5-1979

Structural Geology of the Northern Part of Oxford Quadrangle, Idaho

Jerrold N. Mayer

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STRUCTURAL GEOLOGY OF THE NORTHERN PART OF
OXFORD QUADRANGLE, IDAHO

by

Jerrold N. Mayer

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

Approved:

UTAH STATE UNIVERSITY
Logan, Utah

1979
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The writer also wishes to thank his wife, Shelley, for her encouragement and understanding throughout the entire undertaking of this investigation.
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ABSTRACT

Structural Geology of the Northern Part of
Oxford Quadrangle, Idaho

by

Jerrold N. Mayer, Master of Science
Utah State University, 1979

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

The northern part of the Oxford Quadrangle, Idaho, includes parts of the Bannock Range to the west and the Portneuf Range to the east. These ranges are separated by Marsh Valley to the north and Cache Valley to the south. Red Rock Pass, the outlet of glacial Lake Bonneville, divides the two valleys. The mapped area is north of Preston, Idaho, and south of Downey, Idaho. The north-south dimension of the mapped area is 5.2 miles and the east-west dimension is 6.4 miles.

The stratigraphic units, within the mapped area, are Precambrian, Paleozoic, and Cenozoic in age. The oldest rock unit is the Pocatello Formation of late Precambrian age. Other Precambrian units, in ascending order, are the Papoose Creek Formation and the Caddy Canyon Quartzite. The Precambrian units are dominantly argillite and quartzite with some extrusive and intrusive metagneous rocks. The Cambrian formations, in ascending order, are the Langston, Ute, Blacksmith, Bloomington, Nounan, and St. Charles Formations. The
Cambrian units are dominantly limestone and dolomite, with interbedded shale. Ordovician formations consist of the basal Garden City Formation which is limestone and the Swan Peak Formation which is quartzite. The Tertiary Salt Lake Formation is dominantly tuff and conglomerate. The Quaternary is represented by colluvial deposits, Lake Bonneville Group, and alluvial deposits.

Major structural features, within the mapped area, are thrust faults and normal faults. A major thrust fault places Middle Cambrian rocks on Precambrian rocks and eliminates a significant part of the stratigraphic column. Thrust faults are also present between Papoose Creek Formation and Caddy Canyon Quartzite, Bloomington and Nounan Formations, St. Charles and Garden City Formations, and Garden City and Swan Peak Formations. The evidence, within the mapped area, indicates eastward thrusting. The normal faults postdate the thrust faults and offset Salt Lake Formation. The normal faults generally trend north-northwest.

These structural features are the result of two separate events. The thrust faulting and related deformation is late Jurassic to Eocene in age. The Basin and Range normal faulting began in late Eocene and continued to Holocene.
INTRODUCTION

Purpose and Scope

The purpose of this investigation was to produce a detailed geologic map of the northern part of the Oxford Quadrangle (Plate 1). This map is a contribution to the understanding of the complex structural and stratigraphic relations in the area and also provides a basis for geologic interpretations.

Location and Accessibility

The study area is north of Preston, Idaho, and south of Downey, Idaho (Figure 1). It includes the town of Swanlake in the south-eastern corner. The mapped area includes the northern part of the Oxford Quadrangle, a 7.5-minute series topographic map published by the Geological Survey of the U.S. Department of the Interior. The area lies between lat. 42°18' N. and lat. 42°22'30" N. and between long. 112°00' W. and long. 112°07'30" W. The area measures 5.2 miles in the north-south direction and 6.4 miles in the east-west direction.

The area is readily accessible by U.S. Highway 91, secondary highways, and various light-duty and unimproved roads. The south-western corner, however, is not as accessible by roads and some walking is required.
Figure 1. Index map of part of southeastern Idaho showing location of the northern part of Oxford Quadrangle.
Physiographic Features

The northern part of the Oxford Quadrangle is widely known as the location of Red Rock Pass, the outlet of glacial Lake Bonneville (Figure 1). The mapped area is located at the northern end of Cache Valley, Utah and Idaho, and at the southern end of Marsh Valley, Idaho.

The mapped area is within the Basin and Range province and is dominated by mountain ranges which generally trend north-south. The Bannock Range is to the west and the Portneuf Range is to the east. The Bear River Range is to the east of the Portneuf Range.

The highest peak in the mapped area is near the southern border, west of Swanlake, Idaho, at an elevation of 7,504 feet. The lowest part of the mapped area, located near Marsh Creek at the northern edge of the mapped area, is at an elevation of about 4,760 feet. The local relief is approximately 2,740 feet. Oxford Peak, approximately 2 miles to the south of the mapped area, is 9,281 feet in elevation.

Field Work

The field investigation was conducted in the summer of 1978. Geological features were mapped in the field on a topographic base map at a scale of 1:24,000 and on aerial photographs. This information was later transferred to a topographic base map at a scale of 1:12,000, an enlargement of the northern part of the 7.5-minute series map of the Oxford Quadrangle published by the Geological Survey of the U. S. Department of the Interior. The Rock-Color Chart,
distributed by The Geological Society of America, was used to determine rock color.

Previous Investigations

The southern part of the mapped area overlaps the area studied by Raymond (1971). The adjoining area to the west, the eastern part of the Malad Summit Quadrangle, Idaho, was mapped by Shearer (1975). The adjoining area to the east was mapped by Oriel and Platt (1968) as a reconnaissance geologic map.

The southern part of Elkhorn Mountain in the Bannock Range, Idaho, was studied by De Vries (1977). Similar structural studies in the Malad Range, Idaho, have been done by Axtell (1967) in the northern part, Murdock (1961) in the Weston Canyon area, and Hanson (1949) in the southern part.

The Cambrian stratigraphy of northern Utah and southeastern Idaho was first described by Walcott (1908). Eardley and Hatch (1940) described the younger Precambrian and older Cambrian rocks of Utah. Maxey (1941, 1958) described the Lower and Middle Cambrian stratigraphy of northern Utah and southeastern Idaho. The Precambrian and lower Paleozoic rocks of the northern part of the Bannock Range near Pocatello, Idaho, were described by Ludlum (1942, 1943). Ludlum was the first to assign part of the section to the Precambrian. Williams (1948) described and mapped the Paleozoic formations of the Logan Quadrangle in northern Utah. Adamson, Hardy, and Williams (1955) studied the Tertiary rocks in Cache Valley, Utah and Idaho.
STRATIGRAPHIC UNITS

General Statement

The stratigraphic units, in the mapped area, are mainly Precambrian and early Paleozoic in age. These units are summarized in Table 1. The oldest unit present is the Pocatello Formation of late Precambrian age. It is overlain by the successively younger Papoose Creek Formation and Caddy Canyon Quartzite. A major thrust fault is present between the late Precambrian units and the units of Middle Cambrian age. The oldest Middle Cambrian unit is the Langston Formation. Other Cambrian units, in ascending order, are Ute, Blacksmith, Bloomington, Nounan, and St. Charles Formations. The Ordovician Garden City and Swan Peak Formations overlie the St. Charles Formation. Thrust faults are present between the Bloomington and Nounan Formations, the St. Charles and Garden City Formations, and the Garden City and Swan Peak Formations.

The Tertiary Salt Lake Formation both unconformably overlies and is faulted down next to the Precambrian and Paleozoic rocks. Quaternary deposits consist of colluvial deposits, Lake Bonneville Group, older alluvial deposits, and alluvial deposits. These units unconformably overlie older units.
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*Clarkston Mountain, Malad Range, Idaho (Ross, 1951).*
*bSouthern Malad Range, Idaho (Hanson, 1949).*
*cNorthern Malad Range, Idaho (Axtell, 1967).*
*dHigh Creek, Bear River Range, Utah (Maxey, 1958).*
*ePocatello Range, Idaho (Trimble, 1976).*
*fBannock Range, Idaho (Crittenden and others, 1971).
Precambrian Units

Pocatello Formation

In the type area in the Pocatello Quadrangle, Idaho, the Pocatello Formation consists of four members: (1) lower member, (2) Bannock Volcanic Member, (3) Scout Mountain Member, and (4) upper member (Trimble, 1976, p. 12; Crittenden and others, 1971, p. 583). The lower member is essentially argillite and is at least 700 feet thick (Trimble, 1976, p. 18; Crittenden and others, 1971, p. 583). The Bannock Volcanic Member is made up largely of metavolcanic rocks with minor interstratified metamorphosed sedimentary rocks. It includes volcanic flows, breccia, and tuff. This member is characteristically greenschist facies, consisting of greenstone and greenstone schist (Trimble, 1976, p. 16). The Bannock Volcanic Member is probably at least 1,000 feet thick and interfingers with the lower part of the Scout Mountain Member (Crittenden and others, 1971, p. 583-584; Trimble, 1976, p. 15-17). The Scout Mountain Member consists mainly of metadiamicritic which is probably submarine tillite according to Trimble (1976, p. 13). Also contained within the Scout Mountain Member are considerable amounts of interstratified quartzite and conglomerate with minor amounts of argillite, siltite, limestone, and dolomite. The total thickness of the Scout Mountain Member is considered to be at least 5,000 feet (Trimble, 1976, p. 13-14.) The upper member is similar to the lower member. It also is essentially argillite and is about 1,800 feet thick (Trimble, 1976, p. 17-18).

In the northern part of the Oxford Quadrangle, the Pocatello Formation consists of rock types characteristic of the lower member,
the Bannock Volcanic Member, the Scout Mountain Member, and the upper member. No attempt was made to map the members due to poor exposure. Exposures of the Pocatello Formation are located west of the main marginal fault in the southern part of the mapped area in the southwestern corner of sec. 7, T. 13 S., R. 38 E., and immediately to the west of sec. 7 especially to the north of Chicken Creek. The exposed thickness of the Pocatello Formation, in the mapped area, is probably several thousand feet.

The rocks characteristic of the lower member are fine-grained argillite. The argillite is phyllitic in places. These rocks range in color from dark greenish gray to olive gray.

