5-1975

Structural Geology of Eastern Part of the Malad Summit Quadrangle, Idaho

Jay Nevin Shearer
Utah State University

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STRUCTURAL GEOLOGY OF EASTERN PART OF THE
MALAD SUMMIT QUADRANGLE, IDAHO

by

Jay Nevin Shearer

A thesis submitted in partial fulfillment
of the requirements for the degree
of
MASTER OF SCIENCE
in
Geology

UTAH STATE UNIVERSITY
Logan, Utah

1975
ACKNOWLEDGMENTS

The writer wishes to thank Dr. Clyde T. Hardy of Utah State University for advice on geological problems in the field and constructive criticism of the manuscript. Dr. Donald R. Olsen and Dr. Robert Q. Oaks, Jr., both of Utah State University, reviewed the manuscript and offered suggestions for its improvement. Dr. Richard R. Alexander of Utah State University identified numerous fossils. Those identifications helped to resolve several stratigraphic problems. Wm. Calvin James helped to measure a stratigraphic section.

Financial assistance, provided by the Department of Geology of Utah State University during two years of study, was gratefully received. The writer wishes to express great appreciation to his wife, Christina, for her patience and understanding throughout the preparation of this report. She also typed the manuscript.

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ABSTRACT

Structural Geology of Eastern Part of the
Malad Summit Quadrangle, Idaho

by

Jay Nevin Shearer, Master of Science
Utah State University, 1975

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

The mapped area represents the eastern three-fourths of the Malad Summit Quadrangle, Idaho. It lies mainly in the Bannock Range of southeastern Idaho. The northern and southern margins of the area are 25.5 miles and 17.0 miles, respectively, north of the Idaho-Utah State Line.

The Caddy Canyon Formation of Late Precambrian age is the oldest exposed stratigraphic unit. The youngest unit, exclusively of Precambrian age, is the Mutual Formation. The Brigham Formation is considered to be of Late Precambrian to Early Cambrian (?) age. Younger formations of Cambrian to Silurian age are present. The Precambrian units, as well as the Brigham, consist chiefly of quartzite. Younger Paleozoic units are primarily limestone and dolomite. The Precambrian and Paleozoic units are unconformably overlapped by the Wasatch and Salt Lake Formations of Tertiary age.

A major thrust fault is widely exposed in the mapped area. It places various formations of early Paleozoic age in thrust contact
with the Brigham Formation. Several minor thrust faults are also present. The thrust faulting is related to the Laramide orogeny which was active in western United States from late Jurassic into Eocene.

Normal faults, in the mapped area, trend generally north-south and east-west. The north-south faults, characteristic of the Basin and Range province, are responsible for most of the relief in the area. The normal faulting began as early as Oligocene and has continued intermittently to the present.
INTRODUCTION

Purpose and Scope

The purpose of this investigation was to identify the stratigraphic units and to map the geologic structures of a limited area of southeastern Idaho. The area was heretofore unmapped. A contribution to the understanding of a geologically complex region is the result.

Location and Accessibility

The Malad Summit Quadrangle is located in southeastern Idaho between lat. 42°15'00" N. and lat. 42°22'30"N. and between long. 112°07'30" W. and long. 112°15'00" W. The Malad Summit Quadrangle is a 7.5-minute topographic map published by the Geological Survey of the United States Department of the Interior. The boundaries of the mapped area coincide with the boundaries of the Malad Summit Quadrangle except for the part of the quadrangle that is west of U. S. Highway 191 (Figure 1). That area was not covered in the investigation. The northern boundary of the mapped area is 25.5 miles north of the Idaho-Utah State Line. The north-south dimension of the area is 8.5 miles and east-west dimension ranges from 4 to 5 miles.

Ready access to the area, from the north and south, is provided by U. S. Highway 191 (Figure 1). Any feature of geologic interest is readily accessible from this hard-surfaced road by means of improved and unimproved roads leading into the area on the north, south, and east (Plate 1).
Figure 1. Index map of part of southeastern Idaho showing the location of the Malad Summit Quadrangle.
Physiographic Features

The mapped area is located within the Basin and Range province. The major physiographic feature is a mountain ridge that trends generally north-south (Figure 2). The area lies completely across a narrow part of the Bannock Range with its northeastern corner in Marsh Valley and its southwestern corner in Malad Valley (Figure 1). Marsh Valley lies to the north and is flanked by the Portneuf Range on the east and by the Bannock Range on the west. The Malad Range lies to the south. It is flanked by Cache Valley on the east and Malad Valley on the west. Red Rock Pass, the outlet for Pleistocene Lake Bonneville, connects Cache Valley and Marsh Valley.

The highest peak in the southern part of the Bannock Range, east of the mapped area, is Oxford Peak. It is 9,281 feet in elevation. The surrounding valleys range from 4,430 to 4,950 feet in elevation; within the mapped area, elevations range from 4,951 to 7,208 feet (Plate 1).

Field Work

Field investigations of the mapped area were conducted during the summers of 1971 and 1972. Features of geological importance were plotted in the field on vertical aerial photographs at a scale approximately 1:21,000. This information was later transferred to a base map at a scale of 1:12,000 (Plate 1). A base map was derived from a 1:24,000 7.5-minute topographic map of the Malad Summit Quadrangle. The quadrangle map was trimmed and enlarged to a scale of 1:12,000.
Figure 2. General view of mountain in mapped area; view northwest. Marginal normal fault extends along eastern side of mountain. Transverse normal faults cross mountain; hidden transverse normal fault is indicated by arrow.
A stratigraphic section of the Mutual Formation was measured with a steel tape and representative samples were collected (Appendix). The samples were described in the laboratory and rock colors were determined with the Rock-Color Chart distributed by the Geological Society of America.

**Previous Investigations**

Although the Malad Summit Quadrangle has not been the subject of previous investigations, nearby areas have been studied by other workers. The Precambrian and Paleozoic units and the structural geology of the Oxford Peak area were mapped by Raymond (1971). This area adjoins the eastern boundary of the Malad Summit Quadrangle. Similar studies have been conducted in the southern part of the Bannock Range, near Weston Canyon by Murdock (1961) and in the northern part of the Malad Range by Axtell (1967).

Walcott (1908) studied the stratigraphy and paleontology of the Cambrian formations in northern Utah and southeastern Idaho. Resser (1939) studied and described the fossils in the Spence Shale Member of the Langston Formation. Eardley and Hatch (1940) studied the Precambrian and lower Cambrian units in northern and central Utah. Ludlum (1942, 1943) studied the Precambrian and lower Paleozoic formations of the northern part of the Bannock Range near Pocatello, Idaho. The Paleozoic units of the Logan Quadrangle, in northern Utah, were studied and mapped by Williams (1948). Ross (1951) studied the stratigraphy of the Ordovician Garden City Formation in northern Utah.
The Lower and Middle Cambrian stratigraphy of northern Utah and southeastern Idaho were studied, in detail, by Maxey (1941, 1958). The most notable Cambrian section, described by Maxey, is that at High Creek in the Bear River Range of northern Utah. Armstrong and Cressman (1963) studied the Bannock thrust zone in southeastern Idaho. More recently, the upper Precambrian and Cambrian stratigraphy in northern Utah and southeastern Idaho has been studied by Crittenden, Schaeffer, Trimble, and Woodward (1971) and also by Oriel and Armstrong (1971).
STRATIGRAPHIC UNITS

General Statement

Stratigraphic units of Precambrian and early Paleozoic age, present in the mapped area, are summarized in Table 1. The Caddy Canyon Formation of Late Precambrian age is the oldest exposed stratigraphic unit. The youngest unit, exclusively of Precambrian age, is the Mutual Formation. The Brigham Formation is considered to be of Late Precambrian to Early Cambrian (?) age. Younger formations of Cambrian to Silurian age are present. The Ute Formation, listed in Table 1, is not present, in the mapped area, because of thrust faulting.

Tertiary units, present in the mapped area, are the Wasatch and Salt Lake Formations. They are generally faulted down next to Precambrian and Paleozoic units but, in places, they unconformably overlap the older units.

Quaternary units, in the mapped area, are the Lake Bonneville Group, colluvial deposits, alluvial deposits in fans, and alluvial deposits along streams. All Quaternary units unconformably overlap older formations.

Precambrian Units

Caddy Canyon Formation

The Caddy Canyon Formation in the northern part of the Bannock Range near Pocatello, in southeastern Idaho, consists of several thousand feet of vitreous quartzite (Crittenden and others, 1971, p. 585).
Table 1. Stratigraphic units of Precambrian and Paleozoic age, eastern part of the Malad Summit Quadrangle and surrounding area

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<td>Fish Haven-Laketown Formation</td>
<td>Dolomite</td>
<td>1,540\textsuperscript{a}</td>
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<td>Ordovician System</td>
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<td>Swan Peak Formation</td>
<td>Quartzite</td>
<td>574\textsuperscript{b}</td>
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<td></td>
<td>Quartzite and shale</td>
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<tr>
<td>Garden City Formation</td>
<td>Dolomite</td>
<td>1,764\textsuperscript{c}</td>
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<tr>
<td></td>
<td>Limestone with chert</td>
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<td>Limestone with intraformational conglomerate</td>
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<td>Cambrian System</td>
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<td>St. Charles Formation</td>
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<td>Dolomite</td>
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\textsuperscript{a}Samaria Mountain (Beus, 1968).
\textsuperscript{b}Clarkston Mountain (James, 1973).
\textsuperscript{c}Clarkston Mountain (Ross, 1951)
\textsuperscript{d}Clarkston Mountain (Hanson, 1949).
\textsuperscript{e}Two Mile Canyon (Axtell, 1967).
\textsuperscript{f}High Creek (Maxey, 1958).
\textsuperscript{g}Huntsville (Crittenden, 1972a).
\textsuperscript{h}Cherry Creek (this report).
The lower part weathers white and light brown and the upper part weathers pink and grayish red. The unit has some beds of green argillite. A bed of dolomite, about 50 feet thick, occurs in the upper part of the Caddy Canyon (Crittenden and others, 1971, p. 585).

A unit of quartzite, 1,500 to 2,500 feet thick near Huntsville, Utah, has been tentatively correlated with the Caddy Canyon of the Pocatello area (Crittenden and others, 1971, p. 591). The lower part of the unit is quartzite that weathers light brown to brown. It contains interbedded fine-grained quartzite and argillite. The upper part of the unit is chiefly quartzite that weathers light gray and light brown. The contact with the argillite of the overlying Inkom Formation forms a bench (Crittenden and others, 1971, p. 591).

In the Malad Summit Quadrangle, the Caddy Canyon is a vitreous quartzite that weathers white to light brown. The exposed thickness is approximately 500 feet; however, the base is not exposed. The best exposures of the Caddy Canyon, in the mapped area, are located along the eastern boundary of the area northeast of the Cherry Creek Campground (Figure 3). It is also present, on both sides of the ridge, about 1 mile north of New Canyon (Figure 1, Plate 1). Accurate attitude measurements are difficult to obtain because the unit is badly brecciated.

