyon was not confined within the walls of the canyon but spread out for some distance on either side into other small tributaries of the Logan River. A small tongue of ice, near the mouth of the cirque, extended through a low gap in the wall and into the head of Blind Hollow. Within a few hundred feet of the lake, the ice extended over the low south shoulder and into the head of Bear Creek, Twin Creek, and Tributary #5. The ice in the latter probably extended the entire length of the canyon. On the north Tributary #7 was also supplied with ice from the Tony Grove cirque.

The moraine commences just above the 6,500 foot level and continues up stream to an elevation of about 7,500 feet. It is slightly shorter than 1 mile in length. The upper end stands more than 250 feet above the present creek and the lower end about 45 feet above. The top is irregular and cut by numerous rills. Several depressions are formed along and near the top of the moraine. It is composed largely of quartzite fragments, the other material consisting of dolomite and dolomitic limestone. Quartzite boulders as large as 9' by 4' by 6' are seen along the ridge associated with dolomite fragments 4 and 5 feet in diameter. From the configuration of the moraine and the intermittent stream which enters Tony Grove Creek
A. Tony Grove Lake and lower section of catchment basin.

B. A view down Bunchgrass Canyon from near the head of the catchment basin.

Plate 1
to the north, it appears that the deposit blockaded the small tributary. No evidence of lake deposits were seen behind the moraine, but the stream channel suggests having been diverted to the northeast.

On the south side of Tony Grove Creek, commencing at about the 7,200 foot level, is another lateral moraine which corresponds to the above described deposit. However, this one is only about one-half mile long but is somewhat bulkier. On the north side is an irregular deposit of drift which is cut by numerous small gullies and has the appearance of a recessional moraine. The deposits show abundant coarse material, consisting of quartzite and dolomite fragments subangular in shape. The quartzite boulders show hardly any signs of weathering, but the dolomite fragments contain cherty nodules, some as much as one-half inch in relief. No other glacial markings were located.

Farther up the ridge about 1 mile are 2 similar deposits, apparently recessional moraines of the earlier age. However, post-glacial erosion, as well as the erosive action of the ice of the later epoch, has removed the greater part of the deposits. The remnants are perched high on the sides of the valley. The fragments strewn over their surface consist mostly of quartzite with a minor amount of dolomite. The dolomite boulders show the same cherty nodules, slightly in relief, but no other indication of weathering was observed to discriminate these deposits from the material on the floor of the canyon.

The above-described deposits are all attributed to the ice of the earlier epoch in that they appear to represent drift laid down by the ice when it was at its maximum depth and length. They are located at higher elevations than other morainic deposits within the canyon, which apparently represent a later ice age.
Within the canyon walls and in the upper section of the U-shaped valley are several well-defined morainic ridges. About 1 mile downstream from the lake a recessional moraine flanks the lower part of the canyon walls. Much of the material has been removed by post-glacial erosion and all that remains to be seen of the deposits is a short, stub-like, rounded-off ridge, slightly convex downstream. The height of the deposits is approximately 20 feet. Below these moraines only ground moraine covers the canyon floor. However, in the upper 1 mile several other irregular deposits are seen. Within one-half mile of the lake 4 small, hummocky deposits stretch almost completely across the canyon floor. They vary in height from 15 to 20 feet. Kettle holes are formed in the deposits, some measuring 75 by 50 by 10 feet. Apparently these deposits represent recessional moraines. Between these deposits ground moraine covers the floor of the canyon. A recent road cut near the lake shows bedrock covered over with approximately 8 feet of drift. Erratics scattered over the floor of the canyon measure as much as 14 by 10 by 9 feet.

The smaller deposits, located within the canyon walls, apparently represent drift laid down by the ice of the later age; while the deposits located at much higher elevation and with a lateral spread in places of nearly 13/4 miles were probably deposited by the earlier glacier. The of the later age probably did not advance more than 3 miles out from the head of the basin.

No definite evidence was found to differentiate the older from the younger drift, other than the fact that the outer, more widespread deposits are much larger and bulkier than the system of moraines located with the canyon.
Bunchgrass Creek (fig. 1, no. 8). Bunchgrass Creek is a small tributary stream of the Logan River. It enters the latter stream one-half mile north from the Tony Grove Ranger Station. Bunchgrass canyon is approximately 4 miles long and is beautifully U-shaped in the upper 2 miles. It heads into the southeast slope of Mt. Magog, with an elevation of 9,756 feet, where a small cirque is developed. The cirque measures about one-half mile wide and three-fourths mile long.

Separating Bunchgrass and Tony Grove cirques is a low, rounded-off, bedrock ridge of Garden City limestone, which stands about 150 feet above the floor of Bunchgrass cirque. It is evident from the close relationship and the rounded ridge between the 2 basins that the ice was continuous from the north ridge of Mt. Magog to the south rim of Tony Grove cirque and that the ice overrode the dividing ridge for almost 1 mile down canyon before separating into 2 individual glaciers. (See plate 1 B.) The depth of the ice during the earlier epoch was probably not more than 500 feet and extended at least 3 miles out from its catchment basin. The ice of the later epoch was apparently much thinner and extended only about 2 miles down canyon. The ice of this later epoch was also connected with the ice of Tony Grove basin over the low separating ridge.

Within the cirque are several depressions or small basins. Only one of these, very near the toe of Mt. Magog, contained any water and this was an insignificant amount. Located about 1 mile out from the head of the cirque is a small shallow lake. It is situated about in the center of the canyon floor and is dammed off by glacial material. Springs issuing from bedrock within a half-mile furnish a good quantity of the water to the lake and to lower Bunchgrass Creek, which taps the body of water.

During the earlier glacial epoch the ice extended down the canyon
for a distance of about 3 miles. About 1 mile down from the lake, the
canyon makes a smooth curve to the north for a distance of three-fourths
of a mile and then again swings back toward the south. The entire
curve is rounded out in transverse profile except for a narrow, incised,
stream channel in the floor. At this point, where the canyon swings to
the north, morainic material is perched on top and down the south face
of the south ridge of the canyon. These deposits are lateral moraines
of the earlier epoch. They are very irregular and hummocky, enclosing
several small kettle holes. The material is resting on bedrock which is
exposed in the canyon wall. The moraines stand about 20 to 30 feet high
and are continuous for a distance of one-half mile along the top. Boulders
of quartzite and dolomite make up the coarser material and range in size
from a few inches to 10 by 7 by 6 feet. No appreciable amount of weather-
ing was observed on the fragments other than cherty nodules one-eighth
to one-half inch in relief on the dolomite.

Very nearly connecting with the above-described lateral moraine is
a smaller deposit that continues downstream for about 300 feet. This
material corresponds to a similar deposit on the opposite side of the
canyon. Both swing in towards the center of the canyon and are only
separated by a post-glacial channel. Apparently these deposits represent
recessional moraines of the earlier epoch. Irregular and hummocky de-
posits of drift flank either side of the canyon for another mile down-
stream, but their inner margins are poorly-defined.

The elongated knob, marked 8,600 feet and just south of Bunchgrass
Lake, is covered with large quartzite and dolomite fragments. Some of
these blocks measure 8 and 10 feet in diameter. Smaller limestone
boulders appear among the dolomite and quartzite. All of the fragments
are subangular in shape; some of the quartzite blocks showed smooth
faces but no striae were seen. A lateral moraine continues down the
ridge from this point for a distance of about one-half mile. The lower
end of the deposit trends off towards the south and into the head of
Tributary # 9. The lateral moraine stands about 350 feet above the
stream channel near its upper end. No corresponding deposit is located
on the opposite side of the canyon.

Within this outer set of moraines is a group of smaller irregular
deposits which represent material deposited by the ice of the later
epoch. This material extends about 1 mile down the canyon from the lake.
Near the lower extent the deposits completely cover the valley floor.
They are very irregular and consist of hummocky deposits enclosing several
small depressions. This mass of material represents the terminal deposits
of the later epoch. Post-glacial stream erosion has removed only a small
amount of the material. Ground moraine covers the floor from the terminal
moraine back up canyon to the lake basin. Three sets of small recessional
moraines, on either side of the canyon, coalesce with the ground moraine.
A small medial moraine is located on the north side of the lake. It stands
about 20 feet above a small stream channel on its north. The deposit
is approximately 300 feet or more long and is composed of a heterogeneous
mass of quartzite, dolomite, and limestone. Fragments measuring more
than 3 feet in diameter are scattered over the surface. Apparently this
material has been deposited on a small bedrock ridge, as is indicated by
the stream channel at the toe of the moraine.

There appears very little difference in the age of the inner and
outer groups of deposits as far as the amount of post-glacial weathering.
All of the deposits, except those located within a distance of a mile
from the head of the cirque, are covered with a thick growth of trees
and small shrubs. Those deposits within the above-mentioned distance are notably scantily vegetated, which is probably indicative of their more youthful origin. The essential discriminating factor between the earlier and later glacial deposits is that of a more widespread location of moraines. The fact that these outer moraines and irregular deposits are located at higher elevations and are much greater in size may be a means of differentiating between the 2 glacial epochs. Also, there is a noticeable amount of fracturing in the larger quartzite fragments of the widespread drift. No evidence of a third glacial epoch was observed.

