Pamphlet No. 107 March, 1956

GEOLOGY OF THE SOUTHEAST PORTION OF THE PRESTON QUADRANGLE, IDAHO

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FOREWORD

The field study on which this pamphlet is based was done by Dr. Henry W. Coulter as a requirement of advanced academic work at Yale University. The Idaho Bureau of Mines and Geology considers Dr. Coulter's contribution to be of such excellent scope and caliber as to comprise a good addition to the geologic literature of Idaho, and it is believed that the information imparted will be of splendid use to anyone who is concerned with determining the geologic setting of this section of southeastern Idaho.

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INTRODUCTION

PURPOSE OF THE INVESTIGATION

The present investigation was undertaken to determine in so far as possible by geologic mapping and stratigraphic measurements and observations -- the structural and stratigraphic relationships and the lithologic units which constitute that portion of the Bear River Range lying within the southeast portion of the Preston quadrangle, Idaho-Utah.

PREVIOUS WORK

The earliest geologic work in the area was a traverse of the Cache Valley by a Hayden Survey party in 1871 on its way to Yellowstone Park (1872, pp. 18-21). In 1877 the general geology was described by Peale under the Green River division of the Hayden Survey (1879, pp. 598-608). Gilbert (1890) described many features of the Cache Valley incidental to his Great Basin work. In 1941 Williams (1948, p. 1132) measured a section of the Brigham quartzite along Flat Creek on the western flank of the Bear River Range. Portions of the Preston quadrangle were reconnoitered by members of the Yale summer course in geology during the 1946 field season and their reports (Simpson, H. E. and Partridge, S. 1946; Lombardi, C. E. and L. V. 1946; Meyerhoff, A. A., and McDonald, W. 1946) have been made available to the writer.

In 1946 and 1947 Ross measured sections of the Ordovician rocks in Hillyards Canyon on the west flank of the Bear River Range and in St. Charles Canyon on the east flank of the range which are described in his publications on the Garden City formation (1949, 1951). The geology of the adjoining areas has been mapped -- the Logan quadrangle, Utah, to the south (Williams, 1948), the Randolph quadrangle, Utah, to the southeast (Richardson, 1941), and the Montpelier quadrangle, Idaho-Wyoming, to the east (Mansfield, 1927).

THE PRESENT WORK

The field observations described in this report were carried out over a period of five months during the summers of 1950 and 1951. As a base map photographic enlargements (x4) of portions of the U. S. Geological Survey, 1/125000, topographic sheet of the Preston quadrangle were used. Aerial photographs of the western portion of the area were available from the Production and Marketing Administration, Franklin County Project (DHW, U. S. D. A-475-49, Item 1) at a scale of 1/20,000.

With some exceptions noted below in the chapter on stratigraphy, the lithologic units mapped by Williams in the Logan quadrangle to the south could be traced into and recognized throughout the area under study. Parallel traverses across the regional strike were conducted and formation boundaries were delineated on the field maps.

ACKNOWLEDGMENTS

Portions of this report have been submitted in partial fulfillment of the requirements for the doctor of philsophy degree at Yale University, and the writer acknowledges with thanks the assistance of the Department of Geology at Yale, particularly Professor K. M. Waage, Professor M. L. Jensen, and Professor C. R. Longwell, under whose direction the project was carried out. He also thanks Professor J. Stewart Williams of Utah State Agricultural College for his aid in many phases of the work, to Dr. Jean Berdan and Dr. Helen Duncan of the United States Geological Survey for aid in identifying many of the invertebrate fossils, to Mr. J. R. Pierson for his very able assistance in the field, to Mr. Gene Curtis and family of Preston, Idaho, for the many courtesies extended the writer, and to his wife, Rosemary Coulter, for her continuous aid in all phases of the work.

GEOGRAPHY

LOCATION

The area covered by this report comprises that 235 square miles of the southeast portion of the Preston quadrangle, Idaho-Utah, extending from 42^0 00′ N. Lat. to 42^0 12′ N. Lat. and from 111^0 30′ W. Long. to 111^0 50′ W. Long. (Fig. 1). It includes the east central section of Cache Valley and the west central section of the Bear River Range. All the map area lies within Idaho except a small segment at the southern boundary where a slight divergence of the Utah-Idaho border from the 42nd parallel occurs. The northeast portion of the area is in Bear Lake County and the southeast portion in Franklin County, the county line following the Bear River Range divide.

GENERAL GEOGRAPHY

The climate is semi-arid, the average annual rainfall being about 13.5 inches in the valley and up to 30 inches at elevations above 7,000 feet. It is semi-frigid, the mean annual temperature being about 41^0 F. Temperature variations, both diurnal and seasonal, are large.

The central portion of the Bear River Range lies within the Cache National Forest. The forest administration supervises extensive lumber and grazing enterprises within the highland area. Agriculture is the predominant occupation in the Cache Valley, including irrigation farming in the lower portions and dry farming and grazing on the bordering slopes.

TOPOGRAPHY

Fenneman's (1928, p. 334) boundary between the Basin and Range province and the Middle Rocky Mountain province follows the Bear River valley west of the area here studied, and is so located as "to leave to the west all Quaternary filled basins so highly characteristic of the Great Basin." On Fenneman's later map (Fenneman, 1931, in pocket)

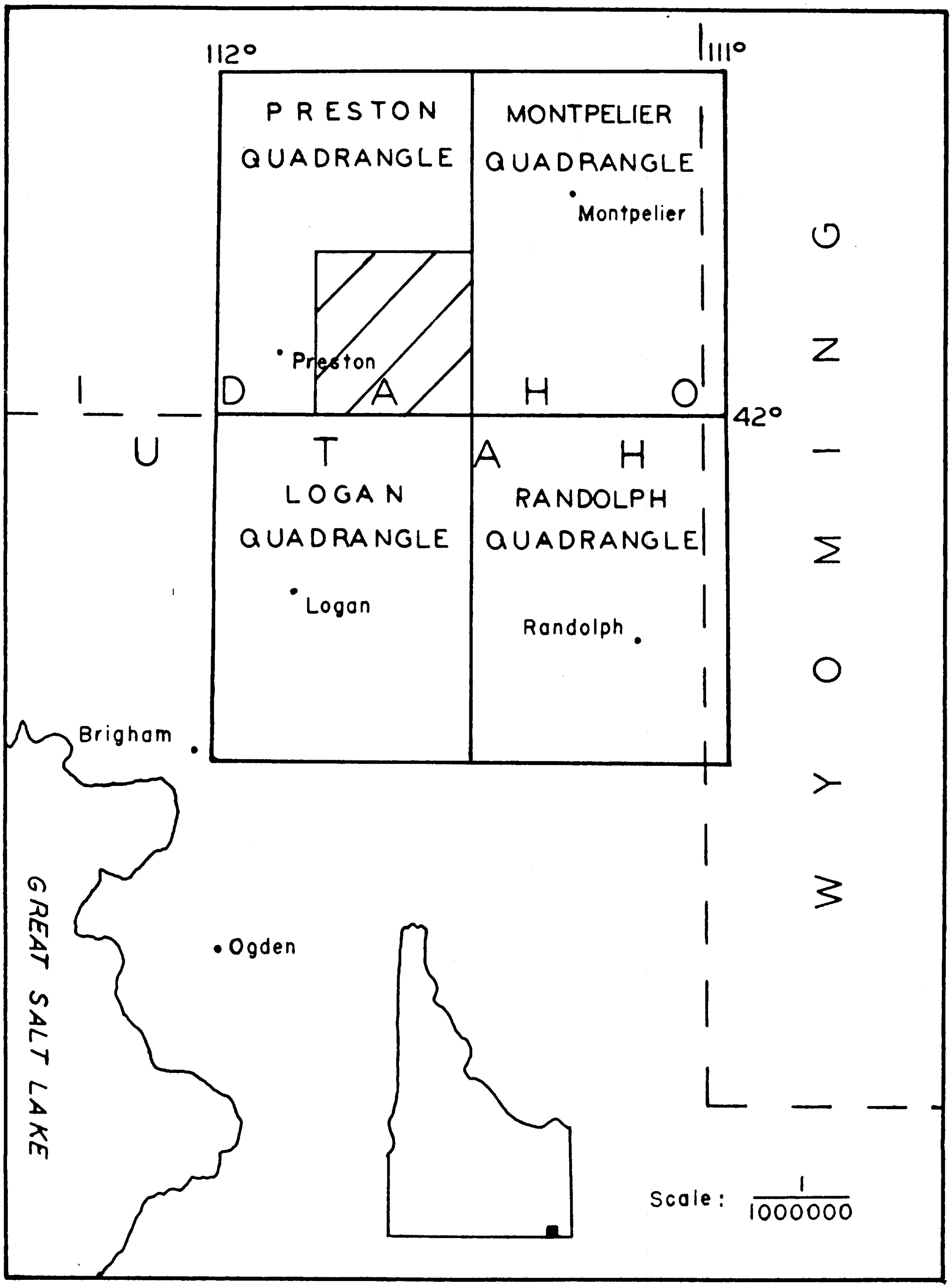


Figure 1.— Index Map

the boundary has been redrawn along the East Cache fault (Williams 1948, p. 1154). Nolan has apparently included the Wasatch Range and the Utah portion of the Bear River Range in the Basin and Range province on his map (Nolan, 1943, Fig. 10) although in his description he notes that ". . . the eastern boundary (is) made up by western borders of the Wasatch Range and the Colorado Plateau."

The essential criteria for the Basin and Range province are individual subparallel ranges bordered by alluvium-filled structural valleys. On this basis it is believed that a northward continuation of Nolan's map boundary along the Bear Lake fault that bounds Bear Lake Valley on the east (Mansfield, 1927, P. 167) would be appropriate. The area studied lies wholly within the Basin and Range province if the province boundary is thus delimited.

Altitudes within the area range from 4,477 feet along Cub River in Franklin, Idaho, to 9,480 feet on the ridge above Eagan Basin. Maximum relief is approximately 5,000 feet.

BEAR RIVER RANGE

Between the Idaho state line and the Cub River and St. Charles Creek re-entrants, the Bear River Range consists of three north-trending parallel ridges: Front Ridge on the west, Horse Lake Ridge on the center, and Temple Ridge on the east. Horse Lake Ridge is composite with two flanking crests divided by the Eagan-Gibson Basin depression. Front Ridge is separated from Horse Lake Ridge by the Cub-Franklin Basin depression. Horse Lake Ridge is separated from Temple Ridge by the Upper Green Canyon Basin depression, Front Ridge is breached by the Cub River re-entrant, north of which it is developed only as a series of spurs separated by lower saddles from the northward continuation of Horse Lake Ridge. Temple Ridge is breached by the St. Charles Creek re-entrant, but continues northward to Paris Peak. North of St. Charles Creek, Horse Lake Ridge and Temple Ridge are separated by a series of irregular, poorly defined depressions and peaks.

CACHE VALLEY

Cache Valley is a long narrow valley, 60 miles by 17 miles, tapering gradually at both ends. The valley floor rises gently northward from from 4,400 feet near Hyrum, Utah, to 4,800 feet near Banida, Idaho. Several buttes -- Smarts Mountain, Little Mountain, Newton Hill, etc. -- rise abruptly from the valley floor. Only a small portion of the east central margin of the valley is considered in this report.

West of the Front Ridge of the Bear River Range lie a series of low rounded hills and dissected foothill benches generally developed on relatively non-resistant Cenozoic rocks. Along the western margin of this complex there are well displayed evidences of former shorelines of Lake Bonneville. Cache Valley proper is floored with a thick mantle of generally flat-lying lacustrine sediments in which the present drainage pattern has been incised.