In addition to the white and light-brown quartzite, the Caddy Canyon contains some pink and pale-purple to medium-purple quartzite and some interbeds of green and light-brown argillite. The quartzite is fine grained to coarse grained. At one location, northeast of
Figure 3. Precambrian and Cambrian quartzite units, east of Cherry Creek; view east. Caddy Canyon (p€c), Mutual (p€m), and Brigham (€b) Formations dip north. Oxford Peak is at upper right.
Cherry Creek Campground, a thin unit of medium-gray to dark-gray dolomite breccia is present near the top of the formation. It is in approximately the same stratigraphic position as the dolomite in the Caddy Canyon described by Crittenden and others (1971, p. 585) near Pocatello.

The lower contact of the Caddy Canyon is obscured by colluvium and faulting. The upper contact is located at the top of a unit of white quartzite which contrasts sharply with the grayish-red quartzite of the overlying Mutual Formation. The top of the Caddy Canyon forms a slight topographic bench.

The age of the Caddy Canyon Formation is considered to be Late Precambrian (Crittenden and others, 1971, p. 581-582).

**Inkom Formation**

The Inkom Formation near Pocatello, Idaho, consists of 800 to 1,000 feet of green and grayish-red argillite that is stratigraphically above the Caddy Canyon Formation and below the Mutual Formation (Crittenden and others, 1971, p. 586). The upper contact with the quartzite of the overlying Mutual is not well defined.

A unit of argillite, east of Huntsville, Utah, has been tentatively correlated with the Inkom near Pocatello (Crittenden and others, 1971, p. 591). The Inkom, near Huntsville, is light green in the lower part and grayish red in the upper part. It is 360 feet to 450 feet thick.

The Inkom Formation is not present as a mappable unit in the Malad Summit Quadrangle, even though it is recognized to the north and south. Small amounts of purple, light-green, light-gray, and light-brown
argillite are present in the talus just above the massive-bedded, white quartzite outcrop of the Caddy Canyon Formation northeast of Cherry Creek Campground. The argillite is also present just above an outcrop of Caddy Canyon, on the western side of the ridge, about 1 mile north of New Canyon (Plate 1). The argillite is not exposed, in the mapped area, but it must be approximately 25 feet thick. It is mapped as part of the overlying Mutual Formation.

The Inkom is either not present or thin, in the mapped area, for one of several reasons. The Inkom may have been locally eroded before deposition of the Mutual, only a thin unit of Inkom was deposited, or a bedding-plane thrust fault between Inkom and Caddy Canyon may have eliminated most of the Inkom. Elimination by a thrust fault is evidenced by the fact that the quartzite of the Caddy Canyon and the lower part of the Mutual is brecciated. The argillite between the Caddy Canyon and the Mutual is also brecciated in places. The relationship between the Caddy Canyon and Mutual is not well exposed and, for this reason, it is mapped as a contact rather than a thrust fault. The Caddy Canyon and Mutual seem to be conformable; however, the argillite, included at the base of the Mutual, is not well enough exposed to prove conformity.

The Inkom Formation is considered to be Late Precambrian in age (Crittenden and others, 1971, p. 581-582).

Mutual Formation

The Mutual Formation has been recognized more widely than any of the other Late Precambrian units of southeastern Idaho and northern
Utah. This is probably due to its distinctive grayish-red quartzite. It has been identified in the northern Bannock Range near Pocatello in southeastern Idaho (Crittenden and others, 1971, p. 586), in the Beaver Mountains of central Utah (Woodward, 1968, p. 1285; Woodward, 1972, p. 4), and in the western Uinta Mountains of eastern Utah (Cohenour, 1959, p. 37).

Near Pocatello, the Mutual consists of 3,000 feet of massive-bedded, coarse-grained, grayish-red quartzite. It is commonly cross-bedded and conglomeratic. The Mutual also contains beds of dusky-red and olive argillite, which may range up to 200 feet thick (Crittenden and others, 1971, p. 586).

The Mutual Formation near Huntsville, Utah, is massive-bedded, coarse-grained, grayish-red quartzite. It is generally cross-bedded and locally conglomeratic. It contains local lenticular beds of grayish-red argillite. The thickness of the Mutual, near Huntsville, ranges from 435 to 1,200 feet (Crittenden, 1972a).

The Mutual Formation, in the mapped area, is characterized by massive-bedded, coarse-grained, grayish-red quartzite. The Mutual is 1,448 feet thick northeast of Cherry Creek Campground (Figure 3, Appendix). Outcrops of the Mutual are also present on both sides of the ridge north of New Canyon and west of Cherry Creek Campground (Plate 1).

The lower part of the Mutual contains chiefly grayish-red quartzite with a few minor beds of white quartzite which range up to about 20 feet thick. The middle and upper parts of the formation are characteristically grayish-red quartzite. At the top of the Mutual, there is a persistent unit of grayish-red argillite with minor amounts of
interbedded grayish-red quartzite. This unit is 177 feet thick at
the measured section; however, it is thinner elsewhere. Minor dis­
continuous beds of grayish-red argillite occur lower in the Mutual and
may range up to 30 or 40 feet thick. The quartzite of the Mutual
contains scattered pebbles and beds of conglomerate. The pebbles are
chiefly white and purple quartz; however, some are jasper and light­
gray feldspar. The quartzite is poorly sorted and crudely cross-bedded.

The grayish-red quartzite of the Mutual contrasts strongly with
the white quartzite of the Caddy Canyon Formation below. The lower
contact of the Mutual is located immediately above the massive-bedded,
white quartzite of the Caddy Canyon. The upper contact is located at
the top of the unit of grayish-red argillite. The Brigham Formation,
consisting of white and brown quartzite, lies above the argillite unit
(Figure 4). The Mutual seems to be conformable with the Caddy Canyon
below and the Brigham above.

The Mutual Formation is the youngest unit in southeastern Idaho
and northern Utah that is considered to be entirely of Late Precambrian
age (Crittenden and others, 1971, p. 581-582, 586).

Cambrian System

Brigham Formation

The term Brigham Formation has been used in two different ways in
northern Utah and southeastern Idaho. The term is applied to the en­
tire sequence of argillite and quartzite below the Cambrian carbonate
rocks and above the Precambrian Blackrock Limestone by Ludlum (1943,
p. 978-979) and by Oriel and Armstrong (1971, p. 7, 15). Studies by
Figure 4. Mutual and Brigham Formations, 0.9 mile north of Cherry Creek Campground; view northwest. Mutual Formation (p€m) and Brigham Formation (€b) dip north. Argillite at top of Mutual forms saddle.
Trimble and Schaeffer (1965, p. 349) indicate that the term Brigham can be restricted to the white and light-brown quartzite which lies immediately below the Cambrian carbonate rocks. Crittenden and others (1971, p. 590), in a more recent study, elevate the term Brigham from formation to group status. The quartzite unit immediately below the Cambrian carbonate rocks is now called Camelback Mountain Quartzite near Pocatello, Idaho, and Geertsen Canyon Quartzite near Huntsville, Utah (Crittenden and others, 1971, p. 586, 592-593). The term Brigham Formation is used in the Malad Summit Quadrangle and is restricted to the white and light-brown quartzite unit immediately below the Cambrian carbonate rocks.

The Brigham Formation (Camelback Mountain Quartzite) near Pocatello, Idaho, consists of approximately 3,500 feet of thick-bedded to massive-bedded, medium-grained to coarse-grained, white and brown quartzite. It is locally cross-bedded and contains only minor amounts of argillite. The base of the unit is conformable and transitional with the underlying Mutual Formation (Crittenden and others, 1971, p. 586).

The Brigham Formation (Geertsen Canyon Formation) near Huntsville, Utah, is represented by 4,200 feet of white, light-brown, and pale-pink quartzite. It is coarse grained and contains beds of conglomerate. Near the top of the formation, there is a unit of interbedded quartzite and argillite, which contains Skolithos. The Brigham (Geertsen Canyon Formation), near Huntsville, is overlain with apparent conformity by the Langston Formation (Crittenden and others, 1971, p. 592-593).
The Brigham Formation, in the mapped area, is characterized by medium-bedded, coarse-grained, white and brown quartzite. It contains beds of conglomerate. Pebbles are scattered throughout. The lower part has some purple quartzite and purple and green argillite. The upper part contains some light-brown argillite and black shale. The Brigham, in the Malad Summit Quadrangle, is estimated to be 1,500 feet thick. The Brigham is more widely exposed, in the mapped area, than any of the other Paleozoic or Precambrian formations but a complete stratigraphic section does not exist in the mapped area. The base is exposed northeast of Cherry Creek Campground (Figure 3, 4), and the top is exposed on the northern side of the canyon of Rattlesnake Creek, about a quarter of a mile from the canyon mouth. The Brigham is exposed on both sides of the mountain ridge from Rattlesnake Creek nearly to the northern boundary of the area (Plate 1).

The quartzite of the Brigham Formation is white, light brown, pink, purple, green, and gray. Pebbles consist of white, pink, gray, and purple quartz, as well as jasper and white feldspar. Cross-bedding and laminae are common. The purple and green argillite, in the lower part of the formation, is thin bedded and is interbedded with quartzite. The light-brown argillite and grayish-brown and black shale of the upper part of the formation are also thin bedded and fissile. No identifiable fossils or fossil fragments were found in the argillite and shale of the Brigham. Some fucoidal markings are present on bedding planes in the quartzite near the top of the formation.

The Brigham is distinctive in that it lacks the grayish-red quartzite of the underlying Mutual Formation except in the lower part.
The lower contact of the Brigham is located immediately above the grayish-red argillite at the top of the Mutual (Figure 4). The Brigham is easily distinguished from the overlying Cambrian carbonate formations. The upper contact, in the mapped area, is at most locations a low-angle thrust fault which cuts across the upper part of the Brigham and places Middle Cambrian, Late Cambrian, and Ordovician formations in direct contact with the quartzite of the Brigham. Outcrops on the northern side of the canyon of Rattlesnake Creek, about a quarter of a mile from the mouth, show that the Brigham is conformable and transitional with the overlying Langston Formation. A small outcrop of the lower part of the Langston is present immediately below the thrust fault at that location. It is mapped as part of the Brigham. The upper part of the Brigham, on the northern side of the canyon of Rattlesnake Creek, consists of brown quartzite and some interbeds of medium-gray limestone. If the Brigham and Langston were mapped separately in the canyon of Rattlesnake Creek, the contact would be placed immediately above the uppermost bed of brown quartzite.

The Brigham Formation is considered to be Late Precambrian to Early Cambrian (?) in age (Crittenden and others, 1971, p. 586, 593).

