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Geology of the Northern Part of the Malad Range, Idaho

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GEOLOGY OF THE NORTHERN PART OF THE MALAD RANGE, IDAHO

by

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of the requirements for the degree

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Drew C. Axtell

TABLE OF CONTENTS

	Page
INTRODUCTION	1
Purpose and Scope	1
Location and Accessibility	1
Field Work	3
Previous Investigations	3
STRATIGRAPHIC GEOLOGY	5
General Statement	5
Cambrian System	5
General statement	5
Brigham Formation	7
Langston Formation	10
Ute Formation	12
Blacksmith Formation	14
Bloomington Formation	16
Nounan Formation	19
St. Charles Formation	20
Ordovician System	23
General statement	23
Garden City Formation	23
Swan Peak Formation	25
Fish Haven Dolomite	27
Silurian System	29
Laketown Formation	29
Devonian System	30
General statement	30
Water Canyon Formation	31
Jefferson Formation	33
Tertiary System	36
Wasatch Formation	36
Salt Lake Formation	37
Boulders	39

TABLE OF CONTENTS CONTINUED

	Page
Quaternary System	40
General statement	40
Lake Bonneville Group	40
Alluvium	41
STRUCTURAL GEOLOGY	42
General Statement	42
Faults	42
East-west-trending faults	42
Northeast-trending faults	43
Northwest-trending faults	44
North-south-trending faults	44
Age of Structures	48
LITERATURE CITED	50
APPENDIX	54

LIST OF PLATES

Plate — Page

1. Geology of the northern part of the Malad Range, Idaho . . . . . .pocket

LIST OF FIGURES

Figure

1. Index map of part of northeastern Utah and southeastern Idaho showing area mapped 2

2. The Brigham Formation on the north side of Two Mile Canyon, sec. 36, T. 14 S., R. 36 E., view looking northeast 8

3. The Blacksmith, Bloomington, Nounan, and St. Charles Formations south of Two Mile Canyon, sec. 1, T. 15 S., R. 36 E., view looking east 18

4. Fault scarp on the Blacksmith Formation on the north side of Two Mile Canyon, sec. 25, T. 14 S., R. 36 E., view northeast 45

5. Swan Peak Formation, Fish Haven Dolomite, and Laketown Formation, sec. 23, T. 14 S., R. 36 E., view east 47

LIST OF TABLES

Table

1. Stratigraphic units of Paleozoic age 6

ABSTRACT

Geology of the Northern Part of the

Malad Range, Idaho

by

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Utah State University, 1967

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Rocks of Paleozoic, Tertiary, and Quaternary age are represented in the northern part of the Malad Range. The Paleozoic rocks are represented by thirteen formations that are characterized lithologically by quartzites, shales, and carbonates. The oldest formation in the mapped area of Paleozoic age is the Brigham Formation, and the youngest formation is the Jefferson Formation of late Devonian age.

The rocks of Tertiary age are conglomerates, shales, and limestones and are represented by the Wasatch Formation, the Salt Lake Formation, and boulders. Quaternary rocks include sediments of the Lake Bonneville Group and alluvium.

The faults in the mapped area were formed during two periods of movement. The east-west-trending faults, northeast-trending faults, and northwest-trending faults are a consequence of compressional forces during Laramide orogenic activity. The north-south-trending faults were the result of Basin and Range block faulting during middle and late Tertiary times.

(71 pages)

INTRODUCTION

Purpose and Scope

The purpose of this report is to contribute to the knowledge and understanding of the regional geology of southern Idaho. The investigation was carried out according to the following plan: first, to study the stratigraphy and relate it to the regional stratigraphy; second, to study the structure and related it to the regional structure; third, to construct a geologic map at a scale of 1:24,000.

Location and Accessibility

The area mapped is in the northern part of the Malad Range, 20 miles north of the Utah-Idaho state line, and 50 miles northwest of Logan, Utah. The communities Cherry Creek and Malad City, Idaho are situated immediately to the west of the mapped area. The area lies between lat 42° 05' N. and lat 42° 15' N. and long 112° 08' 38" W. and long 112° 15' W. and covers an area of 60 square miles (Figure 1).

The area has good accessibility. U. S. Highway 191, 20 miles west of Logan, allows approach to the area from the west, and Idaho Highway 35 allows approach to the area from the east. Several unimproved U. S. Forest Service roads permit east-west access into the area. The road in Two Mile Canyon, 2 miles south of Malad City, traverses the Malad Range in a north-south direction.

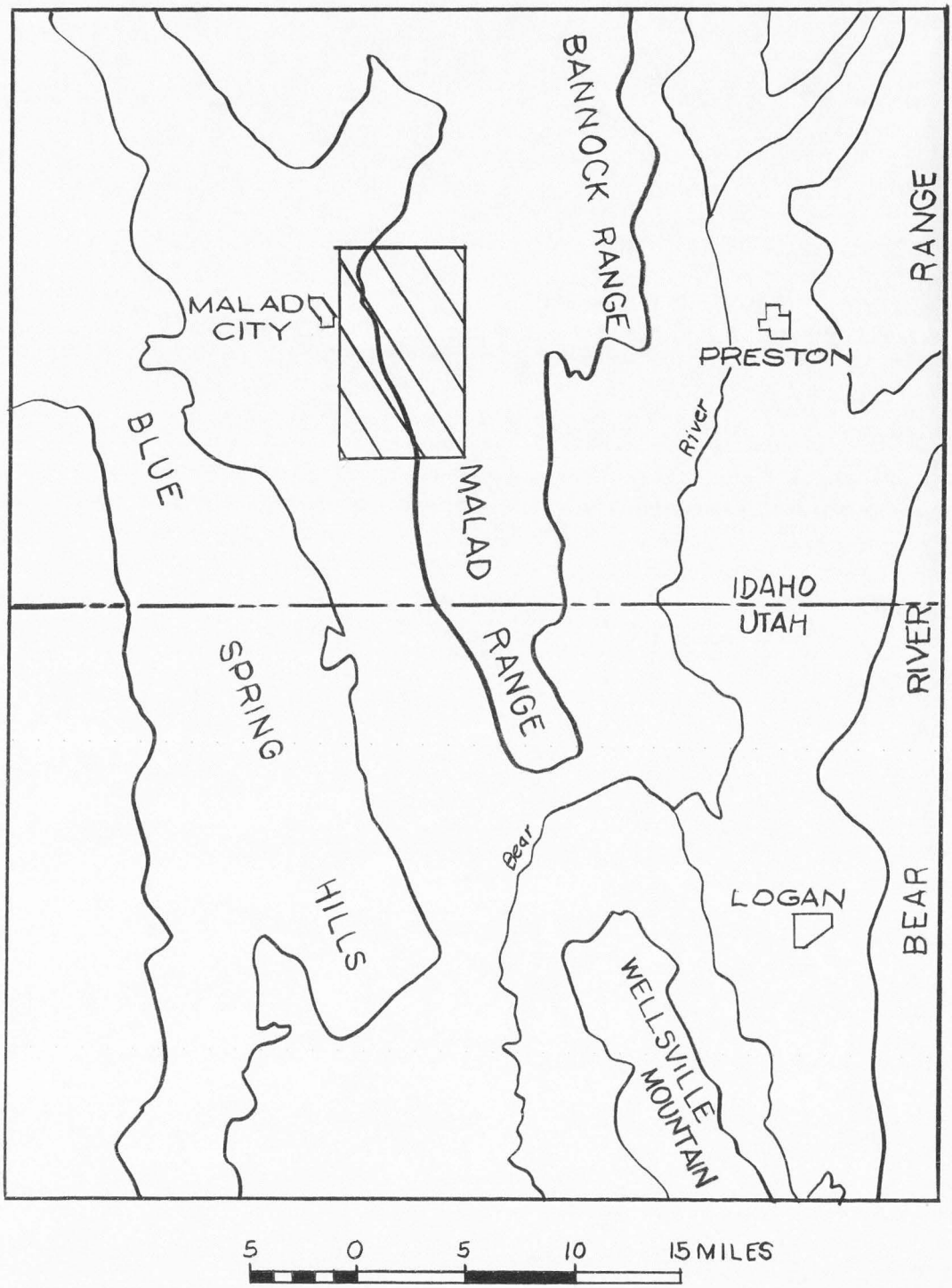


Figure 1. Index map of part of northeastern Utah and southeastern Idaho showing area mapped.

Field Work

The field work was accomplished during the summer and fall of 1966. Formations and faults were mapped in the field on aerial photographs at a scale of 1:20,000. The data were later transferred to a base map at a scale of 1:24,000. The base map was taken from a U. S. Forest Service map of the Caribou National Forest.

Stratigraphic sections were measured with a steel tape. Rock samples were taken from each unit to facilitate detailed description of the stratigraphic units. Terminology for bedding was taken from McKee and Weir (1953, p. 381-389) as modified by Ingram (1954, p. 938). Fossils were collected and later identified in the laboratory by the writer.

Previous Investigations

The earliest geological surveys into southeastern Idaho were made by Hayden (1871, p. 13-27), Bradley (1873, p. 192-207), and Peale (1877, p. 606-609). All three parties made observations of the Malad Range and adjacent areas.

Walcott (1908, p. 5-9) studied the Cambrian rocks of northern Utah and southeastern Idaho and as a result of this study the Cambrian formations were named. Resser (1939b, p. 8-11) published the Cambrian section measured by Walcott in Two Mile Canyon. Resser also published the descriptions of the fossils collected by Walcott and himself from the Spence Shale (1939a, p. 1-29) and the Ptarmigania strata (1939b, p. 1-72). Williams and Maxey (1941, p. 279-281) assigned the Spence Shale of Walcott's Ute Formation (Walcott, 1908, p. 7-8) to the Langston Formation.

Richardson (1913) studied the geology of the Randolph quadrangle in northeastern Utah and thereby completed the naming of the remaining Paleozoic section. Work by Mansfield (1927) in southeastern Idaho further clarified the intrepretation of the stratigraphy and structure of the region. Deiss (1938, p. 1105-1124) modified the section defined by Walcott in Blacksmith Fork Canyon, Bear River Range, south of Logan, Utah.

Other more recent studies of the area were made by Hanson (1949), who mapped the southern part of the Malad Range in northern Utah; Ross (1951), who extensively studied and zoned the Garden City Formation in northeastern Utah. Prammani (1957) studied the geology of the east-central part of the Malad Range in Idaho. Beus (1963) studied the geology of the central Blue Spring Hills in northern Utah and southern Idaho.

STRATIGRAPHIC GEOLOGY

General Statement

Rocks of Paleozoic, Tertiary, and Quaternary age are exposed within the northern part of the Malad Range (Plate 1). The Paleozoic rocks range in age from Cambrian to Devonian and crop out in the western part of the range. Tertiary and Quaternary rocks are well exposed in the eastern part of the range and in the Malad Valley to the west.

Cambrian System

General statement

The three series of the Cambrian System known elsewhere in northern Utah and southeastern Idaho are represented in the mapped area (Table 1). The Lower Cambrian and part of the Middle Cambrian are well exposed on the north side of Two Mile Canyon although highly faulted. The remaining Middle Cambrian and Upper Cambrian series are present on the south side of Two Mile Canyon.

The Brigham, Langston, Ute, Blacksmith, and St. Charles Formations of Cambrian age are only partially represented in the mapped area, and the only complete sections are those of the Bloomington and Nounan Formations of Cambrian age.

Table 1. Stratigraphic units of Paleozoic age.

Devonian System		
Jefferson Formation		
Hyrum Member	Limestone	446
Water Canyon Formation	Limestone and intraformational breccia	
	Dolomite	250
Silurian System		
Laketown Formation	Dolomite	690
Ordovician System		
Fish Haven Dolomite	Dolomite	57
Swan Peak Formation	Quartzite	120
Garden City Formation	Limestone	1,805[a]
Cambrian System		
St. Charles Formation	Limestone and dolomite	704
	Quartzite	
Nounan Formation	Dolomite and limestone	886
Bloomington Formation	Shale, limestone, and intraformational conglomerate	431
Blacksmith Formation	Limestone	350
Ute Formation	Shale and limestone	439[b]
Langston Formation	Shale, limestone and shale	
	Limestone	132
Brigham Formation	Quartzite and shale	657
	Quartzite	

[a]Southern Malad Range (Hanson, 1949, p. 41)

[b]Southern Malad Range (Hanson, 1949, p. 14)

Brigham Formation

The Brigham Formation was named by Walcott (1908a, p. 8-9) from exposures in the southern part of Wellsville Mountain near Brigham City, Box Elder County, Utah. Walcott described the Brigham as a "massive quartzitic sandstone." Near Brigham City Walcott measured 2,000 feet and in Blacksmith Fork Canyon, Bear River Range, he measured 1,250 feet.

In the mapped area on the north side of Two Mile Canyon, Walcott (Resser, 1939b, p. 12) measured 740 feet of reddish-brown quartzitic sandstone and green-arenaceous shale, with a brown sandstone near the top. Deiss (Resser, 1939b, footnote, p. 12) measured 650 feet of the Brigham Formation above a supposed thrust fault in Two Mile Canyon.