ACCESS AND TRANSPORTATION

Access to Cache Valley from north and south is by U. S. Route 91. A road from Malad City to the west enters Cache Valley through Weston Canyon. From the east it may be reached by U. S. Route 89 through Logan Canyon from Garden City, Utah, and from Liberty, Idaho, by Emigration-Strawberry Canyon. The northern terminus of the Oregon Short Line is at Preston, Idaho.

STRATIGRAPHY

GENERAL

A thick section of Paleozoic sedimentary rocks which is exposed within the Bear River Range includes 12 formations ranging in age from Cambrian through Devonian with an aggregate measured thickness of approximately 11,696 feet. Small down-faulted blocks of two additional units crop out: the Devonian Jefferson formation and the Mississippian Madison limestone above St. Charles and Bloomington Creeks, along the Temple Ridge fault. However, because of their structural setting, no stratigraphic measurements of these two units were possible. Within the Paleozoic sequence the proportion of clastic rocks to marine limestone and dolomite is approximately equal.

On the west flank of the Bear River Range approximately 1,500 feet of the Cenozoic Salt Lake formation succeeded by Lake Bonneville sediments and later alluvial and colluvial deposits are exposed.

The pre-Cambrian rocks to which Williams refers (1948, p. 1131) were not found within the area covered by this investigation, nor were they noted during reconnaissance of adjacent canyons farther north within the Preston quadrangle. No igneous rocks are exposed. The nearest outcrops of the Snake River lavas are approximately 5 miles northeast of the town of Mink Creek.

Figure 2 summarizes the formations exposed in the area and Figure 3 shows the distribution and structure of the rock units.

CAMBRIAN SYSTEM

The Cambrian system is represented by more than 7,800 feet of strata. Cambrian rocks occupy the entire west flank of the Bear River Range and are best exposed above Maple Creek east of Franklin, Idaho. The entire section is similar to that defined by Walcott (1908a&b) and studied by Richardson (1913, 1941), Mansfield (1927), Deiss (1938), and Williams (1948) in neighboring regions of Idaho and Utah. The seven Cambrian formations are recognizable by their stratigraphic sequence and in general by their gross lithologic characteristics. Correlations have been established by lateral tracing of the formations from adjacent areas, and where possible, age assignments have been confirmed by identification of included fossils. No stratigraphic evidence of an unconformable relationship between any of the formations of the Cambrian system was seen within the area. Sufficient faunal evidence was not found to support or refute Williams' (1948, p. 1130) hypothesized disconformities between the Blacksmith and the Bloomington and between the Nounan and St. Charles formations.

Considerable confusion exists concerning the type sections and nomenclature of many of the Cambrian formations. An attempt has been made to give the present status of nomenclature under the descriptions of the individual formations. Walcott's Blacksmith Fork section, the best known, most accessible, and most complete section in this region, is taken as a local standard section of reference for the Cambrian system in this general area. It is referred to herein as the standard section.

Brigham Formation

Name

The Brigham formation was named by Walcott (1908a, p. 8) from its occurrence northeast of Brigham in Box Elder County, Utah. As the formation includes appreciable proportions of sandstone, conglomerate, and shale both in the present area and in the type area, the original name Brigham formation is here maintained rather than the more generally used term Brigham quartzite.

Distribution and Character

The Brigham formation in this area is exposed continuously along the western base of the front ridge of the Bear River Range. On the west it is overlapped by beds of the Cenozoic Salt Lake formation and on the east it is bounded by the Langston formation, which lies above it in conformable sequence. At the northern end of the outcrop belt the Brigham formation is in fault contact on the east with the Bloomington formation.

In some portions the formation is a quartzite with a strong greyish red purple to pale reddish brown color. The typical weathered color is moderate to dark yellowish brown. Locally the texture is sandy and the rock is quite friable. Beds and lenses of conglomerate with pebbles as much as two inches in diameter are common. The pebbles are quartz, white to reddish in color and well rounded. Some of the beds are light olive grey to pale olive and, particularly within the sandy layers, very light colors approaching very pale orange are found. The quartzite is generally thick-bedded to massive and in some localities shows two prominent joint sets (N. 60° E., 75° W.: N. 15° W., 50° SW.). The sandstone beds range from about three inches to three feet in thickness and cross bedding is not uncommon within them. Well developed liesegang rings in some portions of the formation are easily mistaken for cross bedding. Some of the bedding planes within the sandy members show an undulatory pattern reminiscent of oscillation ripple marks. The upper 100 feet of the formation contains a large proportion of thin-bedded sandy, micaceous, dark olive grey shale.

Thickness

The base of the formation is not exposed in this area. Walcott (1908a, p. 8) reports 2,000 feet at the type locality and 1,250 feet

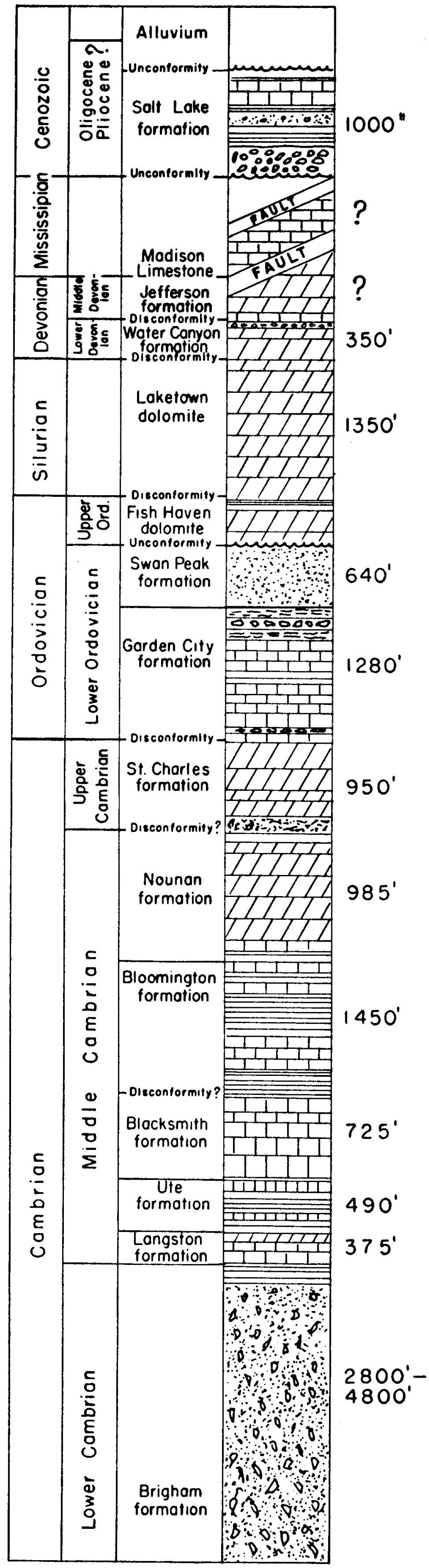


FIG. II COLUMNAR SECTION

1000'

in his Blacksmith Fork section. Williams (1948a, p. 1132) reports a section 4,800 feet thick on Flat Creek in the Preston quadrangle. The section given below, which was measured on the north flank of Maple Creek, totals 2,880 feet.

Age and Correlation

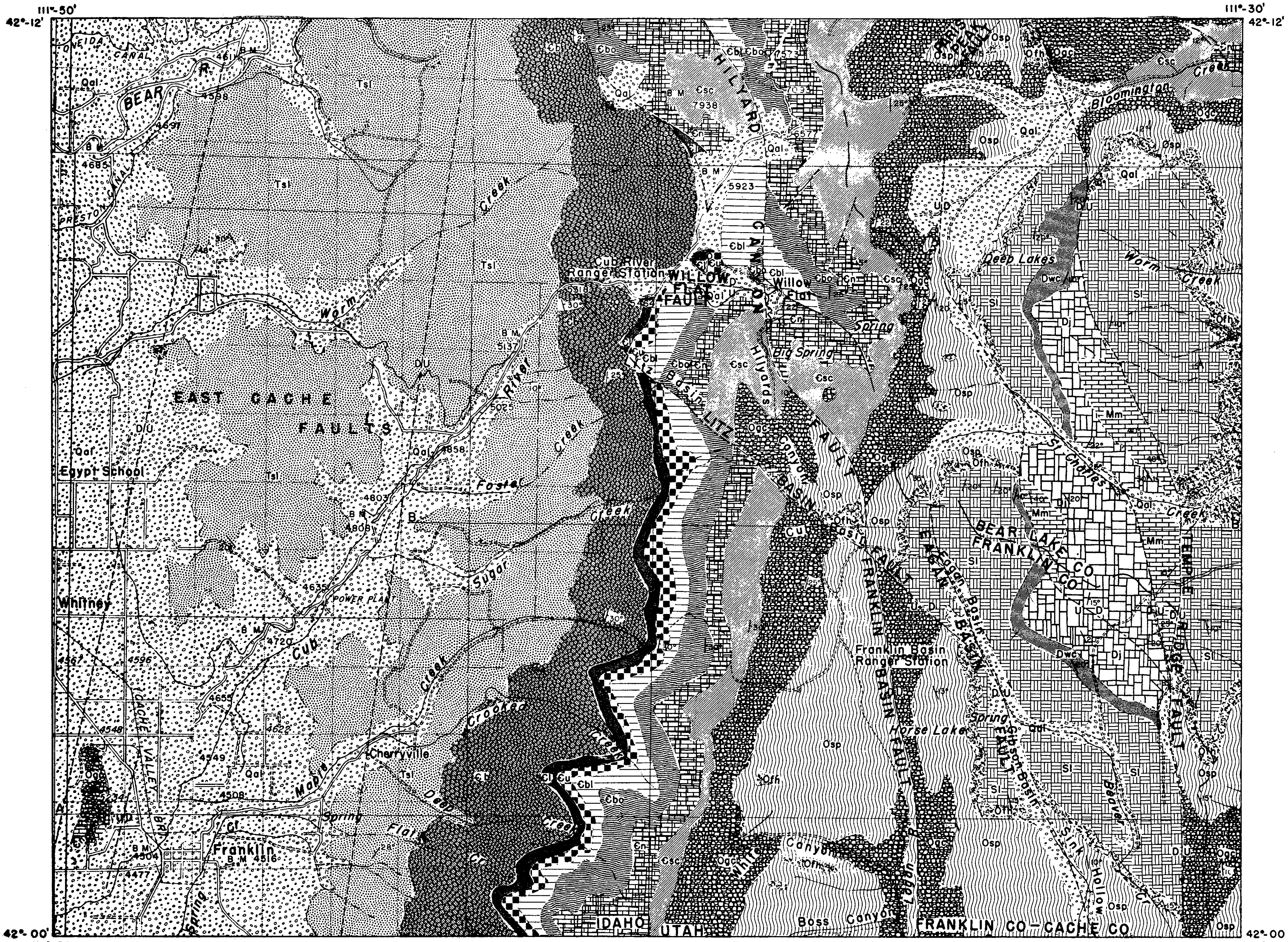
The Brigham formation is everywhere notably unfossiliferous. Fucoidal markings are common in some units. A single specimen of the trilobite Agnostus Cf. A. lautus Resser was collected in this area from the upper shaley member of the Brigham formation. Deiss (1940, pp. 782-785) states that Agnostus did not reach the Cordillerian trough until the time of deposition of the Bathyuriscus-Elrathina fauna which is the sixth youngest of Deiss' 7 Middle Cambrian faunal zones. However, the local specimen was found in rocks underlying beds bearing the Ptarmigania fauna which would be in zone I (Kochaspis) of Deiss.