White Pine Canyon (fig. 1, no. 10). White Pine Creek joins the Logan River approximately one-half mile north of Red Banks. The creek is one of the largest of the northern tributaries to the Logan River. Its supply of water is obtained essentially from White Pine Lake, located more than 5 miles back into the Bear River Range. Minor sources of supply consist of several small intermittent springs and some runoff along its course. The stream has not entrenched itself deeply since the glacial epoch, except near the mouth of the south fork of the catchment basin where it flows for nearly one-quarter mile in a narrow V-shaped channel.

The greater part of this channel, however, was carved out before the glacial period, so that the stream has only removed the drift which was left in it by the ice. This portion of the channel is also the steepest, dropping off about 300 feet in the one-quarter of a mile. Near the mouth of White Pine Canyon the stream makes a long smooth curve to the southeast, entering the Logan River at about a 45 degree angle. This section of the channel appears to be post-glacial, the original channel to the north having been filled in with glacial material.
White Pine Canyon contained a greater quantity of ice than did any other canyon in the Logan quadrangle. This statement is clearly substantiated by the most widespread and complete system of moraines in this area, covering a frontal distance of over 2 miles. The ice sculptured out a beautifully symmetrical U-shaped canyon, characteristic of severe glacial erosion. (See plate 2, A and B.) Only in the proximity of the mouth is the cup shape slightly obscured by thick deposits of drift. Commencing 2\(\frac{1}{2}\) miles up canyon is a relatively flat area about 1 mile long which has some appearance of valley-train. Most of the section is covered with sand and silt, and only here and there is coarser material observed. Within the course of the canyon, several well rounded-off and truncated spurs are seen, especially near the mouth of the catchment basin.

The catchment basin, in which the White Pine glacier was generated, is the largest one described in this report. Its width, along the crest of the range, is over 2 miles and its length is about 1\(\frac{1}{2}\) miles. The catchment area is partly divided into 2 sections by Mt. Gog, which extends nearly 1 mile east of the crest. (See plate 3 A.) Between the peak and the crest of the range is a low divide, 600 feet below the top of the peak, through which the ice extended. It is apparent that Mt. Gog stood out as an isolated island during the period of glaciation. The head of the basin is bounded by the crest of the Bear River Range, with an average elevation of about 9,600 feet above sea level. Some of the loftiest peaks in the range surround the White Pine basin. These include the north part of Naomi Pk with an elevation of 9,980 feet, the north slope of Mt. Magog 9,756 feet, Mt. Gog 9,700 feet and an unnamed peak on the north rim with an elevation of 9,712 feet above sea level. These high peaks
A. View of the south fork of White Pine Canyon showing Mt Magog on the right.

B. View down White Pine Canyon from near the head of the catchment basin.

Plate 2
A. View of upper White Pine Canyon showing the north and south forks of the catchment basin separated by Mt. Cog.

B. White Pine Lake.

Plate 3
were of major importance during the glacial epoch in accumulating great quantities of snow and ice.

The crest of the Front Ridge at the head of White Pine Canyon is very narrow. The west side drops off abruptly, in places over 900 feet vertically within a horizontal distance of about 850 feet. In contrast to this abrupt descent is the step-like cirque on the east. White Pine Lake may thus be said to be formed in the landing of this great stairway. Bounding the lake on the upper side is an almost vertical wall, rising over 200 feet above the surface of the lake. The lake has diminished in size to about 500 feet in length and approximately half that width. (See plate 3 B.) Numerous springs, located throughout the catchment basin, supply the lake with water during the summer. The lake has been sculptured out of the Garden City formation (Ordovician age) at the base of the Swan Peak quartzite, the latter forming the west wall mentioned above. Morainic material partly surrounds the lake basin. From here to the floor of Logan Canyon the longitudinal profile of White Pine is more uniform.

Two epochs of glaciation are represented by the distribution of the drift. During the earlier epoch the ice in White Pine cirque was not less than 600 feet in depth. It extended out from the head for a distance of about 7 miles, a part of which was in Logan Canyon. Near the 8,000 foot elevation, on the confining ridges or walls of the canyon, the ice spread out and into adjacent tributaries, forming a large fan-like body down to the main canyon. The ice of the later epoch was confined within the walls of the canyon and extended only about 4 miles out from the upper end of the catchment basin.

Adjacent to the Logan River and located on the west side of the
stream are great deposits of drift on either side of the mouth of White Pine, covering nearly 2 square miles in area. The topography of this area is very irregular and hummocky with numerous gullies winding in and out. Some conspicuous deposits in the form of moraines are seen with their terminal ends pointing north. Other small ridges, convex east, suggest small lateral moraines, while hummocky ridges trending north and south, which was perpendicular to the direction of ice flow, suggest terminal deposits. It is very probable that this vast amount of drift represents both terminal and recessional deposits left by the ice of the earlier epoch.

The widely spread deposits consist of about the same type of material and are equally well-covered with soil and vegetation. The material ranges in size from silt to boulders as large as 14 by 8 by 7 feet. (See plate 4 A.) Numerous erratics are scattered over the deposits measuring over 6 feet in diameter. The majority of the larger fragments are from the Swan Peak quartzite formation, exposed in the cirque. Many of the fragments retain the characteristic fucoidal markings. The remainder of the material consists of dolomite with some limestone. Most of the coarser material is subangular in shape; however, quartzite boulders comparatively round were not uncommon near the south end. The dolomite blocks were characterized by cherty nodules as much as one-half inch in relief. No striae were observed on the fragments.

Closely bordering and also perched high on the walls of the canyon is a group of moraines of the same age, or earlier epochs. These occur at irregular intervals along the entire course of the canyon. Commencing at the upper end, a group of lateral moraines flank the south side of the canyon from the unnamed peak, in section 29, with an elevation of 9,123 feet
A. Quartzite erratic near the mouth of White Pine Canyon

B. Notched inner lateral moraine on the south side of White Pine Canyon

Plate 4
to the mouth of White Pine. The upper moraines begin at an approximate elevation of 8,100 feet and continue downstream for over three-quarters of a mile, where they swing slightly in toward White Pine Creek near their terminal ends. At its terminal junction it slightly overlaps the upper end of another lateral moraine on the south. This deposit is irregular and hummocky along the top and is cut by numerous rills on either side. At one point a large notch is formed in the moraine and the removed material is observed extending a few hundred feet in towards the stream. (See plate 4 E.) On investigation, several individual levels are seen in which one or more shallow depressions are formed. Large and small erratics are scattered over the surface. The cut-away faces of the moraine show a mass of material both heterogeneous in composition and size. No indication of underlying bedrock was observed in the 60 or 70-foot deep cut-away section. The 3 processes considered by the writer as likely to account for this interesting phenomenon are: (1) that this part of the lateral moraine became over-steepened or loosened and slid down; (2) that the underlying dolomite and limestone were dissolved away and allowed the material to slump down; and (3) that the depressions represent kettle holes which resulted in a subsequent movement of the material. Any one or all of these processes might have caused this material to drop down; however, because the lateral moraine was deposited by the ice of the earlier epoch and the slumped material has not been removed or modified by the later advance of the ice, the third suggestion of origin could hardly be considered.

Near the end of the above-described moraine a second conspicuous lateral moraine commences. Its upper end overlaps the higher moraine by several hundred feet. This moraine can be followed down canyon for nearly
three-quarters of a mile without a break. It forms the top of the south
ridge of White Pine Canyon, standing over 300 feet above the floor at the
upper end. Near its terminal end the moraine drops down and curves
slightly in toward the stream.

Commencing at an elevation of about 7,800 feet, along the south ridge
and connected to the south slope of the above-described deposit, is a
long, irregular, lateral moraine that continues downstream for over 1\frac{1}{2}
miles. The upper one-quarter of a mile overlaps the upper lateral moraine;
however, this deposit stands some distance higher above the inner deposit.
Beyond the overlap, this moraine forms the south wall of the canyon the
remainder of its length. It is cut by rills and small gullies and is
conspicuously outlined by large fragments covering the surface.

From the terminal end of the long lateral moraine to the Logan River
are 3 small deposits that more or less follow the trend of the creek.
These deposits appear to be lateral moraines of the same age as those de-
scribed above. They vary in length from one-quarter of a mile to nearly
one-half. All appear to be perched upon bedrock ridges. At one place
the Wasatch formation, of Tertiary age, is exposed clearly below. The
material composing the above lateral deposits consists mainly of quartz-
zite, with some dolomite and a minor amount of limestone. The dolomite
fragments showed cherty nodules in relief. The quartzite blocks were sub-
angular in shape, with some showing smooth faces. No glacial markings
were observed.