**Langston Formation**

The Langston Formation, at High Creek in northern Utah, consists of three successively younger members: (1) Naomi Peak Limestone Member, (2) Spence Shale Member, and (3) upper limestone member (Maxey, 1958, p. 654, 669-671). The Naomi Peak Limestone at High Creek consists of 32 feet of fossiliferous, medium-gray to light-gray,
sandy limestone. The Spence Shale is black and olive green, calcareous shale with some interbedded siltstone. It is 192 feet thick and contains numerous trilobite fossils. The upper limestone member is 260 feet thick and consists of dark-gray to bluish-gray limestone with some dark-gray to medium-gray, sandy dolomite. The total thickness of the Langston at High Creek is 484 feet (Maxey, 1958, p. 655). In the Portneuf Range, northeast of the mapped area, the Langston is 358 feet thick (Holmes, 1958, p. 25) and in the Malad Range, south of the mapped area, it is 133 feet thick (Axtell, 1967, p. 56). The Langston is conformable with the underlying Brigham Formation and the overlying Ute Formation (Maxey, 1958, p. 669-671).

The Langston Formation, in the mapped area, is represented by about 25 feet of medium-gray to dark-gray limestone, in the lower part, and about 15 feet of black and green shale in the upper part. The total thickness is approximately 40 feet. The only exposure is on the northern side of the canyon of Rattlesnake Creek immediately below the thrust fault (Plate 1). The Langston is mapped as part of the underlying Brigham Formation because it is thin and has limited exposure. The limestone and shale units represent the Naomi Peak Limestone and Spence Shale. Trilobite fragments, present in both members, indicate Middle Cambrian age.

The lower contact, if mapped, would be immediately above the highest quartzite bed of the underlying Brigham. The upper contact is a thrust fault which is located at the top of the shale. The thrust fault places brecciated limestone and dolomite of the Blacksmith
Formation in contact with the shale of the Langston. The Langston, in the mapped area, is transitional and conformable with the underlying Brigham; however, the stratigraphic relationship between the Langston and the overlying Ute Formation is not exposed.

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

**Ute Formation**

The Ute Formation at High Creek, in northern Utah, consists of a lower unit of thin-bedded, bluish-gray limestone with green and yellow shale, 285 feet thick, and an upper unit of thick-bedded, light-gray to dark-gray limestone, 460 feet thick (Maxey, 1958, p. 653-654). The total thickness of the Ute at High Creek is 745 feet. In the Portneuf Range, northeast of the mapped area, the Ute is 958 feet thick (Holmes, 1958, p. 28), and at Calls Fort, in the Wasatch Range to the south of the mapped area, it is 621 feet thick (Maxey, 1958, p. 661-662). The Ute is conformable with the underlying Langston Formation and the overlying Blacksmith Formation (Maxey, 1958, p. 671-672).

The Ute Formation is not exposed in the mapped area. It is eliminated by a thrust fault which places the Blacksmith Formation in direct contact with the Brigham and Langston Formations.

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

The Blacksmith Formation at High Creek, in northern Utah, is 485 feet thick and consists of thick-bedded, medium-crystalline, light-gray to medium-gray dolomite with 60 feet of thin-bedded to medium-bedded, dark-bluish-gray limestone in the upper part of the unit (Maxey, 1958, p. 653). The Blacksmith at Clarkston Mountain, in the southern Malad Range, is represented by 444 feet of thin-bedded to thick-bedded, oolitic, medium-gray limestone (Hanson, 1949, p. 17, Plate 2). It is 1,018 feet thick in the northern part of the Portneuf Range (Holmes, 1958, p. 30). Regionally, in southeastern Idaho and northern Utah, the Blacksmith is largely dolomite to the east, in the Bear River Range, and primarily limestone to the west in the Portneuf, Bannock, and Malad Ranges (Oriel and Armstrong, 1971, p. 48). The Blacksmith Formation lies conformably between the underlying Ute Formation and the overlying Bloomington Formation (Maxey, 1958, p. 672).

The Blacksmith, in the mapped area, consists mainly of medium-bedded to thick-bedded, medium-gray and dark-gray limestone. The lower part of the exposed section contains some thin-bedded, medium-gray limestone with light-brown, silty layers and the upper part of the section contains thick-bedded, light-gray to medium-gray dolomite. The exposed part of the Blacksmith is approximately 700 feet thick in the mapped area. The section is incomplete due to a thrust fault which places the Blacksmith in contact with the Brigham Formation. The Blacksmith, south of New Canyon, occurs as a band on the west-facing slope of the ridge (Plate 1). There, it is in thrust contact
with the underlying Brigham. The Blacksmith crops out on the ridge approximately 2 miles north of New Canyon. It is bounded on the south and west by intersecting normal faults and is overlain by Bloomington Formation on the northeast (Plate 1).

The limestone of the Blacksmith contains numerous beds of oolites, some beds of concentrically banded algal nodules, and minor units with algal stromatolites and intraformational conglomerate. The dolomite, which occurs in the upper part of the formation, is usually brecciated. In some instances, dolomite stringers are perpendicular to limestone beds and are clearly secondary. The dolomite ranges in thickness from about 10 feet to more than 100 feet. The upper contact of the Blacksmith is located at the abrupt change from the thick-bedded limestone and dolomite of the Blacksmith to the shale and thin-bedded limestone of the Bloomington. In places, dolomite is present at the top of the Blacksmith, and, in other places, limestone is present. The limestone and dolomite at the top of the Blacksmith are generally brecciated and the thin-bedded limestone and shale beds of the Bloomington, immediately above the contact, are in some cases distorted. The Blacksmith and Bloomington Formations seem to be conformable even though the intervening contact is disrupted. The lower contact is a thrust fault which places the Blacksmith in contact with the Brigham and Langston Formations.

The Blacksmith is of Middle Cambrian age (Maxey, 1958, p. 672, Figure 3).
Bloomington Formation

The Bloomington Formation at High Creek, in northern Utah, consists of three successively younger members: (1) Hodges Shale, (2) limestone member, and (3) Calls Fort Shale (Maxey, 1958, p. 651-653). The Hodges Shale consists of 540 feet of fissile, olive-green shale and thin-bedded, medium-gray, dark-gray, and blue-gray limestone. The middle limestone unit consists of 775 feet of thin-bedded, medium-gray, dark-gray, and blue-gray limestone. The Calls Fort Shale consists of 180 feet of thin-bedded, medium-gray, dark-gray, and blue-gray limestone with olive-green shale. The total thickness of the Bloomington at High Creek is 1,495 feet (Maxey, 1958, p. 653). It is 429 feet thick in the Malad Range, south of the mapped area (Hanson, 1949, p. 21, Plate 2), and 1,313 feet thick in the Portneuf Range to the north (Holmes, 1958, p. 33). The Bloomington lies conformably between the underlying Blacksmith Formation and the overlying Nounan Formation (Maxey, 1958, p. 672-673).

In the Malad Summit Quadrangle, the Bloomington consists of a lower shale, a middle limestone, a middle shale, and an upper limestone. The lower and middle shale units are composed of fissile, olive-green to light-brown shale with some thin-bedded, bluish-gray, silty limestone. The middle and upper limestone units consist of thin-bedded to thick-bedded, dark-gray and bluish-gray, silty limestone. The thickness of each of the four units ranges from 200 feet to 350 feet. The total thickness of the Bloomington is approximately 1,000 feet to 1,100 feet. The Bloomington is widely exposed, in the mapped area,
and is, in places, in thrust contact with the Brigham Formation below. It is exposed as a band traversing the mountain between Toms Canyon and Cherry Spring in the center of the mapped area (Plate 1). The Bloomington is present at several locations between Cherry Creek Campground and the southern boundary of the mapped area. The best exposures are on the ridge between New Canyon and Rattlesnake Creek (Plate 1). The Bloomington is also exposed 1.5 miles north of Cherry Creek Campground along the eastern boundary of the mapped area (Plate 1).

The limestone of the Bloomington contains oolites, algal nodules, intraformational conglomerate, trilobite fragments, horizontal trails on bedding surfaces, and vertical burrows. The thin, silty layers, in the limestone, are light brown and red. When the rock weathers, the resulting soil is dark red. The shale of the Bloomington contains distinctive green limestone nodules that range up to 3 inches in length.

The Bloomington, composed of thin-bedded limestone and olive-green shale with limestone nodules, is easily distinguished from the underlying Blacksmith Formation and the overlying Nounan Formation. The lower contact with the Blacksmith is placed at the abrupt change from thick-bedded limestone and dolomite to olive-green shale and thin-bedded limestone. The lower contact seems to be disrupted as the upper part of the Blacksmith is brecciated and the shale and limestone in the lower part of the Bloomington are contorted in places. The upper contact, with the Nounan, is a thrust fault. The Bloomington seems to be conformable with the Blacksmith below, but whether or not it is conformable with the Nounan cannot be determined in the mapped area.
The Bloomington Formation is Middle Cambrian in age (Maxey, 1958, p. 673).

**Nounan Formation**

The Nounan Formation at High Creek, in northern Utah, is 1,125 feet thick (Maxey, 1958, p. 651). The lower two-thirds is thin-bedded to thick-bedded, light-gray to dark-gray dolomite; whereas, the upper third is light-gray dolomite with units of thin-bedded, dark-gray, argillaceous limestone. The limestone is sandy and contains some oolites as well as intraformational conglomerate (Maxey, 1941, p. 13, 28-31). The Nounan is 886 feet thick at Two Mile Canyon in the Malad Range (Axtell, 1967, p. 59), and it is 773 feet thick in the northern part of the Portneuf Range (Holmes, 1958, p. 36). The Nounan is conformable with the underlying Bloomington (Maxey, 1958, p. 673) and the overlying Worm Creek Member of the St. Charles Formation (Haynie, 1957, p. 17-18, 29).

The Nounan Formation, in the mapped area, consists of a lower dolomite unit and an upper limestone unit. The lower unit is thin-bedded to medium-bedded, fine-crystalline, light-gray and dark-gray dolomite. The upper unit contains thin-bedded to medium bedded, medium-gray and bluish-gray, silty and sandy limestone. The Nounan, incompletely exposed due to faulting and erosion, is approximately 350 feet thick in the mapped area. The lower unit is represented by approximately 200 feet of dolomite which is thrust over the Bloomington Formation. It is exposed, in the southern part of the mapped area, on the ridge south of Rattlesnake Creek and on the ridge between
Rattlesnake Creek and New Canyon (Plate 1). It is also exposed along the eastern boundary of the mapped area, approximately 2 miles north of Cherry Creek Campground, and on the ridge in the central part of the mapped area approximately 0.5 mile south of Toms Canyon (Plate 1). The upper unit of the Nounan is represented by approximately 150 feet of limestone which underlies the Worm Creek Member of the St. Charles Formation. It is exposed on both sides of the mountain immediately north of the transverse normal fault which trends southwestward from Toms Canyon to Curly Jack Flat (Plate 1).