Although the base of the formation is not exposed in this area, elsewhere it has been described by Blackwelder (1910 and 1949), Hintze (1913), Schneider (1925 and 1949), and Eardly and Hatch (1940) as resting unconformably on various rocks presumably pre-Cambrian in age. The formation is probably not older than Cambrian.

TABLE 1.-Section of Brigham formation on north flank of Maple Creek east of Franklin, Idaho.

(Langston formation)

	Feet
Shale: thinly laminated, micaceous, dusky yellow green	70
Quartzite: thick-bedded, pale yellowish orange to pale yellowish brown	326
Sandstone and shale: thinly interbedded, greyish orange, fine-grained sandstone, and dusky yellow green, micaceous shale	92
Quartzite: vitreous, thin-bedded, greyish orange and very pale orange	210
Quartzite: fine-grained, massive, pale yellowish orange	411
Quartzite: fine-grained, massive, greyish olive with scattered white quartz pebbles	138
Quartzite: fine grained, massive, moderate red	87
Sandstone: quartzitic, medium-grained, thick-bedded, greyish orange. Weathers to peculiar wafer-edged, rounded "hot cake" forms	318
Quartzite: fine-grained, thick-bedded to massive, pale yellowish orange with lenses of quartz pebble conglomerate	120



LEGEND

CENOZOIC

Qal Alluvium

Tsl Salt Lake formation

MISSISSIPPIAN

Mm Madison limestone

DEVONIAN

Dj Jefferson formation

Dwc Water Canyon formation

SILURIAN

Sl Laketown dolomite

ORDOVICIAN

Ofh Fish Haven dolomite

Osp Swan Peak formation

Ogc Garden City limestone

CAMBRIAN

Ꞓsc St. Charles formation

Ꞓn Nounan formation

Ꞓbo Bloomington formation

Ꞓbl Blacksmith formation

Ꞓu Ute formation

Ꞓl Langston formation

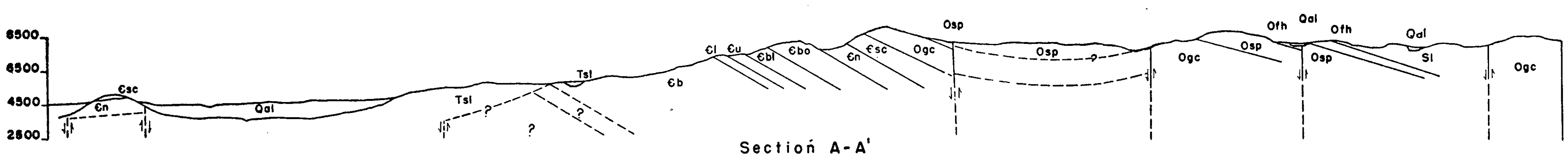
Ꞓb Brigham formation

U/D High angle fault

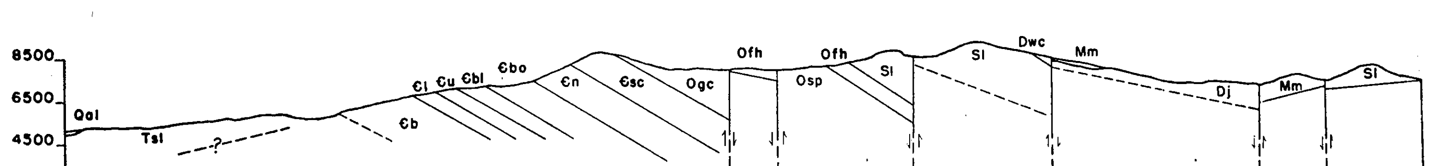
30 Strike and dip of beds

True North 18½°

Scale 1 0 1 2 Miles



Section A-A'



Section B-B'

(No vertical exaggeration)

-7-A

FIG. III

GEOLOGIC MAP OF

THE SOUTHEAST PORTION OF THE PRESTON QUADRANGLE

IDAHO-UTAH

GEOLOGY BY H.W. COULTER, 1950-51

	Feet
Quartzite: medium-grained, medium-bedded, greyish orange and moderate red with some cross bedding..	71
Quartzite: massive blocky ledges, pale red, containing white and pink quartz pebble stringers..	292
Sandstone: medium grained, medium-bedded, friable. Weathers to peculiar wafer-edged rounded, "hot cake" forms..	71
Quartzite: fine grained, medium-bedded, very pale orange to dark reddish brown. Some cross bedding and minor quartz granule lenses. Prominent liesegang rings........................	284
Quartzite: fine-grained, thick-bedded, pale yellowish orange to very pale orange. White quartz pebble stringers and lenses of quartz granules. Bedding planes undulatory.............	254
Quartzite: fine-grained, massive, greyish orange to pale yellowish orange..................	178
	2,922

(Base Covered)

In the absence of diagnostic Brigham fossils, dating is largely dependent on the age assignment of the immediately overlying Langston formation. Walcott (1908b, p. 199) considered the Langston to be early Middle Cambrian and the Brigham to be Middle Cambrian with several hundred feet of Lower Cambrian beds near the base. Deiss (1940, pp. 782-785) discussed the faunal sequence in the Middle Cambrian rocks of the Cordilleran trough and concluded that the Brigham formation is Middle Cambrian in its entirety. However, Williams and Maxey (1941) have shown that the faunal zones proposed by Deiss have no validity in this region and since the basal Ptarmigania fauna of the Langston is believed by them to be earliest Middle Cambrian, an Early Cambrian age seems most appropriate for the entire Brigham formation. Maxey (personal communication) suggests that the Brigham is in large part a correlative of the Prospect Mountain quartzite and that the upper shaly member of the Brigham formation is equivalent to the Pioche shale.

Langston Formation

Name

The Langston formation was named by Walcott (1908, p. 8) for its occurrence in the valley of Langston Creek in the Bear River Range, Utah. Deiss ((1938, p. 1119) states, in his amended definition, that Walcott clearly intended Blacksmith Fork as the type locality and so designates it. Walcott's original name Langston formation characterizes the formation more accurately than the more widely used term Langston limestone.

Distribution and Character

The Langston formation is exposed above the Brigham formation, along the front ridge of the Bear River Range. It is offset by the Litz Basin and Cub River faults and faulted out completely northwest of Willow Flat, where the Bloomington formation rests directly against the Brigham formation. On the east the Langston formation is overlain conformably by the Ute formation. Williams' (1948, p. 1132) tripartite division of the Langston formation is not applicable in this area, nor is there any appearance of a shale bearing the Spence fauna within the formation. The transitional bed of calcareous sandstone described by Deiss (1938, p. 1119) in the basal portion of the Langston formation was not observed. The contact between the upper shaly member of the Brigham formation and the basal Langston limestone bed is abrupt and well defined. As exposed in the Preston quadrangle the Langston formation consists of a lower alternately thin and thick-bedded dark-colored limestone member and an upper thick-bedded light-colored domomite member. The limestone member weathers medium bluish grey and the dolomite member weathers pale yellowish brown or pale red. Oolitic beds are present in the limestone in some localities and peculiar concentric ringed algal-like structures are relatively common in the lower portions of the formation. In one outcrop west of Willow Flat ripple marks were found in very fine-grained black limestone. The limestone in some places is slightly fetid. The dolomite member is generally coarsely crystalline and the limestone member very finely crystalline to aphanitic. In many places the formation shows two prominent joint sets, one striking north 30° west and dipping 65° south, the other striking east-west and dipping vertically.

Thickness

The thickness of the Langston formation ranges from 30 feet west of Liberty, Idaho (Walcott 1908, p. 8) to 485 feet on High Creek in the Logan quadrangle (Williams 1948, p. 1133). The section given below totals 374 feet.

TABLE 2.--Section of Langston formation on north flank of Maple Creek east of Franklin, Idaho.

(Ute formation)

	Feet
Dolomite: thick-bedded to massive, coarse-grained crystalline, grey-white, weathers very rough, weathers to pale red or pale yellowish brown. Prominently jointed.........	191
Limestone: thin-bedded (up to 4 inches), very fine-grained, black. Weathers bluish grey....	57
Limestone: thick-bedded, very fine-grained, black, brecciated at base with calcite vugs and stringers, massive at top, slightly fetid. Weathers very rough and irregular, medium bluish grey................................	46

Limestone: thin-bedded (up to 2 inches), compact, very fine-grained, black. Weathers medium bluish grey.................................. 80

374

(Brigham formation)

Age and Correlation

The Langston formation of the Preston quadrangle can be traced, with only minor breaks in outcrop, into the standard section of the formation in Blacksmith Fork.

Numerous cranidia of the trilobite Pachyaspis typicalis Resser characteristic of the Ptarmigania fauna (Resser 1939b) were found in the lower limestone beds of the formation. Williams and Maxey (1941, p. 227) consider the Ptarmigania fauna to be earliest Middle Cambrian in age.

Ute Formation

Name

The term Ute limestone was first applied by King (1878, pp. 232-233) to the thick limestone sequence overlying the Cambrian quartzites at Ute Peak in the Wasatch Range, Utah. The term was restricted by Walcott (1908a, p. 7) to a single Middle Cambrian formation. Since the section at Ute Peak has not been studied in detail nor adequately described in the literature, Walcott's Blacksmith Fork section is taken as the local standard for the Ute formation. Walcott introduced the name Spence shale for the lower member of the Ute formation, but for the reason given below his usage is not followed in this report.

Distribution and Character

The Ute formation consists of a zone of thin-bedded limestones and shales lying between more massive limestone formations -- the Langston formation to the west and the Blacksmith formation to the east -- along the west flank of the Bear River Range. Thinly interbedded limestone and shale characterize the formation throughout. The proportion of limestone increases upward in the formation with stringers and beds of shale replacing the more abundant bedded shales of the lower part. Oolitic limestone is very common within the formation and thin irregular shale laminae characteristically weather in relief along bedding planes in the limestone.

Thickness

The total thickness of the Ute formation in the standard section is given as 759 feet by Walcott (1908a, p. 8) and 685 feet by Deiss (1938, p. 1114). The section given below, measured on the north flank of Maple Creek, totals 490 feet.

TABLE 3.-Section of Ute formation on north flank of Maple Creek east of Franklin, Idaho

(Blacksmith formation)

	Feet
Interbedded dark yellowish orange and moderate reddish brown shales and thin-bedded, fine-grained medium bluish grey limestone, commonly oolitic..................	351
(Interval covered)	96
Interbedded dark-yellowish orange shales and thin-bedded medium-grained, medium bluish grey, crystalline limestone. Limestone commonly shows red weathering stain.........	43
	490

(Langston formation)

Age and Correlation

The only fossil found within the Ute formation in the present area was a single case of Iphidella Cf. I. grata Resser. Walcott (1908b, pp. 196-197) reports an abundant Middle Cambrian fauna from the type locality at Blacksmith Fork. There are only minor breaks in outcrop between the Preston area and the standard section 20 miles to the southeast.

Spence Shale Member

The Spence shale was originally defined by Walcott (1908a, p. 8), from the type locality in Spence Gulch, as the basal shale member of the Ute formation. Walcott (1908b) and Resser (1939a) have described an abundant and varied early Middle Cambrian fauna from this unit which has been called the Spence fauna. Hence two distinct entities exist: the Spence shale, by definition basal Ute formation, and the Spence fauna, a characteristic fossil assemblage found at the type locality. At the type locality, exposures are poor and the exact stratigraphic position of the fossil bearing beds is equivocal. Furthermore no shale bearing the Spence fauna has been found at the standard section of the Langston and Ute formations in Blacksmith Fork.