The Brigham Formation in the mapped area crops out on the north side of the mouth of Two Mile Canyon. The base of the Brigham is unexposed in the mapped area. It lies conformably below the Langston Formation and is terminated on the south by a northeast gravity fault down to the southeast and on the east by a north-northwest gravity fault with the east side down. No evidence of thrust faulting was observed in the area. A thickness of 657 feet was measured on the north side of the canyon where the Brigham forms bold blocky cliffs and slopes (Figure 2). The Brigham is quartzite, shale, and sandstone. The quartzite is red, white, green and black, medium to coarse grained, thin to thick bedded with cross-bedding displayed throughout. The shale is green and micaceous and is interbedded with quartzite in the lower part. Near the top of the Brigham Formation the shale increases appreciably, and there are a few quartzite interbeds. At the top there is a 10-foot bed of brown calcareous sandstone that is coarse

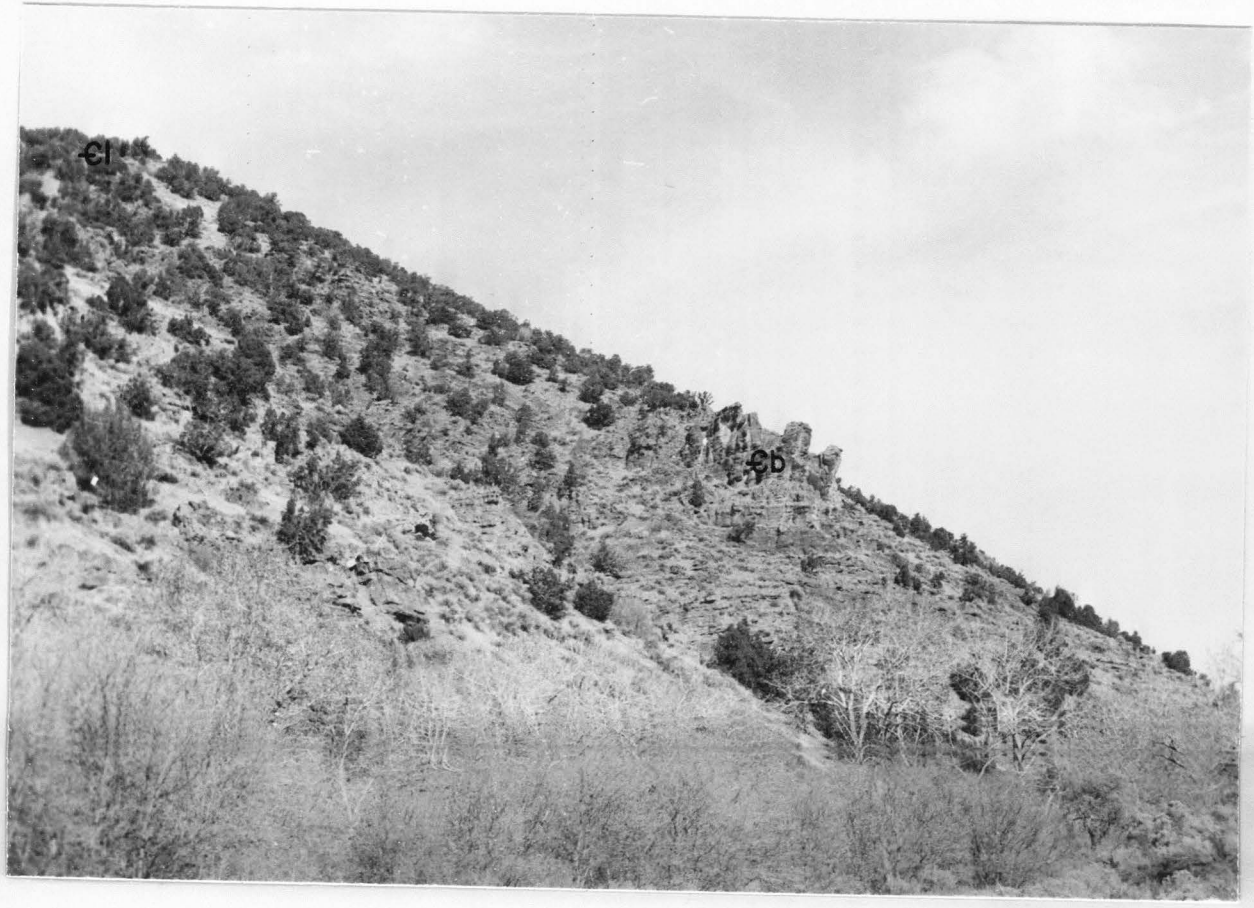


Figure 2. The Brigham Formation on the north side of Two Mile Canyon, sec. 36, T. 14 S., R. 36 E., view looking northeast.

grained, medium bedded and shows cross-bedding and conformably underlies a dark-gray, coarse-grained, fossiliferous basal limestone of the Langston Formation. Worm borings are common near the top of the Brigham; however, no other fossils were found.

The formation name, Brigham, has been the subject of much controversy. Maxey (1958, p. 667-669) proposed that the name Prospect Mountain Quartzite be used for the Tintic Quartzite and Brigham Quartzite of northern Utah and southern Idaho and the name Pioche be used for the upper shaly unit. The justification for this extension is that the lithology and age of the Prospect Mountain Quartzite and Pioche Formation are similar to the Tintic Quartzite and Brigham Quartzite. Maxey (1958, p. 668) defined the Prospect Mountain Quartzite as Early Cambrian because of the absence of fossils and the conformable relationship with the Langston Formation, and the Pioche as late Early Cambrian and early Medial Cambrian because it lies "partly within the Olenellus zone" at its type locality at Pioche, Nevada, and conformably overlies the Prospect Mountain Quartzite. The writer believes that the inception of these formational designations is an over extension and that the established name, Brigham Formation, should be retained.

In northern Utah and southeastern Idaho, the age of the Brigham Formation has been clearly established as Early Cambrian. Williams and Maxey (1941, p. 277) found Albertella sp. and Kochaspis sp. in the basal limestone member, the Naomi Peak Limestone, of the Langston Formation. These mark the base of the Middle Cambrian. Oriel (1964, p. 341) asserted that the "assignment of most of the Brigham to the Middle Cambrian is erroneous." Oriel found an Olenellus sp. 130 feet

above the base of the upper 300 feet of the Brigham Formation in the Portneuf Range of southeastern Idaho.

Langston Formation

The Langston Formation was named by Walcott (1908a, p. 8) from exposures at Langston Creek, Idaho; however, Walcott designated the type locality at Blacksmith Fork Canyon, Bear River Range, where he described the Langston Formation as a "massive bedded, bluish gray limestone with many round concretions," 107 feet thick. At Two Mile Canyon, Walcott defined the Langston Formation as a 6-foot bed of dark-gray coarse-grained limestone (Resser, 1939b, p. 10). At this locality, Walcott included 155 feet of the overlying Spence Shale as the basal member of the Ute Formation. Deiss (1938, p. 1119) modified Walcott's definition of the Langston Formation and measured 575 feet of limestone and dolomite at Blacksmith Fork Canyon. The apparent thickness of the Langston at Blacksmith Fork Canyon and the apparent thinness of Walcott's section at Two Mile Canyon led Deiss to the conclusion that correlation of the shale beds at the base of the Ute Formation at Blacksmith Fork Canyon could not be reconciled with those of the Spence Shale at Two Mile Canyon (Deiss, 1938, p. 1119). Walcott had explained this apparent change in thickness as the result of discontinuous deposition of the Langston Formation throughout the area with the beds of limestone at Two Mile Canyon representing a bioherm at the base of the Ute Formation (Resser, 1939b, p. 16). Williams and Maxey (1941, p. 281) placed the Spence Shale, formerly considered Ute by Walcott, in the Langston Formation.

Resser (1939a, p. 17) collected numerous fossils from the

6-foot bed of the Langston Formation at Two Mile Canyon. He defined this as the Ptarmigania strata based on faunal evidence. Maxey (1958, p. 669-671) changed the name Ptarmigania strata to the Naomi Peak Limestone. Maxey stated that Resser did not describe a type locality, the name may be confused with the Ptarmigan Formation of Canada, and disagrees with naming a formation after a fossil.

In the mapped area, the Langston Formation lies conformably over the Brigham Formation on the north side of Two Mile Canyon. The writer measured a thickness of 132.6 feet. Three members were recognized: (1) the basal Naomi Peak Limestone (Ptarmigania strata), (2) the Spence Shale, and (3) an upper shale and limestone member. The Naomi Peak Limestone is dark gray, coarse grained, medium to thick bedded and fossiliferous. The Spence Shale is a thin-bedded, fine-grained, fissile, black shale grading into a light-brown colored shale. Trilobite fragments and sponge spicules are extremely abundant. The upper member is a dark-gray, thin- to medium-bedded, medium-grained limestone with interbeds of dark-gray shale. The upper contact is drawn below a medium-bedded, coarse-grained, crystalline limestone of the Ute Formation. The Naomi Peak Limestone is an excellent marker bed. It is the first carbonate recognized in the section and forms a conspicuous dark-gray ridge.

The section described at Two Mile Canyon is lithologically similar to the section measured and described by Maxey (1958, p. 659) at High Creek Canyon. The writer, however, disagrees with Maxey's statement that the three overlying units above the Spence Shale should be included within the Langston Formation (Maxey, 1958, p. 650). The reason for this is that the lithology is not correlatable with the

lithology of the Langston Formation in other sections of northern Utah. Walcott did not measure the above units in a straight stratigraphic sequence but rather in different sections on the north side of Two Mile Canyon (Resser, 1939b, p. 10).

The change in lithology from Two Mile Canyon to Blacksmith Fork Canyon results from a lateral change of the Spence Shale and Naomi Peak Limestone Members into a thick basal dolomite (Maxey, 1958, p. 669).

The Langston Formation is lower Middle Cambrian in age. Lockman-Balk (1960, p. 100) placed the Naomi Peak Limestone Member in the uppermost part of the Albertella zone and the remainder of the Langston Formation in the Glossopleura zone.

Fossils collected by the writer from the Spence Shale Member are listed below:

Agnostus bannerensis

Agnostus brighamensis

Alokistocare punctatum

Elrathia spencei Resser

Oryctocephalus walcotti Resser

Spencia typicalus

Zacanthoides idahoensis

Sponge spicules

Ute Formation

The "Ute Limestone" was first described by the Fortieth Parallel Survey under King (1878). Walcott (1908a, p. 7-8) later restricted the name Ute to include a "bluish gray, thin bedded, fine grained

limestone and shale," 759 feet thick at Blacksmith Fork Canyon. Walcott defined the lower contact as lying above a massive limestone of the Langston Formation and the upper contact as lying below the thick cliff-forming dolomite of the Blacksmith Formation. Deiss (1938, p. 1113) defined the Ute Formation as a thin-bedded limestone with olive-green shale interbeds, 685 feet thick in Blacksmith Fork Canyon. Williams and Maxey (1941, p. 281) described the Ute as a "thin-bedded, silty limestone and green shale" in Blacksmith Fork Canyon. Hanson (1949, p. 15) measured 439 feet of thin-bedded limestone with tan silty partings that decrease upward in the southern Malad Range. A thickness of 621 feet was measured by Maxey (1958, p. 661) at Calls Fort and 675 feet at Blacksmith Fork Canyon (Maxey, 1958, p. 657).

At Two Mile Canyon, Walcott (Resser, 1939b, p. 10) measured a total thickness of 797 feet of shale, limestone, and dolomite. The writer did not measure the Ute Formation because of the complexity of the faulting; however, the units that Walcott described were carefully studied and used as a guide for mapping the formation The Ute Formation conformably overlies the Langston Formation. The lower contact is placed above a dark-gray, thin- to medium-bedded, medium-grained limestone with interbeds of dark-gray shale of the Langston Formation. The upper contact is placed below a thin- to medium-bedded, dark- to medium-gray, aphanitic to fine-grained limestone of the Blacksmith Formation.

The age of the Ute Formation is Middle Cambrian. Maxey (1958, p. 672) described two faunal zones: (1) the basal shale of the Ute Formation is assigned to the Glossopleura-Zacanthoides zone,

and (2) the upper units to the Bathyariscus-Elrathania zone, "400 feet above the base of the formation in northern Utah."

The writer collected the following fossil:

Alokistocare lorenz

Blacksmith Formation

The Blacksmith Formation was named by Walcott (1908a, p. 7) from exposures in Blacksmith Fork Canyon, Logan quadrangle, Utah. Walcott described 570 feet of "gray, arenaceous limestone in massive layers." Deiss (1938, p. 1112-1113) amended Walcott's original definition and described 450 feet of thick-bedded dolomite with interbedded magnesium limestone that form light-gray cliffs above the Ute Formation. Williams (1948, p. 1113) defined the Blacksmith Formation in Logan quadrangle as a massive dolomite with silty beds and oolitic beds which show cross-bedding. Maxey (1958, p. 661) measured 805 feet at Calls Fort and 325 feet (1958, p. 657) at the Left Fork of Blacksmith Fork Canyon of massive dolomite and dolomitic limestone that is fine to medium crystalline and oolitic in the lower part. Maxey (1958, p. 672) stated that the Blacksmith Formation thins to the north and east and thickens to the west. Hanson (1949, p. 17) measured 444 feet of thin- to thick-bedded, medium-gray limestone that is largely oolitic in the southern Malad Range.