The dolomite of the lower unit is severely brecciated in places. Brecciation is particularly evident at the thrust contact with the underlying Bloomington. It is also locally banded with alternating beds of light-gray and dark-gray dolomite. In places, the dark-gray dolomite contains white laminae. The limestone of the upper Nounan contains oolites, trilobite fragments, brachiopods, and ripple marks. The weathered limestone colors the surrounding soil dark red. The amount of sand contained in the limestone increases toward the top of the formation so that it tends to grade into the quartzite of the overlying Worm Creek Member of the St. Charles Formation.

The upper contact of the Nounan with the Worm Creek is located at the change from sandy limestone to quartzite. The lower contact, a thrust fault in the mapped area, is placed at the abrupt change from limestone to brecciated dolomite. The Nounan is gradational and conformable with the overlying Worm Creek but, due to thrust faulting, its stratigraphic relationship with the underlying Bloomington is undetermined.
The age of the Nunnan Formation is considered to be Late Cambrian, although the lower few feet may be Middle Cambrian (Maxey, 1958, p. 673).

St. Charles Formation--Worm Creek Member

The Worm Creek Member of the St. Charles Formation, at High Creek in northern Utah, is 75 feet thick and consists of medium-bedded, fine-grained, light-gray quartzite, sandy limestone, sandy dolomite, and medium-grained, white quartzite (Maxey, 1941, p. 13, 28). The Worm Creek is 63 feet thick at Dry Canyon in the northern part of the Malad Range (Haynie, 1957, p. 16-18) and 478 feet thick in the northern part of the Portneuf Range (Holmes, 1958, p. 39).

In the mapped area, the Worm Creek is characterized by thin-bedded, fine-grained, medium-brown to light-brown quartzite. It is approximately 200 feet thick. The Worm Creek is present north of a transverse normal fault that trends southwest from Toms Canyon to Curly Jack Flat and in a down-faulted block on the western side of the ridge immediately south of Curly Jack Flat (Plate 1).

The Worm Creek also contains thin-bedded to medium-bedded sandy limestone, medium-gray limestone, and medium-brown limestone inter-bedded with the brown quartzite. Some beds of light-gray to white quartzite and minor amounts of purple quartzite are also present. A discontinuous unit of light-greenish-gray and dark-gray shale is present near the top of the member. The shale unit is only about 10 feet thick, when present, and is best exposed in the down-faulted block.
immediately south of Curly Jack Flat (Plate 1). The only fossils present are trails on bedding surfaces.

The Worm Creek is easily distinguished from the thin-bedded limestone of the upper Nounan and the limestone and dolomite of the upper member of the St. Charles. The basal contact with the Nounan is located at the change from sandy and silty limestone to quartzite; the upper contact is located immediately above the uppermost quartzite bed or, in places, a bed of greenish-gray and black shale. The Worm Creek is gradational and conformable with the underlying Nounan and the overlying upper member of the St. Charles.

The Worm Creek Member of the St. Charles Formation is Late Cambrian in age (Maxey, 1941, p. 14).

St. Charles Formation--upper member

The upper member of the St. Charles Formation, directly above the Worm Creek Member, is 940 feet thick at High Creek in northern Utah (Maxey, 1941, p. 26-28). The lower part is thin-bedded, coarse-crystalline, fossiliferous, light-gray to dark-gray limestone and the upper part consists of thick-bedded, medium-gray dolomite with elongate chert nodules. The dolomite displays light-gray and dark-gray bands in places (Maxey, 1941, p. 13-14, 26-28). The upper member of the St. Charles is 998 feet thick at Clarkston Mountain in the Malad Range (Hanson, 1949, p. 3) and 931 feet thick in the northern part of the Portneuf Range (Holmes, 1958, p. 39). It is conformable with the underlying Worm Creek Member (Haynie, 1957, p. 16) but the upper contact seems to be a disconformity (Williams, 1948, p. 1136).
The upper member of the St. Charles, in the mapped area, is composed of thin-bedded to medium-bedded, light-gray to dark-gray limestone, in the lower part, and thick-bedded, medium-gray to dark-gray dolomite in the upper part. The limestone is approximately 300 feet thick and the dolomite is approximately 450 feet thick. The total thickness of the upper member is about 750 feet in the mapped area. It is present north of the transverse normal fault which trends southwestward from Toms Canyon to Curly Jack Flat. The upper member is also present on the ridge approximately 1.75 miles east of Malad Summit (Plate 1). At that location, it is thrust over the underlying Brigham Formation.

The limestone of the upper member is sandy and contains interbedded and nodular light-gray and black chert. It also contains numerous fossils including gastropods, cephalopods, brachiopods, trilobite fragments, and concentrically banded algal nodules. The dolomite is medium crystalline. Some beds of light-gray to medium-gray chert are present.

The upper contact of the St. Charles with the Garden City Formation is not exposed because of a thrust fault which places upper St. Charles over the Garden City. The lower contact of the upper member is located at the change from the interbedded quartzite and limestone of the Worm Creek to limestone. The upper member is conformable with the underlying Worm Creek Member, but the stratigraphic relationship with the Garden City is not exposed.

The upper member of the St. Charles Formation is Late Cambrian in age (Maxey, 1941, p. 15).
Garden City Formation

The Garden City Formation, in northern Utah, consists of two unnamed limestone members. The lower member, about two-thirds of the formation, is composed of medium-gray limestone with beds of intraformational conglomerate, silty limestone, and white to light-gray chert stringers (Ross, 1951, p. 7-9). The upper member is thick-bedded, dark-gray limestone with considerable amounts of black chert beds and nodules. A discontinuous unit of gray dolomite is present at the top of the Garden City at some localities. The Garden City, a thick unit throughout northern Utah and southeastern Idaho, is 1,408 feet thick at Green Canyon, northeast of Logan, Utah (Ross, 1951, p. 22), 1,764 feet thick at Clarkston Mountain in the Malad Range (Ross, 1951, p. 19), and 1,408 feet thick in the northern part of the Portneuf Range (Holmes, 1958, p. 42). The stratigraphic relationship of the Garden City to the underlying St. Charles Formation is probably a disconformity; however, the Garden City is conformable and transitional with the overlying Swan Peak Formation (Williams, 1948, p. 1136-1137).

Within the mapped area, only the upper member of the Garden City is exposed. It consists of thin-bedded to medium-bedded, medium-gray to dark-gray limestone. The exposed thickness is approximately 350 feet. The Garden City is present on the ridge about 1.7 miles east of Malad Summit (Plate 1). Several other exposures are present about 0.5 mile farther north on the ridge.
The Garden City, in places, contains black chert interbedded with limestone near the top of the formation. A unit of medium-gray, silty dolomite is present in some places at the top of the Garden City. The dolomite is usually severely brecciated.

Dolomite of the upper part of the St. Charles Formation is thrust over silty limestone of the Garden City; therefore, the lower contact is not exposed. The upper contact, an inferred thrust fault, is located at the abrupt change from limestone or dolomite of the upper Garden City to quartzite of the overlying Swan Peak Formation.

The age of the Garden City Formation is Early and Middle Ordovician; however, only the upper few feet is considered to be Middle Ordovician (Ross, 1951, p. 31-32).

Swan Peak Formation

In the Logan Quadrangle of northern Utah, Williams (1948, p. 1136) recognized three members of the Swan Peak Formation. The members are a lower black shale with interbedded sandy limestone; thin-bedded, brown quartzite with abundant fucoidal structures and interbedded greenish-gray shale; and an upper massive-bedded, light-gray and light-brown quartzite. In Green Canyon, in the Logan Quadrangle, the lower member is 226 feet thick, the middle member is 63 feet thick, the upper member is 111 feet thick and the total thickness is 401 feet (Galloway, 1970, p. 16). At Clarkston Mountain in the Malad Range, the Swan Peak is 574 feet thick. The lower member is 79 feet thick, the middle member is 29 feet thick, and the upper member is 466 feet thick (James, 1973, p. 245-246). At Smith Canyon in the Portneuf Range,
northeast of Downey, Idaho, the lower member is 72 feet thick, the middle member is 126 feet thick, the upper member is 1,037 feet thick, and the total thickness for the formation is 1,235 feet (James, 1973, p. 229-231). The Swan Peak is transitional and conformable with the Garden City Formation below; the upper contact is unconformable with the overlying Fish Haven Formation although no angular discordance is present (Williams, 1948, p. 1137).

In the Malad Summit Quadrangle, only the upper member of the Swan Peak Formation is exposed. It is represented by fine-grained, vitreous, medium-gray to white quartzite approximately 450 feet thick. The Swan Peak is exposed at several locations northeast of Malad Summit along the crest and western side of the mountain ridge (Plate 1). It is also exposed in two outcrops along U. S. Highway 191 north of Malad Summit.

The Swan Peak, in the mapped area, is severely brecciated. The angular pieces of quartzite are cemented together with medium-gray to light-brown silica (Figure 5). Locally the silica is red. The outcrops of quartzite generally weather into large rounded masses.

In the mapped area, the lower contact of the Swan Peak is an inferred thrust fault which is located at the abrupt change from gray limestone or dolomite of the underlying Garden City to light-gray or white quartzite. The upper contact of the Swan Peak is located at the abrupt change from light-gray or white quartzite to gray dolomite of the overlying Fish Haven-Laketown. There is no noticeable angular discordance between the Swan Peak and the Fish Haven-Laketown; however,
Figure 5. Swan Peak Formation, 1.8 miles northeast of Malad Summit. Quartzite is brecciated and recemented. Brunton compass shows scale.
the contact is too poorly exposed to show whether or not they are conformable.

The Swan Peak Formation is Middle Ordovician in age (Ross, 1951, p. 33).

Ordovician-Silurian System

Fish Haven-Laketown Formation

In the Logan Quadrangle in northern Utah, the Fish Haven-Laketown Formation is mapped as two separate formations. The Fish Haven Formation consists of thick-bedded, medium-crystalline, dark-gray dolomite and is about 140 feet thick (Williams, 1948, p. 1137). The Laketown Formation is about 1,150 feet thick and is composed of thin-bedded to thick-bedded, light-gray and dark-gray dolomite (Williams, 1948, p. 1138). In the Logan Quadrangle, the Fish Haven and Laketown are differentiated on the basis of color.

In the Blue Spring Hills of northern Utah and southeastern Idaho, no lithologic distinction is made between the Fish Haven and Laketown and, therefore, they are mapped as one formation (Beus, 1968, p. 784-785). The lower half of the Fish Haven-Laketown is dark-gray to medium-gray dolomite and the upper half is medium-gray to light-gray dolomite. The total thickness is 1,540 feet (Beus, 1968, p. 784).

The Fish Haven-Laketown Formation unconformably overlies the Swan Peak Formation, although there is no angular discordance (Williams, 1948, p. 1137). The Water Canyon Formation of Devonian age unconformably overlies the Fish Haven-Laketown (Beus, 1968, p. 784).
In the mapped area, the Fish Haven-Laketown Formation consists of thick-bedded, medium-crystalline, dark-gray to medium-gray dolomite. The exposed section is about 250 feet thick. It is exposed in several outcrops, on the western side of the mountain ridge, northeast of Malad Summit (Plate 1).

