Structural Geology of Eastern Part of the Smithfield Quadrangle, Utah

Cheryl Leora Galloway
Utah State University

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STRUCTURAL GEOLOGY OF EASTERN PART OF THE
SMITHFIELD QUADRANGLE, UTAH

by

Cheryl Leora Galloway

A thesis submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

in

Geology

Approved:

Major Professor

Committee Member

Committee Member

Dean of Graduate Studies

UTAH STATE UNIVERSITY
Logan, Utah

1970
ACKNOWLEDGMENTS

The writer wishes to acknowledge the technical assistance received from the staff of the Department of Geology of Utah State University. Appreciation is expressed particularly to Dr. Clyde T. Hardy, Dr. Robert Q. Oaks, Jr., and Dr. J. Stewart Williams.

The writer also wishes to thank her parents for financial support provided during graduate studies.

Cheryl Leora Galloway
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ABSTRACT

Structural Geology of Eastern Part of the
Smithfield Quadrangle, Utah

by

Cheryl Leora Galloway, Master of Science
Utah State University, 1970

Major Professor: Dr. Clyde T. Hardy
Department: Geology

The mapped area represents the eastern three-fourths of the
Smithfield quadrangle, Utah. This quadrangle is located in the
central part of northern Utah about 8.6 miles south of the Utah-
Idaho State Line. The Bear River Range, along the eastern margin of
the quadrangle, consists of stratigraphic units ranging in age from
Precambrian to Devonian. The Salt Lake Formation of Tertiary age
rests unconformably on Precambrian quartzite and Paleozoic units
along the western side of the range. The Lake Bonneville Group overlaps Cambrian rocks in the southern part of the area and overlaps the
Salt Lake Formation in the northern part.

The Paleozoic rocks of the mapped area dip generally east on the
western limb of the Logan Peak syncline. The east-dipping beds of
the western limb, along the mountain front, are broken by east-dipping
bedding-plane faults and by west-dipping high-angle and low-angle
thrust faults. A prominent west-dipping surface probably formed as
a thrust fault; however, later westward sliding took place on this
surface. The bedding-plane faults are interpreted to have formed by
eastward sliding of the mountain mass. Progressive local deformation,
on the western limb of the Logan Peak syncline, produced high-angle and low-angle thrust faults successively. The folding and thrust faulting are related to the Laramide orogeny and occurred during the Cretaceous Period and the early part of the Tertiary Period.

Numerous gravity faults extend along the western front of the Bear River Range. The relative collapse of Cache Valley, early in the Tertiary Period, produced great topographic relief. This resulted in slope instability and, as a consequence, large masses moved down the west-dipping surface and two major landslides occurred. The landslides seem to have moved over the lower member of the Salt Lake Formation and seem to have been covered by conglomerate of the upper member. Gravity faulting has continued to the present time.

(126 pages)
INTRODUCTION

Purpose and Scope

The purpose of this investigation is to provide a detailed representation of the structural features of a limited area in the central part of northern Utah. Geologic mapping was accomplished in greater detail than heretofore (Plates 1 and 2). Improved understanding of the sequence of structural events is the principal result.

Location and Accessibility

The mapped area, located in the central part of northern Utah, represents approximately the eastern three-fourths of the Smithfield quadrangle, Utah. The Smithfield quadrangle is a 7.5-minute topographic map published by the Geological Survey of the United States Department of Interior (Figure 1). The northern boundary of the mapped area is about 8.6 miles south of the Utah-Idaho State Line. The area is 8.7 miles long in the north-south direction and 4.6 miles wide in the east-west direction.

Areas of critical geologic importance are readily accessible. All of the major canyons have roads or trails which can be reached from U. S. Highway 91.

Physiographic Features

The mapped area includes part of Cache Valley on the west and the Bear River Range on the east (Figure 1). It is located along the
Figure 1. Index map of central part of northern Utah showing location of Smithfield quadrangle.
central part of the eastern margin of Cache Valley. Cache Valley trends north-south and is about 50 miles long and 10 miles wide. It is bordered on the southwest by the northern part of the Wasatch Range, on the northwest by the Malad Range and the southern part of the Bannock Range, and on the east by the Bear River Range. The lowest elevation of Cache Valley, located in the west-central part, is about 4,417 feet; Naomi Peak, in the Bear River Range, has an elevation of 9,980 feet. Within the Smithfield quadrangle, the mountains rise above the valley as much as 3,000 feet.

Field Work

Field investigations were conducted during the summer and fall of 1967. Geologic features were mapped in the field, on aerial photographs, and the information was later transferred to a topographic base at a scale of 1:12,000.

Stratigraphic units were measured by means of a steel tape and a Brunton compass. Representative samples were collected for laboratory description. Rock colors were determined by using the Rock-Color Chart distributed by The Geological Society of America.

Previous Investigations

The first detailed investigation of features of the Smithfield quadrangle, Utah, was made by Bailey (1927a, 1927b). The next report was a ground-water study of Cache Valley (Peterson, 1946, p. 11-15). A generalized geologic map including the Smithfield quadrangle was published by Williams (1948, Plate 1). Ross (1951, p. 21-36) described the
Garden City and Swan Peak Formations of Green Canyon. Haynie (1957, p. 12-14) examined the Worm Creek Member of the St. Charles Formation in Green Canyon. The latest known investigation of particular significance was a study of the deposits of Lake Bonneville by Williams (1962).
STRATIGRAPHIC UNITS

General Statement

The mountains of the Bear River Range, along the eastern margin of the Smithfield quadrangle, consist of stratigraphic units ranging in age from Precambrian to Devonian (Table 1). The Salt Lake Formation of Tertiary age forms the foothills in the northern part of the mapped area. It rests unconformably on Precambrian quartzite and Paleozoic units. Undifferentiated units of the Lake Bonneville Group overlap Cambrian rocks along the mountain front in the southern part of the area, and they also overlap the Salt Lake Formation in the northern part.

Younger Paleozoic and Mesozoic formations were removed from the area of the Smithfield quadrangle before deposition of the Salt Lake Formation of Tertiary age. This erosion also preceded deposition of the Wasatch Formation of probable Eocene age; however, the Wasatch is not present in the mapped area.

Precambrian Rocks

Precambrian quartzite

The oldest stratigraphic unit exposed in the mapped area is identified as Precambrian quartzite. It seems to correlate with the lower part of the Precambrian-Cambrian section northeast of Huntsville, Utah (Crittenden, 1967, p. 413). The Precambrian quartzite underlies a unit, characterized by purple quartzite, that is regarded as the Mutual Formation in the Huntsville area (Crittenden, 1967, p. 413).
Table 1. Stratigraphic units of Precambrian and Paleozoic age, eastern part of the Smithfield quadrangle and vicinity

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<tr>
<td>Water Canyon Formation</td>
<td>Sandy dolomite and sandstone</td>
<td>606(^a)</td>
</tr>
<tr>
<td></td>
<td>Clayey dolomite</td>
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<td><strong>Silurian System</strong></td>
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<tr>
<td>Laketown Formation</td>
<td>Light-gray and dark-gray dolomite</td>
<td>1,459(^b)</td>
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<td><strong>Ordovician System</strong></td>
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<tr>
<td>Fish Haven Formation</td>
<td>Dark-gray dolomite</td>
<td>140(^c)</td>
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<td></td>
<td>White quartzite</td>
<td>401(^d)</td>
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<td>Swan Peak Formation</td>
<td>Purple quartzite</td>
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<td></td>
<td>Quartzite and shale</td>
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<tr>
<td></td>
<td>Shale, siltstone, and limestone</td>
<td></td>
</tr>
<tr>
<td>Garden City Formation</td>
<td>Cherty dolomite</td>
<td>1,405(^c)</td>
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<td></td>
<td>Cherty limestone</td>
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<td></td>
<td>Limestone with intraformational breccia</td>
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<td>Limestone and dolomite</td>
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<td></td>
<td>Green shale</td>
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<tr>
<td>Ute Formation</td>
<td>Limestone and green shale</td>
<td>745(^f)</td>
</tr>
<tr>
<td>Langston Formation</td>
<td>Dolomite</td>
<td>360(^f)</td>
</tr>
<tr>
<td></td>
<td>Limestone</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Brown and gray shale</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Limestone and siltstone</td>
<td>2,549(^g)</td>
</tr>
<tr>
<td>Brigham Formation</td>
<td>Quartzite and shale</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Quartzite</td>
<td></td>
</tr>
<tr>
<td><strong>Precambrian rocks</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mutual Formation</td>
<td>Purple and white quartzite</td>
<td>336(^g)</td>
</tr>
<tr>
<td>Precambrian quartzite</td>
<td>Quartzite and shale</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\)Logan Canyon (Taylor, 1963).  \(^b\)Logan Canyon (Budge, 1966).  \(^c\)Green Canyon (Williams, 1948).  \(^d\)Green Canyon (this report).  \(^e\)High Creek (Maxey, 1941).  \(^f\)High Creek (Maxey, 1958).  \(^g\)Birch Canyon (this report).
In the Smithfield quadrangle, the unit mapped as Precambrian quartzite underlies the Mutual Formation in Birch and Smithfield Canyons. It also rests on two west-dipping thrust faults along the mountain front from the northern side of Hyde Park Canyon to the northern boundary of the quadrangle.

The Precambrian quartzite seems to be conformable with the overlying Mutual Formation. The exposed thickness may be 1,500 to 2,000 feet; however, this estimate is uncertain because of intense folding and thrust faulting.

In Birch and Smithfield Canyons, the Precambrian quartzite that underlies the Mutual Formation is grayish orange and weathers moderate yellowish-brown. The Precambrian quartzite above the westernmost thrust fault contains basalt flows in Dry Canyon and in Birch Canyon. In Dry Canyon, the lower basalt flow crops out on the northern side of the canyon at the contact with the overlying Salt Lake Formation. The exposed thickness of basalt is 10-20 feet. The upper flow, also 10-20 feet thick, lies about 100 feet higher in the section and is clearly interbedded with the quartzite. A basalt flow is also present on the northern side of Birch Canyon near the top of the ridge. It is covered unconformably by the Salt Lake Formation on its western side. The exposed thickness is only a few feet. The quartzite, stratigraphically above the flow in Birch Canyon, is white, gray, pink, and brown. It contains abundant pebbles in many places. Red, green, and gray to lavender argillite is interbedded with this quartzite.

**Mutual Formation**

A stratigraphic unit, characterized by purple quartzite, overlies...
the Precambrian quartzite and underlies the Brigham Formation of Cambrian age. This unit is presumably of Precambrian age and is correlated with the Mutual Formation of the Huntsville section (Crittenden, 1967, p. 414; personal communication). The Mutual Formation near Huntsville, Utah, as described by Crittenden (1967, p. 413), consists of 800–2,500 feet of quartzite and argillite. The lower part contains thin-bedded siltstone, argillite, and thin-bedded quartzite. The lower half of the lower part is olive to pale green; the upper half is dominantly purple. The upper part consists of coarse-grained grayish-purple to pale-purple and pink quartzite. It contains pebbles locally and displays cross-bedding in many places.

The Mutual Formation is present in Birch and Smithfield Canyons. On the south side of Birch Canyon, the unit identified as Precambrian quartzite is thrust over the lower part of the Brigham. Thus, the Mutual Formation, as well as the underlying Precambrian quartzite, is terminated by a thrust fault.

The Mutual Formation, in the mapped area, seems to be conformable with the underlying Precambrian quartzite and the overlying Brigham Formation. Basalt and argillite are not found at the top of the Mutual as in the area north of Huntsville, Utah (Crittenden, 1967, p. 413). In Birch Canyon, the Mutual is 336 feet thick (Appendix, Section 1).

In Birch Canyon, the Mutual Formation consists mostly of quartzite that is pinkish gray, grayish orange pink, and pale red purple. The quartzite of the Mutual does not contain feldspar. Pebbles of white, pink, and gray quartzite, as well as jasper, are relatively abundant in the Mutual. These characteristics, together with the presence of purple quartzite, seem to distinguish the Mutual from the overlying Brigham.
Cambrian System

Brigham Formation

The Brigham Formation was mapped in the area of the Smithfield quadrangle by Williams (1948, Plate 1); however, he did not recognize underlying units of Precambrian age. A gradational unit of interbedded shale and quartzite is present at the top of the Brigham (Williams, 1948, p. 1132). The Langston Formation, of earliest Middle Cambrian age, overlies the Brigham (Maxey, 1958, p. 667). The Brigham, in large part, is probably of Early Cambrian age; however, it may be Precambrian in the lower part.

The Brigham, in the mapped area, is conformable with the underlying Mutual Formation. It is gradational upward into the Langston Formation. In Birch Canyon, the Brigham is 2,549 feet thick (Appendix, Section 2).

In the mapped area, the Brigham Formation was measured on the ridge between Birch and Smithfield Canyons where exposures are excellent. It consists mostly of quartzite that is pink, orange, brown, purple, and gray. The quartzite generally weathers yellowish brown. Yellow-brown shale, as well as some yellow-brown sandstone, is interbedded with the quartzite. Interbedded shale is especially abundant near the top of the formation.

The Brigham contains abundant particles of limonite which formed by the weathering of hematite. As a result, much of the quartzite is yellow-brown on weathered surfaces. Flakes of muscovite are common in shale and sandstone in the upper part of the Brigham (Appendix, Section 2, units 11-12, 14, 17). The upper part of the Brigham contains notable amounts of feldspar particles in places (Appendix, Section 2,
units 9-11, 13). A red-purple quartzite (Appendix, Section 2, unit 9) contains up to 15 percent feldspar; however, another purple unit (Appendix, Section 2, unit 14) has no obvious feldspar. Biotite flakes are present rarely.

**Langston Formation**

The Langston Formation was mapped by Williams (1948, Plate 1) in the Smithfield quadrangle. Later, Maxey (1958, p. 654-655) measured a section at High Creek, north of Richmond, Utah. He recognized three successively younger members: (1) Naomi Peak Limestone Member, (2) Spence Shale Member, and (3) upper member. The Naomi Peak Limestone Member, 32 feet thick, consists of calcareous sandstone at the base and interbedded limestone and shale above. The Spence Shale Member, 192 feet thick, consists of a lower moderate-brown shale with limestone lenses and an upper light-olive-gray shale. The Spence contains abundant trilobites. The upper member, 260 feet thick, consists of dark-gray limestone at the base, dolomite which weathers light brown, and dark-gray limestone at the top. The total thickness of the Langston is 484 feet.

In the Smithfield quadrangle, the Langston Formation is 360 feet thick on the ridge between Birch and Smithfield Canyons (Appendix, Section 3). It conformably overlies the Brigham Formation as shown by a gradual change upward from detrital to carbonate rock. The Langston also seems to be conformable with the overlying Ute Formation.