Walcott (Resser, 1939b, p. 10) measured 585 feet of light-gray massive dolomite, with bluish-gray layers in the upper part, at Two Mile Canyon. In the mapped area the Blacksmith Formation crops out along the western front of the range to the south of Two Mile Canyon and also approximately 1.5 miles east of the entrance to Two Mile

Canyon. The Blacksmith Formation conformably overlies the Ute Formation. The lower contact is placed above a thin- to medium-bedded, fine-grained, silty limestone of the Ute Formation and below a thin- to medium-bedded, dark- to medium-gray, aphanitic to fine-grained limestone of the Blacksmith Formation. The upper contact is placed below an olive-green shale of the Bloomington Formation. The Blacksmith is a thin- to medium-bedded, dark- to medium-gray, aphanitic to fine-grained limestone with oolites throughout. A thickness of 350 feet was measured. The difference in lithology of Walcott's section and the writer's section results from the fact that Walcott misidentified the Blacksmith Formation and was unable to distinguish limestone from dolomite. The writer assumes that Walcott measured the Blacksmith 1.5 miles east of the mouth of Two Mile Canyon on the north side. At this location there is a dolomite that is medium bedded, fine to medium grained, with alternating dark-gray and light-gray beds. Near the top of this unit the dolomite is light to medium gray, massive, and coarse grained. The upper beds show drag and gouge that indicate faulting. The fault present is a northeast-trending gravity fault with the south side down. The dolomite represents the Nounan Formation which has been placed in juxtaposition with the Blacksmith Formation. The writer believes that Walcott defined this as Blacksmith and also that Walcott misidentified the overlying limestone unit as dolomite. Oriel (1965) described the Blacksmith in the SW¼ of the Bancroft quadrangle as a "medium-gray to buff, medium- to thick-bedded, oolitic limestone." This description, as well as Hanson's (1949, p. 17) seems to substantiate the conclusions of the writer.

The Blacksmith Formation is Middle Cambrian in age (Williams,

1948, p. 1133). Maxey (1958, p. 675) assigned the lower beds to the Bathyuriscus - Elrathina zone and the upper beds to the Thompsonaspis zone. No fossils were found.

Bloomington Formation

The Bloomington Formation was originally defined by Walcott (1908a, p. 7) as a "bluish gray, more or less thin bedded limestone and argillaceous shale" from its type locality 6 miles west of Bloomington, Idaho. Richardson (1913, p. 406-416) defined the basal shale as the Hodges Shale Member from exposures 1½ miles south of Garden City. Richardson described the Hodges Shale as a "persistent zone of drab clay shale about 350 feet thick occurring at the base of the formation (Richardson, 1913, p. 406). Mansfield (1927, p. 55) changed the type section of the Bloomington Formation to Mill Creek, Idaho. Deiss (1938, p. 1122) modified the original definition and described a section in Blacksmith Fork Canyon as 1,275 feet of shale and interbeds of limestone and intraformational conglomerate. Denson (1942, p. 24) defined an upper thick shale unit as the Calls Fort Shale Member. Maxey (1958, p. 660) measured 1,085 feet at Calls Fort and recognized four members: (1) the Hodges Shale Member, (2) a thin-bedded limestone, (3) the Calls Fort Shale Member, and (4) an upper medium- to thick-bedded limestone.

Resser (1939b, p. 9) published Walcott's description of the Bloomington Formation in Two Mile Canyon. Walcott measured 555 feet of thin-bedded limestone and sandy argillaceous shale. The writer measured 431 feet of shale and limestone on the south side of the canyon. The shale is olive green with some red siltstone. There are

interbeds of limestones that are thin bedded, aphanitic to fine grained, bluish gray on weathered surfaces and dark gray on fresh surfaces. The limestone in the section is thin bedded, medium gray, aphanitic to coarse grained, with beds of intraformational conglomerate. The Bloomington Formation is easily recognized since it overlies the massive cliff-forming limestone of the Blacksmith Formation and underlies the massive cliffs of the Nounan (Figure 3). The Bloomington characteristically forms slopes except for small persistent ledges of limestone from 1 to 2 feet thick that stand out on the slopes.

The difference in thickness between the writer's measured section and that of Walcott results from the fact that Walcott evidently measured the Bloomington in a fault block that duplicated much of the section. The measured section of the writer seems more nearly to resemble Hanson's (1949, p. 21) description in both lithology and thickness; however, the writer disagrees with Hanson's suggestion that an unconformity may exist between the Bloomington and the Nounan due to a variation in thickness of the formation in northern Utah. No physical evidence such as a basal conglomerate, discordance of dip, or erosional relief was found on which to base such a conclusion.

Maxey (1958, p. 678) defined the Bloomington Formation as late Middle Cambrian. He placed the Bloomington in the Asaphiscus-Bolaspidella faunal zone overlain by the Cedaria faunal zone of Late Cambrian.

The writer collected the following fossils:

Lingulella sp.

an undetermined trilobite free cheek

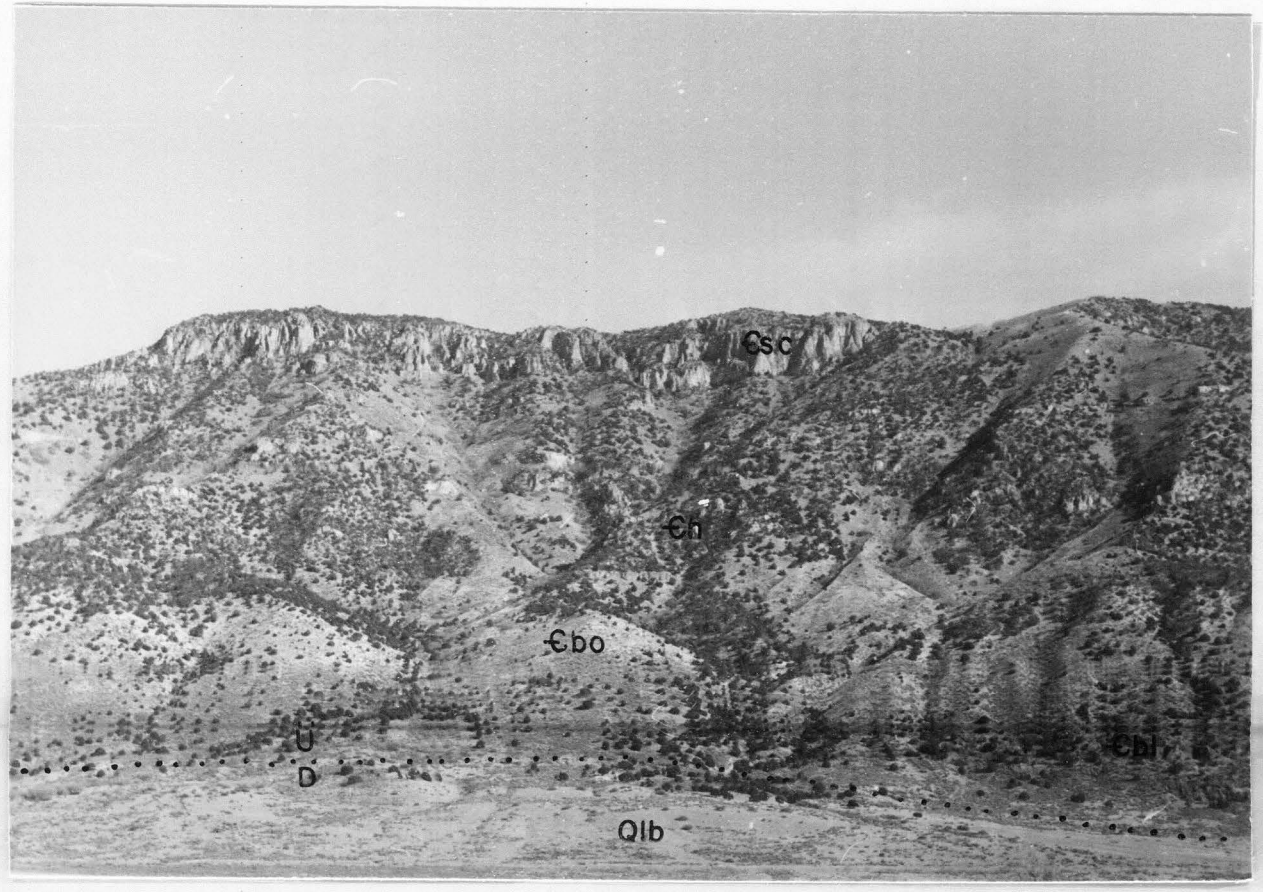


Figure 3. The Blacksmith, Bloomington, Nounan, and St. Charles Formations south of Two Mile Canyon, sec. 1 and 2, T. 15 S., R. 36 E., view looking east.

Nounan Formation

The Nounan Formation was first described by Walcott (1908a, p. 6-7) as a "light gray to dark lead colored arenaceous limestone" from its type locality on the east slope of Soda Peak, west of the town of Nounan, Idaho. Mansfield (1927, p. 55-56) measured 1,050 feet of dolomitic limestone in the lower part and thin- to massive-bedded limestone in the upper part. Deiss (1938, p. 1122-1123) defined the Nounan Formation as 900 feet of thin- to thick-bedded, medium- to coarse-crystalline, light- to dark-gray dolomite with 127 feet of white, massive, cliff-forming limestone 148 feet above the base. Richardson (1941, p. 12) measured 950 feet of massive-bedded unfossiliferous blue-gray limestone in the Randolph quadrangle. Williams (1948, p. 1134) defined the Nounan Formation as a light-gray dolomite with the upper third as dense dark-gray limestone. A thickness of 825 feet was measured at Calls Fort by Maxey (1941, p. 13). Hanson (1949, p. 24-25) measured 908 feet of thick- to massive-bedded, medium-crystalline dolomite that is light gray in the lower part and dark gray in the upper part and 500 feet of overlying thin- to medium-bedded limestone that is oolitic and lithographic locally. Hanson (1949, p. 26) stated that the upper limestone thickens to the north and may be the result of a facies change, a local unconformity, or irregular dolomitization.

In the mapped area the Nounan Formation is well exposed on the south side of Two Mile Canyon. It forms bold cliffs as contrasted to the slope-forming Bloomington Formation below. The lower contact is placed at the base of the massive cliff-forming dolomite and at the

top of a shale and thin-bedded limestone unit of the Bloomington. The upper contact is placed below a brown quartzite of the St. Charles Formation and above a dark-gray, aphanitic limestone. Walcott (Resser, 1939b, p. 10) measured 1,088 feet of massive-bedded dark-gray dolomite with 52 feet of thin-bedded bluish-gray limestone 180 feet above the base. The writer measured 886 feet of dolomite that is massive, coarse crystalline, with light-gray beds and dark-gray beds alternating in the lower part and medium- to dark-gray dolomite above. The dolomite is characterized by numerous small faults throughout. Limestone beds are found throughout the formation and 45 feet of cliff-forming, thick-bedded, white, crystalline limestone that grades into a thin-bedded, aphanitic to fine-grained, dark-gray limestone defines the top of the formation. The differences in measured sections and lithology result because Walcott measured part of the formation in a faulted area and failed to recognize the upper units as part of the Nounan Formation.

Maxey (1958, p. 678) placed the Nounan Formation in the lower Cedaria zone of Late Cambrian age. No fossils were collected.

St. Charles Formation

The St. Charles Formation was named by Walcott (1908a, p. 6) from its type locality west of the town of St. Charles, Idaho. Walcott defined the St. Charles as a "blue to gray, arenaceous limestone, with some cherty and concretionary layers, passing at the base into a thin bedded gray to brown sandstone." He measured a thickness of 1,225 feet at Blacksmith Fork Canyon and 1,197 feet west of Liberty, Idaho. Richardson (1913, p. 408) defined the basal quartzite member as the Worm Creek Quartzite from its type locality along

Worm Creek, Bear River Range, 10 miles north of the Randolph quadrangle. He described the Worm Creek Quartzite as 300 feet of "massive gray quartzite occurring at the base of the formation." Deiss (1938, p. 1123-1124) measured the St. Charles in Blacksmith Fork Canyon and placed 777 feet of Walcott's section in the Ordovician. Deiss placed an arbitrary upper contact "at the base of the lowest limestone which contains fenestellids." Williams (1948, p. 1135) modified Deiss' section and placed 258 feet of limestone and intraformational conglomerate that Deiss considered St. Charles in the Ordovician. Hanson (1949, p. 30-32) measured 1,073 feet of gray quartzite, silty limestone, and massive light-gray dolomite in the southern Malad Range.

Haynie (1957) made a detailed stratigraphic study of the Worm Creek Quartzite in northern Utah. He defined the Worm Creek Quartzite as predominately clastic in the north, east, and west and changing to a carbonate in the south (Haynie, 1957, p. 3.). The source area was a granitic land mass to the north as evidenced by the arkosic quartzite near Soda Springs, Idaho. The detritus was deposited by a transgressing sea "on the shelf area of a stable geosyncline" to the southeast (Haynie, 1957, p. 33). Oriel (1965) measured 1,800 feet of the St. Charles in the Bancroft quadrangle and recognized 900 feet of white and pink arkosic quartzite. This description by Oriel of the Worm Creek is consistent with the conclusions of Haynie as to source area.

In the map area, the St. Charles Formation crops out south of Two Mile Canyon and north and south of Four Mile Canyon. A composite thickness of 704 feet was measured. The base of the St. Charles is

well defined by the presence of the Worm Creek Quartzite. The Worm Creek is brown, white, and gray, medium to coarse grained, medium to thick bedded, and displays excellent cross-bedding. Overlying the quartzite is a massive limestone that forms bold blocky cliffs. The limestone is thin to medium bedded, fine to medium grained, and reddish brown on weathered surfaces. Tan and red silty partings are common throughout as well as numerous trilobite free cheeks and thorax segments. The upper dolomite member is dark gray, medium to coarse crystalline, and contains chert nodules that are black and brown.