The Fish Haven-Laketown is severely brecciated in most places. At some locations, it contains thin beds of medium-gray to dark-gray chert.

The lower contact is located at the change from white quartzite of the Swan Park to gray dolomite. There is no angular discordance between the Swan Peak and the Fish Haven-Laketown; however, the contact is too poorly exposed to show whether or not they are conformable.

The Fish Haven-Laketown Formation is considered to be Late Ordovician through Late Silurian in age (Beus, 1968, p. 784-785).

Tertiary System

Wasatch Formation

The Wasatch Formation, in the Logan Quadrangle of northern Utah, is red conglomerate with pebbles and cobbles of quartzite, limestone, and chert (Williams, 1948, p. 1144-1146). It occurs in scattered outcrops and the average thickness is about 300 feet (Williams, 1948, p. 1146). At the northern end of the Wellsville Mountains in northern Utah, the Wasatch lies unconformably on Paleozoic rocks and is overlapped by the Salt Lake Formation with angular discordance (Adamson, Hardy, and Williams, 1955, p. 4).
In the Malad Summit Quadrangle, the Wasatch Formation is a conglomerate with rounded pebbles and cobbles in a matrix of red silt and clay. The exposed thickness is about 200 feet. The only outcrop of Wasatch, in the mapped area, is south of Rattlesnake Creek in the southeastern corner of the quadrangle (Plate 1).

The rounded pebbles and cobbles in the Wasatch consist mainly of quartzite derived from the Caddy Canyon, Mutual, and Brigham Formations which are exposed high on the western side of Oxford Peak immediately east of the mapped area (Figure 1; Raymond, 1971, Plate 1). Some pebbles and cobbles of limestone and dolomite are present in the Wasatch. These resulted from the erosion of Paleozoic formations in the local area. Conglomerate of the Wasatch Formation, derived from local source areas with minimal transport, has been described from Fossil Basin of southwestern Wyoming (Oriel and Tracy, 1970, p. 28-29).

The lower contact of the Wasatch is not exposed in the mapped area. The upper contact is located at the change from red conglomerate of the Wasatch to light-gray and light-brown conglomerate of the overlying Salt Lake Formation. The contact between the Wasatch and the Salt Lake is probably an unconformity; however, the contact and nearby outcrops are too poorly exposed to reveal the stratigraphic relationship.

The Wasatch Formation is considered to be Paleocene and Eocene in age (Adamson, Hardy, and Williams, 1955, p. 2).

Salt Lake Formation

The term Salt Lake has been given group status in Cache Valley of northern Utah and southeastern Idaho (Adamson, Hardy, and Williams,
Salt Lake is used as a formation name. The Salt Lake Formation has three successively younger members: (1) Collinston Conglomerate, (2) Cache Valley Member, and (3) Mink Creek Conglomerate.

At the northern end of the Wellsville Mountains on the western side of Cache Valley, the Collinston Conglomerate consists of tuffaceous, light-gray, pebble and cobble conglomerate. It is about 1,500 feet thick and intertongues with the tuff of the Cache Valley Member (Adamson, Hardy, and Williams, 1955, p. 4). In Cache Valley, the Cache Valley Member contains light-gray and light-brown tuff, limestone, sandstone, and pebble conglomerate. It ranges in thickness from 2,000 feet at the southern end of Cache Valley to 7,674 feet at the northern end (Adamson, Hardy, and Williams, 1955, p. 6-7). In the northeastern part of Cache Valley, the Mink Creek Conglomerate consists of tuffaceous, light-gray, pebble and cobble conglomerate. It conformably overlies the Cache Valley Member and is about 3,400 feet thick (Adamson, Hardy, and Williams, 1955, p. 7-8, 15, 18). All three members of the Salt Lake Formation unconformably overlap the older Tertiary and Paleozoic formations (Adamson, Hardy, and Williams, 1955, p. 4, 6-7, 10, 12, 21).

In the mapped area, the Salt Lake Formation is light-gray and light-brown pebble and cobble conglomerate. It ranges from a few tens of feet thick, in isolated outcrops, to several thousand feet thick in the valley on the western side of the mountain ridge (Plate 1). The Salt Lake is exposed on the western side of the ridge between the mountain front and Devil Creek. It also is exposed along the
mountain front on the eastern side of the ridge from Dry Creek northward to Toms Canyon. In most places, the Salt Lake is faulted down next to older rocks but, in some places such as 0.5 mile south of Cherry Creek Campground, the Salt Lake overlaps Paleozoic and Precambrian rocks.

Along the mountain fronts, the Salt Lake is primarily pebble and cobble conglomerate but, near the middle of the valley on the western side of the mountain ridge, it is mainly light-gray and light-brown tuff and limestone and light-brown sandstone. The pebbles and cobbles consist of quartzite, limestone, and dolomite, which were derived from the erosion of Paleozoic and Precambrian units in the local area. The degree of rounding decreases with size. The smaller pebbles are distinctly angular.

The Salt Lake Formation unconformably overlaps the Paleozoic and Precambrian formations. It also overlaps the Wasatch Formation but the contact is too poorly exposed to indicate if they are conformable.

The Salt Lake Formation is Oligocene (Williams, 1962, p. 133) to Pliocene (Adamson, Hardy, and Williams, 1955, p. 2) in age.

**Quaternary System**

**Lake Bonneville Group**

The Lake Bonneville Group, in the southern part of Cache Valley in northern Utah, consists of three successively younger formations: (1) Alpine Formation, (2) Bonneville Formation, and (3) Provo Formation (Williams, 1962, p. 137-142). The Alpine and Provo are mainly gravel,
sand, silt, and clay; whereas, the Bonneville is primarily gravel. The upper part of the Bonneville and the Provo are marked by distinctive embankments.

In the mapped area, Lake Bonneville shorelines have not been identified; however, deposits of unconsolidated gravel, sand, silt, and clay exist in the southwestern corner of the mapped area (Plate 1). These deposits are mapped as Lake Bonneville Group based on topographic position and a shoreline elevation of 5,140 feet.

At Red Rock Pass, Idaho, 4 miles east of the mapped area, the upper limit of the Lake Bonneville Group is approximately 5,135 feet in elevation (Williams, 1952, p. 1375). A terrace is present about 2 miles south of the mapped area east of Interstate Highway 15. It is mapped as Lake Bonneville Group (Axtell, 1967, Plate 1). Its upper elevation is between 5,120 feet and 5,160 feet, according to the Malad City East Quadrangle map of the 7.5-minute series distributed by the Geological Survey of the United States Department of the Interior.

Lake Bonneville shorelines, at the 5,300 foot elevation, are present west of the Great Salt Lake; however, that area has risen due to isostatic deformation after Lake Bonneville (Crittenden, 1963, p. 1).

The Lake Bonneville Group is Pleistocene in age (Hunt, Varnes, and Thomas, 1953, p. 16-17).

Colluvial deposits

Colluvial deposits, in the mapped area, consist of unconsolidated silt, clay, and sand with occasional cobbles and boulders of quartzite, dolomite, and limestone. Colluvial deposits occur mainly along the
mountain fronts, in the northern half of the mapped area, and they also extend into the valleys (Plate 1). Some isolated patches are present at higher elevations within the mountain. Some of these, such as that near Curly Jack Spring in the center of the mapped area, may represent an old erosion surface (Plate 1). The colluvial deposits are probably Pleistocene to Holocene in age.

Alluvial deposits--fan

Alluvial fans, in the mapped area, consist of unconsolidated gravel, sand, silt, and clay with occasional cobbles and boulders. The composition of the larger identifiable particles is quartzite, dolomite, and limestone. The alluvial fans occur at the mouths of small canyons and were apparently built by successive mudflows. In some places, they are dissected by stream action. Fans are present along the western mountain front in the southern part of the mapped area. They are also present along the eastern mountain front about 0.75 mile north of Toms Canyon (Plate 1). Small alluvial fans, on the sides of New Canyon and Rattlesnake Creek, are truncated by stream erosion (Plate 1). The alluvial fan deposits are considered to be of Holocene age.

Alluvial deposits--stream

Stream alluvium, in the mapped area, consists of unconsolidated gravel, sand, and silt along stream valleys. The composition of the gravel and sand is quartzite, dolomite, and limestone. The stream alluvium occurs primarily along Birch Creek, Devil Creek, New Canyon
Creek, Rattlesnake Creek, and Cherry Creek (Plate 1). The stream alluvium is of Holocene age.
STRUCTURAL FEATURES

Regional Setting

The structural geology of southeastern Idaho and northern Utah is characterized by low-angle thrust faults and normal faults. The Bannock thrust zone, composed of discontinuous west-dipping imbricate thrust faults, extends from southwestern Montana through southeastern Idaho and western Wyoming to northern Utah (Armstrong and Cressman, 1963). The Paris thrust fault, on the eastern side of the Bear River Range in southeastern Idaho, is part of the Bannock thrust zone and has a stratigraphic throw of about 20,000 feet. The displacement is eastward; its magnitude is unknown but it is presumed to be great (Armstrong and Cressman, 1963, p. 16). The Willard thrust fault, a possible southern extension of the Bannock thrust zone, also exhibits great eastward displacement (Crittenden, 1961, p. 129). The eastward displacement along the Bannock thrust zone and the Willard thrust fault is about 40 miles (Crittenden, 1961, p. 129). This estimate is based on the comparison of isopachs of the same rock units above and below the thrust zone. Rock units, above the thrust faults, are folded in places (Armstrong and Cressman, 1963, p. 1; Armstrong and Oriel, 1965, p. 1857).

The Basin and Range province consists of a series of alternating mountain ridges and valleys, which trend north-south. The valleys have dropped, relative to the mountains, along normal faults. The faults are generally present on both sides of the valleys. This
indicates that the mountain ranges and valleys are horsts and grabens rather than a series of tilted fault blocks with faults on only one side of each valley (Stewart, 1971, p. 1038).

The eastern part of the Malad Summit Quadrangle exhibits two principal types of deformation. They are thrust faulting and normal faulting. The area is located about 25 miles west of the Bannock thrust zone and near the northeastern corner of the Basin and Range province. Normal faults, along the mountain margins, have dropped Marsh and Cache Valleys relative to the Portneuf and Bear River Ranges, on the east, and the Bannock and Malad Ranges on the west. Normal faults, on the western side of the Bannock and Malad Ranges, have dropped Malad Valley relatively.

Folds

An anticline of rather small magnitude is present near the mouth of New Canyon (Plate 1). It involves quartzite of the Mutual and Brigham Formations, on the northern side of the canyon, and quartzite of the Brigham, on the southern side. The anticline trends generally northwest-southeast and is nearly symmetrical. The limbs dip 21°-29° E. and 22°-24° W. South of New Canyon, it is not present neither in the Brigham in the canyon of Rattlesnake Creek nor in the Blacksmith and Bloomington Formations above the thrust fault on the intervening ridge (Plate 1). This anticline trends northwest from New Canyon toward the valley and is broken by two transverse normal faults.