Related to these deposits is a group of moraines along the north
slope of Tributary # 9. The moraines appear to be lateral deposits and
were no doubt deposited by the ice of the earlier epoch. All trend off
at angles between 20 and 40 degrees from the 3 upper moraines flanking
White Pine Canyon. However, these outer moraines are not all connected to the ones along the sides of White Pine. Their lengths range from one-quarter mile to 1 mile and stand as high as 60 feet above adjacent gullies. They are covered with a heavy growth of small trees and brush. Erratics measuring several feet in diameter are scattered over the surfaces. The lower deposits show a noticeable amount of smooth-faced quartzite boulders, which were apparently picked up by the ice from the Wasatch formation in that vicinity.

The north ridge of White Pine Canyon contains a corresponding set of moraines; however, no single lateral deposit forms a continuous ridge as long as the longest moraine on the south. The upper lateral moraine starts at an elevation of about 8,500 feet, on top of the north ridge, and continues about one-half mile down canyon. Near the lower end the moraine swings from the top of the ridge to the upper slope of the canyon wall, making a more conspicuous deposit. About 900 feet from its terminal end, 3 well-defined lateral moraines are perched step-like up from near the floor of the canyon. These deposits very nearly parallel each other and are of about the same dimensions, being a little more than one-half mile in length. The ridge upon which the drift is deposited is made up of dolomite and limestone bedrock. At this point the canyon is quite narrow, and apparently the ice rode high up and over the confining bedrock walls of the canyon, depositing the drift at various stages. Although the limestone and dolomite outcrop along the canyon wall and show a marked rounding-off of the irregular edges, no glacial striae or other ice markings were observed. However, this would be expected as the limestone is rather friable and would weather readily, obliterating all evidence of glacial abrasion. The coarser fragments of the drift consist essentially
of quartzite and dolomite with some limestones. The quartzite makes up about 65 percent of the boulders. The erratics definitely outline the deposits. The boulders range in size from small ones to as large as 10 by 7 by 5 feet.

Drift is found on the north slope of the above-described bedrock ridge down into a small ravine. The drift makes up irregular and hummocky deposits over the slope and from this point down to the Logan River. Kettle holes are very common in this glacial material. Marking the northern limit of the White Pine glacier during the earlier epoch are a few small moraines near the floor of the above-mentioned ravine. The lower deposit appears to be a lateral moraine and curves up the Logan Canyon. It stands about 15 feet high and is about 400 feet long. Two kettle holes are formed in the drift, measuring about 3 feet in depth.

The terminal deposits, along the course of the Logan River, stand more than a hundred feet above the stream in many places. Drift is located on the east side of the river, making up a few small hillocks. The new highway through the canyon had made a 60-foot cut through one of the ridges or knobs. The cross section shows a heterogeneous mass of boulders mixed in with red to light-gray silts, clay, and fine sandstone. The boulders average a little more than a foot in diameter, and quartzite boulders 4 feet in diameter were seen. Quartzite boulders are scattered over the rounded-off knob. Most of the fragments are rounded with smooth sides.

Although the material is not typical glacial drift, the writer considers the possibility that the material could have been pushed up on the east side of the river by the White Pine glacier. Another smaller lobate ridge is located downstream 100 yards, indicating practically the same type of
material except on the south end where patchy deposits of the red Wasatch conglomerate are found. The conglomerate does not appear to have been deposited in its present position, but to have been transported either by the ice of the earlier epoch or the stream or both.

The later glacial epoch of White Pine is characterized by smaller deposits of drift located within the canyon walls. Near the upper end, about 2 miles downstream from Mt. Cog, 2 well-defined crescentic ridges swing almost into the center of the canyon. They are less than one-half mile in length. One mile further down the canyon 2 more moraines almost plug the canyon. (See plate 5 A.) These moraines probably represent the terminal deposits of the later epoch, while the upper 2 were formed as the ice receded. Several other irregular deposits flank either side of the upper section of the canyon, but none are well-defined. Ground moraine covers the floor for some distance below the lake. Kettle holes are observed throughout the drift. One large fragment of quartzite, observed along the trail, showed glacial striae.

There appeared to be very little difference in age between the inner and outer sets of moraines, as far as the amount of weathering is concerned. The dolomite fragments on the canyon floor showed about the same amount of weathering, as determined by the relief of the cherty nodules. No difference could be determined between the quartzite boulders. As for the finer material composing the moraines, several samples from each could not be differentiated under the microscope. A luxuriant growth of trees and shrubs and grasses covers some of the outer as well as the innermost deposits. However, it seems probable from the relationship of the 2 sets of moraines that the inner deposits, confined within the walls of the canyon, represent a younger or later stage of glaciation
A. White Pine Canyon showing a part of the terminal moraine of the later ice age notched by the post-glacial stream.

B. View along the top of a lateral moraine on the north side of White Pine Canyon.

Plate 5
and that the widespread bulkier deposits were laid down by the ice of the earlier epoch.

**Steam Mill Canyon (fig. 1, no. 11)**. Steam Mill Canyon enters Logan Canyon 2 miles north of where Beaver Creek and Logan River combine. It is approximately 4½ miles in length and heads almost perpendicularly into the crest of the Bear River Range. The canyon is quite narrow in sections, particularly midway between the head and the mouth. The upper and the lower parts of the valley are more broad and U-shaped. The constrictions are caused by the more resistant bedrock which in places forms very conspicuous cliffs along the valley. About 2 miles up canyon from the mouth is a noteworthy gorge approximately 75 feet deep and 20 feet wide at the base. It is cut completely in Cambrian dolomite and has been only slightly modified by the Steam Mill glacier. Nearly one-half mile below this point is another smaller gorge cut about 20 feet deep in a light buff, medium-grained sandstone. This ravine appears to be post-glacial, cut by the Steam Mill Creek. Erratics are scattered over the sides of the upper gorge, but only on the south side does any drift appear.

The catchment basin, in which the Steam Mill glacier was formed, is more than a mile wide and about 1 3/4 miles long. It is sculptured into a rough step-like basin and is protected on the end and sides by some of the highest points in Logan quadrangle. The unnamed peak in section 19, with an elevation of 9,712 feet, towers more than 1200 feet above the floor of the basin. The crest of the Bear River Range has about the same height in elevation, while the north rim is about 300 feet lower. Steam Mill Peak on the north side of the canyon, near the
lower end of the catchment basin, is approximately 1,000 feet above
the floor of the canyon and is capped with the Swan Peak quartzite.
These peaks apparently stood out as islands during the glacial epoch.
In the floor of the cirque, near the base of the Swan Peak quartzite
and nestled in between a short protruding bedrock spur and the southwest
wall of the cirque, is a small, clear lake. The lake is situated at
an elevation between 8,400 and 8,500 feet. It appears to be only a
few feet deep at present, having been partly filled in by sediments
carried in by sustaining streams. Talus slopes cover the base of the
bounding walls and one or more rock falls have occurred along the north-
west rim.

The glacier that descended Steam Mill Canyon deposited a number of
well-developed moraines. Those which are most clearly defined repre-
sent material carried by the ice of the earlier epoch. This advance
of the ice extended at least 5 miles out from the head, the last one-
half mile or more being down Logan Canyon. Extending up stream from
the mouth of the canyon on either side are long lateral moraines. The
one on the south is over a mile in length, while the north moraine is
approximately 1 mile long. Both swing slightly down Logan Canyon near
their terminal ends. Adjacent to the deposit on the south and slightly
overlapping it on the side is another small lobate ridge which appears
to be a lateral moraine. Its length is about one-half mile. It stands
nearly 15 feet above the surrounding land surface near its terminal end.
Coarse blocks of quartzite and some dolomite are scattered over its sur-
face. No fragments were observed on this lower deposit larger than
about 3 feet in diameter. The lobate moraines on either side of Steam
Mill Canyon are located near the top of the bounding ridges, nearly
400 feet above the stream channel at their upper ends. Covering the slopes are coarse subangular fragments of quartzite and dolomite, with the former predominating. The dolomite fragments show a noticeable amount of weathering by the cherty nodules, which are as much as one-half inch in relief on some blocks. No striae were observed on the blocks. The soil and, thus, the vegetation are well-developed over the drift. Numerous rills have cut the glacial material, but otherwise it appears undisturbed.

No well-defined moraines are located above the lateral moraines mentioned. However, drift covers both sides of the canyon and the floor as high as 400 feet above the stream channel, near the cirque. The deposits along the canyon slopes are very irregular and patchy. Many places only erratics are scattered over the slopes to mark the limits of the ice. Some of these subangular quartzite boulders are as large as 6 feet in diameter.