The rocks characteristic of the Bannock Volcanic Member consist of phyllitic-schistose greenstone, argillite, and porphyritic metavolcanic rock which is vesicular in places. The greenstone and argillite range from dark greenish gray to light olive brown and the metavolcanic rock ranges from brownish gray to dark greenish gray. A rock taken from colluvium on the Pocatello Formation immediately north of Chicken Creek, approximately 2,500 feet west of the main marginal fault, was analyzed because it is vesicular and aphanitic and has the appearance of an extrusive volcanic rock. Thin-section and X-ray diffraction analysis indicate that it consists dominantly of oligoclase and chlorite with pyroxene and sericite. It is a metavolcanic rock. Chlorite is a common product of low-grade metamorphism. Metamorphosed volcanic rocks in a Precambrian argillite unit, in the southern part of the Oxford Quadrangle, were described by Raymond (1971, p. 8).
The rocks characteristic of the Scout Mountain Member consist of metadiamictite which is light olive gray to dusky yellow green, although it is brown in places due to staining and weathering. The clasts in the metadiamictite are as large as 1 foot in diameter (Figure 2).

The rocks characteristic of the upper member are similar to those of the lower member. They consist of fine-grained argillite which is phyllitic in places. The color of the rocks of the upper member ranges from dark greenish gray to olive gray.

White quartz veins that range from a few inches to a few feet in thickness are scattered throughout the Pocatello Formation. Some of the veins are stained yellowish brown. Small excavations, representing early mining attempts, are present in some of the larger veins.

The upper limit of the Pocatello Formation is placed where the greenish-gray argillite ends and the distinctive gray and brown argillite and quartzite of the Papoose Creek Formation begin. The exact nature of this contact is not known due to the poor outcrops in the area. The Blackrock Canyon Limestone, which is present between the Pocatello Formation and the Papoose Creek Formation in the Pocatello Quadrangle, Idaho, is not present in the mapped area.

The Pocatello Formation, the oldest formation within the mapped area, is late Precambrian in age (Crittenden and others, 1971, p. 581).

Papoose Creek Formation

The Papoose Creek Formation consists of about 1,800 feet of distinctive irregularly bedded gray and brown argillite and fine-grained quartzite in the Pocatello area, Idaho (Crittenden and
Figure 2. Metadiamictite in Pocatello Formation north of Chicken Creek; view northeast. The clast to upper right of hammer is argillite.
others, 1971, p. 585). The distinctiveness is due to penecontempor­
aneous deformation (Figure 3) which resulted in convolutions of
layers of alternating light-gray and light- to dark-brown argillite
(Crittenden and others, 1971, p. 585).

In the mapped area, the Papoose Creek Formation consists of
about 1,280 feet of gray and brown argillite with minor amounts of
quartzite. The penecontemporaneous deformation of the argillite is
evident throughout the formation. The argillite beds range in thickness
from less than 0.05 inch to almost 1 inch. The argillite is light
bluish gray and moderate brown to dark yellowish brown. It is slightly
micaceous in places. The argillite is extensively weathered in places.
A thick-bedded, fine-grained quartzite is exposed in the Papoose Creek.
This quartzite ranges in color from light bluish gray to light olive
gray although it also is commonly stained much darker.

Although much of the Papoose Creek Formation is poorly exposed,
it is well indurated and there are a number of outcrops. The best
exposures are readily accessible along the Left Fork Cherry Creek
in the southwestern part of the mapped area. A large area of outcrop
is also present along the upper part of Aspen Creek including the
generally heavily wooded area eastward to the main marginal fault,
but outcrops are poor in that area due to weathering and thick
vegetation.

Several metamorphosed intrusive bodies are exposed in the mapped
area in Papoose Creek Formation. X-ray diffraction and thin-section
analysis by the writer indicates that these rocks are composed
Figure 3. Specimen of Papoose Creek Formation showing penecontemporaneous deformation. The grid system consists of one-inch squares. The sample was collected north of the Left Fork Cherry Creek.
primarily of chlorite, plagioclase, and epidote, plus accessory minerals. The plagioclase was determined to be 28 mole percent anorthite by the Carlsbad-albite method. The abundance of chlorite and epidote suggests alteration of the original intrusive igneous rock by regional metamorphism. The largest of the metaigneous bodies measures approximately 1,000 feet in the north-south direction and 500 feet in the east-west direction. Most of the metaigneous bodies are concentrated in an area about 3.5 miles west of the town of Swanlake. They crop out west of the main marginal fault between the elevations of 5,920 and 6,480 feet. Two additional metaigneous bodies are located on the northern side of Chicken Creek approximately 3,500 feet west of the main marginal fault. The metaigneous bodies are not present in the overlying Caddy Canyon Quartzite, in the mapped area, and were not observed in the underlying Pocatello Formation. Similar bodies were described in the adjacent area to the south as plutons of amphibolite (Raymond, 1971, p. 44).

The Papoose Creek Formation overlies the Pocatello Formation and is overlain by the Caddy Canyon Quartzite. In the Pocatello Quadrangle, Idaho, the lower Caddy Canyon Quartzite consists of interbedded quartzite and argillite (Crittenden and others, 1971, p. 585). The upper contact of the Papoose Creek Formation is placed at the lowest quartzite of the Caddy Canyon; however, in the mapped area, the Caddy Canyon Quartzite has been thrust faulted over the Papoose Creek Formation as evidenced by the brecciated aspect of the quartzite and the usual lack of the interbedded argillite and quartzite of the lower part of the Caddy Canyon.
The Papoose Creek Formation is late Precambrian in age (Crittenden and others, 1971, p. 581).

Caddy Canyon Quartzite

In the type area in the Pocatello Quadrangle, Idaho, the Caddy Canyon Quartzite is composed of a lower light-colored vitreous orthoquartzite, a carbonate unit about 50 feet thick somewhere above the middle of the formation, and an upper quartzite and argillite which is pink, purplish gray, and maroon (Trimble, 1976, p. 21-22). The Caddy Canyon Quartzite is 6,500 feet thick (Trimble, 1976, p. 21).

In its lower part, the Caddy Canyon Quartzite consists of interbedded argillite and quartzite (Crittenden and others, 1971, p. 585; Trimble, 1976, p. 21-22). The upper part of the formation contains some beds of pale-green argillite similar to the Inkom Formation, which overlies the Caddy Canyon in the Pocatello area (Trimble, 1976, p. 21-23).

Trimble (1976, p. 21) stated that the Caddy Canyon Quartzite is highly variable in lithology. Its great thickness and lithologic variations may cause difficulty in local identification (Trimble, 1976, p. 21). He advised that great thicknesses of the stratigraphic section should be examined before attempting identification (Trimble, 1976, p. 22).

Within the mapped area, the Caddy Canyon Quartzite is exposed north of the western Left Fork Cherry Creek and also in the area northeast of Aspen Creek. The Caddy Canyon is approximately 1,040 feet thick in the northern part of the Oxford Quadrangle and consists of a lower brown to very-light-gray quartzite, a limestone unit, and an upper red quartzite.
The lower part of the Caddy Canyon Quartzite is generally thick-bedded, fine- to medium-grained, vitreous quartzite which is commonly stained yellow, brown, or orange. Most of the rocks are very pale orange, but they range from light brown to grayish brown, depending on the stain. The quartzite is usually severely brecciated in the lower part of the Caddy Canyon, although it is brecciated throughout the formation. The breccia, in the lower part of the Caddy Canyon, is a fault breccia related to the thrust fault between the Caddy Canyon and the underlying Papoose Creek Formation. This thrust fault has generally removed the argillite and quartzite of the lower Caddy Canyon Quartzite; however, the argillite and quartzite beds of the lower Caddy Canyon occur at one locality north of the Left Fork Cherry Creek. That locality is about 1.2 miles from the western edge of the mapped area in the area of the contact between the Papoose Creek Formation and the Caddy Canyon Quartzite below the klippe on the hill with elevation of 6,836 feet. A limestone unit which is 10-15 feet thick is also present at that locality, as well as the beds of argillite and quartzite.

Above the lower quartzite is a weathered and brecciated limestone which is 20-30 feet thick. The limestone is moderate yellowish brown, although less weathered rocks are medium to dark gray. The limestone occurs on the ridge east of Aspen Hollow approximately 1,000 feet northwest of the peak with elevation 7,147 feet. It also occurs on the ridge approximately 3,000 feet due east of the first locality. The limestone unit is generally obscured by colluvium.
Above the limestone unit, purplish quartzite and purplish dusky red argillite are present. The quartzite is thick bedded and fine to medium grained. It is generally severely brecciated. It ranges in color from pale red to very dark red to very dusky purple. The argillite is not continuous and is approximately 50 feet thick at its maximum. It forms a saddle at the western edge of the mapped area, north of the Left Fork Cherry Creek, just below the peak with elevation 7,295 feet (Figure 9). Good exposures of the quartzite, forming peaks, ridges, and high areas which commonly have fairly flat tops, occur northeast of Aspen Creek. In that area, weathered chips are the only evidence of the purple argillite.

The quartzite of the upper part of the Caddy Canyon is very pale orange and resembles the lower quartzite. Pale-greenish-yellow to pale-olive chips of quartzite are also present in the area of outcrop. The upper part of the quartzite crops out in the area north of the Left Fork Cherry Creek, within the first 1.5 miles from the west, northward to the Cambrian rocks.

A concentration of greenish argillite chips, near the top of the formation, is located on the peak with the elevation 7,147 feet which is north of the spring at the head of Aspen Creek. The chips are located on the south-facing slope about 50-80 feet below the top of the peak. The argillite is very pale green but is weathered to dark brown which has a metallic-like appearance.

The Caddy Canyon Quartzite has been thrust faulted over the Papoose Creek Formation. A thrust fault is also present above the Caddy Canyon. This thrust fault places rocks of Middle Cambrian age
directly above the Caddy Canyon Quartzite and completely eliminates the Inkom Formation, the Mutual Formation, and the Brigham Formation or its Cambrian equivalents, the Camelback Mountain Quartzite and the Gibson Jack Formation. Between 7,000 and 8,000 feet of the stratigraphic section is missing based on thicknesses measured in the Pocatello area, Idaho (Trimble, 1976, p. 23-37; Crittenden and others, 1971, p. 586).

The Caddy Canyon Quartzite is late Precambrian in age (Crittenden and others, 1971, p. 581).