The Langston Formation (Maxey, 1958, p. 671) is of Middle Cambrian age (Albertan Series).
Ute Formation

The Ute Formation, at High Creek, was measured by Maxey (1958, p. 653-654). It consists of alternating thin-bedded medium-gray limestone and dusky-yellow shale except for the basal part, which is interbedded sandstone and limestone. The total thickness at High Creek is 745 feet. The Ute seems to be conformable with the Langston Formation below and the Blacksmith Formation above.

The Ute Formation was not measured in the Smithfield quadrangle; however, it is present from Hyde Park Canyon northward. The basal part of the Ute is shale and forms a covered slope in contrast to the dolomite ledges of the Langston below. The upper contact, in Hyde Park Canyon, was placed at the top of a massive-bedded unit of white limestone, 5-10 feet thick, and at the base of the dolomite of the Blacksmith Formation.

The Ute Formation (Maxey, 1958, p. 672) is of Middle Cambrian age (Albertan Series).

Blacksmith Formation

The Blacksmith Formation was measured by Maxey (1958, p. 653) at High Creek. It consists of 345 feet of variegated gray and dark-gray to medium-gray dolomite in the lower part, 60 feet of dark-bluish-gray limestone in the middle, and 80 feet of thick-bedded light-gray dolomite above. The Blacksmith, at High Creek, is 485 feet thick. It seems to be conformable with the Ute below and the Bloomington Formation above.

In the Smithfield quadrangle, the Blacksmith is exposed mainly north of Hyde Park Canyon. It is mostly light- to medium-gray dolomite.
The dolomite weathers light gray and the weathered surface is characterized by a sandy aspect.

Fossils have not been found in the Blacksmith; however, the overlying Bloomington Formation is of Middle Cambrian age (Albertan Series). Therefore, the Blacksmith is also considered to be of Middle Cambrian age (Maxey, 1958, p. 672).

**Bloomington Formation**

Williams (1948, p. 1133-1134) recognized the Bloomington Formation in the Smithfield quadrangle. Maxey (1958, p. 651-653) identified three successively younger members at High Creek as follows: (1) Hodges Shale Member, (2) limestone member, and (3) Call's Fort Shale Member. The Hodges Shale Member, 595 feet thick, consists of gray limestone and green shale. The middle member, 720 feet thick, is medium-gray and dark-gray limestone. The upper Call's Fort Shale Member, 180 feet thick, is gray limestone and olive-brown shale. The Bloomington is 1,495 feet thick at High Creek. It seems to be conformable with the underlying Blacksmith and the overlying Nounan Formation.

The Bloomington Formation of the Smithfield quadrangle is well exposed on the first ridge south of Hyde Park Canyon. There, the section is similar to that of High Creek and consists of three successively younger members as follows: (1) yellow-green shale, the Hodges Shale Member, (2) medium-gray limestone, and (3) interbedded limestone and shale. South of Beef Hollow, the upper part of the Bloomington contains some dolomite. The estimated thickness of the Bloomington at Hyde Park Canyon is 1,500 feet. The Bloomington Formation is intensely deformed near the mountain front.
The Bloomington Formation (Maxey, 1958, p. 673) is of late Middle Cambrian age (Albertan Series).

**Nounan Formation**

Williams (1948, Plate 1) also mapped the Nounan Formation in the Smithfield quadrangle. Maxey (1941, p. 28-31) recognized a lower dolomite and an upper limestone in the Nounan at High Creek. The lower part is mainly light-gray and medium-gray dolomite and is about 735 feet thick. The upper part is thin-bedded gray limestone and is about 390 feet thick. Interbedded sandstone is present near the top. The total thickness of the Nounan at High Creek is 1,125 feet. It is evidently conformable with the underlying Bloomington and is gradational with the overlying Worm Creek Member of the St. Charles Formation.

In the Smithfield quadrangle, the Nounan consists of light-gray and medium-gray dolomite which weathers light gray. Limestone is not present in the upper part of the formation as reported by Maxey at High Creek. The upper part of the Nounan is sandy and grades into the overlying Worm Creek Member of the St. Charles Formation. A distinctive bed of coarse-crystalline white dolomite, 5-20 feet thick, occurs within 20 feet of the top of the formation.

The Nounan (Williams, 1948, p. 1134) is of Late Cambrian age (Croixian Series).

**St. Charles Formation--Worm Creek Member**

The basal Worm Creek Member of the St. Charles Formation was noted in the Smithfield quadrangle by Williams (1948, p. 1134-1135) and was studied by Haynie (1957) in northern Utah and southern Idaho. In Green
Canyon, in the southern part of the Smithfield quadrangle, Haynie (1957, p. 14) recognized five successively younger units in the Worm Creek:
(1) gray quartzite, 6 feet thick, (2) light-gray sandy limestone, 4 feet thick, (3) gray quartzite, 1 foot thick, (4) light-gray sandy dolomite, 80 feet thick, and (5) coarse-crystalline light-gray sandy dolomite, 29 feet thick. The Worm Creek Member is gradational with the underlying Nounan Formation. In Green Canyon, it is 120 feet thick.

The Worm Creek Member of the St. Charles Formation (Williams, 1948, p. 1134-1135) is of Late Cambrian age (Croixian Series).

St. Charles Formation--upper member

Williams (1948, Plate 1) mapped the upper part of the St. Charles Formation in the Smithfield quadrangle. Maxey (1941, p. 26-27) reported lithologic details of the upper member with reference to High Creek. It consists mainly of medium-gray dolomite. Maxey reported a total thickness of 1,015 feet for the St. Charles at High Creek. If the thickness given by Haynie (1957, p. 14) for the Worm Creek in Green Canyon is accepted, the upper member is about 900 feet thick in the Smithfield quadrangle.

In the Smithfield quadrangle, the upper member of the St. Charles Formation consists of thin-bedded limestone at the base followed by massive-bedded light-gray and dark-gray dolomite. The limestone is about 10 feet thick at Green Canyon and thickens northward. It is not found south of Green Canyon probably because of structural thinning. The upper member is gradational with the underlying Worm Creek Member and seems to be conformable with the overlying Garden City Formation of Ordovician age.
The upper member of the St. Charles Formation (Williams, 1948, p. 1134-1135) is of Late Cambrian age (Croixian Series).

Ordovician System

Garden City Formation

Ross (1951, p. 21-22) divided the Garden City Formation into two members: (1) lower limestone characterized by intraformational conglomerate, and (2) upper cherty limestone. The lower member is 1,039 feet thick in Green Canyon and consists of intraformational conglomerate, muddy limestone, and crystalline limestone. The upper member, 366 feet thick in Green Canyon, is mostly limestone with nodules and stringers of black chert. The Garden City may rest disconformably on the St. Charles; it is conformable with the overlying Swan Peak. In Green Canyon, it is 1,405 feet thick.

The members of the Garden City, recognized by Ross, are present throughout the Smithfield quadrangle. The lower member consists of muddy limestone, crystalline limestone, and intraformational conglomerate. The upper member is divided into two parts: (1) lower dark-gray limestone with black chert, and (2) upper limestone or dolomite with a decreasing amount of black chert toward the top. The uppermost part of the Garden City is dolomite between Green and Logan Canyons and in places north of Green Canyon.

The Garden City Formation (Ross, 1951, p. 31) is of Early and Middle Ordovician age (Canadian and Champlainian Series).

Swan Peak Formation

Williams (1948, p. 1136-1137) measured the Swan Peak Formation on
the southern side of Green Canyon, in the southeastern part of the
Smithfield quadrangle, and recognized three members. Ross (1951, p. 21)
also examined the Swan Peak in Green Canyon.

The Swan Peak Formation, in Green Canyon (Appendix, Section 4), may
be divided into four successively younger units as follows: (1) lower
unit, 226 feet thick, which consists of olive-gray shale and quartzitic
siltstone in the lower part, medium-gray limestone and dark-gray shale
in the middle part, and a covered interval, (2) gray quartzite and shale,
24 feet thick, (3) red-purple quartzite and shale, 39 feet thick, and
(4) light-gray quartzite which weathers pinkish and yellowish gray,
111 feet thick. The total thickness in Green Canyon is 401 feet. This
is about 100 feet more than Ross (1951, p. 21) reported due to the fact
that he evidently did not include all of the interbedded limestone and
shale at the base.

The Swan Peak Formation thins southward for stratigraphic reasons;
however, the observed thickness becomes less toward the mountain front
in the area south of Green Canyon. There are also marked changes in
thickness along the outcrop between Green Canyon and Logan Canyon. On
the northern side of Logan Canyon, the Swan Peak is 283 feet thick
(Appendix, Section 5). Most of this reduction is at the expense of the
basal unit characterized by shale and is attributed to obscure bedding-
plane faults.

The Swan Peak is conformable with the underlying Garden City
Formation; however, the overlying Fish Haven Formation seems to rest
unconformably on the Swan Peak (Ross, 1951, p. 21, 37). In places,
detailed evidence indicates a structural relationship between the
Swan Peak and Fish Haven. On the northern side of Green Canyon, a thin layer of breccia of the Fish Haven Formation rests on a sandstone bed at the top of the Swan Peak. The brecciated bed is medium-crystalline grayish-orange dolomite which contains small angular fragments of dark-gray dolomite of the Fish Haven. On the southern side of Green Canyon, large calcite crystals are present at the base of the Fish Haven. Evidently this brecciation and recrystallization of the lowermost part of the Fish Haven occurred as it slid over the Swan Peak Formation.

The Swan Peak Formation (Ross, 1951, p. 31) is of Middle Ordovician age (Champlainian Series).

Fish Haven Formation

Williams (1948, p. 1137) described the Fish Haven Formation of the Smithfield quadrangle as a thick-bedded, medium-crystalline, dark-gray dolomite. In Green Canyon, it is about 140 feet thick as defined by Williams.

The Fish Haven thins toward the mountain front probably as a result of bedding-plane faulting. Where not disturbed, it rests unconformably on the Swan Peak Formation. This hiatus represents part of Middle and Late Ordovician time. The Fish Haven is conformable with the overlying Laketown Formation of Ordovician and Silurian age.

The Fish Haven (Williams, 1948, p. 1137) is regarded as of late Late Ordovician age (Cincinnatian Series).

Silurian System

Laketown Formation

The Laketown Formation was recognized in the Smithfield quadrangle
by Williams (1948, p. 1137-1138). Budge (1966, p. 57-60) measured the Laketown in Logan Canyon and recognized four successively younger members: (1) medium-dark-gray dolomite, 297 feet thick, (2) medium-dark-gray and dark-gray dolomite, 550 feet thick, (3) medium-gray dolomite, 417 feet thick, and (4) dark-gray dolomite, 195 feet thick. The total thickness is 1,459 feet.

The Laketown is conformable with the underlying Fish Haven Formation. It seems to be conformable with the overlying Water Canyon Formation of Devonian age.

Williams (1948, p. 1137) regarded the Laketown Formation as of Silurian age; however, Budge (1966, p. 46-48) assigned the lower part to Late Ordovician and the remainder to Early and Middle Silurian.

Devonian System

Water Canyon Formation

The Water Canyon Formation was named by Williams (1948, p. 1138-1139) for exposures in Water Canyon, a tributary of Green Canyon. He divided the formation into two members: (1) lower clayey dolomite, and (2) upper sandstone. The lower member is 393 feet thick in Green Canyon; the upper member is 150 feet thick in Logan Canyon. The composite thickness for the Water Canyon is 543 feet.

Taylor (1963, p. 8-22, 53-54) recognized two members in the Water Canyon Formation: (1) lower Card Member, and (2) upper Grassy Flat Member. The Card Member, 251 feet thick in Logan Canyon, is clayey dolomite with intraformational breccia. It weathers light gray. The Grassy Flat Member, 355 feet thick in Logan Canyon, consists mostly of
calcareous sandstone, sandy dolomite, intraformational breccia, and clayey dolomite. The lowermost part of this member contains abundant fish fragments and also plant remains. The total thickness of the Water Canyon, measured by Taylor 1.7 miles east of the mouth of Logan Canyon, is 606 feet.

In the Smithfield quadrangle, the Water Canyon crops out only at the southeastern corner. Both members are present. The Water Canyon Formation, according to Taylor (1963, p. 42), lies disconformably on the Silurian Laketown Formation and is conformable with the overlying Jefferson Formation.

An Early Devonian age for the Water Canyon is suggested by the fish fauna (Branson and Mehl, 1931, p. 530).

Tertiary System

Salt Lake Formation

The rocks of the Salt Lake Formation have been redesignated several times with respect to stratigraphic rank. This report will follow generally the terminology of Adamson, Hardy, and Williams (1955) except for the utilization of formational status rather than group status. Thus, the Salt Lake Formation consists of three successively younger members: (1) Collinston Conglomerate Member, (2) Cache Valley Member, and (3) Mink Creek Conglomerate Member.

The Collinston Conglomerate Member (Adamson, Hardy, and Williams, 1955, p. 4) unconformably overlies the Wasatch Formation. It is at least 1,500 feet thick at the northern end of Wellsville Mountain, east of Collinston, Utah. The Cache Valley Member consists of tuff,
tuffaceous sandstone, tuffaceous limestone, oolitic limestone, petroliferous limestone, and pebble conglomerate. It intertongues with the Collinston Conglomerate Member at the northern end of Wellsville Mountain, and it also overlaps older rocks marginal to Cache Valley. In the northern part of Cache Valley, it is 7,700 feet thick; in the southern part, it is at least 2,000 feet thick. Fossils, found in this member, indicate an age of middle to late Pliocene. The Mink Creek Conglomerate Member (Adamson, Hardy, and Williams, 1955, p. 7-8) overlies the Cache Valley Member along the northeastern side of Cache Valley. There, the Mink Creek overlaps Paleozoic rocks on the flank of the Bear River Range. In the Mink Creek area, near the northeastern end of Cache Valley, tuff is interbedded with the conglomerate.

In the Smithfield quadrangle, two members are recognized in the Salt Lake Formation: (1) lower tuffaceous sandstone, and (2) upper conglomerate. The lower tuffaceous sandstone is probably the Cache Valley Member; the upper conglomerate is the Mink Creek Member.

Tuffaceous sandstone of the lower member, which is light gray, crops out in a single small exposure about 0.2 mile south of Dry Canyon. It seems to be discordant with the overlying conglomerate; therefore, an unconformity may exist between the two members. Areas of soil without boulders, east and west of Crow Mountain near the northern boundary of the Smithfield quadrangle, may represent the tuffaceous sandstone member; however, these areas are mapped as part of the conglomerate member.