The later ice epoch is characterized by thick deposits of drift extending out a distance of about 2½ miles from the catchment basin. However, none of this material assumes any definite shape other than hummocky deposits scattered over the valley floor and slightly up on the sides of the canyon walls. Probably the greatest amount represents ground moraine. Within 1 mile of Steam Mill Lake three large kettle holes were observed formed in the drift along the south side of the canyon floor. These holes vary from 10 to 50 feet in depth and from 100 to 300 feet wide. Below the kettle holes the canyon floor broadens out with a gentle slope downstream. This flat has some appearance of a valley train. It is covered with fine sediments, and only here and there erratics protrude out. The stream is entrenched to a depth of
about 2 feet through this area.

The material composing the drift indicates only slight, if any, difference in the amount of post-glacial weathering. At various places the outermost deposits support more abundant vegetation; however, this was not characteristic throughout the glacial material and is thus not considered conclusive criterion in determining the age of the drift. The above observation was also made in respect to the amount of weathering on the coarser material, but again this condition did not prevail at all places. However, the relationship of the outer and inner deposits suggests that the former were laid down by the ice of an earlier age.

**Hell's Kitchen Canyon (fig. 1, no. 12).** Hell's Kitchen Canyon is one of the smaller canyons containing evidence of glaciation. It is approximately 2 2/3 miles long, striking off from the Logan River at an angle of about 35 degrees to the west. The floor and lower slopes of the canyon are heavily-vegetated, while the upper slopes support only a few shrubs and brush. The canyon has a rather smooth U-shaped profile with no projecting spurs. About three-quarters of a mile upstream from where it enters Logan Canyon, a narrow bedrock channel has been carved out by the stream and ice. It is about 20 feet deep, with limestone forming the floor. Quartzite boulders are scattered over the sides.

There is no well-developed cirque at the head of Hell's Kitchen Canyon. However, a small basin is developed, but it apparently was little modified by the ice generated in it. It includes about one-half square mile and is bounded on the west by the east wall of the lower Steep Hollow cirque, with an elevation of 9,000 feet. Steam Mill Peak
forms the bounding wall and slope on the southwest margin of the basin and has an elevation of 9,300 feet above sea level. The basin is well-rounded in transverse profile, showing 1 or 2 short smoothed-off ridges projecting out from the upper wall. The Swan Peak formation exposed in the catchment area revealed no glacial markings. The Swan Peak formation forms wide talus slopes on the north slope of Steam Mill Peak, but these do not reach to the floor of the canyon.

The ice in Hell's Kitchen Canyon did not extend beyond the shoulders and probably not more than 2 miles out from the head. The depth of the ice, generated in the basin, could not be definitely determined, but it is certain that there was a relatively small quantity, as is indicated by the shape and size of the catchment area. Likely ice was formed in the basin only during the earlier epoch and did not reach a lower elevation than about 7,600 feet in the canyon.

The deposits located in the canyon are not characteristic of a large glacier. The drift ranges in thickness from 10 to 15 feet. Three sets of small recessional moraines are located a little more than 1 mile up canyon from the mouth. These deposits are irregular in shape but are clearly-defined. All are convex downstream and range in thickness around 15 feet with lengths of about 250 feet or more. The upper ends of the moraines stand about 25 feet above the present stream channel. Patchy deposits of ground moraine cover the floor between the ridges and a short distance above and below where the ridges begin and terminate. One single moraine flanks the south side of the canyon about 400 feet below the lower set of recessional deposits. This crescentic-shaped deposit probably represents a terminal moraine. It is approximately 25 feet above the stream near its lower end and is about 300 feet
long. Quartzite and dolomite fragments make up the greater part of the drift. They are subangular in shape and vary in size up to 3 feet in diameter. The soil profile is well-developed over all of the drift material and supports abundant vegetation.

Steep Hollow (fig. 1, no. 13). Steep Hollow enters the upper Logan River 4 miles north of the point where Beaver Creek and Logan River join. The mouth of the canyon is just slightly south of Crab Ridge, which forms a steep slope on the east side of Logan River. Steep Hollow creek runs almost directly east and west for a distance of 2 miles and then swings southwest for another mile at the upper end.

The stream is intermittent and is not supplied from any body of water at the head. The entire canyon is beautifully U-shaped and characteristically modified, suggesting vigorous ice erosion. Several truncated spurs are observed on either side of the canyon.

The catchment area consists of 3 sections. The 2 larger basins head directly into the crest of the Bear River Range and are separated only by a short, rounded-off ridge, which was partly covered with ice during the glacial epoch. The third basin is located almost a mile downstream on the south side of the canyon. The east side of the latter basin heads into the north slope of Steam Mill Peak with an elevation of 9,300 feet. The west side is flanked by a ridge with a maximum elevation of 9,100 feet. It rises 1,100 feet above the floor of the basin near the mouth. This basin covers about three-quarters of a square mile or more. During the glacial period it held sufficient ice to be sculptured out into a small typical cirque. Since the ice epoch, however, several small rock falls have occurred. The 2 upper basins combined
occupy more than 1 square mile and are very advantageously situated to receive and protect the snow that accumulated during the glacial period. They head into some of the loftiest peaks in the northern part of the range, varying in elevation from 9,500 to 9,872 feet above sea level.

During the earlier glacial epoch all of the 3 sections contained ice which coalesced to form 1 large glacier. However, the 2 basins on the south are more characteristic of vigorous erosion than is the north fork of the upper catchment area. This may suggest that there was less ice in the north fork during the earlier epoch or that it was relatively free of ice during the later epoch. The south basins are well rounded-out and there are no interlocking spurs or ground moraines. Post-glacial drainage has covered the floor of the basin with fine material. The stream has incised only a very shallow channel in the floor. The depth of the ice of the earlier epoch at the head was not less than 500 feet.

Separating the 2 basins on the south is a ridge with an elevation of 9,100 feet. This ridge is conspicuously rounded and elongated in the direction of the ice flow. Glacial markings were not observed on any of the exposed bedrock surfaces.

The ice extended approximately 4 miles out from the cirque during the earlier ice age, the lower three-quarters of a mile in Logan Canyon. The ice of Steep Hollow and Crescent Lake Canyon coalesced at about the 8,200 foot level and formed the 1 large mass of ice. The lower elevation reached by the glacier was about 7,000 feet. At this elevation, what appears to be lateral moraines flank either side of the main canyon. The moraine on the east continues downstream from the south point of the Crab Ridge for a distance of about one-half mile, where it
swings slightly into the center of the canyon. Post-glacial erosion has removed a vast amount of the material and the ridge is cut by numerous gullies. The upper end of the lateral and probably terminal moraine stands about 70 feet above the present stream. The deposit on the west side which corresponds to this lateral moraine is larger and more irregular. Its size and configuration suggest a terminal deposit. Its height above the stream is about 50 or 60 feet. It is a hummocky deposit, enclosing a few small depressions, and is cut by a number of rills. Ground moraine covers the floor of the canyon on the west side of the river between the 2 deposits. Subangular fragments of quartzite and dolomite make up the mass of the deposits. Quartzite is the most abundant, and it is observed that it is of greater quantity in these deposits than in the drift located in White Pine or Tony Grove canyons. Some boulders were scattered over the surface which showed a marked rounding. These fragments were apparently picked up by the ice as it advanced down the main canyon. The quartzite boulders measured as large as three feet in diameter.

On either side of Steep Hollow is a set of moraines corresponding in age to the above-described drift; that of the earlier epoch. The lateral moraine on the south commences at the 8,000 foot level and extends down canyon for about 1 mile, swinging into Logan Canyon at its lower end. The height of the moraine at the upper is about 300 feet above the valley floor and at the lower end approximately 60 feet. The deposits on the north side of the canyon are very irregular and enclose a number of large and small kettle holes. The drift forms numerous hillocks below the point where the Steep Hollow and Crescent Lake glaciers combined. The lateral moraine is about 1 mile long, continuing
up canyon about one-quarter mile further than the related deposit
on the south side. It curves slightly to the north at its terminal
end. Almost joining the latter end and continuing about 400 feet down
canyon, along the top of the ridge, is another irregular deposit of
drift. It stands about 15 feet above the surrounding ground moraine.
Depressions in and among these deposits vary in size from 15 by 7
feet to 200 by 20 by 100 feet. Fragments scattered over the surface,
mostly quartzite, measured as large as 12 by 6 by 4 feet. Some cherty
boulders of dolomite are mixed in among the quartzite, but none were
seen as large as the latter.

What appears to be 2 small, medial moraines are located near the
lower end of the blunt-nosed ridge between Steep Hollow and Crescent
Lake. These deposits parallel each other for a short distance. They
are approximately 400 or 500 feet long and curve gently down the main
canyon near their terminal ends. These deposits are also very irregular
and are cut by many small gullies.

Between the lateral moraines formed on either side of Steep Hollow
are patchy deposits of ground moraine. Only 1 well-defined deposit
is located on the south side, one-half mile upstream from the mouth of
the canyon. It is about one-half mile long and stands 100 feet above
the creek. The terminal end of the material is at about the 7,600
foot level. This deposit, as well as the patchy material, represents
the later glacial epoch. The ice of the latter epoch probably did not
extend as far as the mouth of the canyon.