Cambrian Units

Langston Formation

In the Bear River Range of northern Utah, the Langston Formation has three members: (1) lower Naomi Peak Limestone Member, (2) Spence Shale Member, and (3) upper limestone member (Maxey, 1958, p. 654). The Naomi Peak Limestone is essentially fossiliferous, light- to medium-gray limestone which is 32 feet thick. The Spence Shale Member is dark-olive to black, calcareous shale which is 192 feet thick and contains abundant trilobites. The upper limestone member is dominantly limestone with some dolomite, generally neutral gray to bluish gray, and is 260 feet thick. The total thickness of the Langston Formation at the High Creek section in the Bear River Range is 485 feet. The Langston Formation is 133 feet thick in the northern Malad Range, Idaho (Axtell, 1967, p. 56).

In the northern part of the Oxford Quadrangle, the Langston Formation is usually recognized by the brown-weathering limestone
or dolomite (Williams, 1948, p. 1134). The Langston is 100 feet thick at its maximum, within the mapped area, which is north of the Left Fork Cherry Creek. The color ranges from light olive gray to light olive brown in weathered areas to light bluish gray to medium gray in unweathered areas. Outcrops consist almost entirely of limestone although weathered brown shale crops out above the limestone north of the upper Left Fork Cherry Creek.

The brown-weathering limestone, with shale above it, is exposed immediately above the thrust fault north of the upper Left Fork Cherry Creek. The limestone is brecciated at that locality. It is not continuous and has been eliminated by the thrust fault in places. It also occurs as a small klippe on top of the peak, with elevation 6,836 feet, north of the Left Fork Cherry Creek approximately 1.2 miles from the western edge of the mapped area. Unidentified trilobite fragments occur in the limestone at both exposures.

A small outcrop of limestone of the Langston Formation is present east of the main marginal fault, near U. S. Highway 91, above Caddy Canyon Quartzite in the southeastern corner of sec. 32, T. 12 S., R. 38 E. The limestone at that locality is not weathered. Sponge spicules and the trilobite Albertella sp. occur at that locality.

Within the mapped area the Langston Formation is thrust faulted over the Caddy Canyon Quartzite. The upper contact of the Langston is mapped where the brown shale ends and the limestone and green shale of the Ute Formation begin. The Ute Formation conformably overlies the Langston Formation in northern Utah and southern Idaho (Maxey, 1958, p. 671).
The Langston Formation is Middle Cambrian in age (Maxey, 1958, p. 671).

Ute Formation

In northern Utah, the Ute Formation in the High Creek section of the Bear River Range consists of a lower part which is essentially shale with minor limestone and is 285 feet thick and an upper part which is essentially limestone and is 460 feet thick (Maxey, 1958, p. 653-654, 672). The Ute is 745 feet thick in the High Creek section. The shale is greenish gray and weathers to pale-reddish-brown chips. It is micaceous in places, especially the lower part. The upper limestone is light gray to dusky blue. Both the lower and upper parts contain some sandstone.

Within the mapped area the Ute Formation is approximately 300 feet thick. It is exposed at two localities. The first is north of the upper Left Fork Cherry Creek where it occurs above the thrust fault and, in part, conformably above the Langston Formation. There, the slope is steep and exposure is poor due to the large amount of colluvium. The outcrops of Ute Formation are characterized by the abundance of greenish-gray shale chips, some of which have weathered pale reddish brown. The upper contact, at that location, has been mapped at the base of the resistant limestone of the overlying Blacksmith Formation. Some limestone has been mapped with the Blacksmith Formation in order to have a mappable contact.

The second location is along U. S. Highway 91 in the southern part of sec. 29 and northeastern part of sec. 32, T. 12 S., R. 38 E.
Outcrops of the shale are exposed in the roadcuts and the railroad cuts at that locality. The rocks are stained brown. The staining is inferred to be localized near a north-northwest-trending normal fault (Plate 1). The isolated limestone outcrops southwest of the highway belong to the upper Ute.

The Ute conformably overlies the Langston Formation. The Ute Formation is conformably overlain by the Blacksmith Formation (Maxey, 1958, p. 671).

Maxey (1958, p. 672) assigned the Ute to the Middle Cambrian.

**Blacksmith Formation**

The Blacksmith Formation is dominantly dolomite in the Bear River Range; whereas, to the west in the Malad, Bannock, and Portneuf Ranges, it is primarily limestone (Oriel and Armstrong, 1971, p. 48). The Blacksmith Formation in the High Creek section, in the Bear River Range of northern Utah, is medium- to thick-bedded, light- to medium-gray, medium-crystalline dolomite which is 485 feet thick (Maxey, 1958, p. 653). Maxey (1958, p. 653) also described 60 feet of dark-bluish-gray limestone 80 feet below the top of the formation. Hanson (1949, p. 17) described 444 feet of limestone in the Blacksmith in the southern Malad Range.

In the mapped area, the Blacksmith Formation consists of thick-bedded, fine- to medium-crystalline limestone with some dolomite in the upper part. It is approximately 400 feet thick in the mapped area. The limestone is generally oolitic and in places contains the alga *Girvanella* up to 0.5 inch in diameter. The limestone is dark
bluish gray to light bluish gray. The dolomite is usually lighter. The Blacksmith Formation is resistant to erosion and commonly forms ledges.

The Blacksmith Formation caps the dislocated mass of Cambrian limestone and shale above the thrust fault north of the upper Left Fork Cherry Creek. At that locality the Blacksmith Formation is underlain by the Langston and Ute.

Blacksmith Formation also forms a significant part of the rounded peaks northeast of U.S. Highway 91. At that area it includes the peak in sec. 3, T. 13 S., R. 38 E.; most of the peak in sec. 34, T. 12 S., R. 38 E.; and most of the hill in the southwestern corner of sec. 28, T. 12 S., R. 38 E. In sec. 28, limestone of the Bloomington Formation is faulted down on the western side of a normal fault next to a relatively thick section of dolomite in the Blacksmith Formation on the eastern side. East of the fault is the thickest dolomite section of the Blacksmith in the mapped area. The brecciated and deformed limestone in the central area of sec. 29, immediately to the west of sec. 28, is also Blacksmith.

North of Chicken Creek immediately west of the main marginal fault, a small carbonate mass is faulted down next to Pocatello Formation to the west (Figure 15). The mass consists of light-gray limestone and dolomite which are weathered and brecciated. The carbonate mass lacks identifying characteristics and cannot be positively identified, but it is probably Blacksmith Formation.

The Blacksmith Formation conformably overlies the Ute Formation. It is generally thought that the Bloomington Formation conformably
overlies the Blacksmith in the region (Maxey, 1958, p. 672).

The Blacksmith is Middle Cambrian in age (Maxey, 1958, p. 651-672).

Bloomington Formation

The Bloomington Formation occurs throughout northern Utah and southeastern Idaho (Maxey, 1958, p. 672). At High Creek in northern Utah, Maxey (1958, p. 651-653, 672) described three members in the Bloomington Formation. They are: (1) lower Hodges Shale Member, (2) limestone member, and (3) upper Calls Fort Shale Member. The Hodges Shale Member consists of 540 feet of light-olive-brown shale with interbedded thin layers of light- to dark-gray limestone. Distinctive green limestone nodules are present within this unit. The lower 200 feet of this member is thin-bedded, medium-dark-gray limestone. The middle member consists of 775 feet of thin- to thick-bedded, light- to dark-gray limestone which is oolitic in places. The Calls Fort Shale Member is 180 feet of essentially light-olive-brown shale with some interbedded platy limestone (Maxey, 1958, p. 651-653, 672). The total thickness of the Bloomington Formation at High Creek is 1,495 feet (Maxey, 1958, p. 653). Axtell (1967, p. 58) described 431 feet of Bloomington Formation at Two Mile Canyon. Hanson (1949, p. 19-21) measured 429 feet of Bloomington in the Clarkston Mountain area. In the Arbon Quadrangle, northwest of the mapped area, the Bloomington Formation is 1,800 feet thick (Trimble, 1976, p. 30).

The Bloomington Formation, in the northern part of the Oxford Quadrangle, consists of the lower shale member and the upper limestone member. The Bloomington is approximately 450 feet thick within the
mapped area. The lower member is shale with interbedded platy limestone. The shale is generally greenish gray and contains limestone nodules of the same color, which are generally 1-2 inches in diameter. The platy limestone is fine to medium crystalline and ranges in color from medium dark gray to light bluish gray. Weathering produces limestone plates which are generally 0.25 to 0.5 inch thick and commonly have red to yellow silty layers which are fossiliferous in places. The trilobite *Bolaspidella* occurs in the Bloomington in the area west of Aspen Hollow. The lower member of the Bloomington Formation occurs west of Aspen Hollow in the area of the boundary between T. 12 S. and T. 13 S. and also on the hills northeast of U. S. Highway 91 in secs. 28 and 34, T. 12 S., R. 38 E. Readily accessible outcrops of the interbedded shale and limestone of the lower member of the Bloomington Formation are located in the small canyon approximately 1 mile south of Red Rock Junction in the north-eastern corner of sec. 31, T. 12 S., R. 38 E. (Figure 4).

The upper limestone member is thin to thick bedded and lacks shale but it is similar to the platy limestone of the lower member in color and texture, although it is oolitic in places. Outcrops of the limestone member occur in the area west of Aspen Hollow and also southeast of Red Rock Pass in secs. 28, 29, and 34, T. 12 S., R. 38 E.

The upper shale member, the Calls Fort Shale, is missing in the mapped area probably as a result of two factors. First, the Nounan Formation has been thrust faulted over the Bloomington and this may have eliminated the relatively thin and incompetent upper shale
Figure 4. Bloomington Formation in small canyon west of U. S. Highway 91, 1 mile south of Red Rock Junction; view north. The outcrop consists of shale with limestone nodules.
member. Secondly, northeast of U. S. Highway 91, the Bloomington Formation is the stratigraphically highest formation present and the upper shale member may have been eroded.

The Bloomington Formation conformably overlies the Blacksmith Formation. The overlying Nounan Formation has been thrust faulted over the Bloomington Formation.

The Bloomington Formation is late Middle Cambrian in age (Maxey, 1958, p. 673).