The St. Charles Formation is Upper Cambrian or Croixian (Williams, 1948, p. 1134). Williams and Maxey (1941, p. 284) assigned the middle limestone member to the Upper Cambrian based on Franconian fossils. Lockman-Balk (1960, p. 100) placed the upper dolomite member in the Saukia zone.

The following fossils were collected from the middle limestone member:

Unidentified trilobite fragments

free cheeks

thorax segments

endopodites

Brachiopods

Billingsella sp.

Ordovician System

General statement

The Ordovician formations that are represented in the mapped area include the Garden City Formation, the Swan Peak Formation, and the Fish Haven Dolomite. Richardson (1913) named and defined these from exposures in the Randolph quadrangle, Utah where he measured a thickness of 2,000 feet (1913, p. 407). Immediately south of the mapped area, Hanson (1949) measured a total thickness of 2,461 feet. The writer measured a partial thickness of 177 feet with the Garden City Formation omitted. Williams (1948, p. 1136) placed a disconformity, representing a relatively small time interval, between the St. Charles and the Garden City Formations. The Garden City-Swan Peak contact is conformable; whereas, an unconformity without discordance (Williams, 1948, p. 1137) separates the Swan Peak Formation from the Fish Haven Dolomite.

Garden City Formation

The Garden City Formation was originally defined by Richardson (1913, p. 408-409) from exposures in Garden City Canyon west of Bear Lake, Randolph quadrangle, Utah. Richardson defined the formation as 1,000 feet of "thick and thin-bedded gray limestone" with the "presence throughout the formation of a conglomerate or breccia consisting of elongated bits of limestone." Deiss (1938, p. 1123-1124), in his study of the Cambrian rocks in the Cordilleran trough, included 777 feet of Walcott's original St. Charles Formation in the Ordovician. Williams (1948, p. 1135-1136) recorded a thickness of 1,400 feet of "dark-gray, thin-bedded, shaly limestone that weathers

olive buff" in Green Canyon. Hanson (1949, p. 41) measured 1,805 feet in the southern Malad Range, and Prammani (1957, p. 26) measured 1,030 feet in Dry Canyon southeast of the mapped area.

The Garden City Formation is exposed throughout the mapped area. The formation is composed of two units following Ross (1951, p. 7): (1) a lower thin-bedded limestone with numerous silty partings that are yellow brown, and (2) an upper cherty dolomite and limestone unit. The lower limestone unit weathers a light to medium gray and is characteristically aphanitic to fine grained. Dispersed throughout the lower limestone member are thin beds of intraformational conglomerate with angular pebbles up to 1 inch in length. The contact between the underlying St. Charles Formation and the Garden City Formation is placed at the top of the massive gray dolomite of the St. Charles and below a thin-bedded limestone of the Garden City. Unlike the section in Green Canyon (Williams, 1948, p. 1135), the intraformational conglomerate in the mapped area does not appear until well into the formation. The upper unit of dolomite and limestone is not as wide spread as the lower unit in the mapped area. Chert nodules are characteristic of the upper unit and in the mapped area occur evenly dispersed throughout the formation. This unit, as well as the lower unit, forms cliff. The contact with the overlying Swan Peak Formation is placed above a cherty dolomitic limestone and below the massive quartzite of the Swan Peak. The intervening 23-foot slope is attributed by the author to a shaly basal unit of the Swan Peak Formation, although this unit was never exposed.

Ross (1951, p. 8-9) attributed the presence of dolomite at the top of Garden City Formation to be associated with faulting because

of the lack of persistence of this unit. Prammani (1957, p. 26) found dolomite at the top; whereas, Murdock (1961, p. 30) did not but the latter, nevertheless, substantiated the conclusions of Ross. The writer believes that the conclusions of Ross are invalid from the evidence found in the mapped area. Half mile east of the entrance of Four Mile Canyon on the south side a major east-west fault zone is observed. Here the Swan Peak Formation has been extensively faulted and no apparent dolomitization of the Garden City Formation occurs.

Ross (1951, p. 31) collected abundant fossils from the Garden City Formation and recognized twelve faunal zones based on trilobites. Zones A through I, Ross placed in the Lower Ordovician. Zone L is considered Chazyan based on the brachiopod genus Anamalorthis. The boundary between the Canadian and Champlainian is placed within the J and K zones, based upon the brachiopod genera Hesperonomia and Tritoechia (Ross, 1951, p. 31).

The writer collected the following fossils:

Trilobites

Protopliomerops celsaora Ross

Brachiopods

Gastropods

Swan Peak Formation

The Swan Peak Formation lies conformably above the Garden City Formation and disconformably below the Fish Haven Dolomite. The formation was named by Richardson (1913, p. 409) from Swan Peak in the Bear River Range, half mile south of the Idaho border. Richardson originally described the formation as 500 feet of "fine textured,

massive- to thin-bedded, white to gray quartzite." Williams (1948, p. 1136-1137) defined three units in the Swan Peak Formation: (1) a lower black shale interspersed with bluish-brown sandy limestone, (2) a brown quartzite, and (3) an upper light-gray quartzite.

In the mapped area, only 97 feet the white vitreous quartzite is present. A 23-foot slope between the quartzite and the underlying Garden City Formation is present and may contain the shale unit; however, no evidence was found to substantiate this. Hanson (1949, p. 44) described two units: (1) a lower black, fissile shale and (2) a reddish-brown quartzite in the lower part and a vitreous quartzite in the upper part.

The lower contact is placed above a cherty dolomitic limestone of the Garden City Formation. The upper contact is placed below a dark-gray, medium-crystalline, thick- to massive-bedded dolomite of the Fish Haven Dolomite.

The thickness and lithology of the Swan Peak Formation varies from the northwest to the southeast. Hanson (1949, p. 44) measured 606 feet on the west side of Clarkston Mountain, and Williams (1948, p. 1136) measured 304 feet in Green Canyon. Ross (1951, p. 35) described a lithologic variation from a calcareous quartzite at the base of the formation to a vitreous quartzite at the top of the formation on the west side of Clarkston Mountain to an extremely thin quartzite with a considerable amount of green shale and siltstone north of Mantua, Utah. Ross, therefore, concluded that there was either a broad upwarp in the southeast or that the source area was to the northwest and only a small amount of material was deposited in the southeast. Ross was inclined to accept the latter conclusion

(Ross, 1951, p. 35).

The presence of fucoidal markings in the Swan Peak, absent in the mapped area, has been the subject of controversy over the years. Coulter (1955, p. 283) suggested that these ridge-shaped structures are the result of the chemical by-product of the decomposition of either plant or animal that might have acted as a cementing agent of coarse sand or organic fragments incorporated into the decomposed material. Hardy (1956, p. 369) rejected the conclusion of Coulter and stated that the fucoidal markings are the result of "deformation before consolidation" initiated by local thickening under load.

Richardson (1913, p. 409) assigned the Swan Peak to the Chazyan stage. Williams (1948, p. 1136) stated that the formation is Champlainian without defining the stage. Ross (1951, p. 36) substantiated a Chazyan age; however, he concluded that the upper vitreous quartzite may be younger. No fossils were found in the formation.

Fish Haven Dolomite

The Fish Haven Dolomite was named by Richardson (1913, p. 410) from Fish Haven Creek, two miles north of the Utah state line in Idaho. Richardson measured 500 feet of "fine textured, medium-bedded, dark-gray to blue-black, locally cherty, dolomite" that contains the Richmond fauna. Mansfield (1927, p. 58) defined a disconformity between the Fish Haven Dolomite and underlying Swan Peak Formation. Williams (1948, p. 1137) measured 140 feet of a "massive unit of dark-neutral-gray, medium-crystalline, thick-bedded dolomite" that is everywhere found at the base of the Laketown Formation with

no variation in lithology. Hanson (1949, p. 46-47) measured 50 feet of dark-gray dolomite that is thick bedded and medium crystalline in the southern Malad Range. Beus (1963, p. 20-27) did not separate the Fish Haven Dolomite from the Laketown Formation because of the fact that a lithologic boundary could not be determined. Beus described a lower 70 feet as a dark-gray massive dolomite that is lithologically similar to the Fish Haven and placed the Ordovician-Middle Silurian boundary 310 feet above the base of the formation. Beus' criteria is the presence of Streptelasma, an Ordovician fossil, within this 310 feet and Halysties sp. and Favosites sp. above this (Beus, 1963, p. 24).

The contact between the Fish Haven Dolomite and the Laketown Formation has been decided primarily on the basis of color. Williams (1948, p. 1137) placed the contact above the first dark-gray dolomite and below the first light-gray dolomite in the section. Oriel (1964) placed the contact above the second dark-gray dolomite and below the overlying light-gray dolomite. The writer has followed Williams' delineation in the mapped area.

In the mapped area only a thin unit is recognized as Fish Haven. This occurs in a fault zone together with the Swan Peak and Laketown Formations. The Fish Haven is a dark-gray thick- to massive-bedded dolomite that is medium crystalline. Chert nodules that are black-colored and brown-colored are dispersed throughout. The writer measured 57 feet of Fish Haven Dolomite.

The age of the formation is Late Ordovician or Cincinnatian from the presence of Streptelasma (Beus, 1963, p. 24). No fossils were collected from this formation; however, what appeared to be remnants of brachiopods were seen throughout the formation.

Silurian System

Laketown Formation

The Laketown Formation is the only formation representative of the Silurian System. It is middle Silurian or Niagaran, but there is no noticeable hiatus between the Laketown Formation and underlying Fish Haven Dolomite and overlying Water Canyon Formation (Williams, 1948, p. 1137-1138). The formation was named by Richardson (1913, p. 410) from exposures in Laketown Canyon, 4 miles southeast of Laketown, Randolph quadrangle, Utah. Richardson measured 1,000 feet of "massive light gray to whitish dolomite" that "contain lenses of calcareous sandstone." Williams (1948, p. 1137) measured 1,500 feet of light- to dark-gray, massive, crystalline dolomite in the Logan Peak syncline. Williams described four units in the Laketown Formation: (1) a lower light-gray dolomite, (2) a dark-gray dolomite, (3) a light-gray dolomite, and (4) an upper light-gray dolomite. Contrary to this, Oriel (1964) included only the upper two light-gray dolomite units in the Laketown, and the lower two units he placed in the Fish Haven Dolomite. Oriel (1964) measured 1,040 feet of the Laketown Formation in the Bancroft quadrangle, Idaho. Hanson (1949, p. 48-49) measured 2,000 feet in the southern Malad Range. Beus (1963, p. 24) measured 1,240 feet of massive, fine- to coarse-crystalline dolomite in the central Blue Spring Hills west of the mapped area. Beus placed an arbitrary contact between the Fish Haven and Laketown based on the presence of a Streptelasma, an Ordovician fossil, in the lower 310 feet of the unit. There exists 130 feet of medium-gray dolomite that Beus neither assigns to the Ordovician nor the Silurian (Beus, 1963, p. 24). In the mapped area a total thickness of 690 feet was

measured. Three units of the Laketown Formation were recognized based on Williams' delineation (1948, p. 1137): (1) 115 feet of dark-gray to black, medium- to coarse-gradined, medium- to thick-bedded dolomite with alternating dark-gray bands and light-gray bands, (2) 350 feet light-gray to brown, medium- to thick-bedded, coarse-grained dolomite, and (3) 225 feet of light-gray, medium- to massive-bedded, coarse-grained dolomite. Chert is found throughout the formation and ranges in color from black to white. The formation weathers into distinct pinnacles that are characteristic of the Laketown Formation.

The upper contact is placed below the white-weathering, aphanitic to fine-crystalline, thin- to medium-bedded dolomite of the Water Canyon Formation. The lower contact, where found, is placed above the first dark-gray dolomite in the section and below the first light-gray dolomite.

The writer collected the following fossils from the formation:

Favosites sp.

Halysites sp.

Rugose corals

Crinoid columnals

Devonian System

General statement

Two formations of the Devonian System are represented in the mapped area. These are the lower Water Canyon Formation and the upper Jefferson Formation. The former was named by Williams (1948, p. 1138), and the latter was defined by Peale (1893) from Three Forks, Montana. A total thickness of 2,203 feet for both units was

measured by Williams (1948, p. 1139-1140) and 2,516 by Beus (1963, p. 16). In the mapped area, a thickness of 696 feet was measured for both units. Only the lower member, the Hyrum Member, of the Jefferson Formation was recognized.

Water Canyon Formation

The Water Canyon Formation was named by Williams (1948, p. 1138) from a tributary in Green Canyon, Logan quadrangle, Utah. Williams described two members: (1) a lower thin-bedded, fine-grained, light-gray dolomite, 393 feet thick, and (2) an upper 150 feet of brown and purple sandstone and sandy dolomite containing fish fossils. Hanson (1949, p. 52) described an outcrop of the Water Canyon Formation half mile south of Bear River Narrows as "thin-bedded silty dolomite containing scattered fish plates." Beus (1963, p. 26-27) measured 455 feet of aphanitic and silty dolomite resting paraconformably on the Laketown Formation. Beus did not recognize the two members superimposed as defined by Williams and therefore suggested a facies change (Beus, 1963, p. 27). Taylor (1963, p. 8) proposed that the lower member be called the Card Member from its occurrence 6.8 miles from the mouth of Logan Canyon and the upper member be called the Grassy Flat Member from its occurrance 1.7 miles east of the mouth of Logan Canyon. Taylor differentiated these two members on the basis of differential weathering, weathering color, percentage of insoluble residue, and the presence of sand-size quartz grains (Taylor, 1963, p. 8).