The difference in the amount of weathering of the material was not
considered sufficient to discriminate between the wider spread drift
and that located within the canyon. The vegetation appeared equally
distributed over the different deposits.

**Crescent Lake Canyon (fig. 1, no. 14).** Adjoining Steep Hollow on the north is a small intermittent creek that drains into the Logan River. This creek extends back into the range for a distance of nearly 3.5 miles. Approximately one-half mile from the head there is a small, crescentic-shaped, intermittent lake. This lake is known as Crescent Lake, probably deriving its name from its configuration. The creek tapping it swings about three-eighths of a mile to the north from the point where it leaves the lake. Here the stream makes a long rounding curve around a bedrock ridge and then flows southeast to a point where it is again on an east and west line with the lake.

The canyon in which this creek flows has a beautiful U-shaped profile in the upper part. Post-glacial drainage has incised itself in the lower part of the canyon to a depth of about 15 to 20 feet, this being cut mostly in glacial material. The upper end of the creek is only a few feet deep, where it is controlled in parts by the bedrock. Near the mouth of the canyon massive deposits of drift almost completely choke up the valley.

The Crescent Lake catchment basin heads into the south ridge of Boss Canyon. The summit is almost 1400 feet above the level of the lake on the southwest side. The basin is about 1 mile wide and three-quarters of a mile long. It is well-protected on either side by the high walls. The head, however, is not typically cirque-like but has 3 short, rounded-off, bedrock ridges projecting out into it. These ridges indicate severe glacial abrasion but were probably subjected to it for only a comparatively short period of time. The ice in the basin during
the earlier epoch was likely not much greater than 400 feet in thickness. It extended about 4 miles out from the head, which includes a short distance down Logan Canyon. Small talus slopes cover the base of parts of the canyon walls. On the north side a large rock fall slide has occurred in the Swan Peak quartzite. Typical trenches and ridges are formed by the massive blocks of quartzite which tumbled down into the basin. Near the top of the fall large blocks of dolomite have slid down on top of the quartzite. The dolomite formation probably gave away sometime after the quartzite, breaking down into blocks 30 to 40 feet in diameter.

The ice of the earlier epoch deposited several well-defined morainic ridges near the mouth of the canyon. About one-half mile upstream from the mouth of the canyon, 2 lateral moraines flank either side of the valley. They are approximately 150 to 200 feet above the floor of the canyon and nearly 35 feet above the surrounding surface. Both are of about equal length, being nearly one-half mile. They extend from the 8,100 foot level on the ridges to about the 7,600 foot elevation. The top of the ridges is very irregular and the sides have been cut by numerous rills. The material on the surface of the moraines consists of quartzite and dolomite, with the former predominating. The dolomite fragments showed many cherty nodules as much as one-half inch in relief, but the quartzite fragments indicated no definite characteristics of weathering.

The above-described deposits correspond in age to the material which almost completely chokes the mouth of the canyon and to a small lateral or medial moraine located on the south side of the canyon very near the mouth. The small moraine is very irregular and is cut by
numerous small gullies. Its boundaries are very indistinct. The front of the deposit stands about 100 feet above the floor of Logan Canyon. The material encloses 1 or 2 depressions identified as kettle holes. The drift blocking the mouth, except for a small post-glacial stream channel, consists of irregular, hummocky deposits with large quartzite and dolomite fragments scattered over the surface. The fragments range in size from a few inches to 4 and 5 feet in diameter; however, no dolomite blocks were observed half this size. No striae were seen on the fragments.

Covering the bedrock ridge between Crescent Lake canyon and Steep Hollow is drift material which measures some place 20 feet in depth. Kettle holes are observed throughout the range of the drift, measuring on an average of about 10 feet in depth and 25 feet wide. Blocks of quartzite covering the surface are as large as 9 by 7 by 4 feet. All are subangular in shape but no glacial markings are observed. The drift commences at about the 8,200-foot level on the ridges and continues down to Logan Canyon. The ridge between the 2 canyons indicates a conspicuous rounding off for a short distance above the drift.

The ice of the later glacial epoch was apparently much less active and extensive, removing only the loose material within the basin and the upper canyon. No definite boundaries differentiate the earlier from the later deposits, but it is very probable that the hummocky hillocks on the floor of the canyon represent material carried by the later glacier. Crescent Lake is formed in the ground moraine of this epoch and is dammed off by an irregular deposit of drift about 10 feet high. The length of the ice was apparently 1 mile from the head of the basin.
During the earlier glacial epoch the ice of Crescent Lake Canyon and that of Steep Hollow coalesced near the 8,200-foot level on the ridge and moved as a large glacier down into the main canyon. Steep Hollow apparently furnished the greater quantity of ice, as indicated by the size of the catchment area, the amount of glacial drift, and the relationship of the moraines.

**Upper Spring Hollow (fig. 1, no. 15).** Spring Hollow is the northernmost tributary of the Logan River within the Logan quadrangle. It is located on the west side of the river about three-quarters of a mile south of the Idaho-Utah line. The canyon is a little more than a mile in length and heads back into the 9,000-foot ridge south of Boss Canyon. The north wall of Spring Hollow stands about 500 feet above the floor of the canyon, near the mouth, and the south wall 700 feet above from the same point. The catchment basin is small, including one-half square mile. No well-developed cirque is formed and evidence indicates that the ice was relatively shallow and inactive. There is no lake at the head and the stream in Spring Hollow is intermittent. Swan Peak quartzite of Ordovician age forms the bedrock floor and parts of the walls of the canyon. The formation is nearly horizontal at this place. Above the Swan Peak, in the higher part of the catchment area, are the Fish Haven and Laketown dolomites of Ordovician and Silurian age, respectively.

If the small stream channel in Spring Hollow were filled in, the canyon would have a beautiful, U-shaped, transverse profile throughout its entire length. Only near the mouth of the canyon is the floor cut to any great depth by the stream. This amounts to approximately 15 feet.
at a maximum. The material into which the stream has cut consists of drift, probably representing ground moraine. Near the middle section of the canyon are 2 or more short, rounded-off, quartzite ridges. Markings, which appear to be due to glacial abrasion, are observed in several places on the stubby bedrock spurs.

Near the mouth of Spring Hollow, on the north side of the creek, are 2 small deposits which appear to be lateral moraines. Numerous small gullies have cut the deposits until their exact boundaries are hardly discernable. Both are about the same size, being about 200 feet long and standing nearly 35 feet above the canyon floor. Several kettle holes are formed within the drift, but none is of great size. The coarser material of the drift consists essentially of quartzite and dolomite. Subangular quartzite blocks as large as 15 by 12 by 10 feet were noted. Ground moraine covers a greater part of the valley floor.

The ice generated in Spring Hollow probably advanced only once throughout the length of the canyon, that being during the earlier epoch. The length of the glacier was not less than 1\(\frac{1}{2}\) miles, and it is very probable that the ice coalesced with that of the main canyon and continued some distance. No conclusive evidence could be found to indicate that there had been a second advance of the ice during the later epoch, but it seems reasonable to believe that some ice was formed in the catchment basin during the later stage.

**Boss and White Canyons.** Boss Canyon enters the Logan River Canyon about one-half mile north of the Utah-Idaho boundary line. It is approximately 3\(\frac{1}{2}\) miles in length, heading south into the crest of the Bear River Range. Nearly three-quarters of the catchment basin of Boss
Canyon is located within the Logan quadrangle, the other quarter being in Idaho. The canyon appears to be very symmetrically U-shaped, as observed from the mouth, and relatively wide as compared to the canyons in the northern part of the Logan quadrangle. The cirque descends in a somewhat step-like fashion from the summit of the range to the basin floor. Several small rock basins are located within the cirque.

The drift, deposited by the Boss Canyon glacier, is not shown on the map in this report for the reason that the greater part of the canyon lies within the state of Idaho and therefore beyond the limits of the area discussed in this paper. However, some general observations were made.

Hummocky deposits of drift, as well as several well-defined moraines, can be seen from the mouth of the canyon. These deposits are covered with large fragments of quartzite, dolomite, and a very minor amount of limestone, the former composing about 75 percent. Drift can be traced from this canyon down Logan River canyon for several miles.

About 1 mile further north, White Canyon joins the Logan canyon. It is approximately 4½ miles long and heads into the north part of the Boss Canyon catchment basin. Looking up the canyon, it appears that the 2 basins are connected and that the ice extended out from the head as 2 large tongues, 1 down Boss Canyon and the other down White Canyon. White Canyon also shows a beautiful, symmetrically U-shaped, transverse profile. Large deposits of drift flank either side of the canyon near the mouth, and what appears to be a terminal moraine almost completely blocks off the view of the canyon from the Franklin Basin road.