An anticline, north of Campbell Creek on the western side of the ridge, involves thin-bedded limestone and shale of the Bloomington
Formation (Plate 1). It trends generally northwest-southeast and is nearly symmetrical. The limbs dip 20°-29° NE. and 24°-35° SW. The anticline is truncated by a normal fault, on the southeast, in the canyon of Campbell Creek. It terminates to the northwest at a thrust fault and it is not evident in the quartzite of the Brigham below the thrust fault.

The anticlines, in the mapped area, may have formed either by compressional forces acting upon rock units above a thrust fault or as a result of drag due to normal faulting. Folding, due to compression in rock units above low-angle thrust faults, has been noted in the Bannock thrust zone (Armstrong and Cressman, 1963, p. 1; Armstrong and Oriel, 1965, p. 1857).

The anticlines, in the mapped area, may be due to folding of rock units above thrust faults. The anticline, near Campbell Creek (Plate 1), is definitely above a thrust fault and the anticline, near the mouth of New Canyon, may also lie above a thrust fault. No thrust fault is exposed below the Brigham or Mutual Formation in New Canyon; however, such a fault is present on the eastern side of Oxford Peak about 2 miles east of the mapped area (Raymond, 1971, Plate 1). It may be present at depth in the mapped area.

The anticlines are both located east of a major normal fault which separates a mountain ridge and a valley. With relatively downward displacement on the valley block, drag could have been produced on the mountain block. The general dip direction of the rock units, in the mountain, is northeast and drag along a normal fault, causing southwest dip, would produce an anticline.
The anticlines, in the mapped area, are probably due to compressional folding of rock units above a thrust fault. If they were due to drag along a normal fault, the rock units near the fault would be more steeply turned down. The drag should be present more continuously along the mountain front rather than at only two locations, and the axis of the anticline should be parallel to the normal fault, not truncated by it (Plate 1).

**Thrust Faults**

**Clifton thrust fault**

A major low-angle thrust fault, which places the Blacksmith and younger formations through the Swan Peak over the Brigham Formation, is widely exposed in the eastern part of the Malad Summit Quadrangle. A similar thrust fault, placing undifferentiated younger Paleozoic rocks over the Brigham Formation, has been recognized by Raymond (1971, p. 27, Plate 1) in the Oxford Peak area, immediately to the east, and named the Clifton thrust fault. The thrust fault, in the mapped area, and the Clifton thrust fault are probably the same because of their proximity and the fact that they involve the same units.

The Clifton thrust fault, in the mapped area, exists as many isolated segments due to normal faulting and erosion subsequent to thrust faulting. It is best exposed, in the southern part of the mapped area, in New Canyon (Figure 6, 7; Plate 1). There, the Blacksmith and Bloomington Formations are thrust over quartzite of the Brigham Formation. Limestone of the Blacksmith is brecciated in
Figure 6. Clifton thrust fault and higher thrust fault on southern side of New Canyon; view south. Blacksmith (€bl) and Bloomington (€bo) Formations rest on Brigham Formation (€b) along Clifton thrust fault. Nounan Formation (€n) rests on Bloomington (€bo) along higher thrust fault.
Figure 7. Clifton thrust fault and normal faults on northern side of New Canyon; view north. Clifton thrust fault curves around hill on right and places Bloomington Formation on Brigham Formation.
places and, in places, the Bloomington is contorted. At New Canyon, the Brigham, below the Clifton thrust fault, dips 15°-45° E. except along the western mountain front where it dips 18°-24° W. The Bloomington, above the thrust fault, dips 23°-66° E. The strike of the beds, both above and below the thrust fault, is generally north-south but ranges from about N. 45° W. to N. 45° E.

On the northern side of New Canyon, the thrust fault dips east; on the southern side, it dips east, on the east, and west, on the west. East and west dips are also present on the northern side of the canyon of Rattlesnake Creek, about 1 mile south of New Canyon (Figure 8, 9; Plate 1).

The Clifton thrust fault is present near the eastern edge of the mapped area, about 1.5 miles east of Toms Canyon Spring (Figure 10, Plate 1). The thrust fault is covered with colluvium but it presumably dips north and separates the quartzite of the Brigham on the hill south of the thrust fault from the thin-bedded limestone of the Bloomington on the hill to the north. The Brigham Formation, below the thrust fault, dips 16°-46° N. The Bloomington Formation, above the thrust fault, dips 15°-28° N.

The Clifton thrust fault is exposed along the western side of the ridge about 0.5 mile south of Curly Jack Flat (Figure 11, Plate 1). A limited outcrop of quartzite of the Brigham Formation is overlain by thin-bedded limestone of the Bloomington Formation. The thrust fault dips east at a low angle. The Brigham, below the thrust fault, dips 26° E. and is severely brecciated. The Bloomington, above the thrust
Figure 8. Clifton thrust fault and normal faults on western side of mountain, north of canyon of Rattlesnake Creek; view north. Clifton thrust fault, offset by longitudinal normal fault, places Blacksmith Formation on Brigham Formation. Marginal normal fault drops Salt Lake Formation, in valley, next to Precambrian and Cambrian units in mountain.
Figure 9. Clifton thrust fault near mouth of canyon of Rattlesnake Creek; view north. Clifton thrust fault, offset by longitudinal normal fault, places Blacksmith Formation (€bl) on Brigham Formation (€b).
Figure 10. Clifton thrust fault and marginal normal fault, east of Cherry Creek; view southeast. Clifton thrust fault places Bloomington Formation (€bo) on Brigham Formation (€b). Nounan Formation (€n) rests on Bloomington (€bo) along higher thrust fault at left. Oxford Peak is at upper right.
Figure 11. Clifton thrust fault, longitudinal normal fault, and marginal normal fault, south of Curly Jack Flat, on western side of mountain; view east. Clifton thrust fault places Bloomington Formation (€bo) on Brigham Formation (€b). Longitudinal normal fault drops St. Charles Formation (€sc) next to Brigham (€b) and Bloomington (€bo). Marginal normal fault extends along base of prominent outcrops and drops Salt Lake Formation in foreground.
fault, is folded into an anticline, but it generally dips about 30° E.

The Clifton thrust fault is exposed on both sides of the ridge about 2 miles east of Malad Summit (Plate 1). The thrust fault dips east on the eastern side of the ridge, and it dips west on the western side. Limestone and dolomite of the upper part of the St. Charles Formation and limestone of the Garden City Formation are thrust over quartzite of the Brigham Formation. The beds of the Brigham, below the thrust fault, dip about 20°-72° E. The beds of the St. Charles and Garden City, above the thrust fault, dip about 17°-59° E. The Clifton thrust fault, near the northern end of the ridge, is exposed on the eastern side (Plate 1). Limestone and dolomite of the upper part of the Garden City Formation and quartzite of the Swan Peak Formation are thrust over quartzite of the Brigham (Figure 12). The thrust fault dips west at a low angle and the beds of the Brigham, below the thrust fault, dip about 36°-42° E. The beds of the Garden City and Swan Peak, above the thrust fault, dip about 26°-37° W.

The Clifton thrust fault, in the southern part of the mapped area, seems to parallel the bedding in the Brigham. The thrust fault lies near the top of the Brigham at the canyon of Rattlesnake Creek. The rock units immediately above the thrust fault, in the southern part of the area, are the Blacksmith and Bloomington Formations of Middle Cambrian age. The Clifton thrust fault cuts across the bedding of the Brigham in some places in the northern part of the mapped area. The rock units immediately above the thrust fault, in the northern part of the mapped area, are the St. Charles of Late Cambrian age, the...
Figure 12. Clifton thrust fault on northern end of mountain, 1.7 miles east of Malad Summit; view southeast. Clifton thrust fault places Garden City Formation (Ogc) on Brigham Formation (Cb).
Garden City of Early and Middle Ordovician age, and the Swan Peak of Middle Ordovician age.

**Thrust faults below Clifton thrust fault**

An inferred thrust fault in the Precambrian Mutual Formation is mapped in the area south of Campbell Creek and west of the Right Fork of Cherry Creek (Figure 13, Plate 1). The thrust fault is believed to be present along the crest and on the western side of the ridge. It dips west at a moderate angle and the quartzite of the Mutual, above the thrust fault, dips 10°-39° NE. The quartzite of the Caddy Canyon and Mutual Formations, below the thrust fault, dips 12°-69° NE.

The thrust fault, which would lie below the Clifton thrust fault, is inferred to explain three problems. They are the seemingly much greater thickness of the Mutual at this location compared to that east of Cherry Creek, grayish-red quartzite of the Mutual on the western side of the ridge below the contact of the Mutual and Caddy Canyon Formations, and a west-dipping zone of breccia on the western side of the ridge. The zone of breccia is well exposed on the southern side of an east-west normal fault, about 1 mile north of New Canyon (Plate 1).

The Oxford Peak thrust fault is mapped on Oxford Peak, about 2 miles east of the Malad Summit Quadrangle (Raymond, 1971, p. 27, Plate 1). It is a major thrust fault and places quartzite of the Caddy Canyon Formation over older Precambrian argillite. A correlative structure is not recognized in the mapped area; however, it may exist at depth below the Caddy Canyon.
Figure 13. Thrust fault and normal faults west of Right Fork of Cherry Creek; view northwest. Thrust fault near mountain top, in Mutual Formation (pɛm), dips west. Transverse normal fault drops Mutual (pɛm) next to Caddy Canyon Formation (pɛc). Longitudinal normal fault drops Brigham Formation (ɛb), in foreground, next to northeast-dipping Caddy Canyon (pɛc) and Mutual (pɛm). Segments of this fault connect behind hill on left.
Thrust faults above Clifton thrust fault

Thrust faults occur at three stratigraphic positions in the Paleozoic section above the Clifton thrust fault in the mapped area. They are between the Bloomington and Nounan Formations, between the St. Charles and Garden City Formations, and between the Garden City and Swan Peak Formations.

The thrust fault, between the Bloomington and the Nounan, disrupts the contact. A similar structure is present between the Bloomington and Nounan in the Malad Range south of the mapped area (Burton, 1973, Plate 1). In the mapped area, it is best exposed on the ridge between New Canyon and the canyon of Rattlesnake Creek (Figure 6, 14; Plate 1). The thrust fault cuts across the bedding of the Bloomington and Nounan at a low angle. East-dipping beds on the Nounan project downward to east-dipping beds of the underlying Bloomington. The dolomite of the Nounan is generally brecciated, and a zone of breccia is present at the thrust fault. The Bloomington, below the thrust fault, dips 23°-52° E. The Nounan, above the thrust fault, dips 19°-71° E. The thrust fault is either horizontal or it dips about 30° E.