In the mapped area, the writer measured 250 feet of dolomite, limestone, and intraformational breccia. The dolomite is thin to

medium bedded, aphanitic to fine grained, and it weathers light gray to white. A brown calaceous sandstone is present in the area but was not measured due to the fact that it was in fault juxtaposition with the Laketown Formation and only a thin veneer was recognized. The dolomite displays many laminations from one-eighth to half inch in thickness and many small fractures. The dolomite is easily recognizable by the white weathered appearance as contrasted to the underlying Laketown Formation and overlying Jefferson Formation. The limestone is lithographic to fine grained, thin bedded, medium gray, and it forms ledges from 2 to 3 feet high. Calcite veins are prominent. The upper contact between the Water Canyon and the Jefferson Formation is placed above a bed of intraformational breccia following Taylor (1963, p. 5). The lower contact between the Water Canyon Formation and the Laketown Formation is placed above a massive-bedded, coarse-grained, light-gray dolomite of the Laketown Formation and below a thin- to medium-bedded, aphanitic to fine-grained, white dolomite of the Water Canyon Formation.

The age of Water Canyon is Early Devonian. Branson and Mehl (1931, p. 530) recognized two Early Devonian fish genera, Glossoidaspis and Protaspis. Bryant (1933, p. 287) found Cardipeltis in the Beartooth Butte Formation of Montana and compared this with the Water Canyon fauna. Williams (1948, p. 1138) cited an Early Devonian, Ulsterian, age, and Taylor (1963, p. 35) indicated an Early Devonian age from its stratigraphic position and its correlative with the Sevy Dolomite of Nevada.

The Water Canyon Formation is correlated with the Sevy Dolomite of Nevada on fossil content (Osmond, 1962, p. 2049) and on lithologic

similarities and stratigraphic position (Taylor, 1963, p. 35). Taylor further correlated the Water Canyon with the Beartooth Butte Formation of Wyoming and southwest Montana on the basis of "similar plant fossils and similar fish fossils" (Taylor, 1963, p. 36).

The environment of deposition varied for the two members of the formation. A shallow marine environment, with transgressing sea, is considered for the lower Card Member because of the "graded nature of the laminae" and the occurrence of mud cracks (Taylor, 1963, p. 38; Williams and Taylor, 1964, p. 43). The overlying Grassy Flat Member is also a shallow marine environment, but with a regressing sea (Williams and Taylor, 1964, p. 43). Taylor (1963, p. 38) indicated that the presence of Lingula, mud cracks, and oscillation ripple marks indicate this type of environment. Taylor believed that the presence of highly fragmented fish fossils indicates a fresh-water environment for the fish fauna with subsequent transport after death to a marine environment (Taylor, 1963, p. 39). Williams and Taylor (1964, p. 42) modified this by the statement that fragmentation could be "accomplished in shallow marine waters," thus they rejected a fresh-water origin. No fossilized fish fragments were recognized.

Jefferson Formation

The Jefferson Formation was originally named by Peale (1893, p. 26-27) from exposures in the vicinity of Three Forks, Montana. Williams (1948, p. 1139) recognized two members of the Jefferson Formation in the Logan quadrangle. The lower member, the Hyrum Dolomite, is composed of limestone and dolomite and was named from the town of Hyrum at the mouth of Blacksmith Fork Canyon. The upper

member, the Beirdneau Sandstone, is a light-gray orthoquartzite and sandstone that was named from exposures at Beirdneau Peak. Beus (1963, p. 31-34) divided the Hyrum Member into three units: (1) the lower Hyrum Dolomite which is limestone and dolomite, (2) the Sarmaria Limestone, which is characterized by the genus Atrypa, and (3) the upper Hyrum Member which is dolomite and limestone. Beus measured 1,308 feet of the Hyrum Dolomite Member and 753 feet of the Beirdneau Sandstone Member.

In the mapped area, only the Hyrum Dolomite member is recognized. The total thickness of the exposed section is 446 feet of limestone. Three units, as described by Beus, were recognized: (1) 62 feet of light- to medium-gray, aphanitic to fine-grained, medium- to thick-bedded limestone that forms small ledges from 2 to 5 feet, (2) the Sarmaria Limestone which is bluish gray, aphantic to fine grained, medium to thick bedded and forms rough, blockly cliffs, and (3) 217 feet of dark-gray, slope-forming, fine-grained, medium- to thick-bedded limestone. The Sarmaria Limestone is characterized by the abundance of the genus Atrypa. The contact between the underlying Water Canyon Formation and the Jefferson Formation is disconformable (Williams, 1948, p. 1140). In the mapped area, the lower contact is placed above a bed of intraformational breccia of the Water Canyon Formation and below a light- to medium-gray, medium- to thick-bedded, aphanitic to fine-grained limestone of the Jefferson Formation. The upper contact was not observed in the mapped area.

The age of the Jefferson Formation is in part Middle Devonian and Late Devonian. Beus placed part of the Jefferson Formation in the Middle Devonian from the presence of Emannella and Ambothyris

and the rest in the upper Devonian based on the correlative with strata containing Allamaria engelmanni in the Devil's Gate Limestone (Beus, 1965, p. 23). Nolan, Merriam, and Williams (1956, p. 51) placed the Upper Devonian contact in the Devil's Gate Limestone at the base of the "Spirifer" argentarius zone which encompasses strata containing Allamaria engelmanni.

Beus (1965, p. 24) correlated the Jefferson Formation with the Allamaria allani fauna of the Water Ways Formation in Alberta and "with fauna associated with Allanaria engelmanni in the lower "Spirifer" argentarius zone of the Devil's Gate Limestone of Nevada." Williams (1948, p. 1140) stated that the Beirdneau "may be the taxonomic equivalent of the Three Forks Shales and Limestone" of Montana.

The Jefferson Formation thins from 1,108 feet (Williams, 1948, p. 1139) at Beirdneau Peak trail south until it is completely absent from the east wall in Mantua Valley where the Madison Limestone of Williams, now considered Lodgepole, rests directly on the Laketown Formation. The Jefferson Formation is not present at Dry Lake and only 200 feet is recognized on the west side of Wellsville Mountain. Williams (1948, p. 1141), therefore, suggested an unconformity between the Jefferson and Lodgepole although no angular discordance is recognized.

Fossils collected from the Jefferson:

Coral

Thamnopora

Brachiopod

Atrypa sp.

Tertiary System

Wasatch Formation

The Wasatch Formation was defined by Hayden in 1870 (p. 147). Veatch (1907, p. 87-96) divided the Wasatch Group into three formations: the lower Almy, Fowkes, and Knight. Williams (1948, p. 1144-1147) recognized one member in the Logan quadrangle, the Cowley Canyon Member. Williams defined 83 feet on the east side of Cowley Canyon as a "red pebble conglomerate with sparse boulders of white quartzite" and stromatolitic, pisolitic, and algal limestone. Tracy and Oriel (1959, p. 130) stated that Veatch's original formational designations are incongruous for the Almy and Knight because an "explicit statement as to their meaning" was not defined and outside the type area the Fowkes is found to overlie the Knight, a relation reverse to the original definition of Veatch.

In the mapped area sparse outcrops of the Wasatch Formation appear throughout the range resting on Poleozoic rocks. At the eastern end of the Two Mile Canyon the Wasatch lies in fault contact with the Blacksmith Formation and the Nounan Formation. The conglomerate has been completely disintegrated; however, the formation is readily defined by the presence of a red soil with angular quartzite boulders and limestone boulders throughout. In the southern part of the mapped area, the Wasatch is well defined by the presence of a red conglomerate. At this location a small fault has placed the Wasatch and Laketown Formations in juxtaposition. The basal Cowley Canyon Member was not recognized in the mapped area.

Hanson (1949, p. 89) defined the Wasatch Formation as being deposited on an eroded surface. Beus (1963, p. 134) stated that the

Wasatch Formation was deposited as a consequence of erosion from uplift areas of sands and gravels. Williams (1948, p. 1145) concluded that the Wasatch "lies upon the Paleozoic rocks as initial Wasatch deposits" and difference in altitude of the present outcrops are measures of post-Wasatch deformation. The Cowley Canyon Member may be synchronous with the Flagstaff since both were deposited at the same time in fresh-water lakes and also with the Almy as defined by Veatch (Williams, 1948, p. 1144-1146). The age of the Wasatch Formation is Paleocene or Lower Eocene in the mapped area (Williams, 1948, p. 1147).

Salt Lake Formation

The Salt Lake Formation was originally described and defined by Hayden (1869, p. 192) from beds occurring in Salt Lake and Weber Valleys. Peale (1877, p. 603) recognized similar rocks in Cache Valley. Williams (Smith, 1953, p. 73-75) divided the Salt Lake Group into three formations: the basal Collinston Conglomerate, the West Spring Formation, and the Cache Valley Formation. Williams defined the former as being in part upper Miocene and lower Pliocene and the latter as being middle and upper Pliocene. Keller (1952, p. 13) defined and named one formation, the Mink Creek Formation, from exposures in northern Cache Valley. This, Keller defined as being composed of two members: (1) a lower tuff member, and (2) an upper conglomerate member. Adamson, et al. (1955) redefined the Salt Lake Group as being upper Miocene and Pliocene and having three formation: the Collinston Conglomerate, the Cache Valley Formation which includes the West Spring Formation that was previously defined by Williams, and the Mink Creek Conglomerate. Recent work completed by Williams

(1962, p. 133) redefined the Salt Lake Group as a formation as follows: (1) a lower conglomerate member, (2) a tuff unit, and (3) an upper conglomerate and sandstone unit. Within the upper conglomerate and sandstone unit, Williams defined four facies: a fanglomerate, a conglomerate, tuff and tuffaceous sandstone, and oolitic limestone.

The age of the Salt Lake Formation has been disputed to whether it is Middle Tertiary or Late Tertiary. Eardley (1944, p. 845-846) dated the Salt Lake Formation as Oligocene from the presence of terrestrial vertebrate fossils in the Norwood Tuff. Mansfield (1929, p. 110) contended that it is Pliocene. Yen (1947, p. 272) stated that, from mollusks and ostracods collected in norhtern Utah, the age is Pliocene. Brown (1949, p. 224) used plant remains, fish bones, mollusks, and bird feathers, collected by Williams from the Salt Lake Formation, to define the formation as Pliocene.

In the mapped area the Salt Lake Formation crops out in the eastern part of the range. The lithology of the formation is a light-gray to white limestone, brown, thick-bedded, porous sandstone, and green, thin-bedded shales. The Salt Lake Formation lies in fault contact with the older Paleozoic rocks. The thickness of the unit could not be obtained; however, in the southern part of the range, north of the Utah border, Wach (1966, personnal communication) measured 902 feet of medium- to massive-bedded tuffaceous limestone, sandstone, and conglomerate of the Salt Lake Formation.

The environment of deposition has been defined by Swain (1947, p. 518) as lacustrine or paludal from the presence of the ostracod species Candona and Cypridopsis, which are restricted to quiet water.

Yen (1944, p. 269) stated that the molluscan fauna is of a lacustrine environment and that continued faulting explains the great thicknesses present in the area.

The Salt Lake Formation is correlated with the Payette Formation of Idaho and the middle and upper members of the Humbolt Formation of Nevada (Smith, 1953, p. 76). No fossils were collected in the mapped area.

Boulders

In the mapped area, boulders as much as sixty feet in diameter are found lying on the surface of Paleozoic rocks. The most prevalent and conspicous of these are found 2 miles east of Cherry Creek at the southern boundary of the area. These were derived locally from the Swan Peak Formation and are scattered at random. Immediately south of the area, well-developed stone stripes are displayed.

These boulders have been interpreted as being Tertiary and Quaternary. Lofgren (1955, p. 83) found boulders, forming trains, resting on the Salt Lake Formation in Ogden Valley. He considered the boulders to be Quaternary in age. Hanson (1949, p. 60) and Prammani (1957, p. 38) found poorly sorted but well-rounded pebbles, cobbles, and boulders capping the "relatively dissected pediments" of the southern Malad Range (Hanson, 1949, p. 60). Both authors considered these gravel deposits to be Tertiary in age. Murdock (1961, p. 37) remained uncommitted and asserted that separate deposits should be interpreted separately. He concluded, nevertheless, that the boulders found in the Weston Canyon area are Quatenary and were derived from the Swan Peak Formation (Murdock, 1961, p. 36).

The writer asserts that the boulders are more probably Tertiary. Assignment to the Quatenary would not explain the relative distance of travel from the source area nor the position in which these are presently found. Hanson (1949, p. 60) believed that the source area must have been higher and to the west. However, the writer has found an adequate and more likely source in the immediate area, to the west but lower. If derived from the lower-lying outcrop, the present position of these boulders must have resulted from the faulting known to have occurred in Late Tertiary times and the time of deposition must have preceded faulting.

Quaternary System

General statement

In the mapped area, the writer recognized two Quaternary deposits. Sediments of the Lake Bonneville Group are found along the western margin of the range, and alluvium occurs along streams and in the lowlands at higher elevations.

Lake Bonneville Group

The sediments of the Lake Bonneville Group of Pleistocene age occur along the western margin of the range below an elevation of 5,135 feet. The unit is well represented in the well-dissected terraces and deltas that border the range and that are preserved at the mouths of Two Mile Canyon and Four Mile Canyon, respectively. The sediments generally are well-sorted sands, gravels, and boulders. Reworked Salt Lake rocks are evident from the white calcareous silt- and sand-sized particles in the basins and along

the mountain fronts. The small delta at the mouth of Four Mile Canyon, sec. 14, T. 15S., R. 36E., shows poorly sorted material that may have resulted from several surges of the river once emanating from the canyon.