The general observations made of these 2 canyons and their catchment basins suggest that both contained a great amount of ice which
extended for at least 7 miles out from the cirques during the earlier epoch. This ice extended for nearly 3 miles into Utah, probably coalescing with the Steep Hollow, Crescent Lake and Spring Canyon glaciers. The drift of the second or later epoch is apparently represented by the terminal deposits near the mouth of both canyons.

**Beaver Creek.** Beaver Creek joins the Logan River 2 1/4 miles north of the Tony Grove Ranger Station. The creek drains 18 or more square miles of land in Idaho and many times that much in the northeast section of the Logan quadrangle. The stream flows about the same quantity of water as does the upper Logan River. Beaver Mountain, with an elevation of 8,845 feet above sea level, separates upper Logan River and Beaver Creek.

At the forks of the Garden City road and Beaver Creek, several hummocky deposits are observed on the north. Within these deposits are a number of depressions, some of which suggest kettle holes. Situated on the east side of Beaver Creek and continuing upstream for nearly 1 mile, an irregular ridge is formed. The material covering the surface is largely quartzite. The fragments range in size from a few inches to 2 1/2 feet in diameter. Most of the boulders show 1 or more smooth faces and are mostly subangular in shape. No evidence of glacial markings were observed on the exposed blocks. The ridge stands approximately 50 to 60 feet above Beaver Creek near its middle section. However, on the east side of the ridge there is only about a 15-foot difference between the top and the surrounding land surface. This material on the east appears to be an alluvial fan covering more than 1 square mile. The configuration of the surface suggests that an old
stream channel existed east of the present creek. The quartzite boulders scattered over the surface of the fan are much smaller than those making up the ridge.

It is very probable that the long ridge which parallels Beaver Creek for nearly 1 mile is a lateral moraine formed by ice of the earlier epoch. Also, it is possible that the deposits to the east represent ground moraine which has since been re-worked by the drainage of the area. The configuration of the deposits, the several depressions, and the nature of the material composing them strongly indicates glacial origin. However, it is possible that floods and mud flows might be the source of the material.

Neither Sink Hollow or upper Beaver Creek are typical of a glaciated canyon. Beaver Creek is narrow and definitely V-shaped north of Sink Hollow with many interlocking spurs. Sink Hollow, as far as the Idaho line, is rather U-shaped, but for 1 mile beyond it is very narrow and more V-shaped. Possibly ice moved through this canyon, but evidence within the canyon could not be located.

Logan Canyon. The transverse profile of Logan Canyon, north of Ricks Spring, is that of a broad U-shaped valley. Its floor is relatively flat and only slightly notched by the Logan River. There are few, if any, spurs projecting out into the canyon that have not been truncated. The canyon is quite straight, except for a few smooth curves within a mile north of Ricks Spring. In general the upper section of Logan Canyon is very similar in configuration to its glaciated tributaries on the west.

Evidence of glaciation in upper Logan Canyon is fragmentary, never-
the-less, conclusive. The canyon does not contain a cirque at its head, and there was no ice generated within the upper basin. However, tributaries of the Logan River valley furnished some ice to the main canyon.

Boss Canyon and White Canyon, north of the Utah-Idaho boundary line, apparently supplied Logan Canyon with the greatest amount of ice. The glaciers from these canyons advance more than 3 miles into the main canyon, depositing a number of well-defined moraines along the sides of the valley.

North of Crab Ridge, on the east side of the river, 3 lateral moraines flank the side of the canyon. They are spaced about a half mile apart, the upper moraine being located 1 mile south of the Idaho line. All of the deposits are slightly convex down stream. They range in length from a few hundred feet to nearly a half mile and are approximately 30 feet thick at their upper ends. Corresponding to these moraines are 3 lateral deposits on the opposite side of the river. The larger of the 3 nearly forms a continuation of the south shoulder of upper Spring Hollow. Its length is about one-half mile, and it is approximately 20 feet thick. A hundred feet or more down the canyon are 2 smaller morainic ridges, apparently lateral deposits. Irregular and hummocky deposits of drift cover the low slopes of the canyon and most of the floor. A number of small kettle holes are located within the drift. The material exposed on the surface is largely quartzite with a minor amount of dolomite. The fragments are mostly subangular in shape, some showing smooth faces. No glacial markings were observed. The soil profile is not completely developed over all of the drift.
Crab Ridge produces a narrow constriction in upper Logan Canyon. However, the projecting spur of the ridge is well-truncated and the transverse profile at this place is definitely U-shaped, indicating that ice passed through this section. Quartzite boulders are scattered over the ridge as high as 75 feet above the stream channel.

Approximately three-quarters of a mile south of the mouth of Steep Hollow 2 large morainic deposits flank either side of the Logan River. The deposits are slightly convex downstream. The deposit on the west is quite irregular and is much bulkier than the ridge on the east. The configuration of the 2 deposits suggests terminal moraine. They terminate at about the 7,100 foot elevation, at which place they stand nearly 20 feet above the surrounding surface. Quartzite boulders over 4 feet in diameter were observed on the surface. Numerous erratics cover the floor of the valley between the above-described deposits and Steam Mill Canyon.

Apparently during the earlier ice age the combined glaciers of Boss Canyon, White Canyon, Spring Hollow, Crescent Lake, and Steep Hollow advanced nearly to Steam Mill Canyon. It is possible that the ice continued down to the junction of Logan River and Beaver Creek. Quartzite boulders scattered over the floor of the valley and over the south spur of Beaver Mountain may be a supporting factor.

Between Beaver Creek and Tony Grove Canyon several irregular deposits located on the canyon floor have the appearance of glacial drift; however, conclusive evidence was not obtained.

At the mouth of Twin Creek several irregular ridges, separated by gullies, are seen. The configuration and type of material composing the ridges suggest a terminal moraine. Subangular quartzite, dolomite,
and very friable sandstone fragments are scattered over the surface. The quartzite blocks often show 1 or more smooth faces. No corresponding deposits were formed on the east side of Logan River. Erratics as large as 12 by 9 by 6 feet were observed, but no glacial markings were showing.

Apparently the glacier from Tony Grove Canyon advanced at least 2 miles down Logan Canyon. It is very probable that the above described deposits represent the terminal end of the ice. Several truncated and rounded-out spurs on the west side of Logan River, between the 2 canyons, seem to substantiate this idea.

THE WEST SLOPE OF THE BEAR RIVER RANGE

The ice that formed on the west slope of the range during the glacial epoch was insignificant as compared to the glaciers generated on the east slope. There appears to have been no advance of the ice beyond the catchment basins in which the ice was formed. Several of these basins are located almost opposite to the severely glaciated canyon on the east. The fact that there was no great accumulation of ice on the west is probably to be accounted for by lower altitude of the catchment basins, capable of generating ice, the unfavorable topographic conditions of others, and the fact that the prevailing winds were such as to carry the moisture from the southwest to the eastern side of the range before condensation took place. The latter process occurred as the winds whipped up and over the crest of the mountains.
Smithfield Canyon. Two small cirques are developed in the upper part of Smithfield Canyon, 1 in the south fork and the other at the head. The south fork cirque is approximately 1 mile long and a little more than one-half mile wide. Looking into this basin from the north, a person observes a cup-shaped, amphitheater-like basin. The steep walls on the east and west are flanked with talus, as is also the south or head of the cirque. The west rim stands nearly 1,000 feet above the floor, while the head and the east tower about 1,300 feet above the basin floor. No lake was observed within the cirque.

It appears that the ice moved about 1 mile out from the head of the catchment basin, just beyond the mouth of the cirque. No conspicuous deposits of drift were seen other than a few irregular and hummocky hillocks over the floor. The ice did not reach the main canyon, as is suggested by the many angular interlocking spurs and the fact that the small tributary lacks any sign of having been rounded out by ice. It is very probable that ice formed only during the earlier epoch, and that during the later epoch the basin was occupied by neve and snow.

At the extreme head of Smithfield Canyon is another small basin that appears to have been scoured out by ice. It is not more than one-half mile wide at the mouth, measuring from rim to rim. The high walls, approximately 900 feet high, are flanked by talus. The bottom is covered with loose, subangular material with no definite arrangement. There is no lake or conspicuous depression in the floor. The basin, however, is rounded-out and the low ridges, flanking either side at the mouth, show a marked rounding-off.

From the general appearance of the basin, it apparently contained some ice during the earlier glacial epoch but not sufficient to sculpture
out a characteristic glacial cirque. The ice probably moved but several hundred feet during the course of the epoch, carrying with it only the loose material of pre-glacial origin.

The divide between the head of Smithfield Canyon and the south fork of High Creek is rounded-off but does not suggest ice action. At the upper end of South Fork a small basin or depression is formed in a heterogeneous mass of material in the bottom. However, there was no water in this basin at the time of this field work. Any evidence of ice having occupied this area was not observed.