The conglomerate member of the Salt Lake Formation crops out in the foothills along the mountain front from Sysnath Hollow northward to the
quadrangle boundary. The conglomerate contains pebbles, cobbles, and boulders of many rock types. The matrix of sand and silt is tuffaceous. It is light gray to light yellow. The conglomerate is cemented by calcium carbonate. South of Smithfield Canyon, it consists mostly of pebbles and cobbles of limestone, dolomite, and chert. Essentially no quartzite is present, although the conglomerate overlaps quartzite between Hyde Park and Smithfield Canyons. North of Smithfield Canyon, near the mountains, boulders and cobbles of quartzite, limestone, and dolomite occur. The particle size decreases westward, and the conglomerate consists mostly of cobbles and pebbles of limestone, dolomite, and chert.

Quaternary System

Boulder deposits

Notable concentrations of boulders are present in three areas in the foothills of the central and northern parts of the mapped area. The most extensive occurrence, mapped as three outcrops, is north of the lower part of Smithfield Canyon. A small deposit is located just north of the lower part of Birch Canyon. Another area is about midway between Hyde Park and Green Canyons. The boulders of each of the three areas consist either of quartzite, carbonate, or mixed quartzite and carbonate. The boulder deposits, in most cases, are closely associated with outcrops of underlying rocks.

The westernmost outcrop, in the area north of Smithfield Canyon, is adjacent to Crow Mountain on the southeastern side. The boulders are exclusively quartzite and probably came from an underlying source. The
mass of Crow Mountain and the brecciated Precambrian-Cambrian quartzite which crops out between it and the mountain front are believed to be remnants of a relatively old landslide. The middle boulder deposit, north of Smithfield Canyon, consists of quartzite and carbonate boulders. It surrounds a small outcrop of Precambrian-Cambrian quartzite. The quartzite boulders were derived largely from this same underlying quartzite; the carbonate boulders came from underlying conglomerate of the Salt Lake Formation. The easternmost boulder deposit, north of Smithfield Canyon, is the largest. It has areas of quartzite boulders only, areas of carbonate boulders only, and areas of mixed quartzite and carbonate boulders. These boulders also weathered from the underlying landslide mass as well as from conglomerate of the Salt Lake Formation.

The boulder deposit, north of Birch Canyon, is composed entirely of quartzite. Most, if not all, of the quartzite is from the Swan Peak Formation. The boulders display burrows, fucoidal markings, and cephalopod molds. Inasmuch as the nearest outcrop of Swan Peak is about 2½ miles east, the boulders must have come from an underlying displaced mass of quartzite. A prominent west-dipping surface, which is discussed later, is exposed just east of this mass.

The southern deposit, between Hyde Park and Green Canyons, contains large boulders of limestone of the Garden City Formation and quartzite of the Swan Peak Formation. Some of these are 10 feet long; most are aligned in an east-west direction. They were probably derived from an ancient landslide of which numerous erosional remnants are present on the mountain front to the east.
Lake Bonneville Group

A report by Williams (1962) pertaining to the Cenozoic geology of Cache Valley, Utah, includes the mapped area. He recognized two units within the Lake Bonneville Group: (1) older Alpine and Bonneville Formations, undifferentiated, and (2) younger Provo Formation.

The Lake Bonneville Group was not subdivided into formations in the eastern part of the Smithfield quadrangle. It consists mainly of gravel, sand, silt, and clay. Exposures are mostly in gravel pits; however, an outcrop is present in a gully half a mile north of Dry Canyon. In the northern part of the mapped area, the highest shoreline of Lake Bonneville is at an elevation of about 5,180 feet. South of the Hyde Park Canyon road, this shoreline seems to drop rapidly, and near Green Canyon it is at an elevation of about 5,140 feet. Intersecting gravity faults, more or less parallel with the mountain front, seem to have caused this difference in elevation.

Colluvial deposits

Colluvial deposits consist of fine-grained unconsolidated material which mantles slopes and covers underlying stratigraphic units. These deposits were mapped only above the highest shoreline of Lake Bonneville; however, they obscure the Lake Bonneville Group in places along the valley side. Colluvial deposits are probably late Pleistocene to Holocene in age.

Alluvial deposits

Alluvial deposits include fine-grained material deposited along streams and also in alluvial fans. Notable alluvial deposits are
associated with Smithfield and Birch Canyons, Dry Canyon, Hyde Park Canyon, and Green Canyon. The alluvial fan of Green Canyon, exposed in a gravel pit about half a mile from the canyon mouth, is 15-30 feet thick. It rests unconformably on the underlying Lake Bonneville Group. The alluvial fans are believed to be of Holocene age.
STRUCTURAL FEATURES

Regional Setting

The Smithfield quadrangle, in the central part of northern Utah, is located on the border of the Basin and Range province and the Middle Rocky Mountain province. The quadrangle occupies part of Cache Valley on the west and the flank of the Bear River Range on the east. This mountain range consists mostly of Paleozoic rocks that are folded into a broad syncline that has a north-northeast trend. The trend of the northern part of the Wasatch Range, southwest of Cache Valley, differs significantly and is north-northwest.

An important structural zone, the Bannock thrust zone, extends along the eastern side of the Bear River Range. It includes imbricate thrust faults which were originally interpreted by Richards and Mansfield (1912) as forming a single large folded thrust fault, the Bannock overthrust. In recent years, areas critical to the interpretation of this feature have been mapped by Armstrong and Cressman (1963). They reinterpreted the Bannock overthrust as an imbricate thrust zone with faults that are slightly folded. Two important thrust faults of the Bannock thrust zone, the Paris and the Woodruff, border the Bear River Range on the east.

Along the west-dipping Paris thrust fault, near Nounan, Idaho, the Brigham Formation rests on the Triassic Thaynes Formation. There, the stratigraphic displacement is 20,000 feet (Armstrong and Cressman, 1963, p. 7). Southward from Nounan, Idaho, the stratigraphic displacement
diminishes, and the Brigham Formation is thrust over the Ordovician Garden City Formation (Armstrong and Cressman, 1963, p. 18). Farther south, a gravity fault evidently drops the thrust fault down on the east. Armstrong and Cressman concluded that the Paris thrust fault terminates southward and does not connect with the Woodruff thrust fault.

The west-dipping Woodruff thrust fault is exposed in Birch Creek at a point about 35 miles south of the Paris thrust fault (Richardson, 1941, p. 39). There, quartzite of the Brigham (?) Formation on the west is separated by slope wash from sandstone of the Nugget Formation on the east. Better exposures exist several miles to the south, in Woodruff Creek, where the Brigham (?) Formation rests on the Permian Park City Formation (Stokes and Madsen, 1961). The Paris and Woodruff thrust faults may connect and form a major north-trending fault zone.

A thrust zone along the Wasatch Mountains near Ogden, Utah, about 30 miles west-southwest of the Woodruff thrust fault, was described in detail by Eardley (1944, p. 847-849). Three thrust faults, in and near Ogden Canyon, dip to the east. The lower two are the Taylor and Ogden thrust faults. Both cut Precambrian and Cambrian rocks. The higher Willard thrust fault places Precambrian rocks over Cambrian-Mississippian rocks.

Evidences for east or west movement on the Willard thrust fault were evaluated by Eardley (1944, p. 867-872) without reaching a conclusion. Crittenden (1961) proposed displacement of great magnitude based on the assumption that the Willard connects with both the Woodruff and the Paris thrust faults. He reported a thick section of rocks above these thrust faults in contrast to a thin section of rocks of the same
age below. Rocks above the Willard thrust fault, north of Ogden, consist of at least 6,000 feet of Precambrian sedimentary rocks and a thick basal Cambrian sequence; rocks below the Willard consist of highly metamorphosed Precambrian rocks older than those of the upper plate and a thin basal Cambrian sequence. Furthermore, the thickness of rocks above the Willard, between the Tintic Formation (Brigham equivalent) and the Devonian-Mississippian unconformity, is 6,000 feet; whereas, the thickness of rocks of the same age below the Willard is only 2,000 feet.

**Folds**

**Logan Peak syncline**

The western flank of the Logan Peak syncline forms a structurally complex zone in the mountains of the eastern part of the Smithfield quadrangle (Figures 2 and 3, Plate 2). The axis of the syncline, located 1½-4 miles east of the quadrangle boundary, trends north-northeast.

In the southeastern part of the Smithfield quadrangle, rocks of Cambrian to Devonian age generally strike N. 15° E. and dip 20°-40° E. Near the base of the mountain front, the dip increases to 60°-80° E. In places, especially near thrust faults, the beds dip more steeply and are overturned to the east.

In the northeastern part of the quadrangle, north of Hyde Park Canyon, rocks of Precambrian-Cambrian age strike about N. 15° E. and dip 50°-70° E. A gradual steepening in dip is evident toward the mountain front.
Figure 2. Western flank of Logan Peak syncline at Logan Canyon; view south near mountain front. Garden City (Ogc), Swan Peak (Osp), Fish Haven (Ofh), and Laketown (Sl) Formations dip east. Dip steepens abruptly near mountain front. Fish Haven thins toward mountain front. High-angle thrust fault displaces formation contact.
Figure 3. Western flank of Logan Peak syncline at Logan Canyon; view north near mountain front. Garden City (Ogc), Swan Peak (Osp), Fish Haven (Ofh), and Laketown (Sl) Formations dip east. Dip of Garden City steepens abruptly near mountain front. Thickness of Swan Peak reduced toward mountain front. St. Charles and Garden City thrust eastward on low-angle fault.
Minor folds

Prominent folds are present in the rock unit designated as Precambrian quartzite throughout the length of its exposure between Hyde Park Canyon and the northern edge of the quadrangle. These folds are well displayed on the northern side of Birch Canyon (Figure 4, Plate 1). At that place, in succession from west to east, are a small syncline, a small anticline, a larger syncline, and a larger anticline. The larger anticline is steeper on the east than on the west. It has dips of 51° W. and 62° E. on the western and eastern limbs, respectively. A low-angle thrust fault, which dips about 30° W., is present just east of this anticline. Southward, in Dry Canyon, this anticline is broken by the thrust fault.

Small tight folds are common within the incompetent rock units of the eastern part of the Smithfield quadrangle. These are especially evident in the Bloomington Formation.

Structural interpretations

A major anticline in Precambrian and Paleozoic rocks probably extends along the eastern side of Cache Valley parallel to the Logan Peak syncline to the east. It presumably underlies covering rock units of Tertiary and Quaternary age. The zone of intense deformation at the base of the mountain front would be on the eastern flank of such an anticline and on the western flank of the adjacent Logan Peak syncline.

The small folds in Precambrian quartzite may have formed at depth under conditions of plastic deformation due to elevated heat or pressure. It is not inconceivable, however, that they formed at a lesser depth during a long interval of time.
Figure 4. Syncline and anticline in Precambrian quartzite on northern side of Birch Canyon; view north.
Thrust Faults

Bedding-plane faults

Bedding-plane faults are found in the St. Charles and Garden City Formations in Green Canyon. An east-dipping bedding-plane fault is exposed near the mouth of Green Canyon, on the southern side, in the lower part of the St. Charles Formation (Figure 5). There, related faults diverge upward from a lower one that is concordant with the east-dipping underlying beds and discordant with the overlying beds.

A notable bedding-plane fault crosses Green Canyon at a point about 1 mile east of the mountain front. It is within the Garden City Formation, just above the St. Charles-Garden City contact, and dips east. The fault surface is exposed on the southern side of Green Canyon between beds that have divergent east dips (Figure 6). Beds below the fault dip east more steeply than beds above. In places, beds below are clearly truncated by the fault; whereas, overlying beds are concordant with the fault. On the northern side of the canyon, the fault is less well exposed but is evidenced by the divergent dips of beds below and above (Figure 7). The beds above are approximately parallel with the fault.

Another bedding-plane fault occurs in the upper part of the Garden City Formation, on the southern side of Green Canyon, about 1 mile east of the more conspicuous one previously described. Beds above and below this fault seem to diverge. It dips east at a low angle and is parallel to the beds above.
Figure 5. Bedding-plane faults in the St. Charles Formation on southern side of Green Canyon; view southwest.
Figure 6. Bedding-plane fault in the Garden City Formation on southern side of Green Canyon; view south. Fault separates beds that have divergent east dips.
Figure 7. Bedding-plane faults in the Garden City Formation on northern side of Green Canyon; view north. A prominent fault separates beds that have divergent east dips.
High-angle thrust faults

High-angle thrust faults are those that dip more than 45° and which involve crustal shortening. A major high-angle thrust fault extends from the southern boundary of the quadrangle northward to Hyde Park Canyon. It strikes north-northeast and dips about 75° W. where it is well exposed 0.2 mile south of Green Canyon (Figure 8).

In a small valley 0.1 mile north of the southern boundary of the quadrangle, the upper part of the Nounan is thrust eastward over the Worm Creek Member of the St. Charles and part of the upper member of the St. Charles Formation. Northward, in places, masses of brecciated white dolomite mark the trace of the fault. The fault surface is exposed where the breccia has been eroded (Figures 9 and 10). Slickensided surfaces are present on the fault surface as well as in the brecciated white dolomite. At a point 0.7 mile south of Green Canyon, the Nounan again rests on the Worm Creek Member (Figure 11). Farther north, 0.4 mile south of Green Canyon, the lower part of the Nounan has been thrust over the Worm Creek so that the Bloomington-Nounan contact is within 50 feet of the base of the St. Charles Formation. There, the displacement is about 1,100 feet or approximately equal to the thickness of the Nounan Formation. This fault is well exposed in a small valley 0.2 mile south of Green Canyon (Figure 8; Plate 2, C-C'). There, the Bloomington Formation on the west, which is represented by dolomite, limestone, and shale, was thrust up next to dolomite of the Nounan on the east. The amount of displacement is at least 550 feet or half of the thickness of the Nounan. On the southern side of Green Canyon, the fault places the Bloomington-Nounan contact on the west opposite the middle part of the Nounan on the east.
Figure 8. High-angle thrust fault 0.2 mile south of Green Canyon; view north. Fault separates prominent outcrop of Bloomington Formation on left from Nounan Formation on right.
Figure 9. High-angle thrust fault illustrated in Figure 8, 0.8 mile south of Green Canyon road; view northeast. Fault is in Nounan Formation. Fault plane is exposed at upper right; brecciated rock in foreground rests on fault plane.

Figure 10. Brecciated Nounan Formation on high-angle thrust fault illustrated in Figure 9; view southwest.
Figure 11. High-angle thrust fault illustrated in Figure 8, 0.7 mile south of Green Canyon; view north. Nounan Formation (6n) rests on Nounan and Worm Creek Member of St. Charles Formation (6wc).
Between Green Canyon and Sysnath Hollow, the fault is difficult to trace because of poor exposures and less displacement than south of Green Canyon. There, also, the fault dips less steeply but, nevertheless, greater than 45° W. North of Green Canyon for about 1 mile, it is within the Bloomington Formation. A dark-gray dolomite on the west has been thrust up next to a limestone on the east. In many places, the limestone east of the fault has been overturned toward the east, and it is also folded tightly (Figure 12). Limonite is present along and near the fault. On the ridge south of Beef Hollow, the Bloomington-Nounan contact has been thrust up nearly to the top of the Nounan. Just across Beef Hollow to the north, the Nounan, the Worm Creek Member of the St. Charles, and part of the upper member of the St. Charles have been thrust up next to the lower part of the St. Charles Formation.