Nounan Formation

In northern Utah the Nounan Formation consists of thin- to medium-bedded dolomite and limestone (Williams, 1948, p. 1134). The Nounan Formation is 1,125 feet thick in the High Creek section in northern Utah (Maxey, 1941, p. 31). It generally consists of dolomite in the lower 735 feet and limestone in the upper 390 feet. The dolomite is commonly thin to thick bedded, medium gray, and fine to medium crystalline. The limestone becomes sandy especially near the top of the unit (Maxey, 1941, p. 28-31). Axtell (1967, p. 20) stated that the Nounan is 886 feet thick in the northern part of the Malad Range. Hanson (1949, p. 22-26) stated that the Nounan is 1,408 feet thick in the southern part of Malad Range. At that locality the lower 908 feet is dolomite and the upper 500 feet is limestone.

In the northern part of the Oxford Quadrangle, the Nounan Formation is characterized by the resistant, thin- to thick-bedded carbonate unit above the limestone and shale of the Bloomington Formation. The Nounan Formation is about 280 feet thick in the mapped area.
The lower part of the Nounan is light-gray, fine- to medium-crystalline dolomite. The upper part of the Nounan is fine-crystalline limestone with minor dolomite and ranges from light gray to medium bluish gray. The Nounan is generally severely brecciated in the lower part. The brecciated dolomite occurs above a thrust fault west of Aspen Hollow in the southwestern corner of sec. 34, T. 12 S., R. 37 E.; west of U. S. Highway 91 in the northwestern corner of sec. 32, T. 12 S., R. 38 E.; and east of the highway in the northeastern corner of sec. 32. It also occurs northeast of Aspen Hollow in the south-central part of sec. 25, T. 12 S., R. 37 E.; in the eastern half of sec. 30, T. 12 S., R. 38 E., as the "Red Rock"; and also as a small outcrop cut through by U. S. Highway 91 in the east-central part of sec. 19, T. 12 S., R. 38 E.

Maxey (1958, p. 673) stated that the Nounan rests conformably on the Bloomington Formation in northeastern Utah and southeastern Idaho, but within the mapped area the high degree of deformation and brecciation present in the Nounan and the lack of the Calls Fort Shale Member of the Bloomington indicate that the Nounan has been thrust faulted over the Bloomington. The upper part of the Nounan is a transitional sequence between the Nounan and the conformably overlying Worm Creek Member of the St. Charles Formation (Maxey, 1941, p. 28). This sequence, a transition from limestone to calcareous sandstone to quartzite, is exposed northeast of Aspen Hollow in the south-central part of sec. 25, T. 12 S., R. 37 E.

The Nounan Formation is Late Cambrian in age (Williams, 1948, p. 1134).
St. Charles Formation

In the Logan Quadrangle in northern Utah, the St. Charles Formation consists of three members: (1) lower Worm Creek Quartzite Member, (2) middle member, and (3) upper member (Williams, 1948, p. 1135). The Worm Creek is gray to brown, fine- to medium-grained quartzite. The middle member is thin-bedded limestone, and the upper member is resistant, thick-bedded dolomite. The St. Charles Formation at the High Creek section in northern Utah consists of three members: (1) lower Worm Creek Quartzite Member, (2) limestone member, and (3) upper dolomite member (Maxey, 1941, p. 26-28). The Worm Creek Quartzite is 75 feet thick. The limestone member is 295 feet thick and consists of a lower sandy limestone which is 225 feet thick and an upper limestone which is 70 feet thick. The dolomite member is 645 feet thick and includes a 95-foot section of cherty dolomite which is 290 feet below the top of the formation. The total section measures 1,015 feet at High Creek (Maxey, 1941, p. 28). Axtell (1967, p. 60) described 704 feet of quartzite, limestone, and dolomite in the St. Charles in the Malad Range, Idaho. Hanson (1949, p. 12, Plate 3, p. 30-32) also recognized three members in the St. Charles in the southern part of Malad Range. The members are: (1) lower Worm Creek Quartzite Member, (2) middle member, and (3) upper member. The Worm Creek consists of 75 feet of light-olive-gray, medium-grained quartzite. The middle member is silty limestone which is 368 feet thick. The upper member is 630 feet of light- to medium-gray dolomite. Trimble and Carr (1976, p. 15-16) reported 1,300 feet of quartzite
and sandstone in the Worm Creek and at least 200 feet of dolomite in
the upper member in the Arbon Quadrangle, Idaho.

The Worm Creek Quartzite, within the mapped area, consists of
about 75 feet of quartzite and calcareous sandstone which are commonly
grayish orange pink. It is fine to medium grained and has irregular
bedding. Worm Creek occurs 2 miles east of Cedar Knoll Road in sec.
25, T. 12 S., R. 37 E.; in the hill with the historical marker near
Red Rock Pass in sec. 29, T. 12 S., R. 38 E.; and also west of
Marsh Creek, southeast of the main outcrop of upper St. Charles. A
significant amount of colluvium, derived from Worm Creek Quartzite,
is present southwest of Red Rock Pass on the eastern side of the
main marginal fault in the appropriate location between St. Charles
to the west and Nounan to the east; however, outcrops of Worm Creek
are not present at that location. The contact between the Worm
Creek Quartzite and the limestone member is not observable, in the
mapped area, due to poor exposure but is probably conformable.

In the northern part of the Oxford Quadrangle, the upper carbonate
part of the St. Charles Formation is not readily divided. It is
approximately 325 feet thick. The lower part of this unit consists
of thin- to thick-bedded, medium-light-gray, fine-crystalline limestone.
The upper part is characterized by thick-bedded, medium-light-gray
dolomite which has dark-gray to brownish-gray chert nodules from one
to several inches in diameter. The lower limestone is somewhat silty.
However, no distinct contact separates the two parts and both form
resistant outcrops. The large outcrop north of Red Rock Pass, located
in the southwestern part of sec. 20, T. 12 S., R. 38 E., is upper
St. Charles (Figure 5). St. Charles Formation crops out east of Cedar Knoll Road north of a normal fault in the central and eastern parts of sec. 26, T. 12 S., R. 37 E. St. Charles Formation is also exposed on the western side of the main marginal fault southwest of Red Rock Pass, and a smaller outcrop is present on the eastern side. The small carbonate outcrop northwest of the hill with the historical marker near Red Rock Pass, sec. 29, T. 12 S., R. 38., is upper St. Charles.

The St. Charles Formation conformably overlies the Nounan Formation. The Ordovician Garden City Formation has been thrust faulted over the St. Charles Formation. The only exposure with Garden City above St. Charles is east of Cedar Knoll Road just north of the east-west-trending intermittent stream in sec. 26, T. 12 S., R. 37 E. At that locality the St. Charles Formation is thick-bedded, highly brecciated dolomite with abundant calcite veins. Above the dolomite is gray limestone of the Garden City Formation. The contact is obscured by colluvium but the brecciation and also the lesser thickness of the St. Charles Formation in this area are indicators of a thrust fault. Williams (1948, p. 1136) considered this contact to be a disconformity in the Logan Quadrangle, Utah.

The St. Charles Formation is Late Cambrian in age (Williams, 1948, p. 1135).
Figure 5. St. Charles Formation in knob north of Red Rock Pass; view east. Salt Lake Formation overlaps St. Charles on the left side of the knob.
Ordovician Units

Garden City Formation

In northern Utah, the Garden City Formation is composed of two members: (1) lower intraformational-conglomerate limestone member and (2) upper limestone member with abundant black chert (Ross, 1951, p. 7-9). The chert generally decreases toward the top of the formation to where little or no chert is present. In the Bear River Range east of Preston, Idaho, the Garden City Formation is 1,441 feet thick (Ross, 1951, p. 15-16). In Clarkston Mountain in northern Utah, it is 1,764 feet thick (Ross, 1951, p. 18-19). In the northern Portneuf Range, southeast of Pocatello, Idaho, the Garden City Formation is 1,408 feet thick (Holmes, 1958, p. 42).

In the mapped area, the Garden City is about 520 feet thick. Both members of the formation are present. The lower member is an irregularly bedded, medium-light-gray to medium-dark-gray, fine- to medium-crystalline limestone characterized by the presence of intraformational conglomerate. A good exposure of the lower member occurs northeast of Aspen Hollow in the northern half of sec. 26, T. 12 S., R. 37 E., where the Garden City Formation forms resistant ledges above an outcrop of St. Charles Formation. A smaller outcrop is located approximately 0.5 mile to the east in the northern part of sec. 25, T. 12 S., R. 37 E.

The upper member is fine-crystalline limestone and ranges in color from medium to dark gray. Black chert beds are present near the top of the member. The upper member is not as resistant as the
lower member except where the chert beds are present. An outcrop of the upper member is located north of Aspen Hollow in the northeastern corner of sec. 27, T. 12 S., R. 37 E. (Figure 6). At that locality limestone with little or no chert is overlain by a chert unit which is 10-15 feet thick. Above the chert beds is 50-60 feet of less resistant, very-light-gray to light-gray, fine-crystalline limestone. The upper limestone is poorly exposed due to extensive weathering and colluvium. The chert beds and the few outcrops of the upper noncherty limestone are somewhat brecciated. Overlying the upper limestone is brecciated quartzite of the Swan Peak Formation. The Swan Peak has been thrust faulted over the Garden City. A smaller outcrop of the upper Garden City Formation is located northeast of the first outcrop in the central part of sec. 23, T. 12 S., R. 37 E.

The Garden City Formation is thrust faulted over the St. Charles Formation. The Swan Peak Formation is thrust faulted over the Garden City. The thrust faults are inferred due to the brecciated nature of the rock units at the contacts. Williams (1948, p. 1137) stated that the Garden City Formation and the Swan Peak Formation are conformable in the Logan Quadrangle, Utah.

The Garden City Formation is Early Ordovician in age and perhaps Middle Ordovician in age in the upper few feet (Ross, 1951, p. 31-32).