Alluvium

Alluvium is found at higher elevations throughout the range. Well-sorted cobble-, pebble-, and sand-sized material from Paleozoic formations are conspicuously exposed along some of the major streams. Reworked Salt Lake deposits veneer higher cultivated fields and are characterized by silty and sandy material. Dispersed throughout these areas are cobble-sized and boulder-sized material from Paleozoic formations that were carried into place by streams once more active.

STRUCTURAL GEOLOGY

General Statement

The northern part of the Malad Range has a prevailing strike of N. 10° W. and a dip of 25° NE. Hanson (1949, p. 78), who worked in the southern Malad Range, Utah, believed that the range is part of the "eastern limb of a Laramide anticline." The north-south-trending fault, which borders the range on the west, is the northern extension of the well-known Wasatch fault.

Faults in the mapped area are extremely abundant. Four major fault trends are recognized as follows: east-west, northeast, northwest, and north-south. The first three are a consequence of northeast-southwest compressional forces during middle and late Mesozoic and early Tertiary time (Oriel and Armstrong, 1966, p. 2620); whereas, the latter is a consequence of Basin and Range block faulting of middle and late Tertiary age (Williams, 1948, p. 1160).

Faults

East-west-trending faults

Two well-defined east-west-trending faults are present in the mapped area. One is located east of Malad City in sec. 23, T. 14 S., R. 36 E. The Garden City Formation on the north has been placed in juxtaposition with the Bloomington Formation on the south. A marked contrast in topographic expression across the fault is evident. The Garden City Formation on the north forms cliffs; whereas, the

Bloomington Formation on the south forms smooth low hills. Features such as gouge, slickensides, and drag are not evident. The stratigraphic displacement is approximately 3,000 feet.

The second major east-west fault is located immediately south of Four Mile Canyon. In the western margin of the range, sec. 13, T. 15 S., R. 36 E., the Garden City and Swan Peak Formations, on the south, are in juxtaposition with the Nounan and St. Charles Formations on the north. At this place the stratigraphic displacement is approximately 2,500 feet. Eastward along the fault in sec. 18, T. 15 S., R. 37 E., the Laketown Formation on the south has been placed in juxtaposition with the Garden City and Swan Peak Formations on the north. The stratigraphic displacement at this place is 1,000 feet. Drag is present along the fault. Vertical slickensides are found on the quartzite of the Swan Peak Formation.

Northeast-trending faults

One major northeast-trending fault of the mapped area is located in Two Mile Canyon. Vertical movement on this fault is evidenced from vertical slickensides on the Brigham Formation. The south side of the fault is down relative to the north side. At the entrance to Two Mile Canyon, the Blacksmith Formation, on the south, was dropped relative to the Brigham Formation on the north. Immediately east of the entrance, in sec. 35 and 36, T. 14 S., R. 36 E., the Ute Formation on the south was dropped relative to the Brigham Formation on the north. A lesser fault, which joins the major fault (Plate 1), has placed the Blacksmith Formation on the south in juxtaposition with the Ute Formation on the north. Eastward in sec. 25 and 26, T. 14 S., R. 36 E., along the major fault, the Nounan Formation on the south

is in juxtaposition with the Blacksmith Formation on the north. Excellent drag and gouge was observed. In sec. 25, T. 14 S., R. 36 E., (Figure 4), a prominent fault scarp is shown on the Blacksmith Formation resulting from this northeast-trending fault. The stratigraphic displacement along the fault is approximately 2,000 feet.

Northwest-trending faults

A major northwest-trending fault is located southwest of Cherry Creek in sec. 25, T. 15 S., R. 36 E. Horizontal movement is well established by excellently preserved horizontal slickensides on the Laketown Formation. The amount of strike-slip displacement was not ascertained but, from local stratigraphic evidence, it was slight. Later vertical movement followed the initial strike-slip movement. The upper white cherty unit of the Laketown Formation was placed in juxtaposition with the lower limestone member of the Garden City Formation on the southwest. The writer believes that gouge along the fault is evidence of later vertical movement for the initial slickensided surfaces appear to be erased in many places along the fault.

The fault could not be followed toward the southeast because it extends beneath Tertiary boulders; it could not be followed toward the northwest because it was lost, either as the result of truncation by a north-south-trending fault, or as the result of a cover by the Lake Bonneville Group. The stratigraphic displacement on the fault is at least 2,000 feet.

North-south-trending faults

North-south-trending faults are more common than those previously mentioned. Most of the north-south faults have the downthrown

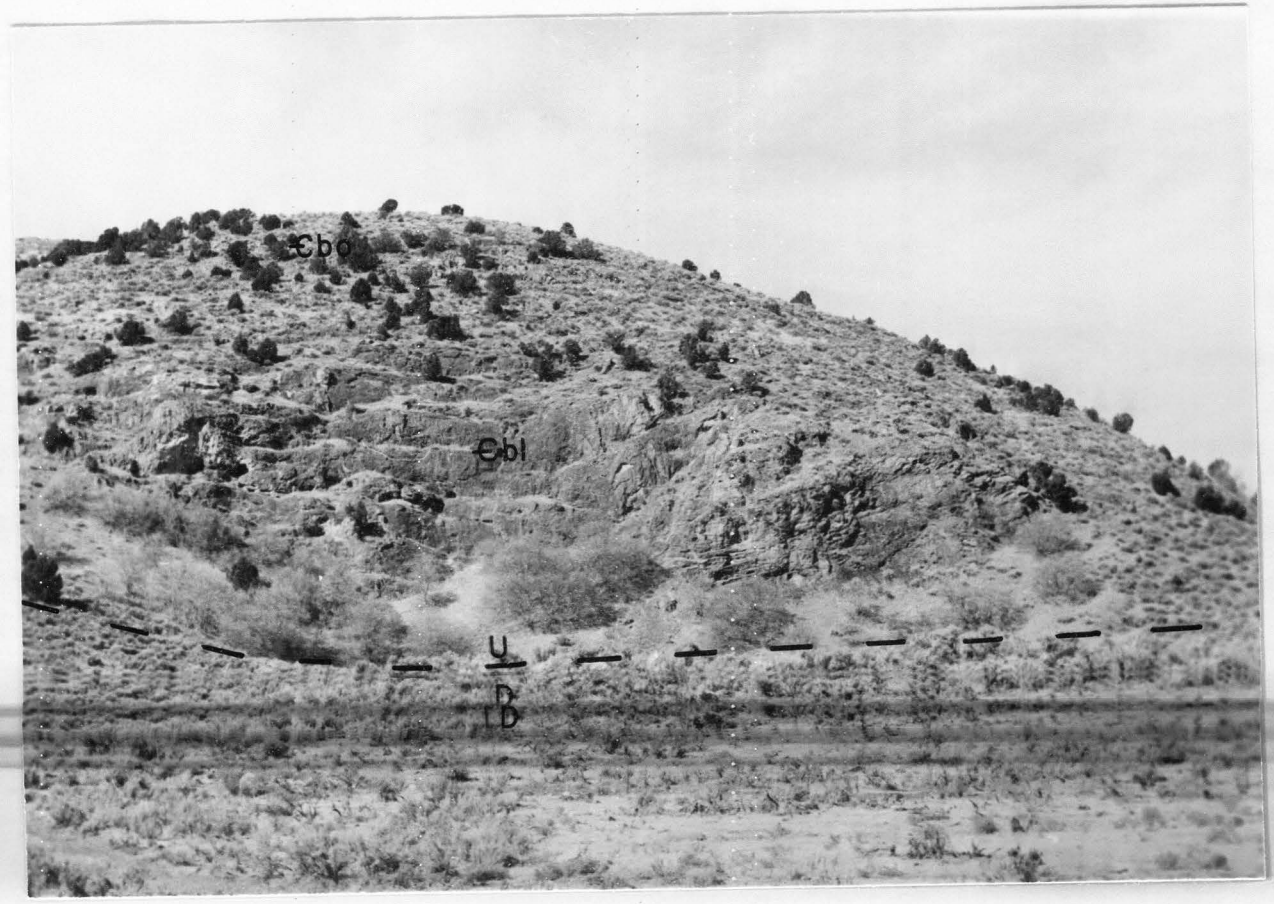


Figure 4. Fault scarp on the Blacksmith Formation on the northside of Two Mile Canyon, sec. 25, T. 14 S., R. 36 E., view northeast.

block on the west side; however, a few show the opposite relationship.

The frontal fault along the west side of the range is concealed by the Lake Bonneville Group and the exact location was not determined relative to the mountain front. Evidence for this fault is quite apparent. South of Two Mile Canyon, in sec. 11, T. 15 S., R. 36 E., an excellent fault scarp is present on the Blacksmith Formation. Northeast of Malad City in sec. 22, T. 14 S., R. 36 E. (Figure 5), gouge is well displayed on the Swan Peak Formation. The west side of the fault is thought to be down relative to the east side; however, the amount of stratigraphic displacement is not known. The frontal fault is the Wasatch fault or a fault of the Wasatch fault zone.

A second major north-south fault, along the east side of the range, has dropped the Salt Lake Formation on the east into juxtaposition with resistant Paleozoic rocks on the west. A marked change in dip of the beds is noted in sec. 25, T. 14 S., R. 36 E. as the plane of the fault is crossed. The faulting post-dates the deposition of the Salt Lake Formation. The writer does not believe the the Salt Lake Formation was deposited upon an older fault scarp as, in part, Hanson (1949, p. 49) postulated.

A third major north-south fault of major significance occurs in sec. 13, 24 and 25, T. 15 S., R. 36 E., about 1 mile northeast of Cherry Creek. The Laketown Formation on the east has been dropped relative to the Swan Peak Formation on the west. The stratigraphic displacement is not in excess of 500 feet. An excellent brecciated zone is well preserved on the quartzite of the Swan Peak Formation.

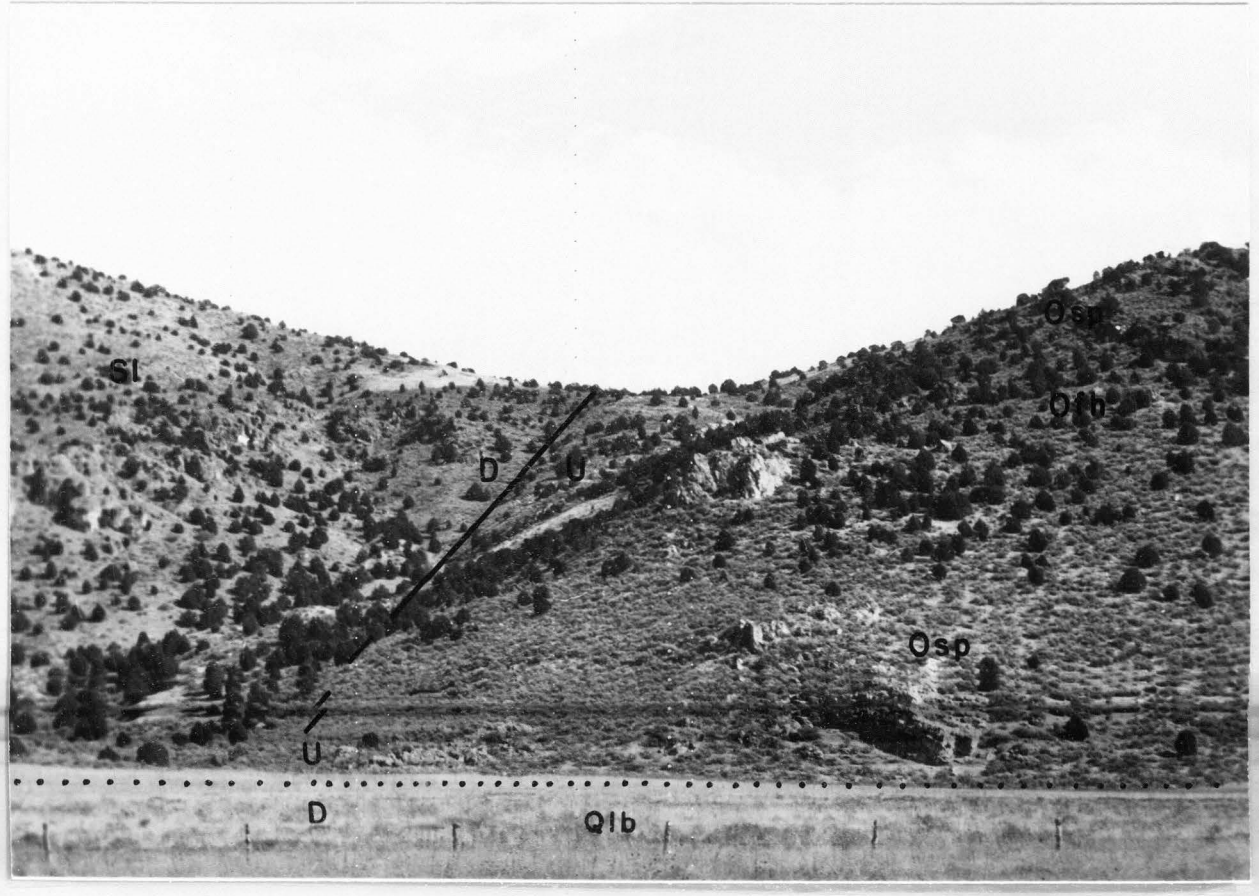


Figure 5. Swan Peak Formation, Fish Haven Dolomite, and Laketown Formation, sec. 23, T. 14 S., R. 36 E., view east.