**Birch Creek.** Birch Creek is located just south of Smithfield Canyon. Near its head the canyon swings abruptly from an east-west direction to the south, where it heads into a somewhat cirque-like basin. It appears that ice occupied this area during the glacial epoch and produced a cup-shaped basin in a general horseshoe figure. The walls of the basin stand above the 9,000 foot elevation and are flanked by high talus slopes. A small lake is located in the floor of the cirque at the head, but contained only a small amount of water. The lake and basin are dammed off by small deposits of drift.

Apparently this basin, like that of the south fork of Smithfield Canyon, contained some ice during the earlier epoch but not sufficient to reach the main canyon or to carve out a typical cirque. The ice did not advance far beyond the mouth of the basin or about three-quarters of a mile out from the head. No definite deposits of drift were observed other than the loose material in the bottom.
LOGAN PEAK AREA

Logan Peak forms one of the highest points in the Logan quadrangle, being 9,713 feet above sea level. From the Utah Agricultural College campus the smooth, rounded-off peak can be seen towering almost 5,000 feet above. It is located just southeast of the college, approximately 4 miles back from the front of the Bear River Range. Several well-marked trails make the Logan Peak area accessible to hikers and horsemen. Probably the most traveled trails are those leading up through Spring Hollow, Providence Canyon, and Millville Canyon, the latter 2 coming in from the south and the former starting from Logan Canyon and coming in from the north.

The Logan Peak area is one of the important water sheds of the Cache National Forest. During a normal year, snow accumulates to depths of 6 and 7 feet on the level. Often drifts may be seen measuring over 25 feet in depth. This snow melts slowly at the higher elevations and thus furnishes a good supply of water to various sections for a good part of the year. Numerous springs in the vicinity unquestionably are fed to a great extent from the water stored around Logan Peak. Several small canyons head directly into Logan Peak, including Dry Canyon on the northwest, Mill Hollow on the north, and Providence Canyon on the south.

In ascending to Logan Peak through Spring Hollow, a beautiful exposure of a part of the Paleozoic section is crossed. Flanking the south side of Logan Canyon at this point is one of the upper terraces of old Lake Bonneville. It stands nearly 200 feet above the level of the river. Adjacent to and above for approximately 1,000 feet lies
the Devonian limestones and shales. Above these lie rocks of Mississippian age, consisting of about 1,000 or more feet of Madison limestone, overlaying by approximately 200 feet of the phosphatic shale zone of the Brazer formation. Topping the shale and continuing to near the level of the lake, at the base of Logan Peak, are several hundred feet of Brazer limestones. The Wells formation, of Pennsylvanian age, forms the cliffs around the lake and continues up to the summit of Logan Peak. The most conspicuous cliffs between the floor of Logan Canyon and Logan Peak are formed from the massive beds of Madison and Brazer limestones.

At the head of Providence Canyon is a small cirque. It is not typical of the more intensively glaciated basins but rather suggests a smaller accumulation of ice which subjected the covered area to only a small degree of ice erosion. The catchment basin is sculptured out of rocks of Pennsylvanian age, consisting essentially of dolomites. The basin measures a little more than a half mile wide and nearly one mile long. Logan Peak stands approximately 1,000 feet above the lake in the floor of the cirque. Bounding the west side of the catchment basin is Providence Peak, with an elevation of 9,588 feet above sea level. These 2 peaks and the high overshadowing wall connecting them acted as a protection to the accumulated snows during the glacial epoch. The east side of the basin is bounded by a ridge about 800 feet above the floor of the canyon; however, this ridge extends only about one-half mile south from Logan Peak.

The upper 2 miles of Providence Canyon, leading into the cirque, is a broad flat-bottomed canyon covered with glacial deposits. Several truncated and rounded-off spurs are observed in this upper section.
Between the 8,600-foot and the 8,700-foot elevation and located at the base of the east slope of Providence Peak is a small lake which apparently was formed by glacial scour. It measures approximately 200 feet long and 80 feet wide and appears at present to be only a few feet deep. The basin, however, in which the lake is located is much larger, and the lake at one time must have been several times as large as at present. At the south end of the basin, forming the dam, is an irregular deposit of morainic material standing about 30 feet above the floor of the basin. The east and west sides of the lake basin is bedrock; however, on the east the bedrock ridge, trending north and south, is covered over with a mantle of drift.

Upstream from the above-described lake is another lake basin. It is located in the small east wing of the cirque near the base of Logan Peak. At the time of this field work, the latter part of July, no water occupied the basin but sufficient evidence was seen to indicate that water had only recently disappeared. Completely surrounding the basin are rounded-off ridges, the lowest one standing nearly 100 feet above the floor. Apparently this lake basin was scoured out by the ice and later occupied by water. However, its present form is that of a sink hole. Post-glacial solution of the underlying rocks has, no doubt, caused a considerable sinking of the floor below the old outlet of the lake.

Extending out from the cirque for a distance of about 2 miles is a U-shaped canyon. The lower half is relatively broad-bottomed as compared to the height of the immediate confining ridges. The shape of the upper section does not suggest severe glacial erosion but more or less a scouring out of the pre-glacial loose material. Apparently the
ice was not more than 400 feet thick and extended but little over 2 miles out from the cirque. Glacial deposits cover a good part of the floor of the canyon. At a point where Providence Canyon swings from the south to the west 2 irregular deposits of drift flank the northwest side. The outermost deposit stands about 60 feet above an adjacent, almost parallel deposit. The higher moraine probably represents a lateral and terminal moraine, while the inner ridge is a recessional moraine. The outer deposit is about 30 feet high and appears to be perched on top of a bedrock ridge. The other ridge is approximately 15 feet above the trail at a point where it turns to the west. On the opposite side of the canyon are 2 small, lateral moraines. The lower one, commencing at about the 8,500 foot level and continuing upstream for about three-eighths of a mile, is convex downstream and probably represents a part of a terminal deposit. It is about 15 feet high at the lower end and about 45 feet in height at the upper. Immediately east and slightly overlapping the above moraine is another deposit. This is a lateral moraine about one-half mile long and approximately 30 feet in height. The top is very irregular and is cut by numerous small gullies.

Between the lateral deposits, flanking either side of the canyon, are several smaller, irregular, and hummocky deposits. Near the lower end of the glaciated section the floor is completely covered with hilllocks, which suggests that the ice terminated at that point. However, working upstream about one-half mile, the floor of the canyon again becomes quite free of such deposits, except a small amount of ground moraine.
All of the above-described deposits are composed of material of the same nature. The predominating fragments are dolomite and limestone, with a minor amount of sandstone. The fragments range in size from 1 to 3 feet in diameter and are subangular in shape. No evidence of glacial striae or markings were observed either on the bedrock ridges or the scattered fragments. There is no apparent difference in the amount of weathering or the growth of the vegetation on the deposits to suggest any difference in age. It appears that the drift represents only 1 glacial epoch or movement of the ice, that being the earlier epoch.

A number of depressions are located within the deposits mentioned. Several were definitely identified as kettle holes, while others appeared to be sink holes or a combination of the two. The drift covering the surface of the depressions complicated the problem. The fact that some of the depressions appeared to be deeper than the surrounding glacial drift led the writer to conclude that they were either sinks or a combination of kettle hole and sink hole.

**Spring Hollow.** One-half mile above the Logan City power dam a small steep canyon enters Logan Canyon known as Spring Hollow. It is about 2 miles long and heads into a cirque-like basin with high towering cliffs. The summit at the head is at an elevation of 8,910 feet above sea level. The Brazer formation forms the high cliffs and range in height from a few hundred feet to 1,000 feet. At the base of the cliff and extending nearly a mile down canyon is an incoherent mass of rock, covered only in spots with a thin mantle of soil. The configuration of the mass is typical of a great rock fall with jagged
trenches and ridges. Within the basin and completely enclosed by loose rock are several depressions. The largest of these appears to be a sink hole and at the time of this field work contained a very small amount of water. The other depressions were dry, with rock bottoms.

Although the cirque-like basin at the head may be suggestive of ice sculpturing, no direct evidence of a glacier was observed.
Within the Logan quadrangle the positions of 3 Pleistocene glaciers exceeding 5 miles in length, 2 glaciers 3 or more miles in length, and 10 exceeding 1 1/2 miles in length were determined. Of the 15 glaciers, generated in the western tributaries of the Logan Canyon, 7 reached the main canyon. At least 6 of the 7 glaciers continued some distance down Logan Canyon.

On the west side of the Front Ridge of the Bear River Range only 3 small cirques are present. The glaciers generated in them moved but a very short distance, hardly out of their respective basins.

The glaciers on the east slope of the Front Ridge descended to altitudes as low as 6,100 feet above sea level, while the small bodies of ice on the west hardly reached the 7,000-foot elevation. The White Pine glacier was apparently the largest body of ice in the area. The ice from this canyon was over 6 miles in length, and the drift along the Logan River, at the mouth of the canyon, suggests that it had a lateral spread of nearly 2 miles. Drift, deposited by the White Pine glacier, is also located on the east side of the Logan River. The next largest body of ice was that generated at the head of Tony Grove Canyon. This glacier extended beyond the mouth of Tony Grove Canyon into Logan Canyon for nearly 2 miles before wasting away.