Swan Peak Formation

The Swan Peak Formation consists of three members in the Logan Quadrangle of northern Utah. The members in Green Canyon in sec. 20, T. 12 N., R. 2 E., in the Bear River Range are: (1) lower member,
Figure 6. Thrust fault between Garden City and Swan Peak Formations east of Cedar Knoll Road; view northeast. Swan Peak (Osp) is thrust faulted over Garden City (Ogc). Salt Lake Formation (Tsl) unconformably overlies both formations.
(2) middle member, and (3) upper member (Williams, 1948, p. 1136). The lower member is 174 feet of black shale. The middle member is 28 feet of thin-bedded, brown quartzite with shale partings. The upper member is 137 feet of thin- to thick-bedded, light-gray to yellowish-gray quartzite. Total thickness at Green Canyon is 339 feet. Hanson (1949, p. 12, Plate 4, p. 44-45) described the Swan Peak in the southern part of Malad Range. There, it is 606 feet thick and has a similar three-fold division of shale, quartzite and shale, and quartzite. Ross (1951) studied the Swan Peak in the Clarkston Mountain area of the southern Malad Range. He recorded 570 feet of white, vitreous quartzite; however, the lowest 50 feet of the formation consists of a crumbly, light-gray to yellowish-gray quartzite with calcite cement (Ross, 1951, p. 18). More recently, James (1973) did a detailed stratigraphic analysis of the Swan Peak Formation. He measured a section in the Elkhorn Mountain area approximately 9 miles due west of the mapped area (James, 1973, p. 239-240). At that locality the Swan Peak Formation is 868 feet thick. The lower member was described as a covered interval of orthoquartzite and shale that is 118 feet thick. The middle member is not present at that location. The upper member consists of 750 feet of white to light-brown orthoquartzite.

Within the mapped area, the Swan Peak Formation is a fine- to medium-grained vitreous quartzite which is about 150 feet thick. The quartzite is generally white to light gray but is commonly moderate reddish brown to dark yellowish orange, especially in the upper part of the formation. The Swan Peak is generally severely
brecciated with most of the bedding obliterated. No traces of shale were found associated with the Swan Peak Formation; therefore, it is assumed that both the lower and middle members are missing due to the thrust fault at the base of the Swan Peak Formation. The Swan Peak is fucoidal in some areas in the Logan Quadrangle, Utah (Williams, 1948, p. 1136) but, within the mapped area, no fucoidal quartzite was found. The outcrops are generally poor due to quartzite rubble and colluvium.

Several outcrops of Swan Peak Formation are located in the northwestern corner of the mapped area in secs. 22, 23, 26, and 27, T. 12 S., R. 37 E. The best exposure is in the southern part of sec. 22 and northern part of sec. 27, where the Swan Peak has been thrust faulted over Garden City Formation.

The Swan Peak Formation is thrust faulted over the Garden City Formation. The Swan Peak is the youngest pre-Cenozoic formation present within the mapped area.

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

**Tertiary Unit**

**Salt Lake Formation**

The Salt Lake Formation in Cache Valley, northern Utah and southeastern Idaho, has been divided into three units: (1) lower conglomerate, (2) tuff unit, and (3) upper conglomerate (Adamson, Hardy, and Williams, 1955, p. 1-2; Williams, 1962, p. 133). The lower conglomerate and the tuff unit are partly equivalent (Adamson,
The lower conglomerate consists of light-gray, tuffaceous conglomerate at least 1,500 feet thick at the northern end of the Wellsville Mountains in Utah (Adamson, Hardy, and Williams, 1955, p. 4). The tuff unit consists of light-colored tuff, limestone, sandstone, and conglomerate, and is 7,647 feet thick in the northern part of Cache Valley (Adamson, Hardy, and Williams, 1955, p. 2, 7). The upper conglomerate consists of light-gray to pale-orange tuffaceous conglomerate and is 3,435 feet thick northeast of Cache Valley (Keller, 1952, p. 15).

Within the mapped area, the Salt Lake Formation consists mostly of tuff with interbedded tuffaceous conglomerate. The tuff is generally white to light gray. Very-light-gray limestone and green sandstone and shale are present in the tuff. The green shale and sandstone are extremely well indurated. The tuffaceous conglomerate is generally light gray although it is very pale green in places. The clasts consist of limestone, quartzite, argillite, and granitic-type rocks.

The Salt Lake Formation both unconformably overlies and is faulted down next to Paleozoic rocks (Figure 5). In general, exposures of tuff and conglomerate of the Salt Lake Formation are located in the northern one-third of the mapped area. Excellent outcrops occur along opposite sides of U. S. Highway 91 north of the Red Rock Pass area. Outcrops are also located in the Aspen Hollow area. The limestone crops out in the general area north of the spring in the northeastern corner of sec. 36, T. 12 S., R. 37 E. It is also located on the hill top east of Cedar Knoll Road in the southwestern corner.
of sec. 23, T. 12 S., R. 37 E., and west of Aspen Creek approximately 1,400 feet south of the farmstead. At both of these locations the limestone has been weathered to various shades of brown, yellow, and red. The Wasatch Formation has not been found within the mapped area.

The Norwood Tuff, in Morgan Valley southeast of Ogden, Utah, is considered to be late Eocene in age (Gazin, 1959, p. 137). It is correlative with the Salt Lake Formation as is the Fowkes Formation of southwestern Wyoming. The Fowkes Formation is also considered to be late Eocene (Gazin, 1959, p. 134, 137). In Cache Valley, Utah, the upper part of the Salt Lake Formation is considered to be Pliocene in age (Yen, 1947, p. 269, 272).

**Quaternary Units**

**Colluvial deposits**

Colluvial deposits consist of unconsolidated sedimentary deposits on slopes or at the foot of slopes where they have been concentrated by gravity. The deposits include fine-grained material as well as boulders which are as large as several feet in diameter. The largest colluvial deposit is located along the mountain front west of U. S. Highway 91 and includes most of the area from the "Red Rock" southward to the edge of the mapped area. Talus deposits are included with colluvial deposits. The colluvial deposits are Quaternary in age.

Some of the colluvial deposits, in the area west of Red Rock Pass, have been involved in minor landsliding which has obscured evidence of Pleistocene river-channel banks. Along U. S. Highway 91, some unusual colluvial deposits are present on the northeastern side.
of the road. These deposits are located in the northeastern corner of sec. 32, T. 12 S., R. 38 E. The deposits consist of blocks of Ute Formation which have moved downslope a few feet. The slope resulted from erosion by the outlet stream of Lake Bonneville. Figure 7 shows a single large block which has moved downslope. The main deposit is located a short distance to the southeast of the area shown in Figure 7.

Lake Bonneville Group

The Lake Bonneville Group consists of three formations. In order of decreasing age, they are: (1) Alpine Formation, (2) Bonneville Formation, and (3) Provo Formation (Williams, 1962, p. 137-142). The Alpine Formation consists of gravel, sand, silt, and clay. The Bonneville Formation is almost exclusively gravel with minor amounts of silt and fine sand. The Provo Formation consists of gravel, sand, silt, and clay. The Provo and Bonneville Formations commonly have marked shoreline features (Hunt, Varnes, and Thomas, 1953, p. 20-23). Williams (1962, p. 137) did not distinguish between the Alpine and Bonneville Formations in southern Cache Valley due to poor exposure and uncertainty of details. Bright (1963, p. 80) stated that the Provo Formation consists of reworked deposits of Bonneville Formation in the area to the north of a line between Whitney, Preston, and Dayton in southern Idaho. The Provo Formation is generally indistinguishable from the Bonneville Formation in that area.

Much work has been done on the history of Lake Bonneville. The highest level of the lake, the Bonneville level, has been determined
Figure 7. Displaced block above road cut 2.5 miles northwest of Swanlake, Idaho; view northeast. The slope resulted from erosion by the outlet stream of Lake Bonneville.
to have been 5,085 feet in elevation by Crittenden (1963, p. 4) and 5,135 feet in elevation by Williams (1962, p. 145). Both figures are from the Red Rock Pass area. Bright (1963, p. 15) determined the elevation of the highest level to have been 5,00±5 feet at Swanlake and stated that the shoreline is obscure north of Swanlake and that a margin of error of ±20 feet is required.

Within the mapped area, the Lake Bonneville Group consists generally of fine sand and silt with some clay, although some coarse sand and gravel are also present. No attempt was made to map the individual formations. The details required to make accurate interpretations about the events of the Pleistocene were not readily available. The Lake Bonneville Group is not mapped as a continuous expanse below the highest lake level. Instead, the deposits are mapped as they are at the present time as altered by erosion or deposition, which postdates Lake Bonneville. Northeast of U. S. Highway 91 between Swanlake and the Paleozoic outcrops next to the road, in the northeastern corner of sec. 32, T. 12 S., R. 38 E., the contact of Lake Bonneville deposits is approximately 5,135 feet in elevation (Figure 8). In some places the contact is slightly lower and in others slightly higher. Southwest of the highway, the contact differs considerably in elevation due to post-Pleistocene changes by erosion or deposition. A small outcrop of probable Lake Bonneville Group is located approximately at 5,135 feet in elevation in a road cut on an unimproved road on the southern side of the canyon in the northwestern corner of sec. 5, T. 13 S., R. 38 E; however, it is not mapped. Elsewhere
Figure 8. Contact of Lake Bonneville Group at tree line on hill 1 mile north of Swanlake, Idaho; view east.
southwest of the highway, the contact was mapped where the deposits become primarily colluvial material which borders the mountain front. The Lake Bonneville Group is Pleistocene in age (Hunt, Varnes, and Thomas, 1953, p. 16-17).

**Older alluvial deposits**

The older alluvial deposits consist of silt, sand, and gravel, all deposited by streams. These deposits are somewhat terrace-like and have gentle slopes below areas of higher elevation. The older alluvial deposits are dissected by intermittent streams. The best example of older alluvial deposits is located in the northwestern corner of the mapped area. In that area, surfaces on the older alluvial deposits gently slope down to the north and west from areas of higher elevation consisting of Salt Lake and older formations. Another example is located in the northeastern part of the mapped area where surfaces on the older alluvial deposits slope down to the south and west from higher outcrops of Salt Lake Formation. These deposits are probably late Pleistocene-early Holocene in age.