The thrust fault, between the Bloomington and the Nounan, is also exposed on the crest of the ridge about 0.5 mile east of Curly Jack Flat (Plate 1). It dips north at that location. The Bloomington, below the thrust fault, dips 21°-60° E., but the Nounan above is severely brecciated making determination of its attitude impossible.
Figure 14. Thrust fault north of Rattlesnake Creek; view north. Thrust fault, near ridge crest, places Nounan Formation (En) on Bloomington Formation (Ebo). Blacksmith Formation (Ebl) underlies Bloomington (Ebo) on left.
The thrust fault, between the Bloomington and the Nounan, is present along the eastern margin of the mapped area about 1.5 miles east of Toms Canyon Spring (Figure 10, Plate 1). The thrust fault dips about 25° N. at that location. The thrust fault nearly parallels the bedding in the Bloomington and the Nounan. A zone of breccia is exposed along the trace of the thrust fault. The Bloomington, below the thrust fault, dips 15°-28° N., and the Nounan, above the thrust fault, dips 25°-29° N.

The dolomite of the Nounan is in thrust contact with the limestone of the upper part of the Bloomington at all exposures of this thrust fault in the mapped area. The fault does not involve the shale beds of the Bloomington in the mapped area.

A thrust fault, which places dolomite of the upper St. Charles Formation over limestone of the Garden City Formation, is located near the crest of the ridge about 2 miles east of Malad Summit (Plate 1). This inferred thrust fault is poorly exposed. The Garden City, below the thrust fault, and the St. Charles, above, have similar attitudes and project toward each other, meeting at the inferred fault. The strike of both units is about N. 30° W. The Garden City dips 17°-58° E., and the St. Charles dips 17°-61° E. The two units are adjacent on the crest of the ridge; however, on both sides of the ridge the Garden City is exposed farther down the slope below the St. Charles. The thrust fault dips about 10° SW. There is no offset of the Clifton thrust fault below, which would indicate that it is a normal fault instead of a thrust fault. There is no evidence of strike-slip displacement along the inferred thrust fault.
A thrust fault, between the Garden City and the Swan Peak Formations, is exposed along the ridge 2 miles east of Malad Summit (Plate 1). It places quartzite of the upper member of the Swan Peak in contact with the limestone and dolomite of the upper part of the Garden City. The thrust fault eliminates the lower and middle members and part of the upper member of the Swan Peak Formation. The Swan Peak is extremely brecciated (Figure 5). This makes accurate attitude determinations difficult.

On the ridge east of Malad Summit, the thrust fault dips about 20° E. The limestone of the Garden City, below the thrust fault, dips 17°-58° E. The Swan Peak, above the thrust fault, is too severely brecciated to permit determination of its attitude. On the ridge northeast of Malad Summit, the thrust fault dips about 15° W. The Garden City, below the thrust fault, dips about 24° E., and the Swan Peak, above, dips 26°-37° W.

**Structural interpretations**

The Clifton thrust fault, a major structural feature of the mapped area, and other thrust faults in the eastern part of the Malad Summit Quadrangle are the result of either horizontal compression or gravity gliding. The compression mechanism implies that thrust faults cut across rock units at a rather high angle and that older units are thrust over younger units. This is not the case in the mapped area.

A study of the central Beaverhead Range, in Idaho and southwestern Montana, indicated that the area was subjected to regional compression which caused an upwarp (Scholten and Ramspott, 1968, p. 53-54).
Large masses of rock slid from the flanks of the upwarp under the influence of the gravity. Gravity-glide planes developed at a shallow depth without high fluid pressure and were facilitated by incompetent rock units below (Scholten and Ransspott, 1968, p. 44-45). Mudge (1970, p. 381) proposed gravity gliding for the origin of thrust faults in the disturbed belt of northwestern Montana. The gravity-glide planes developed within or at the top of mudstone units which probably had high fluid pressures (Mudge, 1970, p. 389). The regional dip was east at an angle as high as 8.5 degrees (Mudge, 1970, p. 389). Large-scale horizontal displacements along gravity-glide planes in gently dipping strata, facilitated by high fluid pressure in the strata near the glide plane, are theoretically possible (Hubbert and Rubey, 1959).

The thrust faults, exposed in the eastern part of the Malad Summit Quadrangle, are characteristic of those caused by gravity gliding. The thrust faults are generally parallel to the bedding or cut across the bedding at a low angle. Incompetent rock units such as shale or thin-bedded limestone are often present immediately above or below the thrust fault. Younger rock units are thrust faulted over older rock units resulting in the elimination of significant parts of the stratigraphic section in some places. The Clifton thrust fault clearly represents this in the mapped area. South of New Canyon (Plate 1), the Blacksmith and Bloomington Formations of Middle Cambrian age are thrust over the Brigham Formation of Early Cambrian age, resulting in the elimination of the Langston and Ute Formations.
Northeast of Malad Summit (Plate 1), the Swan Peak and Garden City formations of Ordovician age are thrust over the Brigham, resulting in the elimination of the Langston, Ute, Blacksmith, Bloomington, Nounan, and St. Charles Formations.

In the mapped area, eastward displacement is postulated on all thrust faults based on evidence of great eastward displacement in the Bannock thrust zone in southeastern Idaho (Armstrong and Cressman, 1963) and on the Willard thrust fault in northern Utah (Crittenden, 1961, 1972b). There is no direct evidence for the direction of displacement of thrust faults exposed in the mapped area. The amount of horizontal displacement is unknown.

The Clifton thrust fault, in the mapped area, has been deformed as evidenced by the diverse dip directions and normal faults that offset it (Plate 1). The diverse dip directions are possibly due to drag along normal faults at the margins of the ridge. Structure section B-B' (Plate 1) illustrates that the Clifton thrust fault dips toward the marginal normal faults. A more likely explanation is that the thrust fault was folded during the period of thrust faulting, not by drag along normal faults. Folding accompanied thrust faulting in southeastern Idaho and western Wyoming (Armstrong and Oriel, 1965, p. 1857; Armstrong and Cressman, 1963, p. 1). The Clifton was probably folded while displacement was occurring on a thrust fault at greater depth such as the Oxford Peak thrust fault. The Oxford Peak thrust fault is exposed below the Clifton thrust fault in the Oxford Peak area, about 2 miles east of the Malad Summit Quadrangle (Raymond, 1971, p. 27,
Plate 1). It is possible that the Oxford Peak thrust fault is present at depth in the mapped area.

**Normal Faults**

**Marginal normal faults**

Marginal normal faults are located along the margins of major mountains in the mapped area. Considerable displacement has occurred on these faults. Three marginal normal faults are present in the eastern part of the Malad Summit Quadrangle.

A normal fault is present along the western margin of the ridge in the mapped area (Plate 1). It extends north from the southern boundary of the mapped area to a point about 1.5 miles north of the mouth of New Canyon. From this point, it trends northwest along the mountain front. This fault is covered by colluvium in the northern part of the mapped area; it is covered by alluvial fans, colluvium, and stream alluvium in the southern part. Fault scarps are present in the Brigham Formation, about 0.5 mile south of Curly Jack Flat (Figure 15), and in the Mutual Formation about 0.75 mile north of the mouth of New Canyon (Plate 1). The surfaces of these scarps dip about 75° W., indicating that the normal fault dips steeply west.

A normal fault is present along the eastern margin of the ridge in the mapped area (Figure 2, Plate 1). It runs north from the southern boundary of the mapped area to a point about 0.25 mile southwest of the Cherry Creek Campground (Plate 1). From this point, it trends northwest along the mountain front to the northern boundary of the mapped
Figure 15. Marginal normal fault on western side of mountain, 0.5 mile south of Curly Jack Flat; view south. Slickensided surface, on Brigham Formation, dips steeply west.
area. The fault is covered by colluvium in the northern part of the mapped area. Fault scarps are not exposed, but the trace of the fault, where it crosses the ridge about 0.75 mile south of Cherry Creek Campground, indicates that the fault dips steeply east (Plate 1).

A normal fault is present along the western margin of a mountain near the eastern boundary of the mapped area (Figure 10, Plate 1). The fault trends northwest from the eastern boundary of the mapped area into an area covered by colluvium on the eastern side of Cherry Creek. The fault probably dips steeply west; however, it may be vertical.

**Longitudinal normal faults**

Longitudinal normal faults, in the mapped area, are located within the mountain and are nearly parallel to the ridge and the marginal normal faults. They trend northwest-southeast, in the northern part of the mapped area, and north-south in the southern part. Three notable examples of longitudinal normal faults, as well as similar smaller faults, exist in the mapped area.

A normal fault, on the western side of the ridge south of New Canyon, trends north-south and offsets the Clifton thrust fault as well as the Brigham Formation below and the Blacksmith and Bloomington Formations above (Plate 1). It dips west at a moderate angle and the western side is down relative to the eastern side (Figure 8, 9). The units on the western side dip $11^\circ-54^\circ$ SE., and the units on the eastern side of the fault dip $23^\circ-51^\circ$ E. Drag is exhibited by the Brigham, on the northern side of Rattlesnake Creek, immediately east of the fault. The quartzite of the Brigham dips $18^\circ$ W. at that location.
A longitudinal normal fault is present, on the western side of the ridge, east of Curly Jack Flat (Plate 1). It intersects the marginal normal fault about 0.5 mile south of Curly Jack Flat and 1 mile north of Curly Jack Flat (Figure 11, 16, 17). This normal fault places the Worm Creek Member of the St. Charles Formation and the upper member of the St. Charles down on the western side relative to Brigham, Bloomington, upper St. Charles, and Worm Creek Member on the eastern side. It dips west at a moderate to high angle. Drag is exhibited by the Worm Creek, immediately east of the fault, about 0.25 mile north of Pine Spring (Plate 1). The Worm Creek dips 18° W. near the fault; the general dip of the units, east of the fault, is 22°-57° E. The units, west of the fault, have diverse dip directions, but the dip is generally west except in the southern end of the fault block where it is east.

A longitudinal normal fault is present on the eastern side of the ridge from a point located 0.25 mile south of Cherry Spring southward to New Canyon (Plate 1). It trends north-south and places the Brigham and Mutual Formations on the eastern side down relative to the Mutual and Caddy Canyon Formations on the western side (Figure 7, 13). The fault dips east at a high angle. The beds of the Mutual and Caddy Canyon, on the western side of the fault, dip 17°-69° NE. The Mutual and Brigham, on the eastern side, dip 30°-63° NE.

Transverse normal faults

Transverse normal faults, in the mapped area, lie within the ridge and are nearly perpendicular to the ridge, the marginal normal faults,
Figure 16. Longitudinal normal fault, east of Curly Jack Flat; view north along mountain top. Normal fault drops upper member of St. Charles Formation (Esc), on left, next to Worm Creek Member of St. Charles (Ewc), on right. Bloomington Formation, in foreground, is south of transverse normal fault in canyon.
Figure 17. Longitudinal normal fault, northeast of Curly Jack Flat; view north along mountain top. Normal fault drops St. Charles Formation (Єsс), in foreground, next to Brigham Formation (Єb).
and the longitudinal normal faults. The transverse normal faults trend east-west and northeast-southwest. They are present between a point located 0.75 mile north of Curly Jack Flat and Rattlesnake Creek in the southern part of the mapped area (Figure 2, 13; Plate 1).