Subsequent workers in the area, Mansfield (1927) and Richardson (1941, 1913) applied the term Spence shale as defined, although they did not map it separately nor did they report having found the Spence fauna at that horizon. Deiss (1938, p. 1120) does not recognize the unit in his amended definition of the Ute formation.

Williams and Maxey (1941) studied the Cambrian section in the Logan quadrangle and adjacent areas, and re-examined the type locality of the Spence shale. They conclude that the Spence fauna-bearing shale is, in all localities, including the type locality, a member of the Langston and not the Ute formation, and they apply the term Spence shale where this fossiliferous shale facies of the Langston formation is present.

Hence the type Spence shale is not a correlative of the basal shale unit of the Ute formation and the term Spence shale is not properly applicable to that unit in the Ute standard section or elsewhere. Furthermore, because of the transient and discontinuous nature of the Spence fauna-bearing shale unit of the Langston formation (it is not present at the type locality of the Langston in the Logan Quadrangle, nor within the present area) and because of the long history of misapplication of the term Spence shale both in the literature and in general usage, the present author questions the advisability of Williams' and Maxey's usage of the term and is of the opinion that it should be dropped.

Blacksmith Formation

Name

The Blacksmith formation was named by Walcott (1908a, p. 7) from exposures in Blacksmith Fork Canyon, Utah. Although Deiss (1938, p. 1121) has used the name Blacksmith dolomite in his amended definition of the formation, the original name and definition are more appropriate to the rocks in this area.

Distribution and Character

The Blacksmith formation crops out continuously along the west flank of the Front Ridge of the Bear River Range. Because of its stratigraphic position between the relatively non-resistant Ute formation and the Hodges shale member of the Bloomington formation, slopes developed on the Blacksmith formation are characteristically steep. Alternation of light and dark colors on the weathered limestone surface imparts a pronounced banded aspect to the formation. Ooolitic and pisolitic beds, many showing cross bedding, are generally confined to the middle part of the formation. In the upper portion of the formation, raised welt-like vermiform markings are common on the bedding planes. They are similar to those described by Calkins and Butler (1943, p. 15) from the Maxfield limestone of Utah.

Thickness

The reported thickness of the Blacksmith formation ranges from 325 feet to 800 feet. The maximum thickness measured in the area was 723 feet.

TABLE 4.-Section of Blacksmith formation on north flank of Maple Creek east of Franklin, Idaho.

(Bloomington formation)

	Feet
Limestone: thin-bedded, very fine-grained, greyish black. Weathers medium bluish grey, prominent vermiform markings on bedding planes..................................	230
Limestone: medium-bedded, coarse-grained, crystalline, medium bluish grey, little shale, some oolitic and pisolitic beds. Weathers to light bluish grey....................	142
Similar to unit below, but thin-bedded (2 to 3 inches), some beds medium bluish grey...........	187
Limestone: thick-bedded, medium grained, crystalline, dark bluish grey, with abundant moderate yellowish brown and moderate reddish brown shale partings and minor lenses not rigidly confined to bedding planes. Limestone weathers to medium bluish grey with shales standing in relief..........................	164
	723

Age and Correlation

No diagnostic fossils are reported from the Blacksmith formation. It has been assigned to the Middle Cambrian on the basis of stratigraphic position. No perceptible discordance was noted in the area between the Blacksmith formation and the underlying and overlying units.

Bloomington Formation

Name

The type locality of the Bloomington formation was designated by Walcott (1908, p. 7) as "Bear River Range, about 6 miles west of the town of Bloomington, Bear Lake Co., Idaho," and the name was taken from Bloomington Creek, which is near the type locality and passes through the formation. Richardson (1913, p. 406) applied the term Hodges shale to the lower 350 feet of the Bloomington formation in the Randolph Quadrangle. Mansfield (1927, p. 55) changed the type locality to Mill Creek near Liberty, Idaho, and included the Hodges shale member in his description of the redesignated type section. Subsequent workers including Deiss (1938, p. 1122) have accepted Mansfield's section.

Distribution and Character

The Bloomington formation is exposed continuously along the west flank of the Bear River Range. It is offset by the Litz Basin fault and at Willow Flat is repeated by the Hillyard Canyon fault. Northeast of Willow Flat it is in fault contact with the Brigham formation on the west.

The stratigraphic setting of the Bloomington formation is somewhat analogous to that of the Ute formation. It is a relatively weak thin-bedded unit underlain and overlain by more resistant massive units. This stratigraphic setting has a general topographic expression throughout the area. The lithologic types present in the Bloomington also closely resemble those of the Ute to the extent that in many places individual beds and even sequences of beds are indistinguishable.

Williams (1948, p. 1133) quadripartite division of the formation into a lower shale (Hodges shale), lower limestone, upper shale, and upper limestone, is generally valid within this area, although only the Hodges shale is sufficiently distinct and continuous to warrant separate designation as a member. A very distinctive bed of intra-formational conglomerate within the upper limestone unit is of sufficient extent to be of some value as a horizon marker. Sandy lenses and siliceous nodules are found in the upper portions of the formation and fucoidal markings are present in some of the shaly beds. Oolitic limestone is common both in lenses and beds within the formation.

Thickness

The maximum measured thickness of the Bloomington formation in the Preston area is 1,445 feet.

TABLE 5.-Section of Bloomington formation on north blank of Maple Creek east of Franklin, Idaho.

(Nounan formation)	Feet
Interbedded fine-grained, dary grey, limestone and dusky yellow shale	86
Shale: prominent ledge, moderate yellowish brown, compact, with sandy lenses and abundant fucoidal markings	21
Interval covered	39
Limestone: thick-bedded, fine-grained, dark bluish grey, with oolitic lenses. Weathers very rough to light bluish grey	76
Limestone: medium-bedded, fine-grained, and oolitic greyish black with oolitic beds and intraformational conglomerates and dusky yellow thin-bedded shales	85
Shales: thin-bedded, dusky yellow and greenish grey with medium-bedded, fine-grained and oolitic dark grey limestone. Shale predominates	54

	Feet
Interval covered shaly float....................	150
Thin inter-bedded, very fine-grained, dark grey limestone and dusky yellow, and greenish grey shale. Limestone weathers medium bluish grey............................	61
Regularly inter-bedded, very fine-grained black limestone, and dusky yellow and greenish grey shale. Limestone weathers dark bluish grey..................................	41
(Hodges shale member)	
Interval covered shaly float....................	179
Moderate yellowish brown to greyish olive shales and thin-inter-bedded, very fine-grained, greyish black limestone. Limestone weathers to medium bluish grey. Shale predominates..................................	79
	871

(Blacksmith formation)

Age

Although no fossils were collected in the area, Walcott (1908b), Mansfield (1927), and Williams and Maxey (1941) report an abundant Middle Cambrian fauna from the Bloomington formation in adjacent regions.

Nounan Formation

Name

The Nounan formation was named by Walcott (1908a, p. 6) who designated the east slope of Soda Peak west of Nounan as the type locality. However, as was the case with the Bloomington formation, the only detailed description of the formation given by Walcott (1908b, p. 193) was of the Blacksmith Fork section. Mansfield (1927, p. 55) gave a detailed description of the original Nounan locality which has been considered to be the type locality by all subsequent workers.

Distribution and Character

The Nounan formation crops out in normal stratigraphic sequence along the Front Ridge of the Bear River Range in the southern portion of the area. It is offset to the west by the Litz Basin fault and by the Willow Flat fault complex farther to the north.

The lower part of the Nounan formation is characterized by an alternation of medium grey and very light grey crystalline dolomite that gives a definite banded appearance to the unit. The darker dolomite is often spotted or mottled with light patches and is very similar to the rock described by Calkins and Butler (1943, p. 15) as "guinea-hen" dolomite from the Maxfield limestone of Utah. In some beds of relatively fine-grained dolomite markings resembling trails or borings, sometimes filled with very fine-grained argillaceous material, are found. Pisolitic beds are common in this lower unit of the formation. The dolomite content decreases upward in the formation and at the top there is a thick bed of massive cliff-making white crystalline limestone.

Thickness

The thickness of the Nounan formation is reported as 1,041 feet in Blacksmith Fork and 814 feet at the type locality. Maxey (Williams 1948, p. 1134) reports 825 feet in the Call's Fort section. In the present area the section measured on the north flank of Maple Creek totaled 985 feet.

TABLE 6.-Section of Nounan formation on north flank of Maple Creek east of Franklin, Idaho.

(St. Charles formation)

	Feet
Limestone: massive, white, coarsely crystalline cligg-making member	78
Interval covered limestone float	430
Dolomite: medium-bedded, medium-grained, crystalline, very light grey and and medium grey banded	86
Dolomite: massive, coarse-grained crystalline. Weathers to very light grey	154
Dolomite: medium-bedded, medium-grained, crystalline, very light grey and medium grey banded	158
Dolomite: massive, coarsely crystalline, very light grey and medium grey, mottled, fetid	79
	985

(Bloomington formation)

Age

No diagnostic fossils are reported from the Nounan formation. Since the lower portion of the overlying St. Charles formation contains Franconian fossils, the Nounan may be late Middle or early Upper Cambrian. It is generally considered to be Middle Cambrian as originally stated by Walcott.

St. Charles Formation

Name

The St. Charles formation was first described by Walcott (1908a, p. 6), who designated St. Charles Canyon, Bear Lake Co., Idaho, as the type locality. Richardson (1913, p. 408) applied the term Worm Creek quartzite to the lower arenaceous member of the formation. Mansfield (1927) and Williams (1948) followed the usage of Walcott and Richardson in their work in adjacent areas. As pointed out by Williams (1948, p. 1135), Deiss (1938, p. 1123) erred in his attempt to redefine the St. Charles section in Blacksmith Fork Canyon.* Apparently Richardson (1941, p. 13) was misled by Deiss' incorrect stratigraphic interpretation of the St. Charles and Garden City formations, since in his 1941 bulletin he has changed the reported thickness of the St. Charles formation from the previous figure of 1,300 feet to 400 feet and the thickness of the Garden City formation from 1,000 feet to 1,900 feet.

Distribution and Character

The St. Charles formation crops out along the west flank of the Front Ridge of the Bear River Range in the southern portion of the Preston area and small outcrop areas of the formation are exposed along St. Charles and Bloomington Creeks on the east flank of the range.

The St. Charles in the Preston quadrangle conforms closely to the description of the formation in the Logan Quadrangle to the south given by Williams (1948, p. 1135). It includes a lower arenaceous member (Worm Creek member) of pale orange to greyish orange sandstone and quartzite, an intermediate limestone member, and an upper dark grey dolomite member.

The contact between the St. Charles and Garden City formations is drawn at the top of the highest dolomite immediately below the first fossil-bearing limestone beds of the Garden City.

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*He failed to find the Worm Creek member of the St. Charles formation and apparently mistook the lower portion of the Garden City limestone beds for those measured as St. Charles formation by Walcott. Since he (Deiss) found Ordovician fossils in 777 feet of beds, supposed by him to be within Walcott's 1,227 feet of St. Charles beds, he limited the thickness of the St. Charles formation in his amended definition to a total of 400 feet, composed apparently of 148 feet of bona fide St. Charles beds and 258 feet of misidentified Garden City beds.