**Alluvial deposits**

Alluvial deposits consist of unconsolidated silt, sand, and gravel resulting from the operations of modern streams. Within the mapped area, alluvial deposits are present along most of the larger intermittent streams and within the broad, flat valley bottom where U. S. Highway 91 is located. The deposits along the valley bottom could partially belong to the Lake Bonneville Group.
Alluvial fans are mapped as a subdivision of the alluvial deposits. The alluvial fans formed where streams flow onto a level plain. Some of the fans have been dissected by later stream erosion. Alluvial fans occur near the mouths of canyons especially along the major valley where the highway is located. A good example of an alluvial fan is located south of Red Rock Pass in the northern part of sec. 5, T. 13 S., R. 38 E. The alluvial deposits are Holocene in age.
Regional Setting

Southeastern Idaho has undergone two dominant and dissimilar structural events resulting in two distinct types of features. The two types are thrust faults and normal faults.

Thrust faults of considerable extent and displacement are present in southeastern Idaho. The area of thrust faulting, which extends from the Snake River Plain to the Wyoming border to the east and to the Utah border to the south, is the Bannock thrust zone (Armstrong and Cressman, 1963, p. 19). This zone is characterized by west-dipping imbricate thrust faults on which the movement was to the northeast. The area of thrust faults is more extensive than the Bannock thrust zone. It extends from north-central Utah into western Wyoming and southwestern Montana. The extensive thrust plates are important because they may conceal deposits of hydrocarbons (Armstrong and Oriel, 1965, p. 1864).

Within the Bannock thrust zone, the Paris thrust fault has undergone a considerable amount of horizontal displacement. Its stratigraphic throw is approximately 20,000 feet (Armstrong and Cressman, 1963, p. 16). Other major thrust faults in the overthrust belt of Idaho and Wyoming also have about the same stratigraphic throw (Armstrong and Oriel, 1965, p. 1857). The Willard thrust fault in the Ogden area, Utah, has a west to east displacement of about 40 miles (Crittenden, 1961, p. 129).
The normal faults are more obvious than the thrust faults due to the generally north-south-trending mountain ranges and the associated valleys. These normal faults are characteristic of the Basin and Range province. The Basin and Range province is a complex of valley grabens which have been faulted down relative to the adjacent mountains on intervening high-angle normal faults (Stewart, 1971, p. 1036-1037). The normal faulting is younger than the thrust faulting.

Within the mapped area, both thrust faults and Basin and Range normal faults are present. One major thrust fault places Paleozoic rocks on Precambrian rocks. Two strike-slip faults, within the mapped area, are associated with the thrust faulting. A considerable number of normal faults are present within the mapped area. Most of the normal faults generally trend north-south. Northwest- to east-west-trending faults are also present.

**Folds**

Folds, within the mapped area, are localized and represent drag folding associated with near-by faults, especially thrust faults. These drag folds are described with the associated thrust faults or normal faults.

**Thrust Faults**

**Thrust fault between Precambrian units**

Within the mapped area, a thrust fault separates the Papoose Creek Formation and the Caddy Canyon Quartzite in the area of the Left Fork Cherry Creek. The quartzite of the overlying Caddy Canyon
Quartzite is severely brecciated near the base of the formation. An outcrop of Papoose Creek Formation, immediately below the thrust fault located north of the fork in the Left Fork Cherry Creek 1.15 miles due east of the western border of the mapped area, shows drag folding related to thrust faulting. The rocks of that outcrop are nearly vertical and indicate an east-northeast direction of movement.

The transitional interbedded argillite and quartzite of the lower part of the Caddy Canyon Quartzite is present at one locality located north of the Left Fork Cherry Creek about 1.2 miles due east of the western map boundary. All other outcrops have quartzite of the Caddy Canyon thrust faulted directly over argillite of the Papoose Creek.

The plane of the thrust fault is at lower elevations to the west and higher elevations to the east, indicating a west dip. The best exposures of the fault occur north of the Left Fork Cherry Creek between 0.8 and 1.3 miles from the western edge of the mapped area (Figure 9).

**Thrust fault between Paleozoic and Precambrian units**

A major thrust fault separates Paleozoic and Precambrian rock units within the mapped area. The thrust fault is located at the top of the Caddy Canyon Quartzite. The thrust fault has eliminated several stratigraphic units. It places Middle Cambrian rocks on Caddy Canyon Quartzite, completely eliminating the Inkom Formation, the Mutual Formation, and the Cambrian equivalents of the Brigham Formation. A total of 7,000-8,000 feet of the stratigraphic section
Figure 9. Bedding-plane thrust fault between Caddy Canyon Quartzite and Papoose Creek Formation north of Left Fork Cherry Creek; view west. Caddy Canyon Quartzite (p6c) is thrust faulted over Papoose Creek Formation (p6pc). The high ridge is also Caddy Canyon. An argillite unit, in Caddy Canyon, is located in the saddle on the ridge at the upper right.
is missing (Trimble, 1976, p. 23-27; Crittenden and others, 1971, p. 586). This thrust fault also occurs in adjacent areas to the west and to the south (Raymond, 1971, p. 27-33; Shearer, 1975, p. 45).

Within the mapped area, the Caddy Canyon Quartzite generally occurs below the thrust fault. Locally the Papoose Creek Formation occurs immediately below the thrust fault. At one locality, north of the Left Fork Cherry Creek between 1.4 and 1.8 miles due east of the western border of the mapped area, the Caddy Canyon Quartzite has been removed by merging thrust faults; however, 1.9 miles due east of the mapped border Caddy Canyon is in position below the major thrust fault indicating a stratigraphic shift in the position of the thrust fault.

At three locations, in the mapped area, Paleozoic rocks have been thrust faulted over Precambrian rocks. The first location is north of the upper Left Fork Cherry Creek (Figure 10). The Paleozoic section, above the thrust fault, consists of Langston, Ute, and Blacksmith. At that locality Papoose Creek and Caddy Canyon are below the thrust fault. Langston is directly above it to the east and Ute is directly above it to the west. The fault dips west at a low angle as indicated by the progressively higher elevation of the plane of the thrust fault eastward. A major drag fold is present in the Cambrian rocks above the thrust fault at that location (Plate 1). There, the Blacksmith Formation shows strong drag which folded the rocks down toward the east (Figure 11).

The second location, northwest of the first location, is southwest of Aspen Hollow. At that locality, Bloomington Formation has
Figure 10. Major thrust fault north of Left Fork Cherry Creek; view northwest. Papoose Creek Formation and Caddy Canyon Quartzite are below the thrust fault. Langston (€l), Ute (€u), and Blacksmith (€bl) Formations are above the fault. Colluvium (Qc) is at the lower right.
Figure 11. Drag fold in Blacksmith Formation above major thrust fault north of upper Left Fork Cherry Creek; view north. The thrust fault crops to the left of the view. The lower area is obscured by colluvium (Qc).
been thrust faulted over Caddy Canyon Quartzite (Figure 12). Again there has been a stratigraphic shift in the position of the thrust fault. The thrust fault dips about 30° N. in that area and was offset by later normal faulting (Plate 1).

The third location is east of the main marginal fault in the southeastern corner of sec. 32, T. 12 S., R. 38 E. At that locality, a small outcrop of Langston Formation is in close proximity to Caddy Canyon Quartzite. A thrust fault relationship is inferred for this situation. The exposure is poor and the contact between the two formations is obscured by colluvium.

**Thrust faults between Paleozoic units**

In the northern part of the Oxford Quadrangle, at least three thrust faults are present above the major thrust fault between Precambrian and Cambrian units. Stratigraphically lowest is the thrust fault between the Bloomington Formation and the overlying Nounan Formation. This fault has been recognized by others in the region (De Vries, 1977; Shearer, 1975; Raymond, 1971). Outcrops, where the thrust fault occurs, are located west of Aspen Hollow in the southwestern corner of sec. 34, T. 12 S., R. 37 E., northeast of U. S. Highway 91 in the northeastern corner of sec. 32, T. 12 S., R. 38 E., and also west of the highway in the northwestern corner of sec. 32, T. 12 S., R. 38 E. Within the mapped area, the upper shale unit of the Bloomington is missing below the thrust fault. The Nounan is brecciated immediately above the thrust fault, and the bedding is distorted, especially in the outcrop in the northwester corner of sec. 32.
Figure 12. Major thrust fault 1,000 feet south of Aspen Hollow; view east. Bloomington Formation (€bo) is thrust faulted over Caddy Canyon Quartzite (p€c). The fault dips north.
Southwest of Red Rock Pass, the St. Charles and Nounan Formations display diverse attitudes. Immediately east of the main marginal fault, the St. Charles Formation strikes N. 2° E. to N. 27° E. and dips 21° W. to 29° W. To the east, the Nounan Formation strikes N. 68° E. and dips 30° S. Farther to the east, the Nounan of the "Red Rock" strikes N. 80° W. and dips 27° S. The different attitudes probably formed in response to thrust faulting.

A second thrust fault, involving Paleozoic formations, is located between the St. Charles Formation and the overlying Garden City Formation. The only exposure where it occurs, within the mapped area, is located east of Cedar Knoll Road north of the east-west-trending intermittent stream in sec. 26, T. 12 S., R. 37 E. There, the underlying St. Charles Formation is severely brecciated dolomite with abundant calcite veins. The thrust fault is obscured by colluvium. The Garden City Formation is also brecciated above the thrust fault in places. In addition, the St. Charles Formation is thinner, within the mapped area, than in other areas where it is as thick as 630 feet (Hanson, 1949, p. 12, Plate 3, p. 30-32).

The third thrust fault separates the Garden City Formation and the overlying Swan Peak Formation. This thrust fault is exposed east of Cedar Knoll Road in the northeastern corner of sec. 27, T. 12 S., R. 37 E. (Figure 6). The Garden City consists of brecciated limestone and black chert. The overlying quartzite of the Swan Peak Formation is severely brecciated due to the thrust faulting. Another locality, with Swan Peak thrust faulted over Garden City, is located due east of the first exposure in the northeastern corner of sec. 26.
At the second locality, the exposure is poor and the thrust fault is obscured by colluvium.

**Structural interpretation**

In the northern part of the Oxford Quadrangle, thrust faults are a major structural feature. One of the thrust faults is of considerable importance and displacement as it places Middle Cambrian rocks on upper Precambrian rocks. This eliminates a significant part of the upper Precambrian and lower Cambrian section.