Age of Structures

The structures of the northern part of the Malad Range formed during the Laramide orogeny and Basin and Range block faulting. The east-west-trending faults, northeast-trending faults, and northwest-trending faults formed as the result of compressional forces during Laramide orogenic activity. Oriel and Armstrong (1966, p. 2620) gave a more precise date for Laramide structures as middle and late Mesozic and early Tertiary. They believe (Armstrong and Oriel, 1965, p. 1863) that east-west-trending faults and northeast-trending faults in the Bear River Range, Utah, may be tear faults resulting from thrusting. Williams (1948, p. 1144) attributed tear faulting in Wellsville Mountain, the northern end of the Wasatch Range to Laramide deformation. Armstrong and Cressman (1963, p. 20) believed that east-west-trending faults and northeast-trending faults are a consequence of Laramide orogenic events and that northwest-trending faults in the area are a consequence of Pliocene block faulting. In close proximity to the mapped area, Murdock (1961, p. 49) reported a thrust fault in the Bannock Range with movement to the west. Beus (1963, p. 120) reported a thrust fault, with movement to the east, of Pennsylvanian rocks over Permain rocks near the northwest corner of Samaria Mountain, Blue Spring Hills, west of the mapped area. Both writers attributed thrust faulting to Laramide orogenic activity.

The writer believes that in the mapped area the three faults mentioned above had initial horizontal movement equaling the width of the range, about 2 miles, during Laramide orogenic activity. Vertical movement, which preceded the deposition of the Salt Lake

Formation, followed horizontal movement for the writer was unable to trace these faults into the Salt Lake Formation.

The north-south vertical faults in the mapped area are associated with Basin and Range faulting. Williams (1948, p. 1153) defined Basin and Range structures as "high-angle faults of essentially N.-S. trend that cut the Wasatch and Salt Lake groups." The topography of the area is controlled by Basin and Range faults (Williams, 1948, p. 1153). The frontal fault, the northern extension of the Wasatch fault, was active during mid-Tertiary time (Eardley, 1944, p. 885) and movement continued through Salt Lake deposition (Williams, 1948, p. 1153).

The writer believes that a few north-south-trending faults in the mapped area are post-Salt Lake Formation or Pliocene in age. The major north-south-trending fault along the eastern part of the range has dropped the Salt Lake Formation into juxtaposition with older Paleozoic rocks. No evidence to suggest deposition on an older fault scarp was found. Hanson (1949, p. 58), in the southern Malad Range, Utah, found this same relationship.

LITERATURE CITED

Adamson, Robert D., Clyde T. Hardy, and J. Stewart Williams. 1955. Tertiary rocks of Cache Valley, Utah and Idaho. Utah Geol. Soc., Guidebook to the Geology of Utah 10:1-10.

Armstrong, Frank C., and Earle R. Cressman. 1963. The Bannock thrust zone, southeastern Idaho. U. S. Geol. Survey Prof. Paper 374-J.

Armstrong, Frank C., and Steven S. Oriel. 1965. Tectonic development of Idaho-Wyoming thrust belt. Am. Assoc. Petroleum Geologists Bull. 49:1847-1866.

Beus, Stanley Spencer. 1963. Geology of the central Blue Spring Hills, Utah-Idaho. Unpublished PhD dissertation. University of California Library, Los Angeles.

Beus, Stanley Spencer. 1965. Devonian faunal from the Jefferson Formation, central Blue Spring Hills, Utah-Idaho, J. Paleontology 39:21.

Bradley, F. H. 1873. Report of the Snake River Region. United States Geological Survey of the Territories. (Hayden) 6th Ann. Report. p. 189-271.

Branson, E. B., and M. G. Mehl. 1931. Fishes of the Jefferson Formation of Utah. J. Geology 39:509-531.

Brown, Roland W. 1949. Pliocene plants from Cache Valley, Utah. Washington Acad. Sci. J. 39:224-229.

Bryant, W. L. 1932. The fish fauna of Bear Tooth Butte, Wyoming. Am. Philos. Soc. Proc. 72:285-314.

Coulter, Henry W. 1955. Fucoidal markings in the Swan Peak Formation, southeastern Idaho. J. Sedimentary Petrology 25:282-284.

Deiss, Charles. 1938. Cambrian formations and sections in part of the Cordilleran trough. Geol. Soc. America Bull. 49:1067-1168.

Denson, Norman. 1942. Late Middle Cambrian trilobite fauna and stratigraphy of Alberta, Montana, Wyoming, and Utah. Unpublished PhD dissertation. Princeton University Library, Princeton.

Eardley, A. J. 1944. Geology of the north-central Wasatch Mountains, Utah. Geol. Soc. America Bull. 55:819-894.

Hanson, Alvin M. 1949. Geology of the southern Malad Range and vicinity in northern Utah. Unpublished PhD dissertation. University of Wisconsin Library, Madison.

Hardy, Clyde T. 1956. Fucoidal markings in the Swan Peak Formation, southeastern Idaho. J. Sedimentary Petrology 26:369.

Hayden, F. V. 1869. Colorado and New Mexico. United States Geological Survey of the Territories. 3rd Ann. Report. p. 103-229.

Hayden, F. V. 1870. Preliminary report of the United States Geological Survey of Wyoming and portions of contiguous Territories. 2nd Ann. Report. p. 147-160.

Hayden, F. V. 1871. Preliminary report of the United States Geological Survey of Montana and portions of adjacent territories. 5th Ann. Report. p. 13-27.

Haynie, Anthon V., Jr. 1957. The Worm Creek Quartzite Member of the St. Chalres Formation, Utah-Idaho. Unpublished MS thesis. Utah State University Library, Logan.

Ingram, Roy L. 1954. Terminology for the thickness of stratification and parting units in sedimentary rocks. Geol. Soc. America Bull. 65:937.

Keller, A. S. 1952. Geology of the Mink Creek region, Idaho. Unpublished MS thesis. University of Utah Library, Salt Lake.

King, Clarence. 1876. Geology of the 40th parallel, Art. 65--Paleozoic subdivisions on the 40th parallel. Am. J. Science, 3rd ser. p. 474-482.

Lochman-Balk, Christina. 1960. The Cambrian section of western Wyoming. Wyoming Geol. Assoc. Guidebook, 15th Ann. Field Conf. p. 99-108.

Lofgren, Ben E. 1955. Resume of the Tertiary and Quaternary stratigraphy of Ogden Valley, Utah. Utah Geol. Soc., Guidebook to the Geology of Utah 10:70-84.

Mansfield, G. B. 1927. Geography, geology, and mineral resources of part of southeastern Idaho. U. S. Geol. Survey Prof. Paper 152.

Maxey, George Burke. 1941. Cambrian stratigraphy in the northern Wasatch region. Unpublished MS thesis. Utah State University Library, Logan.

Maxey, George Burke. 1958. Lower and Middle Cambrian stratigraphy in northern Utah and southeastern Idaho. Geol. Soc. America Bull. 69:647-688.

Murdock, Clair N. 1961. Geology of the Weston Canyon area, Bannock Range, Idaho. Unpublished MS thesis. Utah State University Library, Logan.

McKee, E. D., and G. W. Weir. 1953. Terminology for stratification and cross-stratification in sedimentary rocks. Geol. Soc. America Bull. 64:383.

Nolan, T. B., C. W. Merriam, and J. Stewart Williams. 1956. The stratigraphic section in the vicinity of Eureka, Nevada. U. S. Geol. Survey Prof. Paper 276.

Oriel, Steven S. 1964. Brigham, Langston, and Ute Formations in Portneuf Range, southeastern Idaho (abstract). Geol. Soc. America, Spec. Paper 82:341.

Oriel, Steven S. 1965. Preliminary geologic map of the SW 1/4 of the Bancroft quadrangle, Bannock and Caribou Counties, Idaho. U. S. Geol. Survey Map MF-299.

Oriel, Steven S., and Frank C. Armstrong. 1966. Times of thrusting in Idaho-Wyoming thrust belt (reply). Am. Assoc. Petroleum Geologists Bull. 50:2614.

Osmond, John C. 1962. Stratigraphy of the Devonian Sevy Dolomite in Utah and Nevada. Am. Assoc. Petroleum Geologists Bull. 46: 2033-2054.

Peale, A. C. 1877. Report on the geology of the Green River District. United States Geological Survey of the Territories. (Hayden) 11th Ann. Report. p. 511-643.

Peale, A. C. 1893. The Paleozoic section in the vicinity of Three Forks, Montana. U. S. Geol. Survey Bull. 110:1-38.

Parammani, Prapath. 1957. Geology of the east-central part of the Malad Range, Idaho. Unpublished MS thesis. Utah State University Library, Logan.

Resser, C. E. 1939a. Spence Shale and its fauna. Smithsonian Misc. Coll. 97:1-12.

Resser, C. E. 1939b. The Ptarmigania strata of northern Wasatch Mountains. Smithsonian Misc. Coll. 98:1-72.

Richardson, G. B. 1913. The Paleozoic section in northern Utah. Am. J. Science, 4th ser. p. 406-416.

Richardson, G. B. 1941. Geology and mineral resources of the Randolph quadrangle, Utah-Wyoming. U. S. Geol. Survey Bull. 923.

Ross, Reuben James, Jr. 1951. Stratigraphy of the Garden City Formation in northeastern Utah, and its trilobite faunas. Peabody Mus. Nat. History Bull. 6.

Smith, Neal. 1953. Tertiary stratigraphy of northern Utah and southeastern Idaho. Intermountain Assoc. Petroleum Geologists, Guide to the Geology of northern Utah and southeastern Idaho, 4th Ann. Field Conf. p. 73-77.

Swain, Frederick M. 1947. Tertiary non-marine ostracoda from the Salt Lake Formation, northern Utah. J. Paleontology 21:518-528.

Taylor, Michael E. 1963. The Lower Devonian Water Canyon Formation of northeastern Utah. Unpublished MS thesis. Utah State University Library, Logan.

Tracy, Joshua I., and Steven S. Oriel. 1959. Uppermost Cretaceous and lower Tertiary rocks of the Fossil Basin. Intermountain Assoc. Petroleum Geologists, Guidebook to the Geology of the Wasatch and Uinta Mountains, 10th Ann. Field Conf. p. 126-130.

Veatch, A. C. 1907. Geography and geology of a portion of southwestern Wyoming. U. S. Geol. Survey Prof. Paper 56.

Walcott, C. D. 1908. Nomenclature of some Cambrian Cordilleran formations. Smithsonian Misc. Coll. 53:1-12.

Williams, J. Stewart. 1948. Geology of the Paleozoic rocks of the Logan quadrangle, Utah. Geol. Soc. America Bull. 59:1121-1164.

Williams, J. Stewart. 1962. Lake Bonneville: Geology of southern Cache Valley, Utah. U. S. Geol. Survey Prof. Paper 257-C.

Williams, J. Stewart, and G. B. Maxey. 1941. Cambrian section in the Logan quadrangle, Utah and vicinity. Am. J. Science 239: 276-285.

Williams, J. Stewart, and Michael E. Taylor. 1964. The Lower Devonian Water Canyon Formation of northern Utah. University of Wyoming. Contributions to Geology 3, n. 2, p. 38.

Yen, Teng-Chien. 1947. Pliocene fresh-water mollusks from northern Utah. J. Paleonotology 21:268-277.

APPENDIX

Section No. 1. Brigham Formation, measured on north side of Two Mile Canyon in sec. 36, T. 14 S., R. 36 E. from bottom of canyon to top of a calcareous sandstone unit below Naomi Peak Limestone Member of the Langston Formation.

Langston Formation

Brigham Formation	Thickness (feet)
10. Sandstone, calcareous, medium gray, weathers brown, coarse grained, medium to thick bedded, corss-bedded.	10.0
9. Shale, quartzite, and calcareous sandstone interbedded. Shale, olive green, fine grained, thin bedded, resistant. Quartzite, reddish brown, coarse grained, thin to medium bedded, cross-bedded. Sandstone, calcareous, brown, coarse grained, thin to medium bedded.	103.0
8. Quartzite and shale interbedded. Quartzite, dark gray, weathers dark gray, coarse grained, medium to thick bedded. Shale, olive green, fine grained, thin bedded, forms cliffs.	54.5
7. Quartzite, reddish brown, weathers red, coarse grained, medium bedded, forms ledges 18 in. high.	87.2
6. Quartzite and shale interbedded. Quartzite, reddish brown, weathers brown, coarse grained, medium bedded. Shale, arenaceous, olive green, find grained, thin bedded, 1 to 8 in. thick dispersed throughout, forms cliffs.	112.0
5. Shale, micaceous, olive green, fine grained, thin bedded, alternating beds of reddish-brown quartzite 6 to 36 in. thick, forms cliffs.	79.0
4. Quartzite, dark red, weathers reddish brown, coarse grained, thick to massive bedded, cross-bedded, forms cliffs.	28.0
3. Covered slope.	83.0
2. Quartzite, white, red stains, coarse grained, massive, cross-bedded, forms cliffs.	47.9
1. Covered slope.	52.7
Total	657.3

Section No. 2. Langston Formation, measured on north side of Two Mile Canyon in sec. 36, T. 14 S., R. 36 E. beginning at top of Brigham Formation and terminating at base of a medium-gray, red-weathering, medium-bedded, coarse-crystalline limestone of Ute Formation.