On the southern side of Mahogany Hollow, the low-angle thrust fault extends under a slide block. It may be present on the slide block, but, if so, it is difficult to recognize. An outcrop of limonite and white limestone which is apparently somewhat recrystallized, on the northern side of Bogus Hollow near the Bloomington-Nounan contact, may mark the trace of this fault on the slide block. Locally, the thrust fault coincides with the slide block surface. Between Mahogany Hollow and Dry Hollow, east of the slide block, the Bloomington on the west is thrust up next to the Nounan. Thus, in Bogus Hollow, a wedge of thin-bedded limestone of the Bloomington is caught between the thrust fault on the east and the slide-block surface on the west. The Nounan crops out both east of the thrust fault and west of the slide-block surface. A similar situation exists on the ridge north of Bogus Hollow. There,
Figure 12. Small folds in the Bloomington Formation 0.5 mile north of Green Canyon; view north.
also, a wedge of thin-bedded limestone of the Bloomington is between the thrust fault on the east and the slide-block surface on the west. East of the thrust fault is a light-gray dolomite of the upper part of the Nounan; west of the slide-block surface is light-gray dolomite of the upper part of the Nounan and sandy dolomite of the base of the Worm Creek Member of the St. Charles Formation.

This fault probably extends northward from Dry Hollow but cannot be recognized because of diminished displacement. The thrust fault that crops out about 0.2 mile to the west at the base of the mountain, between Dry Hollow and Hyde Park Canyon, is a low-angle thrust fault which dips about 25° W.

A separate high-angle thrust fault, in the Langston Formation, extends northward from Hyde Park Canyon for about 1 mile. It follows the outcrop of the Langston Formation in a north-northeast direction and dips about 65° W. The lower limestone of the Langston is thrust eastward over the upper dolomite thereby cutting out the intermediate shale. Northward, the fault dies out and the shale unit, although thin and somewhat metamorphosed, is present. Also, the width of the Langston outcrop near Hyde Park Canyon is about half of what it is 1 mile to the north.

Another high-angle thrust fault is present in Hyde Park Canyon near the eastern boundary of the quadrangle. This fault is within the Bloomington Formation and the displacement is slight (Figure 13). South of Hyde Park Canyon, the dip becomes less, and the fault is classified as a low-angle thrust fault.
Figure 13. High-angle thrust fault in Bloomington Formation, Hyde Park Canyon; view north. Fault truncates light-gray beds on left side of valley. Drag is evident beneath fault.
Low-angle thrust faults

Low-angle thrust faults are those that dip less than $45^\circ$, usually $20^\circ$-$30^\circ$, and which involve crustal shortening. An important low-angle thrust fault (Figure 3) was recognized on the northern side of Logan Canyon near the mountain front by Peterson (1936, Plate 9). This fault extends into the Smithfield quadrangle at least as far north as Dry Canyon. It strikes about N. $15^\circ$ E. The attitude was calculated by the three-point method at a location about 0.2 mile south of Green Canyon. There, it strikes about N. $20^\circ$ E. and dips $25^\circ$ W. Between Green and Hyde Park Canyons, the dip increases but is probably not more than $45^\circ$ W. In Hyde Park Canyon, it is $65^\circ$-$75^\circ$ W., and there the fault is best classified as a high-angle thrust fault. South of Green Canyon, the displacement is 150-300 feet eastward, and north of Green Canyon, it ranges from a few feet to perhaps as much as 800 feet eastward.

Just south of the quadrangle boundary, the upper cherty dolomite of the Garden City is thrust onto the middle part of the Swan Peak Formation. A window in the dolomite permits exposure of the quartzite of the lower plate. Within the mapped area, evidence of this fault is particularly striking between the southern margin of the quadrangle and Green Canyon. On the first ridge south of Green Canyon, about 0.3 mile south of the canyon, yellowish-gray dolomite of the St. Charles Formation is thrust over the medium-gray limestone of the Garden City Formation. Across the valley south of this ridge (Figure 14), the St. Charles-Garden City contact, above the fault, is displaced eastward about 300 feet relative to the same contact below the fault.
Figure 14. Low-angle thrust fault in Garden City Formation 0.5 mile south of Green Canyon; view south.
This low-angle thrust fault is present on the northern side of the lower part of Green Canyon (Figure 15). On the ridge, the Nounan Formation and the Worm Creek Member of the St. Charles Formation have been thrust eastward over the Worm Creek Member and the upper part of the St. Charles Formation. At the canyon bottom, the Worm Creek Member dips about 26° E. Near the fault, it suddenly steepens so as to dip 77° E. Northward for about half a mile, only the lower part of the Worm Creek Member is present west of this fault. In the valley about 0.4 mile south of Beef Hollow, the Worm Creek Member has been thrust up near the top of the St. Charles Formation. Between Reeder and Sysnath Hollows, the upper part of the St. Charles and the lower part of the Garden City are thrust over the Garden City. Between Sysnath Hollow and the southern side of Hyde Park Canyon, the fault crosses the Worm Creek Member several times and in places the Worm Creek is thin or absent. North of Hyde Park Canyon, the fault dips steeply west (Figure 13), and it is evidently within the Bloomington Formation.

Another low-angle thrust fault extends for 1 mile between Dry Hollow and Hyde Park Canyon near the base of the mountain. In Hyde Park Canyon (Figure 16), this fault dips about 25° W. Between Dry Hollow and Hyde Park Canyon, the Blacksmith Formation is thrust eastward over the Bloomington Formation. On the northern side of Hyde Park Canyon, this fault displaces the nearly vertical Ute-Blacksmith contact eastward by about 20 feet (Figure 16). Northward, it seems to disappear in the Blacksmith Formation.

Two east-dipping thrust faults, also in Hyde Park Canyon, cut the Bloomington Formation only (Figure 17). The displacement is only 10–20 feet eastward.
Figure 15. Low-angle thrust fault on northern side of Green Canyon; view north. Nounan Formation (6n) thrust over Nounan Formation and St. Charles Formation (6sc). Quartzite of Worm Creek Member of St. Charles is nearly vertical just beneath fault.

Figure 16. Low-angle thrust fault on northern side of Hyde Park Canyon; view north. Ute Formation on left; Blacksmith Formation on right. Formation contact at right of prominent outcrop in center is displaced by fault.
Figure 17. Two low-angle east-dipping faults in Bloomington Formation on northern side of Hyde Park Canyon; view north. Lower fault truncates vertical light-gray bed in center.
Two nearly parallel low-angle thrust faults, involving Precambrian rocks, extend from Hyde Park Canyon to the northern boundary of the quadrangle. These faults strike about due north and dip 20°-30° W. In Birch Canyon, displacement on the eastern fault is at least 800 feet.

On the northern side of Hyde Park Canyon, Precambrian-Cambrian quartzite, above the eastern fault, is thrust over the lower limestone unit of the Langston Formation. Northward, in Dry Canyon, the Precambrian-Cambrian quartzite rests on the Brigham Formation of Cambrian age (Figure 18). The Brigham, below the fault, is severely crushed. In Birch Canyon, the eastern fault is especially well displayed. There, Precambrian quartzite is thrust eastward over Precambrian quartzite, the Mutual Formation, and the lower part of the Brigham Formation. Quartzite beds below the fault dip steeply east and, in places, are vertical to overturned eastward. Similar relationships are evident in Smithfield Canyon where Precambrian quartzite below the fault dips steeply east and that above the fault dips gently northwest.

The western low-angle thrust fault places Precambrian quartzite over Precambrian-Cambrian quartzite between Hyde Park and Dry Canyons. On the northern side of Dry Canyon (Figure 18), the fault separates west-dipping Precambrian quartzite from east-dipping Precambrian-Cambrian quartzite. On the ridge between Dry Canyon and Birch Canyon, Precambrian quartzite above the western fault has been thrust over the eastern fault and onto the Brigham Formation. In Birch Canyon, this fault separates folded Precambrian quartzite on the west from east-dipping Precambrian quartzite on the east.
Figure 18. Two low-angle thrust faults in Precambrian and Cambrian quartzite on northern side of Dry Canyon; view northwest. Quartzite shows drag beneath lower fault. Salt Lake Formation in upper left rests on Precambrian quartzite.
Structural interpretations

The three kinds of thrust faults found in the Smithfield quadrangle seem to reflect progressive deformation. The east-dipping bedding-plane faults are interpreted to have formed at an early stage. They may have resulted from eastward sliding in conjunction with more extensive gliding. The latter might have involved the mass between the east-dipping Willard thrust fault on the west, and the west-dipping Paris-Woodruff thrust faults on the east. Such faulting may account for the drastic thinning of the Swan Peak and Fish Haven Formations along the mountain front between Green and Logan Canyons (Figures 2 and 3) as well as the breccia between these formations in Green Canyon and elsewhere. The steep east dip of the beds beneath the bedding-plane faults, compared with the beds above, suggests that the overriding mass was emplaced after moderate folding of the beds beneath (Figures 6 and 7).

The high-angle thrust faults, on the eastern limb of the anticline located immediately west of the Logan Peak syncline, formed generally after the bedding-plane faults. These thrust faults dip west and undoubtedly formed as a consequence of stretching of the steeply dipping beds on the eastern flank of the rising anticline.

A similar situation is found along the western side of the Nacimiento uplift in New Mexico (Baltz, 1967, Figure 2). The bordering Nacimiento fault is analogous to the high-angle thrust faults of the Smithfield quadrangle.

Low-angle thrust faults, which involve relatively greater horizontal displacement, probably formed during extreme steepening and overturning of the eastern limb of the anticline inferred to exist west of the
Logan Peak syncline. In at least one case, a low-angle thrust fault must offset a major high-angle thrust fault that formed earlier (Plate 2, C-C').

West-Dipping Surface

General statement

A prominent west-dipping structural surface on Precambrian quartzite extends from Hyde Park Canyon to the northern boundary of the Smithfield quadrangle and beyond. Brecciated dolomite of Cambrian (?) age rests on this surface just north of Hyde Park Canyon. Elsewhere, in the Smithfield quadrangle, it is covered by the Salt Lake Formation in depositional contact. This surface was described by Bailey (1927b, p. 501-502) as a gravity fault that dips 30° W. toward Cache Valley. Evidence presented here suggests that it formed as a west-dipping thrust fault on which later sliding, in a reverse direction, took place.

Description

The west-dipping surface is exposed on the northern side of Hyde Park Canyon, and it extends northward, a distance of 4 miles, to the quadrangle boundary. It is clearly evident on the northern side of Smithfield Canyon (Figure 19) and was reported in City Creek, 2 miles north of the quadrangle boundary, by Bailey (1927b, p. 501). This surface truncates Precambrian quartzite and forms the western boundary of the zone of folds and thrust faults previously described (Figure 20). In the Smithfield quadrangle, the surface trends generally north and is slightly convex toward the west. At Hyde Park Canyon, it strikes about N. 10° W. Near the ridge top, south of Birch Canyon, it strikes about
Figure 19. West-dipping surface on northern side of Smithfield Canyon; view north. At upper right, brecciated dolomite and limestone rest on Precambrian and Cambrian quartzite. Arrow indicates surface.
Figure 20. Salt Lake Formation, above trees in valley bottom, on folded Precambrian quartzite on southern side of Dry Canyon; view southwest. Top of quartzite is west-dipping surface on which brecciated dolomite rests about 0.1 mile south.
due north (Figure 21). North of Birch Canyon, it strikes about
N. 10° E.

The surface has an average dip of about 22° W. It dips 20°-23° W.
between Hyde Park and Dry Canyons, 20°-23° W. in Dry Canyon, 23°-24° W.
between Dry and Birch Canyons, 22° W. in Birch Canyon, 20°-30° W.
between Birch and Smithfield Canyons, and 15°-19° W. in Smithfield
Canyon. These dips were obtained by the three-point method utilizing a
composite topographic and geologic map. Dips of 22° W. were found in
both Dry and Birch Canyons by sighting across the canyons with a Brunton
compass. The larger irregularities are in Smithfield Canyon and
probably result from destruction of the original surface by erosion and
landsiding. A dip of 23° W. was secured from the actual surface in
Birch Canyon. Bailey (1927b, p. 501-502) reported somewhat greater dips,
32° W. and 30° W., for Dry and Birch Canyons, respectively.

On the northern side of Hyde Park Canyon, a severely brecciated
dolomite rests on the west-dipping surface which truncates Precambrian
quartzite. The dolomite is medium gray and contains gray chert. It is
broken into angular fragments that are cemented by calcite. The
dolomite with chert resembles the cherty dolomite of the St. Charles
Formation; however, it might also represent the cherty dolomite at the
top of the Garden City Formation. It is mapped as brecciated dolomite
of Cambrian (?) age. Conglomerate of the Salt Lake Formation of
Tertiary age, characterized by subangular to subrounded particles of
diverse rock types, was deposited on the breccia. Similar conglomerate
rests on the west-dipping surface elsewhere in the Smithfield
quadrangle.
Figure 21. Salt Lake Formation, at upper right, on prominent Precambrian quartzite on southern side of Birch Canyon; view south. Top of quartzite is west-dipping surface that was later covered by Salt Lake Formation.
Quartzite boulders, evidently from the Swan Peak Formation, are present on the northern side of Birch Canyon west of the exposure of the west-dipping surface. The boulders consist of white and purple quartzite with burrows, cephalopod molds, and fucoidal markings. They are surrounded by conglomerate of the Salt Lake Formation. The boulders probably weathered out from part of the underlying Swan Peak which is inferred to rest on the west-dipping surface.

A remarkable exposure of the west-dipping surface exists in Smithfield Canyon just north of the quadrangle boundary (Figure 19). There, extremely brecciated dolomite and limestone rest on the surface which truncates Precambrian and Cambrian quartzite. Brecciation of the overlying carbonate rock is notably severe within 50 feet of the surface. The lower 5-20 feet of brecciated carbonate rock contains intermingled angular fragments of quartzite less than a quarter of an inch wide. The underlying quartzite is also brecciated. The carbonate beds, which dip 50°-80° E., closely resemble the St. Charles Formation and also the overlying Garden City Formation. Conglomerate of the Salt Lake Formation overlaps the disturbed mass on the western side.

Possible interpretations

An evaluation of evidence previously submitted suggests several possible interpretations for the origin and subsequent history of the west-dipping surface. First, the surface might represent a thrust fault along which younger carbonate rocks moved eastward over Precambrian quartzite and Paleozoic rocks. Erosion later destroyed much of the thrust plate. Conglomerate of the Salt Lake Formation was deposited on the exposed surface except locally where it rests on dislocated masses.
Second, the surface might represent a plane along which younger rock slid from the Bear River Range onto older rock at lower elevations. Erosion later removed most of the slide mass before deposition of conglomerate of the Salt Lake Formation. Third, the surface might represent a thrust fault along which later backsliding occurred because of removal of support due to collapse of Cache Valley by gravity faulting. The surface was largely cleared by sliding and erosion; later, conglomerate of the Salt Lake Formation was deposited.