Thickness

There is a large variation in the reported thickness of the St. Charles formation. A considerable portion of this variation appears to be within the Worm Creek member which increases in thickness from 6 feet at Call's Fort to 400 feet in the Randolph quadrangle. The Worm Creek member totals 170 feet in the present area and the entire formation is 941 feet thick above Willow Flat.

TABLE 7.-Section of St. Charles formation east of Willow Flat, Idaho.

(Garden City Formation)

	Feet
Dolomite: thick-bedded, medium-grained, medium dark grey crystalline...........	10
Limestone dolomitic: thick-bedded, medium-grained light grey and medium grey mottled.................................	86
Dolomite: alternate thick and thin-bedded, fine-grained, light grey. White chert nodules abundant.......................	233
Limestone dolomitic: thin-bedded, fine-grained, medium light grey, with reddish brown shale partings and scattered white chert nodules.........	42
Interval covered, shaly dolomitic float...	95
Dolomite: alternate thick and thin-bedded, medium-grained, light grey. Weathers to yellowish grey.....................	70
Thinly interbedded pale yellowish brown and pale reddish shales with saccharoidal limestone nodules..................	40
Dolomite: thick-bedded, coarsely crystalline, grey with yellowish grey and medium light grey lenticular, fine-grained, limestone beds...............	25
Worm Creek Member	
Quartzite: massive, medium-grained, very pale orange. Weathers to moderate yellowish brown........................	89
Sandstone: thick-bedded, medium-grained, greyish orange, quartzitic, somewhat shaly at base.........................	81
	771

(Nounan formation)

Age and Correlation

No fossils are reported from the Worm Creek member nor from the upper dolomite member of the St. Charles formation. Williams and Maxey (1941, p. 284) report a Franconian fauna from the middle lime-stone member. Trilobite fragments tentatively identified as Crepicephalus and a single specimen of Billingsella were found immediately above the Worm Creek member in Bloomington Canyon. The St. Charles formation of the area can be traced directly into the type locality in the Montpelier quadrangle.

Summary

Because the Cambrian stratigraphic units in this general area are difficult to distinguish, a brief summary of some of the major aspects of the formations and the criteria whereby they are delimited is given here. The formations are thick units and are to be recognized only by their gross lithologic aspects. Detailed variations within the major units are infinite.

The Langston formation is a relatively resistant carbonate unit lying between less resistant shales. The basal contact is marked by the first appearance of limestone above the shale member of the Brigham formation. The upper contact is marked by an abrupt change from thick-bedded dolomite to thin-bedded shale.

The Ute is a relatively weak, predominately shale formation, lying between the more resistant carbonate beds of the Langston formation below and the Blacksmith formation above. The upper contact of the formation is marked by the change from thinly inter-bedded shale and limestone to thick bedded limestone with only scattered shale partings.

The Blacksmith formation is a relatively resistant, thick-bedded, predominately carbonate unit lying between the weaker Ute and Bloomington formations. The contact between the Blacksmith and Bloomington formations is marked by the change from very pure limestone at the top of the Blacksmith to shale at the base of the Bloomington containing only minor amounts of limestone.

The Bloomington formation is a relatively weak unit lying between the more resistant Blacksmith and Nounan formations below and above. The contact between the Bloomington and Nounan formations is marked by the change from thin inter-bedded limestone and shale to massive crystalline dolomite.

The Nounan is the highest of the sequence of alternating weak and resistant Cambrian formations. It overlies the relatively weak, thin-bedded Bloomington formation, but is itself overlain by the relatively resistant, thick-bedded, carbonate St. Charles formation. The contact between the Nounan formation and the St. Charles formation is marked by the first appearance of sandstone at the base of the basal Worm Creek member of the St. Charles.

ORDOVICIAN SYSTEM

Approximately 2,400 feet of Ordovician strata are extensively exposed along the axial portion of the Bear River Range and along the crest of the eastern flanking ridge.

The Ordovician rocks of this general area were first described by Richardson (1913, pp. 408-410) from the Randolph quadrangle, Utah. Richardson's original subdivision of the Ordovician system into a lower limestone, a middle clastic unit, and an upper dolomite which he named, respectively, the Garden City formation, the Swan Peak formation, and the Fish Haven dolomite is applicable in the present area.

As stated above the boundary between Cambrian and Ordovician rocks is arbitrarily drawn at the top of a thick section of unfossiliferous dolomite. This dolomite overlies, with apparent conformity, St. Charles rocks bearing Franconian fossils and underlies, with apparent conformity, Garden City rocks bearing Canadian fossils, and thus may belong in either system. Until diagnostic fossils are found in the dolomite it seems most advantageous to have the inter-systemic boundary coincide with the most clear-cut lithologic boundary.

Garden City Formation

Name

The Garden City formation was originally described by Richardson (1913, pp. 408-409) from the exposures in Garden City Canyon in the Randolph quadrangle, Utah. In a later report Richardson (1941) modified his original definition to conform with the stratigraphic work of Deiss (1938, p. 1123). See discussion on pp. 17-18 of this report. A subsequent restudy of the type locality and adjacent sections of the formation by Ross (1949, 1951) has established the essential validity of Richardson's original definition.

Distribution and Character

The Garden City formation crops out along both flanks of Franklin Basin and in the upper portion of Hillyard's Canyon. It is well exposed in the headwall above Willow Flat, in the basin west of Bloomington Lake (Deep Lake), and on the flanks of Paris Peak. Small blocks of brecciated Garden City limestone are exposed in the East Cache fault zone, one on Smarts Mountain and one above Maple Creek due north of Cherryville, Idaho. In the southeastern portion of the map area it is exposed above Beaver Creek on the north flank of Swan Peak.

The lithology of the Garden City formation may best be described in three separate parts, none of which is sufficiently distinctive or continuous to warrant classification as a member.

The lower part of the formation is composed of thin, irregularly laminated, fine-grained to aphanitic, light grey, limestone pebble conglomerate. Medium bluish grey and bluish white chert nodules and thin shale partings are scattered sparsely throughout this portion of the formation. Thin zones of medium crystalline, light grey dolomite occur in some sections.

The middle part of the formation is characterized by relatively abundant dark yellowish orange and moderate reddish brown shale partings in fine-grained to aphanitic medium grey limestone, and by an increase upward in chert content from scattered black nodules to irregular beds making up approximately 60 per cent of the formation.

Above the chert zone of the formation lie approximately 200 feet of carbonate beds which, wherever well exposed, contain a high percentage of dolomite and were reported as a dolomite member by Williams (1948, p. 1136). Ross (1951, p. 8) has questioned whether or not this dolomite is a bona fide sedimentary unit and has presented evidence which indicates that the unit has been subjected to secondary dolomitization related to zones of faulting or to replacement as a result of weathering. The following phenomena observed within this area give support to Ross' suggestion of postcontemporaneous dolomitization.

a. Dolomitization is a persistent and characteristic feature of zones of faulting within the present area.

b. The Swan Peak formation has a very high relative resistance to weathering as compared to the Garden City formation. Hence not only does it form a persistent ledge-making unit protecting and underlying Garden City beds but it also forma a ubiquitous masking rubble which effectively covers all down slope units for a considerable distance.

Thus the prospects for observing the uppermost beds of the Garden City formation in this area are limited to areas adjacent to zones of faulting where concomitant dolomitization has greatly increased the relative resistance of the uppermost beds of the formation.

The single case of possible dolomitization during a post-depositional weathering interval reported by Ross (1951, p. 9) is found in an unusual stratigraphic environment, wherein the Fish Haven formation directly overlaps the Garden City formation with no intervening arenaceous beds.

In all sections remote from zones of faulting the highest beds observed in the Garden City formation were limestone, and only limestone was found intermingled with quartzite float between the highest Garden City and the lowest Swan Peak exposures.

Therefore it is the opinion of the present author that the observed phenomenon of widespread dolomitization adjacent to zones of faulting coupled with a physiographic environment which prevents adequate observation of the Garden City formation except near zones of faulting has resulted in the erroneous reporting of an upper dolomite member of the formation.

Thickness

Ross (1951, p. 16) reports a 1,764 foot section of Garden City beds on Clarkson Mountain and a 1,441 foot section in Hillyards Canyon in the Preston quadrangle. The section given below, totaling 1,288 feet was measured approximately two miles north of Ross' section.

TABLE 8.-Section of Garden City formation on ridge east of Willow Flat.

(Swan Peak formation)

	Feet
Slope covered Swan Peak float	112
Limestone: fine grained, thin-bedded, nodular, medium grey. Weathers moderate yellowish brown	79
Limestone: fine-grained to aphanitic, thick-bedded, medium grey. Black chert stringers abundant, increasing upward to 60 per cent of the rock	338
Limestone: fine-grained, medium bedded, medium grey. Moderate reddish brown shale partings. Black chert nodules abundant	167
Interval covered, shaly limestone float	172
Limestone: aphanitic, medium-bedded, medium grey, with dark yellowish orange shale partings	80
Limestone: coarsely crystalline, thick-bedded, medium grey	42
Interval covered, thin-bedded limestone float with intraformational conglomerate	126
Limestone: fine-grained, muddy, thin irregularly laminated with lenses of intraformational conglomerate	42
Dolomite: medium crystalline, thin-bedded, light grey with greyish orange shale partings	44
Limestone: aphanitic, thin-bedded, light grey with bluish white chert nodules	86
	1,288

(St. Charles formation)

Age and Correlation

Since the bulk of the fauna collected by Ross (1951) were found within the area covered by this report no paleontologic determinations have been attempted by the writer. Ross places the Canadian-Chazyan boundary approximately 50 feet below the top of the Garden City formation, based on his study of its trilobite fauna.

Swan Peak Formation

Name

The Swan Peak quartzite was named by Richardson (1913) from the exposures on the southeast flank of Swan Peak in the Randolph quadrangle, Utah. Williams (1948, p. 1136) subdivided the formation in the Logan quadrangle, Utah, into three informal members. Since the unit in this area contains considerable shale, calcareous sandstone, and sandstone, the name Swan Peak formation is used in preference to the more generally used term Swan Peak quartzite.

Distribution and Character

The Swan Peak formation crops out throughout the axial portion of the Bear River Range: along the east flank of Front Ridge, in Cub and Franklin Basins, on Horse Lake Ridge, along Temple Ridge and on Paris Peak. In addition to the areas of actual outcrop, in many localities very resistant rubble shed from the Swan Peak formation effectively masks underlying formations downslope from the Swan Peak formation. This masking effect gives an erroneous impression of much greater extent of Swan Peak outcrop than actually exists.

In the Logan quadrangle Williams (1948, p. 1136) subdivided the Swan Peak formation into three members: a lower black shale, a middle brown quartzite and an upper buff quartzite. This sub-division is applicable to the formation in the southern portion of the area; however farther north the shale member is replaced by calcareous sandstone. The middle member is composed of medium-grained quartz sand with siliceous cement. The degree of cementation in most beds is insufficient to warrant classification as a quartzite and the term quartzitic sandstone is more appropriate. It is generally massive and medium to dark reddish brown in color. The upper member is a medium-grained medium-bedded pale yellowish orange quartzitic sandstone.