Two mechanisms for the thrust faulting are considered: (1) lateral compression in the upper part of the Earth's crust, and (2) gravitational gliding. Rubey and Hubbert (1959, p. 202) stated that a combination of the two, aided by abnormal fluid pressures, was the most probable cause of the thrusting in the overthrust belt of western Wyoming.

Armstrong and Cressman (1963, p. 19) stated that the thrust faulting in the Bannock thrust zone was the result of east-northeast compression. The motion of the thrust plates was to the northeast. Crittenden also favored compression over gravity gliding and stated that movement was eastward on the Willard thrust fault and associated thrust faults in the Ogden area, Utah (Crittenden, 1972, p. 2873-2879).

In contrast, Mudge (1970) stated that gravitational gliding was the cause of thrust faulting in the disturbed belt in northwestern Montana. Mudge (1970, p. 381-387) suggested that great uplift in the west produced tilting which caused glide masses to move eastward, possibly aided by abnormal fluid pressures. Gravity gliding down the
flank of the uplift on an east-dipping plane resulted in west-dipping imbricate thrust faults to the east which are progressively older and more deformed eastward (Mudge, 1970, p. 379-387). The more deformed eastern thrust masses represent the leading edge of the glide masses (Mudge, 1970, p. 382).

The thrust faults, within the mapped area, are generally low-angle, west-dipping faults which place younger rocks on older rocks. In some places, normal faulting has resulted in north-dipping and east-dipping thrust faults. The thrust faults generally parallel bedding although localized drag folds and stratigraphic shifts are present. The thrust faults and relatively undeformed stratigraphic units, in the mapped area, correlate with the less deformed units in the western part of the disturbed belt in northwestern Montana. The more deformed units in the eastern Bannock thrust zone correlate with the more deformed units in the eastern part of the disturbed belt (Mudge, 1970, p. 382).

The evidence, within the mapped area, suggests that the mechanism responsible for the thrust faults is gravity gliding. The asymmetry of the drag folds in the Papoose Creek and Blacksmith Formations indicates east-northeast-directed movement of thrust plates. The amount of horizontal displacement has not been determined in this area.

**Strike-slip Faults**

Two strike-slip faults are present within the mapped area. The most readily accessible exposure of a strike-slip fault is located approximately 1,000 feet northeast of U. S. Highway 91 between two
light-duty roads in the north-central part of sec. 29, T. 12 S., R. 38 E. The fault strikes N. 89° E. and dips 58° N. The rake of the fault is 30° W. (Figure 13). The fault separates Blacksmith Formation to the south from the St. Charles Formation at outcrops approximately 1,000 feet to the northwest.

A smaller strike-slip fault is located approximately 1 mile southeast of the first strike-slip fault in the southwestern corner of sec. 28, T. 12 S., R. 38 E., on the eastern side of a normal fault which strikes N. 17° W. The strike-slip fault strikes N. 64° W. and is nearly vertical. The rake of the fault is 28° W. This strike-slip fault has limestone of the Bloomington Formation on the south faulted eastward relative to dolomite of the Blacksmith Formation on the north. The strike-slip fault is not present on the western, down-faulted side of the normal fault; therefore, the strike-slip fault predates the normal fault.

The two strike-slip faults have similar strike and are located in the same general area. The two faults are inferred to have a similar origin. The evidence that the second strike-slip fault predates normal faulting suggests that the strike-slip faults are related to earlier movement associated with thrust faulting.

Normal Faults

General statement

The majority of the normal faults, in the northern part of the Oxford Quadrangle, trend north-northwest. Most of the faults are vertical or nearly vertical. For purposes of description, the faults
Figure 13. Slickensides on strike-slip fault northeast of Red Rock Pass; view south. The fault strikes N. 89° E. and dips 58° N. The rake is 30° W.
are subdivided as follows: (1) north-northwest-trending faults, (2) north-trending faults, (3) northwest-trending faults, and (4) east-west-trending faults.

North-northwest-trending normal faults

Seven north-northwest-trending normal faults are present in the mapped area. The strike of individual faults in this group ranges from N. 10° W. to N. 36° W. The faults are described in order from west to east.

The first two normal faults are similar in trend and displacement and are described together. The first fault strikes approximately N. 10° W. and the second fault, located about 1,600 feet east of the first fault, strikes approximately N. 15° W. Both are high-angle normal faults. Relative displacement on both faults is down on the eastern slide. The southern extremities of both faults are not clear. Offset within the Papoose Creek Formation immediately north of the Left Fork Cherry Creek is not apparent; however, fault breccias are located in Caddy Canyon Formation on the high ridge north of the creek. The greatest displacement on this pair of faults is to the north in the area southwest of Aspen Hollow. At that locality both faults offset the thrust fault between the Caddy Canyon Quartzite and the overlying Bloomington Formation. The displacement on the first fault is approximately 150 feet. The second fault has approximately 80 feet of displacement. Both faults become obscure in the area of Salt Lake Formation to the north.

The third north-northwest-trending fault is located approximately
2,000 feet east of the second fault. It strikes N. 15° W. and is a high-angle fault. East of Cedar Knoll Road, this fault is a main marginal fault along which the valley block to the west has been faulted down relative to Caddy Canyon Quartzite at high elevation to the east. The displacement decreases southward to where the thrust-fault plane between Caddy Canyon and Papoose Creek has been offset approximately 160 feet. The fault continues to the south beyond the mapped area where it separates the Papoose Creek and Pocatello Formations. This fault is extensively covered by colluvium or is obscured in Salt Lake Formation throughout much of its length.

The fourth north-northwest-trending fault, located approximately 1 mile east of the third fault, is similar to the third fault in strike and relative displacement but it is not as long and the displacement is not as great. It strikes about N. 10° W. and is a high-angle fault. It extends from a point between the outcrops of Garden City Formation to the north and continues southward for a least 2 miles to a fault breccia where the Caddy Canyon Quartzite is faulted down on the west next to Papoose Creek on the east. The northern part of the fault is obscured by colluvium. This fault intersects a north-west-trending fault and an east-west-trending fault approximately two-thirds the distance from the southern mapped extent of the fault.

The fifth north-northwest-trending fault roughly parallels the main valley channel in the area within 1 mile south of Red Rock Pass. The fault strikes N. 27° W. and is a high-angle normal fault.
At the southern end, the fault extends at least beyond the outcrop of Caddy Canyon Quartzite approximately 2 miles northwest of Swanlake, northward to about 0.5 mile northwest of Red Rock Junction. The western block has been faulted down relative to the eastern block. Caddy Canyon Quartzite is exposed on the eastern block. A fault breccia is present on the western block near the mid-point on this fault on the eastern side of an outcrop of Nounan Formation. The fault is covered by colluvium, Lake Bonneville Group, and alluvium for most of its length.

The sixth north-northwest-trending fault also parallels the main valley channel in the area adjacent to the fault. It strikes N. 36° W. and is a high-angle fault. The fault extends about 0.75 mile to the northwest from the locality about 2.25 miles northwest of Swanlake where U. S. Highway 91 cuts through outcrops of Cambrian rocks. At that locality Blacksmith Formation is faulted down on the eastern side relative to Ute Formation on the west. A change in dip is present on opposite sides of the fault at that locality (Plate 1). On the western side of the fault, the Ute Formation strikes N. 20° W. and dips 23° E. On the eastern side the Blacksmith strikes N. 70° W. and dips 9° S. The exact length of the fault is indeterminant because it is overlain by alluvium both to the north and south.

The seventh north-northwest-trending fault is located in the Paleozoic hill southeast of Red Rock Pass. It strikes N. 17° W. and is a high-angle fault. It is about 0.5 mile long but may be longer. It is covered by Lake Bonneville Group to the south and is obscure in the area of Salt Lake Formation to the north. Limestone
of the Bloomington Formation is faulted down on the west relative to dolomite of the Blacksmith Formation on the east. An anticline representing a drag fold is present in the Blacksmith Formation at that locality. Generally, the rocks in that area strike north-south and dip to the east; however, adjacent to the fault the rocks strike northwest-southeast and dip to the southwest (Plate 1). This is drag showing relative downward movement on the western block.

North-trending normal faults

Three normal faults are described together under the heading of north-trending normal faults. Two of these faults trend north and the third trends northeast. It is described with the north-trending normal faults because it has the same relative displacement and is in the same general area.

The first north-trending fault is the main marginal fault located along the eastern side of the mountain (Figure 14). The low-lying valley to the east has been faulted down relative to the mountain of Precambrian and Cambrian rocks to the west. The fault strikes N. to N. 5° W. Nearly vertical slickensides are exposed on the fault plane west of Red Rock Junction. This fault is a continuation of the main marginal fault along the eastern face of the mountain (Raymond, 1971, Plate 1).

The displacement on this fault can be determined using offset of the contact of the Caddy Canyon Quartzite and Papoose Creek Formations. West of the fault the contact is about 5,600 feet in elevation in the southern part of sec. 31, T. 12 S., R. 38 E. East
Figure 14. North-trending normal fault at base of mountain west of Swanlake, Idaho; view northwest. This is the main marginal fault along the eastern margin of the mountain. The valley block is faulted down next to the Precambrian formations in the mountain block.
of the fault the contact is about 4,800 feet in elevation in the northeastern part of sec. 32, T. 12 S., R. 38 E. The displacement is about 800 feet; however, this determination is complicated by the fifth north-northwest-trending normal fault which is located between the main north-trending fault and the outcrop in sec. 32. Downward displacement on the western side of the fifth north-northwest-trending fault decreases the apparent offset of the Caddy Canyon-Papoose Creek contact. This suggests that the displacement on the main marginal fault is greater than 800 feet.

The displacement on the fault decreases to the north. In the central part of sec. 30, T. 12 S., R. 38 E., St. Charles and Nounan Formations are faulted down 200-300 feet relative to St. Charles Formation to the west of the fault. The displacement is inferred to continue decreasing to the north to where the fault is obscure in an area of Salt Lake Formation. The fault is covered by colluvium for most of its northern extent.