The first interpretation, that the surface involves eastward thrusting only, is suggested by the presence of two west-dipping low-angle thrust faults and related folds just to the east. The extent of the trace of the surface, more than 4 miles, is evidence in favor of a thrust origin. The presence of relatively younger rocks above the thrust surface is unexpected because of the necessary inference of a large anticline west of the Logan Peak syncline.

The second interpretation, that a large mass of younger rock slid from the Bear River Range onto older rock exposed at lower elevations, explains the presence of younger rock on older. Appropriate stratigraphic units are present on the western flank of the Bear River Range. The extreme brecciation of the dislocated mass may also be taken as evidence of downslope movement. The planar aspect of the west-dipping surface, instead of multiple curved slide surfaces, is evidence against sliding. Convexity of the trace of the west-dipping surface toward the dip direction is also evidence against this interpretation. Finally, the low westward dip of the surface makes sliding seem unreasonable.
A third interpretation, that the surface formed as a thrust fault on which later westward sliding took place, is most attractive. The dislocated quartzite of the Swan Peak Formation, on the northern side of the lower part of Birch Canyon, is at a low elevation between masses of carbonate rock of Cambrian age located north of Smithfield Canyon and just north of Hyde Park Canyon. The anomalous location of the quartzite is evidence of sliding of independent masses on a previously formed west-dipping surface.

Features similar to the west-dipping surface and related rocks of the Smithfield quadrangle are found at other places in Utah and elsewhere. In the Paradise quadrangle, on the western flank of the Bear River Range about $8\frac{1}{2}$ miles south of the Smithfield quadrangle, Mississippian rocks rest on Devonian and older Mississippian rocks along a surface which dips $20^\circ-40^\circ$ W. (Mullens and Izett, 1964, Plate 1). Above the surface, the beds dip west and are locally extremely broken; below the surface, they dip east (Mullens and Izett, 1964, p. 19). Mullens and Izett interpreted this feature as a gravity fault; however, they also stated that it could be a thrust fault with younger rocks over older ones. On the western side of the Malad Range in Utah, Hanson (1949, p. 73-74) mapped a block of the Nounan and St. Charles Formations on a plane which dips $25^\circ$ W. The Blacksmith, Bloomington, and Nounan Formations underlie this mass. A block of the Swan Peak and Fish Haven Formations rests on the St. Charles, about 4 miles to the south. The intervening surface dips about $25^\circ$ W. Hanson interpreted these features as low-angle gravity faults.

The turtleback surfaces of southeastern Death Valley, which dip toward the valley, are remarkably similar to the west-dipping surface
of the Smithfield quadrangle. Curry (1954, p. 59) regarded the turtle-back surfaces as thrust faults which were exposed by erosion. He recognized that the overlying rocks might have slid into the valley in places (Curry, 1954, p. 54). Drewes (1959, p. 1506) interpreted these surfaces as low-angle gravity faults; however, he admitted that they might be landslide surfaces. Hunt and Mabey (1966, p. 150) favored detachment of blocks overlying thrust faults. These studies, in general, confirm an explanation of westward sliding along a pre-existing thrust fault for the origin of the west-dipping surface of the Smithfield quadrangle.

Gravity Faults

General statement

Gravity faults, within the Smithfield quadrangle, trend northward along the eastern side of Cache Valley. Numerous discontinuous faults are mapped with reference to geologic and topographic evidence. A fault zone, rather than a single gravity fault, is indicated. The valley side is inferred to have dropped in nearly all instances.

The gravity faults of the southern half of the quadrangle will be discussed first starting with the westernmost and proceeding to the easternmost. A similar procedure will be followed for the northern half of the quadrangle.

Southern part

The westernmost gravity fault of four, in the southern half of the quadrangle, extends northward from the southern boundary of the quadrangle for a distance of 2.0 miles. This fault strikes about due
A west-facing fault scarp is present where it cuts the Lake Bonneville Group between 0.8 and 1.0 mile north of the quadrangle boundary. Because the scarp follows the margin of a delta, it is not as noticeable as it would be otherwise. Elsewhere, this fault is recognized by lineations on aerial photos. Its trace seems to be evident across the Green Canyon alluvial fan.

The second gravity fault extends northward from the southern boundary of the quadrangle for a distance of 3.6 miles. This fault is known solely on the basis of indications seen on aerial photos. It strikes about due north. The middle part of the trace, from 0.6-1.1 miles north of the quadrangle boundary, is easily seen as a dark line which extends through both the Lake Bonneville Group and the Green Canyon alluvial fan. Between 2.2 and 2.6 miles north of the quadrangle boundary, the fault is also distinctly evident. In addition to a dark line, a relatively low area or sag is evident on the photos.

The third gravity fault is traceable for 4.9 miles from the southern boundary of the quadrangle. It also strikes about due north. This fault cuts the Salt Lake Formation as well as the Lake Bonneville Group and may also cut some Quaternary alluvial deposits. This fault is recognized mostly by occasional dark lines on the aerial photos. Between 1.5 and 2.1 miles north of the quadrangle boundary, both a dark line and a sagged area are present. There, the western side seems to have dropped. The fault projects along the eastern sides of two isolated hills of the Salt Lake Formation, Round Hill and Long Hill. A dark line and a change in slope or a sag are evident, on the photos, along the eastern side of both hills.
The fourth fault, nearest the mountain front, trends north and is concave toward the west (Figure 22). It extends northward at least 4.0 miles from the southern boundary of the quadrangle or nearly to Hyde Park Canyon. The strike is N. 20° E. from the quadrangle boundary northward for 2.0 miles, north from 2.0-2.9 miles, N. 13° W. from 2.9-3.6 miles, and N. 38° W. from 3.6-4.0 miles. This curvature suggests that the fault is concave in depth (Plate 2, C-C'). Moore (1960, p. 411) concluded that many Basin and Range gravity faults are convex toward the direction of tilt of the range and doubly concave toward the downthrown side. This fault cuts the Salt Lake Formation, the Quaternary boulder unit, and the Lake Bonneville Group. It is inferred to cut landslides as well as younger colluvial and alluvial deposits. The displacement is unknown; however, it seems to diminish northward.

This fault displays a prominent west-facing scarp, where it cuts the Lake Bonneville Group, on the golf course of the Logan Country Club located about 0.2 mile south of the Smithfield quadrangle. The scarp is 5-10 feet high, and the displacement in a highway excavation through the golf course was estimated at 16 feet (Peterson, 1936, Plate 10).

The west-facing scarp of the easternmost fault extends into the Smithfield quadrangle for 0.1 mile and is perhaps as much as 5 feet high. Between 0.5 and 0.6 mile north of the quadrangle boundary, it is evidenced by a white line on the aerial photos. Both north and south of Green Canyon, located about 1.3 miles north of the quadrangle boundary, the fault is indicated by a gentle slope involving relief of 10-15 feet. It is just west of the transformers located near the mouth of the canyon.
Figure 22. Mountain front south of Hyde Park Canyon. Gravity fault, along distant mountain front on left, curves to right just beyond low hills of Salt Lake Formation. Salt Lake overlaps Paleozoic rocks of mountains.
on the southern side. From 2.3-2.5 miles north of the quadrangle boundary, the fault may cut a landslide of probable Tertiary age. It seems to cut through slide masses of the Bloomington and Swan Peak Formations. Between 2.9 and 3.3 miles north of the quadrangle boundary, a definite west-facing scarp, about 3 feet high, is present where the fault extends through an area of Quaternary boulders. A dark line on the aerial photos reveals the fault in the boulder area. From 3.1-3.4 miles north of the quadrangle boundary, a low scarp is present in conglomerate of the Salt Lake Formation. West of the fault, the beds dip southeast and east of the fault they dip northeast. Northward, the fault is covered by colluvial deposits.

The easternmost gravity fault crosses the Bonneville shoreline near the Hyde Park Canyon road. Northward, the shoreline is cut into the Salt Lake Formation at an elevation of about 5,180 feet. For about 1 mile south of the Hyde Park Canyon road, it is not distinct. Farther south, it is again evident but at an elevation of about 5,140 feet. This type of shoreline disruption was reported by Crittenden (1963, p. 28-29) at the front of the Wasatch Mountains between Salt Lake City and Ogden, Utah.

Northern part

The westernmost gravity fault of three, in the northern half of the quadrangle, extends southward from the northern boundary of the quadrangle for a distance of about 1.3 miles. This fault strikes about due north. A west-facing fault scarp, 3-5 feet high, is present in the Lake Bonneville Group from the quadrangle boundary southward for about
0.5 mile. Between 0.5 and 0.8 mile south of the quadrangle boundary, the fault is indicated by a tonal difference on the aerial photos.

The second fault from the west is traced southward from the northern boundary of the quadrangle for a distance of 4.1 miles (Figure 23). North of Smithfield Canyon, it cuts the brecciated St. Charles Formation on the western side of Crow Mountain and, farther south, an outcrop of the Salt Lake Formation. Elsewhere, it is inferred to cut the Lake Bonneville Group and younger alluvial deposits. The strike is generally north, but some change is evident. Near the quadrangle boundary, where it cuts the brecciated St. Charles Formation, it strikes about N. 22° W. Between 0.7 and 2.1 miles south of the quadrangle boundary, the strike is about N. 10° W. South of Birch Canyon, it strikes nearly north. This fault seems to have controlled erosion on the brecciated St. Charles Formation of Crow Mountain. There, a small valley marks the place where it enters the Lake Bonneville Group on the southern side of the St. Charles outcrop. From 0.7-1.0 mile south of the quadrangle boundary, it cuts the Salt Lake Formation. There, a low scarp and a slight depression are produced. Another small valley is present, along the fault, on the southern side of this outcrop. Southward, the fault is traced as a dark line on aerial photos.

The easternmost fault extends southward from the quadrangle boundary for at least 1.2 miles. This fault parallels the one immediately to the west and is inferred to cut the same outcrops of brecciated St. Charles Formation and Salt Lake Formation. For a short distance, between these outcrops, it is also inferred to cut boulder deposits and the Lake Bonneville Group.
Figure 23. Aerial view of mountain front south of Smithfield Canyon; view southeast. Salt Lake Formation in foreground hills overlaps Precambrian and Paleozoic rocks of mountains; Salt Lake Formation is truncated by gravity faults.
Structural interpretations

The upper conglomerate member of the Salt Lake Formation overlaps Precambrian and Paleozoic rocks along the mountain front in the central and northern parts of the Smithfield quadrangle. This conglomerate is not known to be down faulted against older rocks of the Bear River Range. In the southern part of the quadrangle, where a major gravity fault approaches the base of the mountain, the conglomerate may be down faulted. There, field relations are obscured by cover of the Lake Bonneville Group. The great thickness of the lower part of the Salt Lake Formation, in the northeastern part of Cache Valley, is indicative of relative collapse of the valley contemporaneous with deposition.

A zone of gravity faults, instead of a single major gravity fault, generally parallels the mountain front in the southern part of the quadrangle. It also extends along the western side of the foothills of the Salt Lake Formation in the central and northern parts of the quadrangle. The existence of numerous faults is suggested by details evident on aerial photographs. A small fault, down on the east, cuts the Lake Bonneville Group east of Hyde Park, Utah (Figure 24). This fault may bound a graben adjacent to a larger fault which is down on the west. Earthquake epicenters, distributed along the eastern side of Cache Valley, indicate the presence of several gravity faults (Cook and Smith, 1967, p. 703-718).

The gravity faults probably dip steeply toward the valley; however, actual fault surfaces are not exposed. The westward concavity of the easternmost fault, in the southern part of the quadrangle, strongly suggests a westward dip. Westphal and Lange (1966, p. 428) attributed
Figure 24. Small gravity faults in Lake Bonneville Group 0.8 mile east of Hyde Park City Limit; view north.
some aftershocks of the 1962 earthquake to two east-dipping surfaces; however, the same data might indicate parallel west-dipping faults within a fault zone.

Several instrumental epicenters seem to be closely associated with mapped faults (Cook and Smith, 1967, p. 703-718). One is 2.2 miles north of Smithfield, Utah, and the other is half a mile northeast of Smithfield. These epicenters are probably associated with the gravity faults which extend northward beyond the boundary of the quadrangle (Plate 1). The other epicenter is near the southern boundary of the quadrangle. It is located on the third gravity fault from the west and is about 0.8 mile north of the southern boundary of the quadrangle. The depth of the focus is 40 kilometers; therefore, this earthquake might have resulted from movement on the easternmost fault if west dip is a reality.

The existence of relatively few fault scarps, in the highly seismic eastern part of the Smithfield quadrangle, suggests deep-seated activity. The two earthquakes described above, located north and northeast of Smithfield, Utah, occurred at depths of 10 and 20 kilometers, respectively. The focus of the earthquake, with an epicenter 0.8 mile north of the southern boundary, is at a depth of 40 kilometers. The focus of the major earthquake of August 30, 1962, centered a quarter of a mile east of Richmond, Utah, is also at a depth of 40 kilometers.

Landslides

General statement

A major landslide is present along the mountain front between
Green Canyon and Sysnath Hollow. Some evidence suggests that Round Hill and Long Hill, located between the lower parts of Hyde Park and Dry Canyons, may be part of a landslide. Crow Mountain, northeast of Smithfield, is probably part of an exceedingly large landslide from the mountain front in the vicinity of Smithfield Canyon.

**Green Canyon to Sysnath Hollow**

Erosional remnants of a major landslide are scattered along the mountain front from 0.9-2.0 miles north of Green Canyon. They consist of blocks of Cambrian-Silurian rock, Swan Peak Formation, Fish Haven Formation, and Mississippian limestone. Dislocated blocks of the Swan Peak and Laketown Formations are present near the top of the mountain to the east.