Fucoidal Markings

There is a long history of discussion of fucoidal markings in geologic literature. (See Newberry, 1885). They were first noted by Locke in Ohio in 1838, and were named <u>Fucoides biloba</u> by Vanuxem in 1842; similar markings were called <u>Cruziana</u> by D'orbigneyin 1842, <u>Fraena</u> by Roualt in 1850 and <u>Rusophycus</u> by Hall in 1852. All of the above men regarded them as impressions of seaweeds. This contention was reaffirmed by Saporta (1884) although he erroneously referred them to the genus <u>Bilobites</u>. Comparable markings were considered by Dawson (1864), Hughes (1884), Nathorst (1881), and James (1884) to be the tracks of various organisms or in some cases to be of inorganic origin. James (1884, p. 151) objected to the promiscuous application of the term fucoid and recommended that it be restricted to its original sense (i.e.) to the fossilized remains of seaweed. Similar features of indeterminate origin he believed should be called fucoidal markings. The term fucoidal marking used herein is intended simply as a form designator implying a physical resemblance to, but not a genetic relationship with, the modern seaweed, Fucus.

One of the most striking features of the Swan Peak formation is the presence of abundant fucoidal markings developed along bedding planes in the quartzitic sandstone members of the formation. Although these markings are scattered throughout the formation there is a definite concentration within the middle dark reddish brown member. Several interesting details of these markings throw some light on their mode of origin.

The fucoidal markings of the Swan Peak formation are irregular, cylindrical, raised welts on the bedding planes of the quartzitic sandstone. The individual welts vary in length from a fraction of an inch to 8 inches and in diameter from approximately 1/8 of an inch to 3/8 of an inch. Some of the ridges radiate outward from a central node and others branch dichotomously from single stems with no apparent central node. Complex intertwining of wales is common. The distal terminations are acuminate. The surfaces of the individual welts, although somewhat irregular, have no systematic transverse or longitudinal markings. In section, parallel to the bedding planes, many of the welts are found to contain concentrations of relatively coarse organic particles, ostracods and trilobite fragments, and a higher percentage of large sized quartz grains than the enclosing ground mass. In some places the trilobite fragments penetrate one or both walls of the welt.

The various hypotheses of origin for the many features of sufficient similarity to be referred to as fucoids or fucoidal markings may be summarized as follows:

1. Fossilized remains of various organisms.
2. Impressions of various organisms.
3. Back-filled burrows or borings of small annelids, mollusks or crustaceans.
4. Burrows or borings of small annelids, mollusks, or crustaceans which have been filled by later collapse of overlying material.
5. In-filled tracks or trails of small organisms.
6. In-filled mud cracks.

It is believed that the observed features of the Swan Peak fucoidal markings militate against any of the above hypotheses of origin for these particular features, for the following reasons:

1. There are no observable cellular microstructures to suggest that these markings are fossilized remains of organisms nor does it seem likely that coarse fragments of this type would become incorporated within the body of any organism which possessed sufficient structural rigidity to allow subsequent fossilization.

2. If these features were casts of impressions on bedding surfaces they would necessarily be underside markings as pointed out by Grabeau (1913, p. 463) whereas they are topside positive markings.

3. The size of the transverse fragments within the markings argues strongly against their origin as back-filled borings.

4. The fact that transverse fragments within the markings in some cases penetrate both walls, and the complex intertwinings of the welts makes their origin by filling of borings by later collapse of overlying material improbable.

5. In-filled tracks or trails would necessarily be underside features rather than topside features.

6. In-filled mud cracks would not show the complex intertwining pattern of these markings.

A possible mode of origin for these particular features is suggested by Raymond's (1922, p. 109) description of the preservation of jelly fish. He observed partially dehydrated, stranded jelly fish to which sand grains had adhered with the gelatinous material cementing the grains of sand together and the mass of the sand grains preventing excessive shrinkage of the jelly fish. The sand varied from fine to coarse with one case of incorporation of a flat pebble 14 mm. in diameter.

It is believed possible that, given an original gelatinous organism, either plant or animal, of proper configuration, subsequent incorporation of coarse sand fractions and organic fragments plus possible influence of the chemical by-products of decomposition of the organism on the cementation process during diageneses could result in forms similar to those described above.

Thickness

The Swan Peak formation thickens very rapidly northward from 339 feet measured by Williams (1948, p. 1136) in Green Canyon to 646 feet measured by the present author on the south flank of Paris Peak, a linear distance of approximately 30 miles.

There is no discernible unconformity between the Swan Peak formation and the underlying Garden City formation within this area, although the changing lithology of the lowermost Swan Peak beds at the contact with the Garden City formation is perhaps indicative of a disconformable relationship. In the cliff exposures above Bloomington Lake (Deep Lake) the uppermost beds of the Swan Peak formation can be seen to wedge out against the lowest beds of the Fish Haven dolomite. This angular discordance coupled with Ross' (1951, p. 9) observation at the Buck Spring locality of the Fish Haven dolomite directly overlapping the Swan Peak formation appears to indicate that the entire variation in thickness of the Swan Peak formation takes place at the upper contact.

Age and Correlation

Although the Swan Peak is generally unfossiliferous there are several beds within the middle member which are abundantly fossiliferous. From these beds the author collected the following:

Eleuthrocentrus petersoni Clark
Orthis michaelis Clark
Orthis swanensis Ulrich and Cooper
Anomalorthis sp.
Lingulella bellesculpta Clark
Bellefontia (?) chamberlaini Clark
Tuzoia (?) subtile Clark

Numerous ostracods were found in the Swan Peak beds. The degree of silicification which these ostracods have undergone has rendered them unidentifiable; however, they are definitely not *Leperditia*, which has been reported elsewhere associated with this fauna.

No graptolites were found in this area, although *Didymograptus bifidus* is reported from other localities associated with this fauna. Ross (1951, p. 33) gives an earliest Middle Ordovician age for the Swan Peak formation.

TABLE 9.-Section of Swan Peak formation on south flank of Paris Peak

(Fish Haven dolomite)

	Feet
Sandstone: quartzitic, medium-grained medium-bedded, pale yellowish orange to very pale orange	331
Sandstone: quartzitic, medium-grained massive, dark reddish brown. Fucoidal markings prominent	115
Sandstone: calcareous, medium-grained, medium-bedded, pale yellowish orange with pale yellowish brown shale partings	200
	646

(Garden City limestone)

Fish Haven Dolomite

Name

The type locality of the Fish Haven dolomite was designated by Richardson (1913, p. 410) as the head of Fish Haven Creek five miles north of the Idaho-Utah state boundary. Richardson's original definition has been accepted by all subsequent workers in the area.

Character and Distribution

The Fish Haven dolomite is exposed above the Swan Peak formation throughout the axial portion of the Bear River Range. It is a fine-textured, medium-to-thick-bedded, greyish-black, rough weathering dolomite. In the northern part of the area the upper 100 feet of the formation contain thin-bedded dark yellowish brown calcareous shale partings. The middle portion of the formation contains a high proportion of black chert nodules and bedded chert. The dolomite is very fetid on freshly fractured surfaces.

Thickness

In the Logan quadrangle and the southern portion of the Preston quadrangle the Fish Haven dolomite is relatively thin (approximately 200 feet) and the overlying Laketown dolomite rests directly on the cherty unit of the Fish Haven. Farther north the shale bearing unit of the Fish Haven intervenes between the cherty Fish Haven and the Laketown dolomite and the Fish Haven thickens to approximately 450 feet.

TABLE 10.-Section of Fish Haven dolomite on headwall above Bloomington Lake (Deep Lake).

(Laketown dolomite)

	Feet
Shale: calcareous, thin-bedded, dark yellowish brown...........................	25
Dolomite: very fine-grained, medium-bedded, medium dary grey dolomite with interbedded dark yellowish brown shale and calcareous beds..............................	86
Dolomite: very fine-grained, medium to thick-bedded, dark grey, with abundant black chert nodules and beds near the top..	158
Dolomite: very fine-grained, thick-bedded, greyish black, fetid. Weathers to very rough pitted surface......................	182
	451

(Swan Peak formation)

Age and Correlation

The following fossils were collected from the Fish Haven dolomite:

Halysites (*Catenipora*) sp. cf. H. *gracilis*
Paleophyllum sp.
Streptelasma sp.
Paleofavosites sp. cf. P. *prolificus* (Billings)

This assemblage is similar to those reported from the Fish Haven dolomite in other sections and indicates a Cincinnatian age for the formation.

The absence of intervening faunas between the Swan Peak formation and the Fish Haven dolomite has been interpreted as indicating a considerable hiatus. Also Williams (1948, p. 1137) has interpreted the variation in thickness of the Swan Peak formation and the changing lithology of its upper beds at the contact with the Fish Haven dolomite as proof of an unconformable relation between the two. In support of this contention the author observed in the cliff exposures above Bloomington Lake (Deep Lake) that the uppermost beds of the Swan Peak formation dip more steeply than the Swan Peak-Fish Haven contact. It should be noted, however, that a considerable thickness of unfossiliferous beds intervenes between the highest reported occurrence of fossils in the Swan Peak formation and the lowest reported occurrence of fossils in the Fish Haven dolomite.

SILURIAN SYSTEM

The Silurian system in the present area is represented by a single thick dolomite formation, the Middle Silurian Laketown dolomite.

Laketown Dolomite

Name

The Laketown dolomite was named by Richardson (1913, p. 410) from its occurrence in Laketown Canyon in the Randolph quadrangle, Utah.

Character and Distribution

The Laketown dolomite crops out along the eastern crest of Horse Lake Ridge and along the crest of Temple Ridge north of the south fork of Fish Haven Canyon.

Williams (1948, p. 1137) has divided the Laketown dolomite, in the Logan quadrangle, into three members which can be recognized in this area. They are: a lower, medium light grey, medium-bedded dolomite member; a middle, medium-grey, medium-bedded to massive dolomite member; and an upper medium light grey, medium to thick-bedded dolomite member. The dolomite varies from fine-grained to coarsely crystalline.

Thickness

The only complete section of the Laketown dolomite exposed in the area is found on the ridge northeast of Bloomington Lake (Deep Lake). It is 1,340 feet thick.

TABLE 11.-Section of the Laketown dolomite measured on the northwest flank of the ridge northeast of Bloomington Lake (Deep Lake).

(Water Canyon formation)

	Feet
Dolomite: medium light grey, medium to thick-bedded, medium-grained crystalline. Silicified corals and stromatoperiods common..............................	565
Dolomite: medium grey, medium-bedded to massive, medium to coarsely crystalline......	540
Dolomite: medium light grey, medium-bedded, fine to medium-grained........................	235
	1,340

(Fish Haven Dolomite)

Age and Correlation

Although poorly preserved fossils are scattered throughout the Laketown dolomite, very few of them, particularly in the lower portions of the formation, are identifiable. In the upper member of the formation, however, several outcrops containing assemblages of relatively well preserved silicified fossils were encountered. From these outcrops the following fossils were collected:

Conchidium sp.
Pentameroides sp.
Alveolites sp. indet.
Cladopora reticulate species
Favosites sp.
Halysites (Cystihalysites) sp. indet. (with large corallites)
Halysites sp. indet. (with small corallites)
Heliolites sp. indet.
Porpites sp. indet.
Syringopora sp.

Abundant Stromatoperoids

This assemblage is characteristic of the Middle Silurian in Utah, Nevada, and California. The faunal break and the contact relationship described above indicate a considerable hiatus between the Fish Haven dolomite and the Laketown dolomite.

Insufficient evidence is available to determine whether the biota represented by these fossils constituted a reef community or simply a biohermal concentration. There would appear to be sufficient similarity between the above listed fauna and that described from the Niagaran reefs of the Great Lakes region to fulfill Lowenstam's (1950, p. 430) criteria of true reefs that "they possess the biologic potential to erect rigid topographic structures by frame building, sediment retention, and binding and to create a wave-resistant structure." The occurrence of all the pentameroid brachiopods as broken fragments which appear to have been washed into crevices in the coral structure is also suggestive of a wave-resistant form.