Two relatively small normal faults are associated with the main north-trending marginal fault. Both of these faults are less than 1,000 feet long. The first associated fault is north of Chicken Creek immediately west of the main marginal fault (Figure 15). At that locality a Cambrian carbonate unit is faulted down next to Pocatello Formation to the west. This fault dips 30° E. to 40° E. The carbonate outcrop is small and consists of limestone and dolomite which are weathered and brecciated. No fossils or other characteristic evidence were found to enable identification with any degree of certainty, but it is probably Blacksmith Formation faulted down
Figure 15. Low-angle normal fault north of Chicken Creek; view north. Carbonate rock of Blacksmith (?) Formation is faulted down onto Pocatello Formation. The fault is located immediately west of the main marginal fault on the eastern side of the mountain.
from the high area to the west. The second associated fault is located immediately west of the main marginal fault about 1.3 miles north of the first associated fault. The second fault also dips 30° E. to 40° E. At that locality Caddy Canyon Quartzite has been faulted down on the east relative to Papoose Creek Formation on the west.

The second north-trending fault strikes N. 15° E. It is a high-angle fault. This fault is located east of Aspen Hollow and about 0.25 mile west of the main marginal fault. Relative displacement on the fault is down on the east placing Caddy Canyon Quartzite to the east next to Papoose Creek Formation to the west. The displacement on this fault is approximately 200 feet near the southern end where the Caddy Canyon-Papoose Creek contact is offset. This fault is approximately 0.75 mile long and is obscured by colluvium in the northern part.

The third north-trending fault is located near the southern edge of the mapped area and approximately 0.5 mile west of the main marginal fault. The exact location, length, and attitude of this fault are uncertain due to poor exposure. To the east Papoose Creek Formation, with a metamorphosed Precambrian intrusive body, is faulted down relative to Pocatello Formation to the west. This fault is less than 1 mile long and displacement is inferred to decrease to both the north and south to where outcrops of Papoose Creek Formation terminate. No direct evidence is available for linking this fault to the second north-trending fault approximately 1.5 miles to the north. The intervening area between the faults is heavily vegetated and has extremely poor exposures.
Northwest-trending normal faults

The two northwest-trending normal faults, within the mapped area, are described in order from southwest to northeast. The first northwest-trending normal fault extends southeast from the third north-northwest-trending fault in Aspen Hollow and is approximately 2 miles long. It strikes N. 50° W. and is a high-angle fault. The southwestern side is down relative to the northeastern side. The displacement, which was determined by the amount of offset of the generally north-dipping thrust fault between Caddy Canyon Quartzite and Papoose Creek Formation, is approximately 200 feet. A drag effect near the fault is exposed on the ridge top southeast of the spring at the head of Aspen Creek. At that locality argillite of the Papoose Creek Formation strikes N. 58° E. and dips 75° N. No further evidence of the fault was found to the southeast. The fault is covered for much of its extent by colluvium and alluvium, especially along Aspen Creek and farther to the northwest.

The second northwest-trending fault extends about 1.5 miles from the northern terminus of the fourth north-northwest-trending fault and strikes N. 50° W. The fault is extensively covered by colluvium but it cuts through an outcrop of St. Charles and Garden City Formations. Garden City Formation is down on the northeastern side of the fault relative to upper St. Charles and lower Garden City on the southwestern side of the fault.
East-west-trending normal faults

Two normal faults, within the mapped area, strike approximately east-west. Both are high-angle faults. The first east-west-trending fault, located east of Cedar Knoll Road, extends eastward from the third north-northwest-trending fault. It strikes N. 82° W. and continues approximately 2.5 miles to the east where it encounters the main north-trending marginal fault. The Nounan and St. Charles Formations are faulted down on the north relative to Caddy Canyon Quartzite on the south. Displacement on the fault, estimated from the stratigraphic section, is approximately 1,300 feet at the mid-point where Nounan is faulted down next to Caddy Canyon. It is approximately 1,600 feet near the western end where St. Charles is faulted down next to Caddy Canyon. The fault is covered throughout most of its extent. Near the western end of the fault, brecciated blocks of Caddy Canyon Quartzite are in close proximity to the fault.

The second east-west-trending fault is located approximately 1,000 feet north of the first east-west fault and extends to the east from the fourth north-northwest-trending fault. It strikes N. 80° E. and is approximately 2,000 feet long. On the northern side of the fault, Worm Creek overlying Nounan is faulted down relative to Nounan to the south. Drag folding, related to downward movement on the northern side of the fault, is evident immediately south of the fault. At that outcrop the rocks strike parallel to the fault and dip 64° N.
Structural interpretation

The mountain ranges and intervening valleys in the Basin and Range province have been produced by movement on generally north- to northwest-trending normal faults. Two mechanisms are considered for the formation of these faults: (1) broad uplift with simultaneous normal faulting (Ekren and others, 1974, p. 109-110, 116), and (2) east-west directed extension at depth (Stewart, 1971, p. 1026, 1036-1039).

A nearly symmetrical graben exists in the central Great Basin with anticlinal symmetry displayed on opposite sides (Ekren and others, 1974, p. 109). The rocks of the ranges to the east of the graben generally dip east and the rocks of the ranges to the west generally dip west (Ekren and others, 1974, p. 109). The anticlinal form and the normal faults of the Great Basin are the result of a broad uplift (Ekren and others, 1974, p. 116).

East-west directed extension at depth would also result in dominantly north-south-trending horsts and grabens (Stewart, 1971, p. 1036-1037). Northeast- and northwest-trending ranges could be produced by this mechanism (Stewart, 1971, p. 1036-1037).

The evidence, within the mapped area, does not indicate which mechanism is more likely. The faults are high-angle normal faults and are typical of the Basin and Range province. Obvious topographic differences are evident along the main north-trending fault at the eastern side of the mountain front, the east-west-trending fault east of Cedar Knoll Road, and the third north-northwest-trending fault also in the area east of Cedar Knoll Road (Plate 1).
other faults have less topographic expression although the main valley channel, where U. S. Highway 91 is located, is indirectly if not directly fault-controlled.

**Landslides**

Minor landsliding, in the northern part of the Oxford Quadrangle, involves colluvial deposits and possibly Salt Lake Formation (Williams, 1958, Plate 11). The slumping is most readily apparent west of U. S. Highway 91 to the north of the "Red Rock". The material has moved downslope and to the east and northeast onto the main valley floor. A smaller area of slumping is located in a small valley southwest of the "Red Rock". Major landslides are not present within the mapped area.
STRUCTURAL EVENTS

General Statement

Two major structural events have taken place in southeastern Idaho. The first event, thrust faulting with associated folding, has been assigned to the Laramide orogeny by various workers (Crittenden, 1972; Mudge, 1970; Armstrong and Oriel, 1965; Armstrong and Cressman, 1963). The direction of thrusting was generally eastward.

The second major event is Basin and Range normal faulting. The normal faulting is responsible for the ranges and valleys of the Basin and Range province.

Laramide Events

Within the mapped area, Laramide features consist of thrust faults and associated folds, involving Precambrian and Paleozoic formations. Precambrian Papoose Creek Formation is the oldest unit involved and Ordovician Swan Peak Formation is the youngest. The Salt Lake Formation, late Eocene to Pliocene, has not been affected by thrust faulting. This evidence indicates that the thrust faulting took place during post-Ordovician and pre-Eocene time.

The thrust faulting of the Idaho-Wyoming thrust belt probably began in late Jurassic in the west and ended in Eocene in the east (Armstrong and Oriel, 1965, p. 1861, Figure 19; Oriel and Armstrong, 1966, p. 2619). The Paris thrust fault is one of the westernmost
thrust faults in the Idaho-Wyoming thrust belt. This fault has been dated by the age of the youngest unit it offsets and by the oldest unit which covers it without offset. The Thaynes Formation, Lower Triassic, is cut by the fault which is overlain by Wasatch Formation, Eocene (Armstrong and Cressman, 1963, p. 8-9). This brackets the time of thrusting between Early Triassic and Eocene.

Using the Ephriam Conglomerate of the Lower Cretaceous Gannett Group, Armstrong and Cressman (1963, p. 9-14) further narrow the time of thrusting by concluding that the pebbles and cobbles in the Ephraim must have come from a Paleozoic source area to the west which was uplifted. The Paris thrust fault is associated with that uplift. Their analysis suggests a more precise date of late Jurassic or early Cretaceous for initial movement on the Paris thrust fault (Armstrong and Cressman, 1963, p. 14).

One of the easternmost thrust faults, therefore one of the youngest, is the Prospect thrust fault. The Prospect thrust fault cuts the lower part of the Hoback Formation, Paleocene and earliest Eocene, but not the upper part of the Hoback which is Eocene (Armstrong and Oriel, 1965, p. 1857). In another area, the Prospect is overlain by Wasatch Formation of late early Eocene age (Armstrong and Oriel, 1965, p. 1857). Major thrusting must have taken place during middle early Eocene and must have stopped prior to late early Eocene (Armstrong and Oriel, 1965, p. 1857). Therefore, most of the thrust faulting in the region must have occurred between late Jurassic and early Eocene.
Basin and Range Events

The normal faults, within the mapped area, are Basin and Range faults. These faults postdate the Laramide thrust faulting and folding. The Paleozoic and older rocks are broken by normal faults. The Salt Lake Formation both overlies normal faults and is cut by normal faults. No fault scarps were found, within the mapped area, on either Tertiary or Quaternary units to indicate relatively recent movement on the faults.

The Wasatch Formation, Paleocene to lower Eocene (Gazin, 1959, p. 132), is considered to have been deposited prior to the formation of Cache Valley by Basin and Range faulting (Williams, 1958, p. 69); however, the Salt Lake Formation, late Eocene to Pliocene (Gazin, 1959, p. 137; Yen, 1947, p. 269-272), was deposited in Cache Valley which was created by subsidence on Basin and Range boundary faults (Williams, 1948, p. 1160; Adamson, Hardy, and Williams, 1955, p. 21). Thus, the oldest Basin and Range faulting is late Eocene in age. The faulting is active, to some extent, as indicated by recent earthquakes in northern Utah and southeastern Idaho. Therefore, Basin and Range faulting has continued from late Eocene to Holocene.
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GEOLOGIC MAP OF THE NORTHERN PART OF OXFORD QUADRANGLE, IDAHO