The largest remnant of the slide extends from about 0.9 mile north of Green Canyon to Beef Hollow. It consists of a mass of limestone and dark-gray and light-gray dolomite. The mass is stratigraphically complex and was mapped as a Cambrian-Silurian unit. It is about 1,600 feet long in the north-south direction and from 800-1,400 feet wide in the east-west direction. A block of brecciated quartzite of the Swan Peak Formation lies adjacent to the Cambrian-Silurian mass on the southern side. It measures 1,100 feet in both the north-south and east-west directions. Both the Cambrian-Silurian mass and the quartzite block rest on the Bloomington Formation. A small block of white dolomite, identified as the Nounan Formation, rests on the Bloomington Formation just west of the Cambrian-Silurian mass. A similar block also rests on the Bloomington Formation at a point about 0.2 mile south of the large Swan Peak remnant.
An isolated block of limestone, evidently of Mississippian age, seems to rest on the Bloomington just west of the Cambrian-Silurian and Swan Peak remnant. It is 1,200 feet long in the north-south direction and about 200-500 feet in the east-west direction. The limestone is dark gray and petroliferous. It contains nodules and stringers of gray chert. Abundant brachiopods and bryozoans, as well as a few gastropods and corals, occur in the limestone. The most common fossil is a small brachiopod which resembles Composita. The fossil assemblage is indicative of Mississippian age. A block of white quartzite of the Swan Peak Formation rests on the limestone block along its western side. A mass of limestone and green shale of the Bloomington Formation seems to rest on the limestone block. These masses may have slid downslope after the major landslide.

Other remnants of the major landslide are present to the north between Beef and Sysnath Hollows. A single block of quartzite of the Swan Peak Formation rests on the Bloomington between Beef and Reeder Hollows. The additional remnants all rest on dolomite of the Nounan Formation between Reeder and Sysnath Hollows. The southern block contains the Swan Peak and Fish Haven Formations in depositional contact and is broken by two internal vertical faults which offset the contact. The middle block also displays Swan Peak and Fish Haven in depositional contact. The northern block, however, consists of Swan Peak only. The boulder deposit west of the mountain front, between Reeder and Sysnath Hollows, may represent part of the landslide. The boulders consist of limestone and quartzite, probably from the Garden City and Swan Peak Formations, respectively. They are unusually large, some over 10 feet
long, and are oriented mainly in an east-west direction. The boulder area is surrounded by Quaternary colluvium.

The extensive destruction of the slide mass, notably in Beef and Reeder Hollows, suggests a pre-Quaternary date for the sliding. It is possible that the Salt Lake Formation, north of the boulder area, overlaps the margin of the slide.

Two landslide remnants are present near the top of the ridge east of those previously described. South of Beef Hollow, a block of quartzite of the Swan Peak Formation rests on the lower part of the shale of the Swan Peak and the upper part of the Garden City Formation. A block of dolomite of the Laketown Formation rests on this dislocated mass of Swan Peak. North of Beef Hollow, a mass of Laketown slid down-slope onto the upper part of the Swan Peak Formation. Beds exposed directly beneath these masses seem to have been dragged by sliding of the overlying masses. They dip less steeply eastward, directly below the slide surfaces, than they do a short distance away.

Round Hill and Long Hill

Round Hill and Long Hill, between lower Hyde Park and Dry Canyons, may be parts of a slide from the hill immediately to the east. They consist of conglomerate of the Salt Lake Formation which is isolated from the extensive outcrop to the east by Quaternary colluvium. A topographic re-entrant is present in the conglomerate east of Round Hill and Long Hill. The lower tuffaceous sandstone member of the Salt Lake Formation, which crops out northeast of Long Hill and which must underlie both Round Hill and Long Hill, could have facilitated sliding. The evidence is not definitive but is certainly highly suggestive of sliding.
If sliding took place, it was before the formation of the high shoreline of Lake Bonneville that cuts both Round Hill and Long Hill.

**Crow Mountain**

Crow Mountain, northeast of Smithfield and near the northern boundary of the quadrangle, is composed of severely brecciated dolomite and limestone (Figure 25). These rocks resemble the upper part of the St. Charles Formation and the Garden City Formation, respectively. The dolomite on the west evidently underlies the limestone on the east. Both units strike about N. 45° W. and dip steeply northeast. The area of quartzite boulders, immediately southeast of Crow Mountain, suggests the presence of an underlying block of quartzite. The Salt Lake Formation overlaps the brecciated limestone on the eastern side of Crow Mountain.

Several outcrops of brecciated Precambrian-Cambrian quartzite are present between Crow Mountain and the main part of the Bear River Range. A small outcrop, 0.6 mile south of Crow Mountain, consists of brecciated light-brown quartzite which strikes N. 45° E. and dips 69° W. It is surrounded by quartzite and carbonate boulders as well as by the Salt Lake Formation. A large mass of brecciated light-brown quartzite, located about 1.0 mile east of Crow Mountain, is composed of several disoriented blocks (Figure 26). Conglomerate of the Salt Lake Formation overlaps the southern side of the mass and is also present on the west and north. An area of quartzite and carbonate boulders bounds the eastern side. A third mass of brecciated quartzite is located about 1.5 miles east of Crow Mountain. It consists of reddish-brown quartzite on the southwest and white quartzite on the northeast. The beds strike
Figure 25. Brecciated limestone of Garden City Formation of Crow Mountain.
Figure 26. Brecciated Precambrian-Cambrian quartzite about 1.0 mile east of Crow Mountain; view south.
about N. 30° W. and dip 20° NE. The upper conglomerate member of the Salt Lake Formation clearly overlaps this quartzite mass on the southwestern side. Quartzite and carbonate boulders surround the brecciated quartzite and adjacent outcrop of the Salt Lake Formation.

The anomalous location of the dolomite and limestone of Crow Mountain, as well as the disoriented masses of brecciated quartzite to the east, resulted from westward sliding on the flank of the Bear River Range. The carbonate rock and quartzite of Crow Mountain could have moved downslope from an area located about 3 miles to the east where a brecciated mass of the St. Charles and Garden City Formations rests on the prominent west-dipping surface. The brecciated quartzite, which crops out between Crow Mountain and the Bear River Range, could have come from the area of Precambrian and Cambrian quartzite that extends along the base of the Bear River Range. A broad re-entrant along the mountain front seems to represent the site of a large landslide. This re-entrant is evidenced by subdued ridges north and south of Smithfield Canyon. The upper end of the slide surface was located below the west-dipping surface and presumably sloped steeply westward. The lower part, above the west-dipping surface, probably slopes gently westward.

It seems reasonable to conclude that the slide moved over unconsolidated and water-saturated sediments of the lower member of the Salt Lake Formation. Under these circumstances, according to Hubbert and Rubey (1959, p. 152), a large mass of rock could be transported a considerable distance down a surface of low slope. The sudden load would be supported mostly by water in a sedimentary unit that is not highly permeable. An alternative interpretation, not favorably
considered, involves westward sliding of the carbonate rock of Crow Mountain over previously brecciated Precambrian-Cambrian quartzite.

**Slide Blocks**

**General statement**

A slide block is an intact mass that has moved downslope a relatively short distance. The trace of the slide-block surface is usually concave with the result that the length, along the mountain front, is about twice the width. The mass of brecciated dolomite, which rests on the prominent west-dipping surface just north of Hyde Park Canyon, is mapped as a slide block. It is unlike other slide blocks and, therefore, has been described separately.

**Descriptions**

Three slide blocks are present between Green Canyon and Dry Hollow, south of Hyde Park Canyon. One additional example, which is unusual because of its straight trace, extends northward from Hyde Park Canyon.

The southern slide block is located about 1 mile north of Green Canyon and terminates, on the northern side, at Beef Hollow. This slide block is about 3,600 feet long and 1,800 feet wide. The slide-block surface, near the southern end of the block, crops out in a small valley about 0.8 mile north of Green Canyon. There, it slopes westward at a low angle and cuts the Bloomington Formation. Medium-bedded limestone rests on thin-bedded limestone and shale. A short distance to the north, a landslide remnant of the Swan Peak Formation has dropped downward, along the slide-block surface, next to the Bloomington Formation. The limestone of the Bloomington, adjacent to the slide-block surface, is
locally white and partly recrystallized. Northward, the slide-block surface extends through the Cambrian-Silurian dolomite of a landslide mass. Its trace is evidenced by a low fault scarp. This slide block is closely associated with the largest remnant of the major landslide previously described.

Another slide block is located between Reeder and Sysnath Hollows. It is about 2,000 feet long and 900 feet wide. There, light-gray dolomite of the Nounan Formation slid downslope onto the Bloomington Formation. Three landslide remnants of the Swan Peak and Fish Haven Formations are superposed on the slide block. The basal surface is well exposed in the bottom of Reeder Hollow. There, medium- to light-gray dolomite of the Nounan rests on thin-bedded limestone and green shale of the Bloomington. The surface is slightly concave. On the northern side of Reeder Hollow, the limestone of the Bloomington is white and slightly recrystallized. It is also dragged down to the west beneath the surface. At the northern end of the slide block, dislocated Nounan rests on Bloomington.

A larger slide block extends from Mahogany Hollow to Dry Hollow. It is 3,600 feet long and 1,200-1,600 feet wide. It involves the Bloomington Formation, the Nounan Formation, and the Worm Creek Member of the St. Charles Formation. At the southern end, the Bloomington-Nounan contact on the slide block is offset only about 100 feet westward from its location south of the slide block. In Bogus Hollow, a short distance to the north, Nounan of the slide block rests on the Bloomington and Nounan Formations. The Bloomington on the west is separated from the Nounan on the east by a west-dipping high-angle thrust fault which
is truncated by the slide-block surface (Figure 27). Between Bogus Hollow and Dry Hollow, the Nounan Formation and the Worm Creek Member of the St. Charles Formation both rest on the Bloomington and Nounan Formations. There, also, a segment of the high-angle thrust fault separates the Bloomington and Nounan Formations. It is covered at both ends by the slide block. Along the northern end of the slide block, the Nounan opposes nearly the full width of the outcrop of the Bloomington Formation to the north. There, the slide block moved about 1,000 feet westward.

On the northern side of the lower part of Hyde Park Canyon, a slide-block surface cuts the Ute Formation (Figure 28). It separates divergent dips and is somewhat concave to the west. The unusually wide outcrop of the Ute Formation resulted from the sliding. Northward, the slide-block surface dies out in the Ute.

**Structural interpretations**

The slide blocks formed later than the landslides. In two instances, weight added by the landslides may have activated the slide blocks. This applies to the slide block located between Green Canyon and Beef Hollow as well as to the one between Reeder and Sysnath Hollows. The larger slide block, between Mahogany Hollow and Dry Hollow, may have been controlled by the west-dipping high-angle thrust fault near its eastern side.
Figure 27. Slide block of Nounan Formation on Bloomington and Nounan Formations on northern side of Bogus Hollow; view north. High-angle thrust fault at lower left, separating Bloomington and Nounan, is truncated by slide-block surface.
Figure 28. Slide block of Ute Formation on northern side of Hyde Park Canyon; view north.
STRUCTURAL EVENTS

General Statement

Two major events of crustal deformation are recognized in the eastern part of the Smithfield quadrangle. The first is folding and thrust faulting of rocks of Precambrian and Paleozoic age; the second is gravity faulting. The folding and thrust faulting are effects of the Laramide orogeny which involved much of western United States. It is generally believed to have started by late Cretaceous time and to have continued into the early part of the Tertiary Period.

Gravity faulting began early in the Tertiary Period, evidently after the cessation of folding and thrust faulting. It resulted in the collapse of Cache Valley relative to the mountain along the eastern margin of the Smithfield quadrangle. This faulting probably started before the deposition of the Salt Lake Formation of Tertiary age. It continued during the deposition of Tertiary and Quaternary rocks and is active at the present time. This event is part of the Basin and Range faulting that is operative throughout western Utah and Nevada. Major downslope movements have occurred along the western front of the Bear River Range as a consequence of the down faulting of Cache Valley.

Laramide Events

Major folding and related faulting

The earliest Laramide event recognized in the Smithfield quadrangle is the folding and related faulting of the Precambrian and Paleozoic...
rocks along the front of the Bear River Range. There, east-dipping beds form the western limb of the Logan Peak syncline. The bedding-plane faults probably formed before and during early folding; the high-angle thrust faults formed generally later.

The youngest formation, known to have been folded in the Logan Peak syncline, is the Oquirrh. Only the lower part, which is almost certainly of Pennsylvanian age, is present. On the eastern flank of the Logan Peak syncline, stratigraphic units as young as the lower part of the Brazer Formation of Williams are overlapped by the Wasatch Formation of presumed Eocene age. This evidence indicates that folding occurred within the interval that extends from early Pennsylvanian to early Tertiary time. Younger folded rocks of late Paleozoic and Mesozoic age were removed by erosion before the deposition of the Wasatch Formation. It seems appropriate, therefore, to assign the folding and related faulting to the Laramide orogeny.

The Laramide orogeny is generally considered to have started by late Cretaceous time and to have extended into the early part of the Tertiary Period. Armstrong and Cressman (1963, p. 8-9) have presented some evidence which suggests that deformation in the Bear River Range began as early as Jurassic time. Cobbles and boulders of Paleozoic units as old as the Swan Peak Formation of Ordovician age are present in the Ephraim Formation of southeastern Idaho, east of the Bear River Range. Stratigraphic details of the Ephraim indicate that the source area was not far to the west. Evidently much erosion had taken place, at the site of the Bear River Range, by the time of deposition of the Ephraim. Inasmuch as the Ephraim is thought to be of late Jurassic (?)
to early Cretaceous age, the deformation probably started as early as Jurassic time. This deformation had ended, in the vicinity of the Bear River Range, by the time of deposition of the Wasatch Formation of Eocene age.

In summary, folding in the Smithfield quadrangle probably started as early as late Jurassic time. Precambrian and Paleozoic rocks of the eastern part of the quadrangle, in the Bear River Range, were tilted eastward on the western flank of the Logan Peak syncline. A major anticline, and perhaps other folds, formed just west of the Bear River Range.

Eastward movement on the bedding-plane faults probably occurred before and during initial folding. As folding progressed, the beds steepened on the eastern flank of a major anticline and high-angle west-dipping thrust faults formed.

Low-angle thrust faulting

The latest Laramide event, in the Smithfield quadrangle, is eastward movement on west-dipping low-angle thrust faults. Deformation of this type is to be expected with greater steepening and local overturning of the beds along the eastern side of Cache Valley on the eastern limb of a major anticline. Deformation, characterized by crustal shortening, ended in the vicinity of the Bear River Range by the time of deposition of the Wasatch Formation of Eocene age.

Basin and Range Events

Gravity faulting and related features

Gravity faulting followed the folding and thrust faulting of the
Laramide orogeny. It probably started soon after the deposition of the Wasatch Formation. The Wasatch was deposited on a surface of relatively low relief and is presumed to be of middle Eocene age. The Salt Lake Formation, which overlies the Wasatch, seems to have accumulated during down faulting of major valleys. It ranges in age from late Eocene or early Oligocene to Pliocene. The gravity faulting, therefore, began as early as Eocene time and continued up to the present.

The relative collapse of Cache Valley produced great topographic relief along the western side of the Bear River Range. This resulted in slope instability. As a consequence, large masses moved down the west-dipping surface. Two major landslides seem to have moved over the lower member of the Salt Lake Formation and to have been covered by conglomerate of the upper member. Slide blocks, with relatively little movement, evidently formed after emplacement of the large landslides. Accelerated erosion of the mountains, east of the gravity faults, resulted in the deposition of the upper conglomerate member of the Salt Lake Formation.