Evidence is lacking because of the inadequacy of exposures as to the presence or absence of bioclastic debris fans and windward and lee sedimentary facies. The external form of the deposits at ele. 8,650 on the ridge northeast of Bloomington Lake (Deep Lake) very strongly suggests a reef structure; however, how much of this external form may be attributed to original configuration and how much to later fortuities of exposure is indeterminate.

DEVONIAN SYSTEM

The Devonian system is represented in this area by the Lower Devonian Water Canyon formation and by several down-faulted blocks of the Middle Devonian Jefferson formation.

Water Canyon Formation

Name

The Water Canyon formation was first described by Williams (1918, p. 1138) from exposures in Water Canyon, a tributary of Green Canyon in sec. 4, T. 12 N., R. 2 E. of the Logan quadrangle, Utah.

Character and Distribution

In this area narrow outcrop belts of the Water Canyon formation occur along the eastern crest of Horse Lake Ridge and along Temple Ridge between St. Charles Canyon and Bloomington Canyon.

The lower member of the formation is composed of very fine-grained medium to thin-bedded, light grey dolomite. Although the dolomite characteristically weathers to a greyish orange pink to moderate orange pink color no red beds, as reported by Williams were found in the formation in this area. In several localities small (pea sized) limonite nodules were found weathered in relief on the surface of the dolomite.

A rectilinear pattern, resembling mud crack markings, in some cases filled with chert stringers, is displayed along bedding planes in some portions of the lower member of the formation.

The upper member of the formation consists of a medium-bedded, medium-grained, light brown sandstone with very strong cross bedding displayed in some sections. The sandstone member is in general less resistant than the underlying and overlying dolomite beds and is not well exposed.

Thickness

Williams (1948, p. 1139) gives a thickness of 393 feet for a composite section of the Water Canyon formation in the Logan quadrangle. The best exposed section of the formation in this area totaled 357 feet.

TABLE 12.-Section of Water Canyon formation on ridge northeast of Bloomington Lake (Deep Lake).

(Jefferson formation)

	Feet
Upper member	
Sandstone: medium-grained, medium-bedded light brown, some cross bedding........	40
Lower member	
Dolomite: very fine-grained, medium to thin-bedded, medium light grey to light grey. Weathers very rough. Irregular alternation of light and dark beds............................	149
Dolomite: similar to unit below with stronger red tinge assuming greyish orange pink to moderate orange-pink color on weathered surface.............	126
Dolomite: very fine-grained, medium-bedded, light grey. Weathers to very rough granular surface and very pale orange color. Some beds show evidence of mud cracks............................	42
	357

(Laketown dolomite)

Age and Correlation

Scattered fish fragments were collected from the lower dolomite and upper sandstone beds of the formation on the ridge southwest of St. Charles Creek. Williams (1948) cites Bryant (1932, 1933, 1934) and Dorf (1934 a & b) in correlating the Water Canyon fauna with the fauna at Beartooth Butte, Wyoming.

Later studies of the Water Canyon fishes by Denison (1952) confirm the Early Devonian age of the formation. There is no measurable discordance in this area between the Water Canyon formation and the underlying and overlying beds.

Jefferson Dolomite

The Jefferson dolomite is widely exposed in the Montpelier and Randolph quadrangles. In the Logan quadrangle Williams (1948, p. 1139) has divided the formation into two members: the Hyrum dolomite and the Beirdneau sandstone. In this area several large outcrop belts of the Hyrum dolomite member occur as down-faulted blocks along the Temple Ridge fault in upper Green Canyon basin, in upper St. Charles Canyon and on the south flank of Bloomington Canyon. Several outcrops on the ridge above Minnetonka Cave in St. Charles Canyon bear a strong lithologic similarity to the Beirdneau sandstone.

The following fossils were collected from the basal limestone bed of the Hyrum dolomite member.

Atrypa cf A. nevadana Miller
Atrypa aff. A. missouriensis Merriam
Atrypa cf A. montanensis Kindle

Above the thin basal limestone bed the Hyrum dolomite is a relatively uniform, very dark grey, medium-grained, medium-bedded dolomite. Because of the structural setting no stratigraphic measurements were possible. Williams (1948, p. 1139) gives the age of the Jefferson dolomite as Senecan and (?) Chautauquan.

MISSISSIPPIAN SYSTEM

The Mississippian system is represented by a narrow outcrop belt of the Madison limestone which occurs along the Temple Ridge fault in St. Charles Canyon.

Madison Limestone

The Madison limestone is a medium grey, medium-bedded, granular limestone containing a very abundant early Mississippian fauna. The most common Madison fossils in this area are:

Syringopora sp.
Schuchertella cf. S. chemungensis
Spirifer centronatus
Eumophalus luxus

The Madison outcrops in St. Charles Canyon show very marked effects of ground water solutional activity. The largest cavern in the region, Minnetonka Cave, is developed in a block of Madison limestone on the south side of St. Charles Canyon. In many parts of Minnetonka Cave fossils have been etched in relief on the limestone wall-rock and are remarkably displayed. No stratigraphic measurements of the Madison limestone were possible.

CENOZOIC SYSTEM

The Cenozoic system is represented by the Salt Lake formation, Lake Bonneville sediments, and post-Bonneville alluvial and colluvial deposits. All post-Salt Lake deposits are represented on Fig. III by a single symbol.

Salt Lake Formation

Name

The name Salt Lake group was originally applied by Hayden (1869, p. 92) to a complex of light-colored sands, sandstones, and marls in the valley of Weber River from Morgan City to Devils Gate. Mansfield (1920, pp. 402-406) quoted Hayden's definition and stated: "This term was introduced into S.E. Idaho by Peale (1879, pp. 588-640). In the above citation the name appears to be used in a strictly geographical sense with neither definite implication of lacustrine origin of the beds nor implication of connection with Great Salt Lake.... The long usage of the name in this region and the fact that it was directly applied by Peale to the beds under consideration makes its retention desirable." Mansfield modified the term to Salt Lake formation and stated his belief that the beds, though probably partly lacustrine, were largely of fluviatile origin.

Eardly (1944, p. 845) applied the name Norwood tuff to beds, bearing Oligocene titanothere bones, at the type locality of Hayden's Salt Lake group and considered it (the Norwood tuff) a division under Hayden's Salt Lake group.

Distribution and Character

The Salt Lake formation forms foothill slopes along the West flank of the Bear River Range. The maximum elevation at which it crops out in this area is approximately 6,500 feet. On the east it overlaps unconformably the Brigham formation and on the west it is overlain by Lake Bonneville sediments.

The formation in this area is composed of coarse fanglomerates, greyish yellow green tuffaceous sandstones, pale yellowish brown marls and sandstones, and very fine grained white tuffaceous beds. The fanglomerates are composed of subangular to well rounded pebbles, cobbles and boulders, the most of which appear to have been derived from the local Cambrian formations, in a fine-grained light grey siliceous matrix. The individual units of the formation are exceedingly transitionary and discontinuous.

Thickness

The thickness of the Salt Lake formation, like its lithology, is extremely variable. The basal fanglomerate member in this area varies from approximately 75 feet in the exposures east of Franklin, Idaho, to over 800 feet in the exposures at Deer Cliff along Cub River. The maximum reported thickness of the formation measured in a single section is 1,140 feet (Williams, 1948, p. 1147). The measurements given below represent a composite section.

TABLE 13.-Composite section of the Salt Lake formation measured east of Franklin, Idaho.

(Alluvium)

	Feet
Sandstone: medium to coarse-grained, pale yellowish brown. Some calcareous lenses..	100
Marl: pale yellowish brown....................	230
Sandstone: coarse-grained, non-calcareous greyish, yellow-green.....................	85
Claystone: tuffaceous, greyish, yellow-green..	120
Claystone: tuffaceous, very pale orange to white. Some coarser slightly calcareous lenses....................................	350
Fanglomerate: subangular to well-rounded pebbles, cobbles, and boulders of local derivation, fine-grained grey siliceous matrix..................................	75
	960

(Unconformity)
(Paleozoic Rocks)

Age and Correlation

The different units of the Salt Lake formation without doubt vary greatly in age from place to place. The formation as a whole is remarkably unfossiliferous and correlations with the few existing fossil localities are very tenuous and serve at best only as limiting ages. Mollusks from beds within the Salt Lake formation in northern Utah have been identified by Yen (1947) as Pliocene forms. The titanothere remains from the Norwood tuff are Oligocene. Eardly 1944, p. 845) Mansfield (1927, p. 112) states that the Early Eocene to Early Pliocene Fort Hall andesitic tuffs are interbedded with and overlain by correlatives of the Salt Lake formation. The tuffaceous material in the Salt Lake formation is andesitic in composition. The Plio-Pleistocene Fort Hall rhyolites and basalts overlie topography developed by erosion of the Salt Lake formation. Hence the various units of the Salt Lake formation in all probability range in age from Oligocene to Pliocene.

Several of the outcrops of light-colored Wasatch formation in the Randolph and Montpelier quadrangles on the east flank of the Bear River Range bear a striking lithologic similarity to various units of the Salt Lake formation. In the absence of faunal or structural evidence to the contrary in this area the possibility of actual equivalence of some units of these formations cannot be entirely discounted.

Lake Bonneville Sediments

A thick section of lacustrine sediments fills Cache Valley below an altitude of 5,135 feet., the highest level of Lake Bonneville in this area. In this complex are included both the lake bottom deposits and the various short line depositional features comprising beach veneers, bars, spits and deltaic deposits. Since the area under consideration includes such a relatively small fraction of the vast Lake Bonneville complex no attempt was made to study or map it in detail.

Post-Bonneville Deposits

Because the topography is rough and the streams are actively degrading, alluvial deposits in most localities are relatively thin. Unconsolidated deposits of sand, gravel and clay occupy the valley bottoms, and the lower slopes of the upland areas are covered with hill wash debris of local derivation. Several areas of large scale solution-subsidence, particularly in upper Bloomington and St. Charles Canyons, are covered with collapse-colluvium. Elongate landslide areas are developed on shaly slopes of the Salt Lake formation in sec. 6, T. 14 S., R. 40 E.

STRUCTURAL GEOLOGY

GENERAL STATEMENT

The Paleozoic rocks of the southeastern portion of the Preston quadrangle are folded into northward and southward trending flexures and dislocated by high-angle faults. The Cenozoic beds, in most localities, dip eastward at relatively low angles and are displaced only to a minor degree by faulting. They overlie the older rocks with pronounced unconformity.

In this report types of structure, analyses of structures in localized areas, and character of movements are considered. Since the absence of Mesozoic and Early Cenozoic rocks within the area prevents close dating of structural features, a brief resume' of structural evolution in adjacent areas is given and an attempt is made to relate the local structural features to the regional pattern.

FOLDING

The uniform opposed dips along the east and west flanks of the Bear River Range indicates that the included Paleozoic rocks have been folded into a broad, relatively symmetrical syncline. Later high angle faulting along the crestal portion of the range has to some extent obscured the exact location of the synclinal axis. This broad flexure represents the northward continuation of the Logan Peak syncline mapped by Williams (1948) in the Logan quadrangle to the south. The Fish Haven syncline mapped by Mansfield (1927) in the Montpelier quadrangle passes laterally into a fault which terminates east of the Preston quadrangle. The regional trend of the folding is reflected in the attitude of the Paleozoic formations which, except adjacent to zones of faulting, show a remarkably persistent strike of approximately N. 10° E. No evidence was found within this area to indicate any regional folding moment divergent from this single N.E. trend.