Ute Formation

Langston Formation	Thickness (feet)
3. Limestone and shale interbedded. Limestone, medium gray, weathers dark gray, fine to medium crystalline, thick bedded, forms ledges 12 to 24 in. high. Shale, dark gray, fine grained, thin bedded.	53.2
Spence Shale Member	
2. Shale, dark-gray grading into a light-brown shale at top, fine grained, thin bedded, fissile, forms slopes, abundant trilobites and sponge spicules.	74.8
Naomi Peak Limestone Member	
1. Limestone, dark gray, medium to coarse grained, massive, forms ledges, fossiliferous.	4.5
Total	132.5

Brigham Formation

Section No. 3. Blacksmith Formation, measured on front part of range in sec. 12, T. 15 S., R. 36 E. beginning at first massive limestone above Lake Bonneville Group and terminating at base of an olive-green shale.

Bloomington Formation

Blacksmith Formation	Thickness (feet)
1. Limestone, black, weathers dark gray, red stains near top, aphanitic to fine grained, individual beds are thin to medium, collectively massive, forms cliffs, light-gray and dark-gray banding, oolites common throughout, random calcite veins 1/8 to 1 in. thick.	350.0

Lake Bonneville Group

Section No. 4. Bloomington Formation, measured on south side of Two Mile Canyon in sec. 36, T. 14 S., R. 36 E. from top of Blacksmith Formation to base of Nounan Formation.

Nounan Formation

Bloomington Formation	Thickness (feet)
7. Limestone, dark gray, weathers bluish gray, fine to medium grained, thin bedded, silty shale partings, nonresistant, forms slopes.	26.6
6. Shale and limestone interbedded. Shale, olive green, fine grained, poorly exposed, forms slopes. Limestone, dark gray, weathers light bluish gray, fine to medium grained, thin bedded, forms ledges 12 in. high.	123.0
5. Shale, olive green, fine grained, poorly exposed, forms slopes.	37.0
4. Limestone, shale, and intraformational conglomerate interbedded. Limestone, dark gray, weathers light bluish gray, medium grained, nonresistant, forms ledges 6 in. high. Shale, olive green, fine grained, thin bedded, forms slopes. Intraformational conglomerate, bluish gray, aphanitic, medium bedded.	96.4
3. Shale, olive green, fine grained, poorly exposed, forms slopes, dendrites common.	20.4
2. Limestone and shale interbedded. Limestone, dark gray, weathers medium gray, aphanitic to fine grained, thin bedded, oolitic in part, forms slopes. Shale, olive green, fine grained, beds 12 to 36 in. thick dispersed throughout limestone, forms slopes.	96.4
1. Shale, olive green and red, poorly exposed, forms slopes, dendrites common.	31.6
Total	431.4

Blacksmith Formation

Section No. 5. Nounan Formation, measured on south side of Two Mile Canyon in sec. 36, T. 14 S., R. 36 E. from top of Bloomington Formation to base of Worm Creek Quartzite Member of St. Charles Formation.

St. Charles Formation

Nounan Formation	Thickness (feet)
7. Limestone, dark gray, fine grained, thin bedded, tan-silty partings common.	30.0
6. Limestone, light gray, weathers white, aphanitic to fine grained, thick to massive bedded, forms a distinct white ledge.	45.0
5. Dolomite, sandy, dark gray, weathers medium gray, coarse grained, medium to thick bedded. A 6 ft. bed of dark-gray, coarsed-grained, medium-bedded limestone with tan-silty partings occurs 97 ft. from the base.	170.0
4. Limestone, dark gray, weathers medium gray, aphanitic to fine grained, thin bedded, forms slopes.	19.0
3. Dolomite, sandy, dark gray, weathers medium gray, fine to coarse crystalline, thin to massive bedded, jointed, forms cliffs, oolites present in upper beds, light-gray and dark-gray alternation of beds, micro-faults with less than 2 in. of displacement throughout unit perpendicular to bedding planes.	249.0
2. Limestone, dark gray, weathers medium gray, aphanitic to fine grained, thin to medium bedded, tan-silty partings common, forms 12 in. ledges.	68.0
1. Dolomite, light-gray and dark-gray alternating beds, coarse grained, thick to massive bedded, highly fractured and jointed, forms cliffs.	305.0
Total	

Bloomington Formation

Section No. 6. Composite section of St. Charles Formation. The lower two members were measured south of Two Mile Canyon in sec. 36, T. 14 S., R. 36 E. from top of Nounan Formation to crest of ridge. The upper member was measured in a fault block south of Four Mile Canyon in sec. 13, T. 15 S., R. 36 E. from bottom of canyon to base of Garden City Formation.

Garden City Formation

St. Charles Formation	Thickness (feet)
3. Dolomite, dark gray, weathers medium gray, mottled throughout with light-gray dolomite, medium to coarse grained, medium to thick bedded, black and brown chert nodules in upper part, forms cliffs.	277.0
2. Limestone, medium gray, weathers reddish brown and purple, aphanitic to fine grained, thin to medium bedded, tan and red-silty partings 1 to 3 in. thick, forms blocky cliffs, trilobite thorax and free cheek segments.	342.0
Sorm Creek Quartzite	
1. Quartzite, brown, dark gray and white, weathers brown and medium gray, medium to coarse grained, medium to thick bedded, cross-bedded, forms blocky ledges 12 to 36 in. high.	85.0
Total	704.0

Nounan Formation

Section No. 7. Swan Peak Formation, measured on front of range in sec. 24, T. 15 S., R. 36 E. from top of Garden City Formation to crest of ridge.

Swan Peak Formation	Thickness (feet)
2. Quartzite, white, fine to medium grained, thin to thick bedded, highly jointed, forms cliffs.	97.0
1. Covered slope, may contain the lower shale member.	23.0
Total	120.0

Garden City Formation

Section No. 8. Fish Haven Dolomite, measured in a fault block with Swan Peak Formation in sec. 23, T. 14 S., R. 36 E. from top of Swan Peak Formation to base of Laketown Formation.

Laketown Formation

Fish Haven Dolomite	Thickness (feet)
1. Dolomite, dark gray, weathers dark brown, fine to medium grained, crystalline, thick to massive bedded, black and brown-colored chert nodules and stringers, fetid, forms ledges.	57.0

Swan Peak Formation

Section No. 9. Laketown Formation, measured approximately 1 3/4 miles northeast of Cherry Creek in sec. 24, T. 15 S., R. 36 E. from bottom of canyon to top of ridge.

Laketown Formation	Thickness (feet)
3. Dolomite, light gray, medium to coarse grained, crystalline, sucrose, thin to massive bedded, forms cliffs, fetid, crinoid columnals, Halysites sp.	225.0
2. Dolomite, light gray and brown, medium to coarse grained, crystalline, sucrose, medium to thick bedded, forms cliffs, fetid, crinoid stems and columnals.	350.0
1. Dolomite, dark gray, black on weathered surfaces, medium to coarse grained, crystalline, medium to thick bedded, forms slopes, fetid, alternating dark-gray and light-gray bands 1 to 18 in. thick, black and brown chert nodules.	115.0
Total	690.0

Section No. 10. Water Canyon Formation, measured in sec. 24, T. 24 S., R. 36 E. approximately 2 miles northeast of Cherry Creek from bottom of canyon to base of Jefferson Formation.

Jefferson Formation

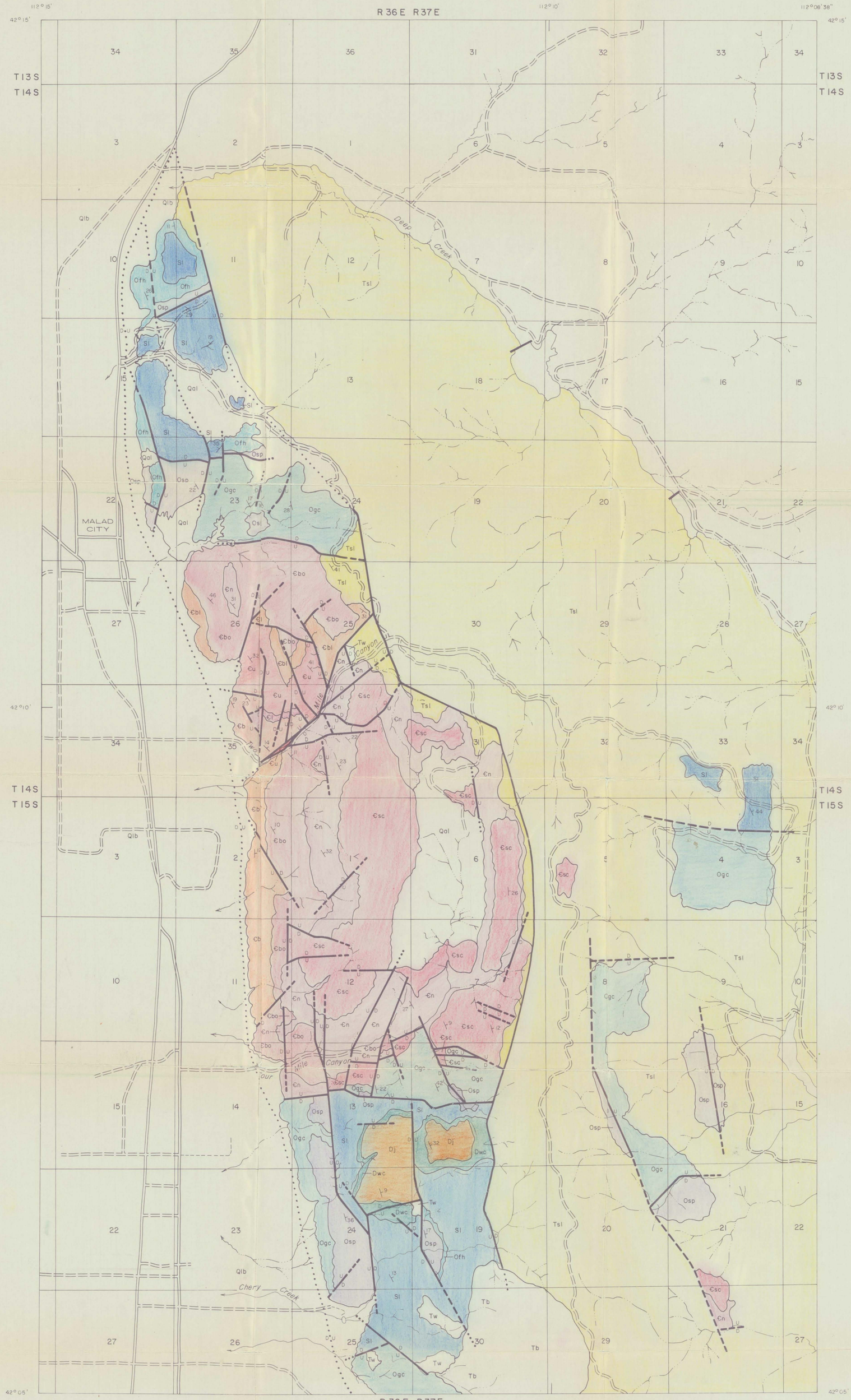
Water Canyon Formation	Thickness (feet)
3. Limestone breccia, medium gray, weathers reddish brown and purple, aphanitic to fine grained, thin bedded, particles angular to subangular, forms slopes 0.5 to 18 in. high.	15.0
2. Limestone, light gray, weathers reddish brown, aphanitic to fine grained, thin bedded, forms ledges 24 to 36 in. high, calcite veins prominent.	33.0
1. Dolomite, light gray to bluish gray, weathers white to light gray, aphanitic to fine grained, thin bedded, laminations 1/8 to 1/2 in. thick, forms ledges 2 to 5 ft. high.	202.8
Total	250.8

Section No. 11. Jefferson Formation, measured in sec. 24, T. 15 S., R. 36 E. from top of Water Canyon Formation to top of ridge.

Jefferson Formation - Hyrum Dolomite Member	Thickness (feet)
3. Limestone, dark gray, fine to medium grained, medium to thick bedded, forms ledges 3 to 6 ft. high.	217.0
2. Samaria Limestone. Limestone, dark gray, weathers bluish gray, aphanitic to fine grained, medium to thick bedded, Atrypa common, forms rough-blocky ledges.	167.0
1. Limestone, medium gray, weathers light gray, aphanitic to fine grained, medium to thick bedded, forms ledges 5 ft. high.	62.0
Total	446.0

Water Canyon Formation

PLATE I



EXPLANATION

- **Cenozoic**
  - **Quaternary**
    - Qal — Alluvium
    - Qlb — Lake Bonneville Group
  - **Tertiary**
    - Tb — Boulders
    - Tsl — Salt Lake Formation
    - Tw — Wasatch Formation
- **Paleozoic**
  - **Devonian**
    - Dj — Jefferson Formation, Hyrum Member
    - Dwc — Water Canyon Formation
  - **Silurian**
    - Sl — Laketown Formation
  - **Ordovician**
    - Ofh — Fish Haven Dolomite
    - Osp — Swan Peak Formation
    - Ogc — Garden City Formation
  - **Cambrian**
    - €sc — St. Charles Formation
    - €n — Nounan Formation
    - €bo — Bloomington Formation
    - €bl — Blacksmith Formation
    - €u — Ute Formation
    - €l — Langston Formation
    - €b — Brigham Formation

U / D — Fault
Dashed where approximately located or probable: dotted where concealed

Base taken from a U.S. Forest Service grid of the Caribou National Forest

By Drew C. Axtell 1967

GEOLOGIC MAP OF THE NORTHERN PART OF THE MALAD RANGE, IDAHO

Scale 1:24,000

½ 0 1 MILE

1000 0 1000 2000 3000 4000 5000 FEET