**Continued gravity faulting**

Cache Valley continued to drop relative to the foothills of Salt Lake Formation in the northern part of the mapped area and relative to Paleozoic rocks along the mountain front in the southern part. Gravity faults definitely break the Salt Lake Formation between Smithfield Canyon and Crow Mountain, on the eastern sides of Long Hill and Round Hill, and west of Sysnath Hollow.

Gravity faulting continued during the deposition of the Lake Bonneville Group. A west-facing fault scarp cuts the Lake Bonneville
Group at the southern edge of the map. Faulting of alluvial deposits is, in most cases, inferred; however, good evidence is present west of Green Canyon.

Local earthquakes indicate continued gravity faulting (Cook and Smith, 1967). The unusually severe earthquake, magnitude 5.7, of August 30, 1962, had an epicenter about 3 miles north of the mapped area. The epicenter was located about a quarter of a mile east of Richmond, Utah, and the focus was at a depth of 40 kilometers.
LITERATURE CITED


Haynie, Anthon V., Jr. 1957. The Worm Creek Quartzite Member of the St. Charles Formation, Utah-Idaho. MS thesis, Utah State Agricultural College, Logan, Utah.


Peterson, Vic E. 1936. The geology of a part of the Bear River Range and some relationships that it bears with the rest of the range. MS thesis, Utah State Agricultural College, Logan, Utah.


APPENDIX
Section No. 1. Mutual Formation, measured on northern side of Birch Canyon in sec. 19 (unsurveyed), T. 13 N., R. 2 E.

Brigham Formation

Mutual Formation

<table>
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<th>Thickness (Feet)</th>
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7. Quartzite

Types
- Quartzite, pale pink, medium to coarse grained with pebbles, weathers pale red to light brown
- Quartzite, grayish orange pink, medium grained, weathers pale red to pale reddish brown
- Quartzite, grayish orange pink, medium to coarse grained, weathers pale red

Bed thickness
0.8 to 1.2 feet

Structures
- Pebbles of white quartz, jasper, gray quartz, and pink quartzite scattered along cross-beds and bedding planes

6. Quartzite

Types
- Quartzite, pale red purple, medium grained, muscovite, weathers grayish red purple
- Quartzite, grayish purple and pale red purple in bands, medium grained, biotite, weathers grayish purple and pale red in bands
- Quartzite, light grayish purple, medium grained, biotite, muscovite, weathers brownish gray

Interbeds
- Pebbles of white quartz, jasper, and pink quartzite in layer

Bed thickness
0.5 to 2.2 feet

Structures
- Cross-bedding
- Liesegang banding

5. Quartzite

Types
- Quartzite, pinkish gray, medium grained, weathers pinkish gray
- Quartzite, grayish pink, medium grained, hematite, weathers grayish orange pink
Quartzite, grayish pink, medium grained, hematite, muscovite, weathers pale red

Bed thickness
0.5 to 2.1 feet

Structures
Cross-bedding
Pebbles of white quartz scattered
Liesegang banding near top

4. Quartzite

Types
Quartzite, pale red purple with pale-pink to moderate-orange-pink bands, medium to coarse grained with very coarse-grained layers, weathers grayish red purple to blackish red
Quartzite, pale red purple, medium grained, weathers grayish red purple to pale red purple

Bed thickness
0.45 to 2.1 feet

Structures
Cross-bedding
Pebbles of white quartz
Liesegang banding

3. Quartzite

Types
Quartzite, grayish orange pink, medium grained, hematite, weathers pale red
Quartzite, grayish orange pink, medium grained, hematite, weathers grayish orange pink
Quartzite, grayish orange pink, medium grained, hematite, weathers grayish pink
Quartzite, grayish pink, medium grained with small pebbles, hematite, weathers pinkish gray

Interbeds
Pebbles of white quartzite, pink quartzite, gray quartzite, jasper, and white quartz

Bed thickness
1.2 to 3.8 feet

Structures
Cross-bedding
2. Quartzite

Types
Quartzite, pinkish gray and brownish black with pale-pink, grayish-red-purple, and dusky-red pebbles, pebbles in medium- to coarse-grained matrix, weathers brownish black with pale-pink and grayish-red-purple pebbles
Quartzite, grayish red purple, medium grained, weathers grayish red purple to blackish red
Quartzite, grayish red purple, medium grained, weathers grayish red purple to blackish red
Quartzite, grayish red purple, coarse to very coarse grained, weathers blackish red
Quartzite, grayish purple and pale purple, medium to coarse grained

Interbeds
Pebbles of white quartzite, pink quartzite, gray quartzite, and jasper

Bed thickness
0.9 to 2.4 feet

Structures
Cross-bedding
Scattered pebbles of white quartzite
Liesegang banding

1. Quartzite

Types
Quartzite, grayish pink, medium grained, weathers pale red
Quartzite, pale pink, coarse grained, weathers grayish orange pink
Quartzite, pale red purple with grayish-red-purple bands, medium grained, hematite, weathers pale red with blackish-red bands
Quartzite, pale red purple and grayish red purple, medium grained, weathers grayish red purple
Quartzite, grayish purple and pale pink in bands, medium grained, weathers grayish red purple and red purple in bands

Interbeds
Alternates with quartzite described below

Bed thickness
0.8 to 2.4 feet

Structures
Cross-bedding
Pebbles of white quartz and quartzite scattered
Types
Quartzite, grayish pink, medium grained, weathers grayish orange pink
Quartzite, pale pink, medium grained, weathers grayish orange pink

Interbeds
Pebbles of white quartzite, pink quartzite, and jasper

Bed thickness
1.0 to 2.2 feet

Structures
Cross-bedding

Total Mutual Formation . . . . . . . . . . 335.9

Precambrian quartzite
Section No. 2. Brigham Formation, measured on ridge between Birch and Smithfield Canyons in secs. 17 (unsurveyed), 18, and 19 (unsurveyed), T. 13 N., R. 2 E.

Langston Formation

Brigham Formation

<table>
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<td>17. Quartzite and shale</td>
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Types
- Quartzite, light olive gray, very fine grained, muscovite, weathers light olive gray and dark yellowish brown with particles of limonite
- Quartzite, dark greenish gray, fine grained, weathers olive gray with particles of limonite
- Quartzite, pale yellowish brown and grayish olive in bands, fine grained, weathers pale yellowish brown and grayish olive in bands

Interbeds
- Alternates with micaceous shale described below

Bed thickness
- 0.13 to 3.7 feet

Fossils
- Worm burrows

Type
- Micaceous shale, moderate yellowish brown to dusky yellow, weathers moderate yellowish brown

Bed thickness
- Fissile

Fossils
- Tracks and trails

16. Quartzite | 19.0 |

Types
- Quartzite, medium dark gray, coarse grained, weathers medium dark gray with particles of limonite
- Quartzite, medium gray, medium to coarse grained, biotite, weathers medium dark gray

Bed thickness
- 0.4 to 3.0 feet
Structures
Cross-bedding

Fossils
Worm burrows

15. Quartzite .......................... 30.0

Types
Quartzite, yellowish gray, fine grained, muscovite, weathers grayish orange to light olive gray
Quartzite, light olive gray and grayish orange, muscovite, medium grained with coarse-grained beds, weathers moderate yellowish brown
Quartzite, very pale orange and grayish olive in bands, coarse grained, muscovite, weathers grayish orange with light-olive-gray bands and with particles of limonite

Interbeds
Brown shale, 0.6 feet thick, 4.0 feet above base

Bed thickness
0.4 to 3.9 feet

Structures
Cross-bedding

Fossils
Worm burrows

14. Quartzite and shale .................. 38.2

Types
Quartzite, grayish purple with light-olive-gray bands, medium grained, muscovite, jasper, weathers grayish red purple and medium gray
Quartzite, grayish red purple, fine grained, jasper, weathers grayish purple
Quartzite, grayish purple, medium to coarse grained, muscovite, weathers brownish gray to brownish black with particles of limonite
Quartzite, grayish olive, fine grained, weathers moderate yellowish brown with particles of limonite

Interbeds
Alternates with micaceous shale described below; quartzite 90 percent

Bed thickness
0.3 to 2.0 feet
Structures
Cross-bedding
Banding

Fossils
Worm burrows

Type
Micaceous shale, moderate yellowish brown to dusky yellow, weathers moderate yellow brown to dusky yellow

Bed thickness
Platy

13. Quartzite

Types
Quartzite, medium gray, very fine grained, hematite, weathers medium dark gray with particles of limonite and altered feldspar
Quartzite, medium gray and light olive gray in bands, fine grained, hematite, weathers medium gray and medium dark gray with particles of limonite and altered feldspar
Quartzite, medium gray, very fine grained, muscovite, weathers medium dark gray with particles of limonite and altered feldspar
Quartzite, medium dark gray, very fine grained, weathers dark gray with particles of limonite and altered feldspar

Interbeds
Alternates with quartzites described below; 50 percent

Bed thickness
0.15 to 2.7 feet

Structures
Cross-bedding

Fossils
Worm burrows

Types
Quartzite, light olive gray, very fine grained, weathers light olive gray with particles of limonite
Quartzite, greenish gray, fine grained, weathers olive gray with particles of limonite
Quartzite, pale to moderate yellowish brown, silt size to very fine grained, muscovite, weathers dark yellowish brown with particles of limonite

Interbeds
Alternates with quartzites described above; quartzite 50 percent

Bed thickness
0.4 to 2.3 feet

Structures
Cross-bedding

Fossils
Worm burrows

12. Quartzite and sandstone

Type
Quartzite, pale yellowish brown and pinkish gray, medium to coarse grained, muscovite, abundant hematite, weathers grayish orange to pale yellowish brown with particles of limonite

Interbeds
Alternates with sandstone described below; quartzite 90 percent

Bed thickness
0.5 to 4.9 feet

Structures
Cross-bedding excellent

Fossils
Worm burrows abundant

Types
Micaceous sandstone, moderate to dark yellowish brown, abundant hematite, silt size to coarse grained, weathers dark yellowish brown with particles of limonite
Micaceous sandstone, moderate yellowish brown, silt size to coarse grained, hematite, weathers dark yellowish brown with particles of limonite

Bed thickness
0.4 to 0.5 feet
11. Shale and quartzite

Types

Micaceous shale, dark yellowish brown, clay size, weathers grayish orange to moderate yellowish brown
Micaceous shale, moderate yellowish brown, clay size with medium-grained sand, weathers grayish orange
Micaceous shale, moderate yellowish brown, clay size, weathers grayish orange
Micaceous shale, moderate yellowish brown, clay size to very fine to medium sand, weathers grayish orange to pale yellowish orange
Micaceous shale, moderate to dark yellowish brown, clay to silt size, weathers grayish orange to moderate yellowish brown
Micaceous shale, dark to moderate yellowish brown, clay and silt size with medium to coarse sand, weathers grayish orange with dusky-yellowish-brown and light-brown stains

Interbeds
Alternates with quartzite, quartzitic siltstone, and quartzitic sandstone described below

Bed thickness
Platy

Structures
Pinches out

Fossils
Worm burrows
Tracks and trails

Types
Quartzite, dark yellowish to dusky yellowish brown, medium to coarse grained, weathers dark yellowish brown
Quartzite, light olive gray, medium to coarse grained, weathers dark yellowish brown with moderate-brown stains
Quartzite, light olive gray to dark yellowish brown, medium grained, weathers dark yellowish brown and moderate yellowish brown
Quartzitic siltstone, light olive gray, silt size, muscovite abundant, weathers dark yellowish brown with particles of altered feldspar
Quartzitic sandstone, light olive gray, fine grained, muscovite, dark yellowish brown with moderate-brown stains and particles of weathered feldspar
Bed thickness
0.1 to 3.0 feet
Pinches out

Structures
Cross-bedding excellent

10. Quartzite

Types
Quartzite, pinkish gray, medium to coarse
grained with some coarse grains, muscovite,
feldspar, weathers very pale orange to grayish
orange
Quartzite, pinkish gray, coarse to very coarse
grained, feldspar, weathers pale yellowish brown
Quartzite, pinkish gray, medium grained,
muscovite, feldspar, weathers pale yellowish
brown

Bed thickness
0.5 to 2.8 feet

Structures
Cross-bedding excellent

9. Quartzite

Types
Quartzite, grayish red purple, medium to coarse
grained with very coarse grains, feldspar
abundant, weathers moderate blackish red
Quartzite, pale red purple and grayish red
purple in bands, medium grained with some
coarse grains, abundant feldspar, hematite,
weathers pale red to grayish red
Quartzite, pale red purple and grayish red
purple in bands, fine to medium grained,
feldspar abundant, weathers grayish red
purple and moderate blackish red in bands
Quartzite, pale purple to pale red purple, fine
grained, weathers grayish red purple
Quartzite, grayish red purple with grayish-
purple bands, coarse to very coarse grained
with some medium grains and granules, feldspar,
weathers grayish purple

Bed thickness
0.4 to 3.6 feet

Structures
Cross-bedding excellent with white quartz
pebbles along cross-beds
Liesegang banding
8. Quartzite

Types
- Quartzite, light gray to light olive gray, medium grained with some coarse and very coarse grains, muscovite, weathers yellowish gray with grayish-orange stains
- Quartzite, very light gray, coarse to very coarse grained, hematite, feldspar, weathers dark yellowish brown with particles of limonite

Bed thickness
0.2 to 2.4 feet

Structures
- Cross bedding small scale
- Cross bedding large scale

7. Quartzite

Types
- Quartzite, grayish orange, coarse grained with some very coarse grains, weathers grayish orange pink
- Quartzite, grayish orange, coarse grained with some very coarse grains, weathers grayish orange pink
- Quartzite, moderate yellowish brown, medium grained, muscovite, weathers pale yellowish brown with light-brown stains
- Quartzite, grayish orange, medium grained, hematite, weathers grayish orange
- Quartzite, very pale orange, very coarse grained with small pebbles, weathers moderate yellowish brown

Interbeds
- Few beds of quartzite described below

Bed thickness
0.3 to 3.5 feet

Structures
- Cross bedding in places with layers of quartz pebbles along cross beds

Types
- Quartzite, very pale orange, medium grained, weathers grayish orange
- Quartzite, very light gray, medium grained, muscovite, weathers grayish orange with dark-yellowish-orange and light-brown stains
Bed thickness
0.5 to 1.8 feet

6. Quartzite

Types
Quartzite, light gray with pale-red pebbles, fine grained with some coarse grains and small pebbles, weathers light olive gray
Quartzite, very light gray, medium to very coarse grained, weathers very pale orange
Quartzite, very light gray, medium to coarse grained with small pebbles, weathers pinkish gray with light-brown stains