Logan Peak, located about 12 miles south of Tony Grove Canyon along the crest of the Bear River Range, contains the southern-most evidence of glaciation in the area considered in this report. Logan Peak is located at the head of Providence Canyon and has an elevation of 9,713 feet. Into its southeast slope is sculptured a small cirque, wherein the Providence Canyon glacier was formed. The glacier advanced
about 2 miles out from the head of the catchment basin to an elevation of about 8,100 feet. Providence Peak forms the high protecting wall on the west of the cirque.

Most of the basins in which glaciers were formed are above the 8,500 foot elevation. In 3 of the catchment basins sufficient ice was formed to extend beyond the basin walls into adjacent canyons. The depth of the ice in the larger cirques was probably not less than 500 feet.

The catchment basins on the east side of the Front Ridge are larger and are situated at higher elevations than the basins on the west. In addition to greater size and elevation, the eastern basins are more favorably located in relation to the high peaks of the area and to the prevailing winds in this section. The prevailing winds, being from the southwest, would have whipped up and over the crest of the range, depositing and precipitating their load on the east.

**Topographic Features of the Glaciated Region.** Lakes are located within the cirques of most of the glaciated canyons in the Logan quadrangle. These lakes are the result of glacial action, either by the ice scouring out a basin in the underlying bedrock or by morainal dams blocking off the drainage, or both. The lakes are small, ranging from 40 to about 500 feet in length, 40 to 200 feet wide, and from 2 to 30 feet deep. Some of the smaller basins are intermittently filled with water, while others retain their full capacity of water the year around. The drainage of the area has been changed but slightly by the advancing ice. Several small streams have been diverted somewhat from their original courses by moraines. Most of the canyons occupied by
ice are typically U-shaped. Some have been notched by subsequent drainage, but not to any great depth. Those canyons in which the ice advanced only a short distance show a striking contrast in transverse profile -- the glaciated section with its U-shaped and the lower stream with a V-shape.

Most of the glaciated valleys are flanked by lateral moraines, especially near their mouths. Some of these deposits are located on top of the canyon walls or ridges, while others parallel the ridges near the base. The floors of most of the canyons are covered with ground moraine. Some recessional moraines almost cross the valleys, as irregular and hummocky ridges curving downstream. Terminal moraines are located near the mouth of some of the canyons, almost blocking the valleys off. The terminal moraine of White Pine is the most conspicuous in this respect.

The glaciated canyons have been somewhat straightened out by the erosional effects of the ice. The interlocking spurs, of the pre-glacial canyons, have been truncated and rounded off. The sharp bends in the valleys have been carved into long rounding curves. In a number of places the confining ridges of the valleys have been notably rounded-off by the overflow of the ice.

**Influence of Glaciation on Drainage.** Glacial lakes and marshes, located in the catchment basins, indicate that the drainage of the glaciated area has been somewhat modified by the ice. There are 6 lakes in the area, gouged out by ice or dammed off by morainic material, that apparently contain water the entire year. Several small basins, containing intermittent lakes, are likewise located near the upper ends of
the glaciated canyons. Most of the lakes are less than 400 feet in length and vary in depth from a few feet to 30 feet. Marshes are located above and below some of the lakes. In some canyons the consequent streams have been diverted by morainic material and have apparently assumed new courses.

It is very probable that the direct run-off on the east slope has been materially reduced in the glaciated area and that the delayed run-off has been increased. The drift in this area does not appear sufficiently compact to prevent the precipitation from seeping into it readily. Also important in this respect is the fact that most of the drift supports a luxuriant growth of vegetation, which would itself retard rapid run-off. The water seeping into this incoherent material later issues forth as springs at lower elevations.

**Glacial Epochs.** In the preceding description of the phenomena of glaciation in the canyons, certain deposits of drift have been referred to as either of the earlier or later glacial epochs. The means by which the 2 epochs of glaciation were determined in the Logan quadrangle are primarily based upon the following observations: (See figure 2.)

1. There appears, within a relatively short distance out from the catchment basins of White Pine and Tony Grove canyons, a distinct set of moraines bordered by a system of widespread deposits.

2. That the inner lateral moraines are at least 200 feet lower in elevation than the outer lateral moraines which parallel them in several of the canyons.

3. The bulk of the outer deposits, with a lateral spread of nearly 2 miles in White Pine and Tony Grove canyons, is many times greater than
that of the deposits located within the walls of these canyons.

4. In Bunchgrass Canyon, what are considered terminal moraines appear about 2 miles apart.

5. The widespread deposits are noticeably cut by a greater number of gullies.

6. In White Pine Canyon, located on the north side in the upper section, material has been removed from the outer moraines in such a way as to suggest ice erosion.

7. Over many of the outer moraines the quartzite fragments showed a marked degree of fracturing.

Many of the widespread deposits were covered with a more luxuriant growth of shrubs and trees; however, this did not exist throughout the glaciated area and was thus not considered a means of differentiating the material.

Samples of drift, taken from deposits in the upper part of White Pine Canyon and from the widespread material beyond the canyon walls, revealed no conspicuous difference in type of material or in the amount of weathering, as observed under the microscope. The coarser fragments, consisting of quartzite, dolomite, and some limestone, likewise showed no conclusive evidence of weathering by which a definite differentiation could be made in age. The dolomite fragments of the ground moraine contained cherty nodules as much as one-half inch in relief in various places, but this same observation was also true on the fragments beyond the mouth of some of the canyons in the drift material. The fact that most of the coarser material of the drift consisted of quartzite of a very resistant nature complicated the problem.
Correlation of the Glacial Epochs with Other Glaciated Areas.

There is no doubt a close correlation of the growth and decay of the glaciers in the Bear River Range in northern Utah and those of the Wasatch Mountains, southeast of Salt Lake City. Wallace W. Atwood (1) who made a detailed study of the glaciation of a section of the Wasatch Mountains, states in his report: "It is certain that there were at least two ice epochs separated by a long interglacial interval. Evidence of more than two epochs was not found." He lists as one point of evidence "...the moraines of the earlier epoch are more extensive and much more bulky than the moraines of the later epoch." This one point is particularly analogous to the relationship between outer and inner deposits located within this reported section. Also, there was no evidence found in this portion of the Bear River Range to suggest a third glacial epoch. Other investigations made in the Utah-Nevada region are similar. King (11) suggests a relation between the 2 periods of humidity recorded in lacustrine beds and the 2 glacial epochs. King writes: "The first long-continued period of humidity is probably to be directly correlated with the earliest and greatest glacier period, and the second period of humidity with the later Reindeer Glacier period."

G. K. Gilbert, in his report on Lake Bonneville, states: (10) "...the Pleistocene lakes of the western United States were coincident with the Pleistocene glaciers of the same district and were produced by the same climatic changes." Further: "It follows as a corollary that the glacial history of this region was bipartite, two maxima of glaciation being separated, not by a mere variation in intensity, but by a cessation of glaciation." Therefore, it seems very reasonable to assume that the same climatic conditions that governed the growth and decay of
the glaciers in the Wasatch Range also favored the growth and decay of the bodies of ice in the Bear River Range within the Logan quadrangle, and furthermore, that the climatic elements that favored the growth of the old Lake Bonneville also favored the growth of the glaciers in this section as well as in other basin ranges.

There is only a very indirect correlation of the glacial stages in this section of the Bear River Range with the standard section of the United States. Such a correlation is possible only by means of analogy with other glaciated regions. Blackwelder (5), who studied the moraines and shore features along the Weber River in Utah, concluded that Gilbert's 2 glacial and high-water lake stages -- the first and the second Bonneville epochs -- may be correlated with the 2 youngest stages of glaciation in the Uinta and Wind River Ranges. Furthermore, he suggests that these 2 youngest stages of glaciation may be the respective equivalents of the Wisconsin and Iowan stages of the standard section. By such an analogy it is then possible that the earlier and later epochs of glaciation in this section of the Bear River Range are the equivalents of the Iowan and Wisconsin stages. (See table 2, p. 78.)
Table 2. Summary of tentative correlation of glacial stages in Utah, Nevada and Wyoming

<table>
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<th>Standard section</th>
<th>(Blackwelder) Sierra Nevada</th>
<th>(Blackwelder) Wind River Wyoming</th>
<th>(Bradley) Uinta Mts.</th>
<th>(Atwood) Central Wasatch</th>
<th>Front Ridge Logan Quadrangle</th>
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<td>Pinedale</td>
<td>Smith Fork</td>
<td>&quot;Younger&quot;</td>
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<td>Tahoe</td>
<td>Bull Lake</td>
<td>Blacks Fork</td>
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