The most conspicuous feature formed by the transverse normal faults is a graben on the ridge in the central part of the mapped area (Figure 2, Plate 1). It trends east-west and is bounded, on the north, by a transverse fault located 0.75 mile north of Curly Jack Flat and, on the south, by a transverse fault immediately south of Cherry Spring. There is little topographic difference along the crest of the ridge. The Blacksmith, Bloomington, Nounan, and St. Charles Formations are exposed in the graben. The Brigham, below the Clifton thrust fault, is exposed within the graben in a limited area, which is located 0.5 mile south of Curly Jack Flat. The Mutual and Caddy Canyon Formations are not exposed in the graben. The Brigham, Mutual, and Caddy Canyon are undoubtedly present at depth, in the graben, inasmuch as the Brigham is widely exposed to the north and the Caddy Canyon, Mutual, and Brigham are all exposed to the southeast.

**Structural interpretations**

Marginal normal faults, in the mapped area, trend north-south and northwest-southeast and are responsible for most of the relief. Displacement along these faults is unknown but it is probably great. The most recent displacements, in the mapped area, undoubtedly occurred along the marginal normal faults. The normal faults in the Basin and Range province were produced by tensional forces which resulted from a plastically extending substratum (Stewart, 1971, p. 1038, Figure 8).
Longitudinal normal faults, located within the mountain, trend north-south and northwest-southeast. They probably originated at the same time as the marginal normal faults. As displacement occurred along the marginal normal faults, support was removed from below the hanging-wall block of the longitudinal normal fault causing it to be displaced downward toward the valley. Displacements along the longitudinal normal faults are not great. In some places, the displacement is only a few hundred feet.

Transverse normal faults are cut by longitudinal normal faults and, although evidence is lacking, they are probably cut by marginal normal faults also. Transverse normal faults are also recognized in the Samaria Mountain area about 10 miles southwest of the mapped area (Beus, 1968, p. 801, Figure 2). The Woodruff fault, near Samaria Mountain, is a major east-west normal fault and probably has considerable displacement. There are two trends of normal faults in the thrust zone of southeastern Idaho and western Wyoming (Armstrong and Oriel, 1965, p. 1862-1863). Older east-west to northeast-southwest normal faults are cut by younger north-south and northwest-southeast normal faults. In the mapped area, transverse normal faults predate the marginal and longitudinal normal faults, although the time of displacement certainly overlaps.

Considerable displacement is evident on the transverse normal faults of the mapped area; however, their topographic expression is not particularly evident on the ridge. It is possible that some of these are strike-slip faults similar to those mapped by Raymond (1971,
Plate 1) in the Oxford Peak area about 2 miles east of the mapped area. There is no evidence, however, of strike-slip displacement along these faults in the mapped area. Small-scale faults, slickensides, and drag indicate that the displacement has only a vertical component.

**Landslides**

A landslide is recognized, in the mapped area, on the western side of the ridge about 1 mile north of Curly Jack Flat (Plate 1). No scar is present on the ridge; however, it is evident that quartzite of the Brigham Formation moved downslope to the west over the limestone and dolomite of the upper part of the St. Charles Formation. There are quartzite boulders in the colluvium along the mountain front that may be remnants of the landslide.

The landslide occurred during the relative down-faulting of the valley and the fault block within the ridge. As faulting occurred, support was removed, which resulted in downslope movement under the influence of gravity.
STRUCTURAL EVENTS

General Statement

The two major structural events of the eastern part of the Malad Summit Quadrangle are thrust faulting, with associated folding, and later normal faulting. The thrust faulting and folding occurred during the Laramide orogeny which was active from late Jurassic to early Tertiary. It caused similar deformation throughout western and northern Utah, southeastern Idaho, and western Wyoming. The thrust faults are usually low angle and in some cases have great eastward displacement (Crittenden, 1961). Gravity gliding has been proposed as the mechanism by which the thrust faults formed (Rubey and Hubbert, 1959).

Normal faulting occurred, in the Basin and Range province, after the Laramide orogeny. This faulting began in early Tertiary and has continued to the present. A series of alternating valleys and mountain ranges, which trend generally north to south, is the result. The normal faults formed due to tensional stresses caused by a plastically extending substratum (Stewart, 1971).

Laramide Events

The Laramide events, recognized in the eastern part of the Malad Summit Quadrangle, are thrust faulting and folding of Precambrian and Paleozoic units. The oldest unit involved is the Precambrian Caddy Canyon Formation and the youngest unit involved is the Ordovician-Silurian Fish Haven-Laketown Formation. The Clifton thrust fault,
a low-angle thrust fault which generally follows bedding planes, is considered to be a gravity-glide structure. The thrust faults above and below the Clifton are similar in nature and are also considered to be gravity-glide structures. They probably formed either at the same time or after the Clifton. The folding of the thrust faults and the rock units, in the mapped area, probably occurred during or after the thrust faulting.

The youngest Paleozoic unit, exposed in the mapped area, is the Fish Haven-Laketown Formation of Ordovician-Silurian age. Elsewhere, in southeastern Idaho and western Wyoming, units as young as Permian and Triassic are involved in thrust faulting and folding of the Laramide orogeny (Armstrong and Cressman, 1963). Therefore, it is evident that a great thickness of upper Paleozoic and Mesozoic units was removed by erosion preceding the deposition of the Wasatch and Salt Lake Formations of Tertiary age. Thrust faulting of the Laramide orogeny, in southeastern Idaho, began as early as Late Jurassic and ended during Eocene (Armstrong and Cressman, 1963, p. 8-16). The Ephraim Conglomerate, an orogenic detrital unit of Late Jurassic to Early Cretaceous age, was derived mainly from upper Paleozoic rock units. The oldest rock fragments, present in the Ephraim, are white quartzite pebbles from the Swan Peak Formation of Ordovician age. There are no fragments from Mesozoic units; therefore, a considerable thickness of Mesozoic units must have been removed by erosion before deposition of the Ephraim. The Wasatch Formation of Eocene age overlaps thrust faults in the Bannock thrust zone (Armstrong and Cressman, 1963, p. 16).
Basin and Range Events

Normal faulting, in southeastern Idaho and northern Utah, occurred after the thrust faulting and folding of the Laramide orogeny. The Wasatch Formation of Eocene age apparently was deposited on a relatively horizontal surface which predated the normal faulting (Williams, 1948, p. 1159-1160). The Salt Lake Formation, Oligocene (Williams, 1962, p. 133) to Pliocene (Adamson, Hardy, and Williams, 1955, p. 2) in age, was generally deposited in the valleys which formed as a result of normal faulting. Therefore, the normal faulting began as early as Oligocene.

In the mapped area, displacement occurred first along transverse normal faults. It was followed by displacement along marginal and longitudinal normal faults, although the times of displacement certainly overlap. The marginal normal faults are responsible for the present trend of the mountains and valleys, and they apparently controlled the deposition of the Salt Lake Formation. The landslide occurred rather late during this period because boulders from the slide rest on the Salt Lake Formation.

There is no evidence, in the mapped area, for normal faulting after the deposition of the Salt Lake Formation. Isolated outcrops of Salt Lake occur on the ridge, but these may be erosional remnants. Normal faulting, after deposition of the Salt Lake Formation, has undoubtedly occurred in the mapped area, although there are no fault scarps present in Tertiary or Quaternary units. Fault scarps are present in the Salt Lake Formation, Lake Bonneville Group, and alluvial
fan deposits in the Logan Quadrangle of northern Utah (Galloway, 1970, p. 85-86). Southeastern Idaho and northern Utah are tectonically active at the present time.
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.


Stratigraphic Section

Mutual Formation, measured on ridge north of Middle Fork of Cherry Creek in sec. 10 (unsurveyed), T. 13 S., R. 37 E.

Brigham Formation: Light-brown quartzite

<table>
<thead>
<tr>
<th>Thickness (feet)</th>
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</thead>
<tbody>
<tr>
<td>101.7</td>
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</table>

5. Argillite

<table>
<thead>
<tr>
<th>Type</th>
<th>Thickness (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micaceous argillite, grayish red, clay size to very fine grained, weathers pale reddish purple to grayish red</td>
<td>101.7</td>
</tr>
</tbody>
</table>

Bed thickness
Fissile

4. Argillite and quartzite

<table>
<thead>
<tr>
<th>Types, argillite</th>
<th>Thickness (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micaceous argillite, grayish red, clay size to very fine grained, weathers pale reddish purple to grayish red</td>
<td>74.8</td>
</tr>
<tr>
<td>Argillite, very light gray, clay size to very fine grained, weathers yellowish gray to pinkish gray</td>
<td>74.8</td>
</tr>
</tbody>
</table>

Interbeds
Quartzite as described below

Bed thickness
Fissile

Structure
Wavey parallel laminae

Types, quartzite
Quartzite, pale red, fine to medium grained, weathers reddish purple to grayish red
Quartzite, grayish red, fine grained, weathers pale red to grayish red
Quartzite, very light gray, fine grained, weathers light olive gray to pale brown
Interbeds
Argillite as described above

Bed thickness
0.05-1.0 feet

3. Quartzite
Types
Conglomeratic quartzite, pale red,
medium to coarse grained, weathers
grayish red to pale reddish purple to
pale brown
Quartzite, grayish red, coarse to very
coarse grained, weathers grayish red
to pale reddish purple
Quartzite, blackish red, medium to very
coarse grained, weathers very dusky
reddish purple

Interbeds
Pebbles of white quartz, gray quartz,
pink quartz, black chert, and jasper

Bed thickness
0.2 to 2.3 feet

Structures
Cross-beds
Parallel laminae
Scattered pebbles of very-light-gray
feldspar, and quartz as described above

2. Quartzite
Types
Quartzite, grayish red, medium to
coarse grained, weathers grayish red
to grayish purple
Quartzite, very dusky red, fine to coarse
grain, weathers very dusky purple
to grayish purple
Quartzite, grayish purple, medium to
coarse grained, weathers grayish red
to pale red to pale reddish purple
Quartzite, pale red, medium grained,
weathers pale red reddish purple to pale red
Quartzite, pale red, medium to coarse
grain, weathers grayish red to pale
reddish purple
Interbeds
Pebbles of white quartz, gray quartz, pink quartz, black chert, and jasper

Bed thickness
0.6-1.8 feet

Structures
Cross-beds
Scattered pebbles of very-light-gray feldspar, and quartz as described above
Brecciated quartzite

1. Covered interval . . . . . . . . . . . 736.7

Slope covered with talus consisting of quartzite as described above; some grayish-red to yellowish-gray to light-olive-gray argillite is present in slope at base of section

Total Mutual Formation 1448.4

Caddy Canyon Formation: White quartzite
GEOLOGIC MAP OF EASTERN PART OF THE MALAD SUMMIT QUADRANGLE, IDAHO