Bed thickness
0.3 to 3.0 feet

Structures
Cross-bedding

5. Quartzite

Types
Quartzite, grayish orange, coarse grained, muscovite, weathers pale yellow
Quartzite, moderate orange pink, fine to coarse grained, hematite, weathers light brown
Quartzite, grayish orange, medium to coarse grained, weathers pale yellowish brown to moderate brown
Quartzite, light olive gray, fine grained with some coarse grains, weathers moderate brown
Quartzite, light olive gray, fine grained with coarse grains, weathers dark yellowish brown

Bed thickness
0.2 to 2.5 feet

Structures
Cross-bedding prominent with layers of white quartz pebbles along cross-beds

4. Quartzite

Types
Quartzite, pinkish gray, medium grained, weathers grayish orange pink
Quartzite, pinkish gray, medium to coarse grained, weathers grayish orange to light brown
Quartzite, grayish pink, fine to medium grained, weathers grayish orange pink
Quartzite, grayish orange pink, medium to coarse grained, weathers grayish orange pink

Bed thickness
0.2 to 2.5 feet

Structures
Cross-bedding prominent with layers of white quartz pebbles along cross-beds
Bed thickness
1.1 feet, range 0.3 to 4.0 feet

Structures
Cross-bedding in places
Pebbles of white quartz, red quartzite, and gray quartzite scattered

3. Quartzite

Types
Quartzite, greenish gray, medium grained, weathers pale yellowish brown
Quartzite, grayish orange, medium to coarse grained, weathers light brown with particles of limonite
Quartzite, pale yellowish brown, medium to coarse grained, weathers light brown
Quartzite, grayish orange, coarse to very coarse grained, hematite, weathers grayish orange pink with particles of limonite

Bed thickness
0.3 to 2.0 feet

Structures
Cross-bedding
Pebbles of white quartzite in layers

2. Quartzite

Types
Quartzite, grayish orange pink, fine to medium grained, weathers grayish orange pink
Quartzite, grayish pink, fine grained, weathers orange pink

Bed thickness
0.5 to 1.9 feet

Structures
Cross-bedding

1. Quartzite

Types
Quartzite, yellowish gray, fine to coarse grained, weathers pale yellowish brown
Quartzite, grayish orange pink, medium to coarse grained, hematite, weathers light to moderate brown
Quartzite, pinkish gray, medium to coarse grained, hematite, weathers pinkish gray to light brownish gray
Quartzite, pinkish gray, medium to coarse grained, weathers grayish orange pink
Bed thickness
0.3 to 2.8 feet

Structures
Cross-bedding in places
Pebbles of white quartz in places

Total Brigham Formation . . . . . . . 2,549.0

Mutual Formation
Section No. 3. Langston Formation, measured on ridge between Birch and Smithfield Canyons in sec. 17 (unsurveyed), T. 13 N., R. 2 E.

Ute Formation

Langston Formation

<table>
<thead>
<tr>
<th>Thickness (Feet)</th>
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<tbody>
<tr>
<td>6. Dolomite</td>
</tr>
</tbody>
</table>

Type

Dolomite, medium light gray, medium crystalline, weathers moderate yellowish brown

Bed thickness

0.4 to 3.5 feet

Structures

Bedding planes irregular

<table>
<thead>
<tr>
<th>Thickness (Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Dolomite</td>
</tr>
</tbody>
</table>

Types

Dolomite, medium light gray, very fine crystalline, weathers yellowish gray
Dolomite, medium gray, very fine crystalline, weathers yellowish gray with medium-light-gray bands with yellowish-gray spots
Dolomite, light gray, very fine crystalline, weathers yellowish gray
Dolomite, medium light gray, very fine crystalline, weathers yellowish gray with light-gray bands with yellowish-gray spots

Interbeds

Dark-gray dolomite in irregular layers 0.01 to 0.07 feet thick

Bed thickness

2.2 to 3.3 feet

Structures

Bedding planes irregular

<table>
<thead>
<tr>
<th>Thickness (Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Limestone</td>
</tr>
</tbody>
</table>

Types

Limestone, medium dark gray, coarse crystalline with quartz sand, weathers medium light gray
Limestone, dark gray, very fine crystalline with silt, weathers medium light gray

Interbeds

Thin irregular silty layers which weather brown
Bed thickness
0.05 to 0.67 feet

Structures
Bedding planes irregular

Fossils
Shell fragments
Trilobite fragments

3. Shale
Type
Calcareous shale, medium dark gray, clay and silt size, weathers medium gray

Bed thickness
Fissile

Relation
Lower third of unit

Type
Shale, light olive gray, clay size, weathers light olive gray

Bed thickness
Fissile

Relation
Upper two-thirds of unit

2: Limestone
Types
Limestone, medium light gray, very fine crystalline with quartz and muscovite sand, weathers medium gray
Limestone, medium dark gray, very fine crystalline with quartz and muscovite sand, weathers medium gray

Bed thickness
0.3 to 1.0 feet

Structures
Bedding planes irregular

Fossils
Trilobite fragments
1. Limestone and sandstone  . . . . . . . . . . . 17.0
   
   **Type**
   Sandy limestone, light gray, very fine crystalline
   with very fine-grained quartz and muscovite
   sand, weathers medium light gray
   
   **Bed thickness**
   0.01 to 0.17 feet
   
   **Types**
   Calcareous sandstone, pale yellowish brown and
   medium light gray, very fine grained, muscovite,
   weathers with grayish-orange to moderate-brown
   sandy surface
   Calcareous sandstone, light gray, very fine grained,
   muscovite, hematite, weathers with grayish-
   orange to moderate-yellowish-brown sandy crust
   
   **Bed thickness**
   0.03 to 0.4 feet
   
   **Total Langston Formation**  . . . . . . . . . . . 360.3

**Brigham Formation**
Section No. 4. Swan Peak Formation, measured on northern side of Green Canyon in sec. 17, T. 12 N., R. 2 E.

Fish Haven Formation

Swan Peak Formation

8. Quartzite and sandstone . . . . . . . . . . 111.0

Types

Quartzite, very light gray, fine grained, weathers pinkish gray
Quartzite, very light gray, very fine grained, weathers yellowish gray
Quartzite, yellowish gray, silt size, weathers grayish orange
Quartzite, very light gray, very fine grained, weathers light brown with pale-yellowish-orange and moderate-reddish-brown spots
Sandstone, very light gray, very fine grained, weathers grayish orange

Bed thickness
0.7 to 5.7 feet

Structures
Ripple marks in places

7. Quartzite . . . . . . . . . . . . . . . . . . 30.8

Types

Quartzite, grayish red purple and light gray in bands, silt size in purple layers, fine grained in gray layers, weathers grayish red to blackish red with medium-light-gray bands
Quartzite, pale red purple and grayish red purple, very fine grained, weathers pale red and grayish red
Quartzite, grayish red purple, silt size, weathers brownish gray with moderate-yellowish-brown stains
Quartzite, pale pink to pale red purple, silt size, weathers pale pink to pale purple

Interbeds
Pink and light-gray quartzite

Bed thickness
0.28 to 3.1 feet

Structures
Cross-bedding
Fossils
Fish fragments

6. Quartzite and shale . . . . . . . . . . . . . . . 8.5
Types
Quartzite, pale brown and pale red purple, silt size, weathers grayish red with moderate-yellowish-brown stains
Quartzite, very dusky red and grayish yellow green, silt size, weathers very dusky red and light greenish gray
Quartzite, pale red purple, silt size, weathers greenish gray and grayish red to grayish red purple

Interbeds
Alternates with shale described below

Bed thickness
0.15 to 1.15 feet

Structures
Ripple marks in places

Fossils
Gastropods
Fish fragments
Fucoidal markings abundant

Type
Shale, grayish red to grayish red purple, weathers grayish red to grayish red purple

Bed thickness
Fissile
Units 0.11 to 0.23 feet

5. Quartzite and shale . . . . . . . . . . . . . . . 14.3
Types
Quartzite, light olive gray, silt size with coarse to very coarse grains of hematite, weathers light greenish gray with moderate-yellowish-brown stains
Quartzite, pale yellowish brown with moderate yellowish brown in thin bands and light olive gray, weathers dark yellowish brown, moderate yellowish brown, and greenish gray

Interbeds
Green shale described below; quartzite 90 percent
Bed thickness
0.46 to 1.6 feet

Fossils
Fucoidal markings

Type
Shale, grayish olive, weathers grayish olive with moderate-yellowish-brown stains

Bed thickness
Fissile

4. Quartzite . . . . . . . . . . . . . . . . . . . . 10.2

Types
Quartzite, light gray and dark gray in bands, silt size, weathers olive gray with moderate-brown stains
Quartzite, light gray, silt size, weathers pale yellowish brown and moderate yellowish brown with particles of limonite
Quartzite, pale yellowish brown, silt size, weathers greenish gray and dark greenish gray
Quartzite, light olive gray, silt size, weathers greenish gray with dusky-yellow stains, dark yellowish brown, and greenish gray
Quartzite, light olive to olive gray, silt size, weathers dark yellowish brown

Interbeds
Thin interbeds of dark-gray shale
Bottom of quartzite gradational to shale by interbedding

Bed thickness
0.12 to 0.63 feet

Structures
Ripple marks on top of quartzite beds in places

Fossils
Fucoidal markings

Type
Shale, dark gray to olive gray, weathers dark gray to olive gray with yellow-brown stains

Bed thickness
Fissile
Units 0.28 to 0.75 feet
### 3. Covered

<table>
<thead>
<tr>
<th>Types</th>
<th>72.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covered Limestone and shale</td>
<td>16.6</td>
</tr>
</tbody>
</table>

#### Interbeds

Alternates with shale described below

| Bed thickness | 0.08 to 0.38 feet |

| Structures | 0.04 to 0.09 feet thick, along bedding planes |

| Fossils | Brachiopods |

<table>
<thead>
<tr>
<th>Type</th>
<th>136.9</th>
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</table>

#### 1. Shale and quartzitic siltstone

<table>
<thead>
<tr>
<th>Types</th>
<th>16.6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shale, dark gray, weathers medium gray with moderate-yellowish-brown to dark-yellowish-orange stains</td>
<td>0.5 to 0.8 feet</td>
</tr>
</tbody>
</table>

| Bed thickness | 0.08 to 0.38 feet |

| Structures | Limestone lenses, 0.04 to 0.09 feet thick, along bedding planes |

| Fossils | Brachiopods |

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| Bed thickness | 0.08 to 0.38 feet |

| Structures | Limestone lenses, 0.04 to 0.09 feet thick, along bedding planes |

| Fossils | Brachiopods |

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| Bed thickness | 0.08 to 0.38 feet |

| Structures | Limestone lenses, 0.04 to 0.09 feet thick, along bedding planes |

| Fossils | Brachiopods |

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| Bed thickness | 0.08 to 0.38 feet |

| Structures | Limestone lenses, 0.04 to 0.09 feet thick, along bedding planes |

| Fossils | Brachiopods |

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</thead>
<tbody>
<tr>
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<td>0.5 to 0.8 feet</td>
</tr>
</tbody>
</table>

| Bed thickness | 0.08 to 0.38 feet |

| Structures | Limestone lenses, 0.04 to 0.09 feet thick, along bedding planes |

| Fossils | Brachiopods |
Silty limestone, medium gray, medium crystalline, weathers grayish orange to moderate yellowish brown
Calcareous quartzitic siltstone, pale red, silt size, weathers pale red, and grayish red to pale reddish brown

Fossils
Trilobite fragments
Cephalopods
Gastropods
Brachiopods

Total Swan Peak Formation  . . . . . . . 400.8

Garden City Formation
Section No. 5. Swan Peak Formation, measured on northern side of Logan Canyon in sec. 30, T. 12 N., R. 2 E.

Fish Haven Formation

Swan Peak Formation

<table>
<thead>
<tr>
<th>Thickness (Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Quartzite . . . . . . . . . . . . . . . . . . .</td>
</tr>
</tbody>
</table>

Types
Quartzite, light gray, very fine grained, weathers yellowish gray
Quartzite, light brownish gray, silt size, weathers pale brown
Quartzite, medium dark gray, very fine grained, weathers light olive gray

Bed thickness
0.07 to 3.6 feet

Structures
Cross-bedding

Fossils
Fish fragments
Fucoidal markings

3. Quartzite and shale . . . . . . . . . . . . . . . 29.3

Types
Quartzite, pale pink and grayish red, silt size, weathers pale red and brownish gray
Quartzite, pale red purple, silt size, weathers grayish red purple with moderate-yellowish-brown stains
Quartzite, grayish red, silt size, weathers grayish brown
Quartzite, grayish red purple, silt size, weathers grayish red

Interbeds
Alternates in lower part with shale described below

Bed thickness
0.01 to 2.3 feet

Structures
Cross-bedding

Fossils
Cephalopods
Fucoidal markings
Types
Shale, grayish red
Shale, light brownish gray
Shale, light olive gray
Shale, greenish gray

Bed thickness
Fissile
Units 0.05 to 0.35 feet

2. Quartzite and shale

Types
Quartzite, pale yellowish brown and moderate yellowish brown, silt size, weathers pale yellowish brown, moderate yellowish brown, and moderate brown
Quartzite, pale yellowish brown, silt size, weathers dark yellowish brown
Quartzite, pale yellowish brown, silt size, weathers light olive gray and dark yellow brown
Quartzite, pale red purple and pale reddish brown, silt size, weathers pale red and grayish red

Interbeds
Alternates with shale described below; quartzite 95 percent

Bed thickness
0.01 to 1.2 feet

Structures
Beds irregular

Type
Shale, light greenish gray, weathers greenish gray with grayish-orange stains

Bed thickness
Fissile
Units 0.03 to 1.8 feet

1. Shale, quartzitic siltstone, and limestone

Type
Shale, dark gray, weathers medium gray

Interbeds
Alternates with quartzitic siltstone, and limestone described below

Bed thickness
Fissile
Types
Calcareous quartzitic siltstone, light olive gray, silt size, weathers moderate yellowish brown
Silty limestone, pale yellowish brown, silt size, weathers moderate yellowish brown
Silty limestone, medium gray and pale yellowish brown, silt size, weathers light brown
Calcareous quartzitic siltstone, moderate yellowish brown, silt size, weathers moderate yellowish brown
Calcareous quartzitic siltstone, grayish orange, silt size, weathers moderate yellowish brown
Calcareous quartzitic siltstone, pale yellowish brown, silt size, weathers moderate yellowish brown

Bed thickness
0.01 to 0.27 feet

Fossils
Brachiopods
Shell fragments

Types
Limestone, medium gray, weathers olive gray and pale yellowish brown
Limestone, medium gray, fossiliferous, weathers medium light gray with pale-yellowish-brown to moderate-yellowish-brown stains

Bed thickness
0.04 to 0.2 feet

Fossils
Brachiopods
Gastropods
Trilobites

Total Swan Peak Formation . . . . . . . 282.7

Garden City Formation