FAULTING

Figure III shows the principal faults or zones of faulting within the area. The faults appear to fall into two major categories: longitudinal faults which roughly parallel the trend of the Bear River block, and transverse faults which intersect the regional strike at relatively high angles. Branching, anastomosing, and recurving are characteristic of the traces of the longitudinal faults whereas the transverse fault trace patterns are relatively straight. No exposures of major faults were found; however in all cases where fault surfaces of subsidiary faults within major zones of faulting were observed the dips of the faults are steep, 75° or higher and features related to the fault indicate downward movement of the hanging wall relative to the footwall. The maximum stratigraphic displacement observed in the area was approximately 4,000 feet along the Temple Ridge fault in St. Charles Canyon, where the Madison limestone is brought into contact with the Swan Peak formation. However, the aggregate displacement along the East Cache faults must be of the order 10,000 feet.

Three distinct types of field evidence -- stratigraphic, lithologic, and morphologic -- were found to be useful in delimiting faults and fault zones within this area. Stratigraphic offset, which in most cases is of necessity accompanied by some structural displacement, is best displayed along faults of large displacement wherein recognizable stratigraphic units far separated in the normal stratigraphic sequence are juxtaposed. Lithologic eivdences of faulting consist of brecciation, such as that developed along the Hillyard Canyon fault at Willow Flat or on Smarts Mountain and dolomitization of limestone beds along the locus of faulting such as that developed in the Garden City formation along the White Canyon fault. The morphologic effect of faulting in this area is twofold. There is, in most cases, a direct topographic expression of the faults; also the fact that ground water activity is in general intensified along fault zones imparts an important secondary effect. Hence not only are sink holes and solution-subsidence basins concentrated along faults, but the development of subsurface drainage systems related to faults has had widespread topographic effects.

There is no evidence of thrust faults within the area. Williams (1948, p. 1148) refers to the Bear River Range thrust block and apparently considers the entire Bear River Range as a portion of the overriding mass of the Bannock Thrust. From an examination of the exposures of the Bannock fault and of the outcrop pattern of its trace immediately adjacent to the present area, this author considers this particular portion of the Bannock fault a higher angle reverse fault rather than a low angle thrust fault. Hence although Mansfield's (1927, p. 158) horizontal displacement figures of 12-35 miles for the Bannock fault may apply farther north where a true low angle thrust relationship does exist, much less horizontal displacement is involved in this segment of the fault. Consequently it is not necessary to consider the entire Bear River Range as a great overriding mass thrust from the west.

Williams (1948, p. 1149) interpreted overturned beds in the face of the Bear River Range between Blacksmith Fork and Dry Canyon as drag due to a large thrust that cut the rocks at a greater angle than the slope angle of the present face of the range and hence is not now represented by any part of the overriding mass. No comparable evidence was encountered in this area.

East Cache Faults and Smarts Mountain

From his structural studies in the Wasatch Range, Eardley (1944) concluded that middle or late Eocene folding defined the ranges and valleys of the Wasatch region and that most of their relief was due to this folding and not to later high angle faulting. He (1949, pp. 20-21) states: "In middle or late Eocene time a system of broad gentle north-south folds was superposed over the older and divergently trending folds and thrusts to define for the first time the modern ranges and intermontane valleys of the region. The amplitude of the folds as they occur is at least 5,000 feet and the anticlines are still the sites of major relief; the synclines, the great valleys. The frontal Wasatch is one of these anticlines and Morgan Valley on the east and the Great Salt Lake Valley on the west representative synclines.... The ranges of the Great Basin immediately west of the Wasatch owe most of their relief to this folding and not to the much later high angle faulting of the Basin and Range orogeny."

The essential synclinal structure of the Bear River Range suggests that Williams' (1948, p. 1160) concept of the development of Cache Valley as a graben delineated by Basin and Range faults rather than by original down-folding is correct for this area. This conclusion requires a much greater displacement along the East Cache boundary faults than Eardley believes to be necessary along the Wasatch boundary fault.

The mapping of boundary faults covered by thick alluvial fills must of necessity be somewhat arbitrary. It is believed, however, that the location of the east and west branches of the fault as shown on Figure 3 adjacent to blocks of strongly brecciated Paleozoic rocks is the closest possible approximation to their actual position.

As shown on Figure 3 Smarts Mountain is composed of a southern block of strongly brecciated Nounan and St. Charles beds striking N. 25° W. and dipping 60° S.W. separated by a high angle cross fault from a northern block of Garden City limestone, striking N. 60° E. and dipping 38° S.E. A minor fault striking N. 60° W. and dipping 75° S.W. is exposed in a cave at the southern tip of Smarts Mountain. Slickensides indicate downward relative movement of the west side. Portions of the fault are plastered with very dense re-cemented gouge. Another fault is exposed in a quarry face at the northwest corner of Smarts Mountain. It strikes N. 20° E. and dips 82° W.

Lake Bonneville shoreline features are developed around the flanks of Smarts Mountain below an altitude of 5,135 feet and lacustrine deposits completely mask the basal portions of the mountain.

Three hypotheses of origin of the Smarts Mountain block have been considered:

1. It is an outlier of an eastward moving thrust mass, possibly the same thrust to which Williams (1948, p. 1148) attributed the overturning of beds in the face of the Bear River Range.

2. It is a massive landslide block derived from the west flank of the Bear River Range.

3. It is a horst within the East Cache fault zone.

No evidence supporting hypothesis No. 1 could be discovered. Furthermore it is believed that the remarkable straight-line arrangement of the Smarts Mountain block with additional blocks of the same stratigraphic units at Worm Creek and Oneida Narrows is too symmetrical to be explained by the fortuities of erosion coincident to the reduction of a large-scale thrust mass.

Hypothesis No. 2 likewise fails to explain the linear pattern of the Smarts Mountain, Worm Creek, and Oneida Narrows blocks nor does it explain the intense brecciation in the higher portions of Smarts Mountain. Hence origin as a horst along relatively straight faults of relatively uniform displacement seems best to fit the circumstances.

Several minor shear zones were observed in rocks of the Salt Lake formation along the East Cache fault zone just south of Oneida Narrows. These shear zones are interpreted as indicating minor movements along the East Cache faults subsequent to the major period of faulting, since the contact between the Salt Lake formation and the Paleozoic rocks of the Bear River Range is a depositional contact, not a fault contact.

Longitudinal Faults Within the Bear River Range

There are three major, subparallel, north-trending, longitudinal faults within the Bear River Range: the Temple Ridge fault, the Eagan Basin fault, and the Franklin Basin fault and its northward continuation the Hillyards Canyon fault. The relative movement along these faults, except for a small graben between branches of the Temple Ridge fault, is consistently west side down, indicating a tilted fault block pattern rather than a typical horst and graben pattern. The trace patterns of these faults are sinuous.

The Temple Ridge fault enters the Preston quadrangle along the valley of Beaver Creek, and defines the eastern base of Horse Lake Ridge and the western base of Temple Ridge. Immediately north of the quadrangle boundary the Laketown dolomite is brought into fault contact with the Garden City limestone, giving stratigraphic displacement of approximately 2,500 feet. The fault branches in upper Green Canyon Basin. The eastern branch crosses St. Charles Canyon and brings the Madison limestone into contact with the Swan Peak formation with a stratigraphic displacement of approximately 4,000 feet. It continues northward along the east flanking ridge of St. Charles Canyon, crosses Bloomington Canyon, and passes out of the area along the west flank of Paris Peak. The central branch follows upper St. Charles Canyon, crosses the south fork of Bloomington Creek, and disappears under the alluvium in the basin at the head of the middle fork of this creek. The relative movement on the western branch is east side down; hence the block between the western and central branches of the fault is essentially a graben.

The traces of the Temple Ridge fault and its various branches are characterized by the development of ground water solution phenomena and by intense dolomitization in some localities. Large solution-subsidence basins are developed at the juncture area of the three branches in upper Green Canyon Basin. Extensive caverns, including Minnetonka Cave, are developed along the eastern branch where it crosses St. Charles Canyon, and sink holes and collapse-colluvium are common along the entire zone of the fault.

The Eagan Basin fault enters the Preston quadrangle along the valley of Sink Hollow. The downthrow along the fault is on the west. Stratigraphic displacement at the southern end of the fault is approximately 600 feet and decreases northward through Gibson and Eagam Basins. The fault passes under alluvium in the valley of the west fork of St. Charles Creek and a continuation of the fault could not be traced north of the alluvium. The Litz Basin fault terminates against the Eagan Basin fault at the southern end of Eagan Basin. Sink Hollow, Gibson Basin, and Eagan Basin show widespread evidence of solutional activity. There is no surface drainage from Gibson Basin, the sole drainage exit being by springs developed along the fault at the head of Sink Hollow.

The Franklin Basin fault enters the Preston quadrangle along the left fork of Logan River. It defines the western base of Horse Lake Ridge. It strikes northward through Franklin Basin to Cub Basin, where it is offset to the west by the Litz Basin fault. The stratigraphic displacement in Franklin Basin is approximately 1,500 feet. For ease of identification the continuation of the Franklin Basin fault north of Cub Basin is called the Hillyards Canyon fault. North of Cub Basin the Hillyards Canyon fault swings westward to define the northern portion of Hillyards Canyon, crosses Willow Flat, and passes out of the area across Birch Creek summit. The big springs which supply the major portion of the discharge of Cub River are developed along the fault at the mouth of Hillyards Canyon. The alluvium in Willow Flat obscures the relationship of the Willow Flat fault to the Hillyards Canyon fault; however, immediately north and south of the juncture there are zones of intense brecciation and dolomitization.

As in the case of the East Cache faults, the dips of minor fault planes and the trace patterns of the longitudinal faults within the Bear River Range indicate high angle fault relationships throughout the area.

Transverse Faults within the Bear River Range

There are four major transverse faults within the Bear River Range: the Litz Basin fault, the Willow Flat fault, the Worm Creek fault, and the Paris Peak fault.

The Litz Basin fault strikes approximately N. 50° W. and can be traced from the northern end of Eagan Basin to a point northwest of Cub River where it disappears beneath the Salt Lake formation. Along most of its length the fault zone may be recognized by its topographic expression as a narrow depression. Carbonate rocks adjacent to the fault are intensely brecciated and calcite-filled vugs and stringers are common in them. The sandstones and quartzites are shattered and brecciated to a lesser degree.

The Franklin-Basin-Hillyards Canyon fault is offset by the Litz Basin fault with an apparent relative movement north side west; however, the Litz Basin fault terminates abruptly against the Eagan Basin fault.

Although no exposures of the Litz Basin fault were found, the minor shear planes and the trace pattern of the fault indicate a steep dip. The stratigraphic offset along the fault is most easily explained by a strike-slip displacement of approximately 1,000 feet; however, drag effects observed along the fault appear to indicate dip-slip rather than strike-slip movement. If dip-slip movement only is involved the displacement must be of the order of 2,000 feet. In all probability oblique slip of between 1,000 feet and 2,000 feet, with the relative movement north side down and west is responsible for the observed displacement.

The offset stratigraphic relationships on opposite sides of Cub River indicates a transverse fault striking east-west beneath the alluvial fill in the Willow Flat Basin. This fault is called the Willow Flat fault. A second transverse fault swings east out of the first canyon east of Hillyards Canyon and disappears beneath the alluvium in Willow Flat. It is impossible to determine whether this fault originally was continuous with the Willow Flat fault. If such were the case the present relationship indicates displacement of the Willow Flat fault by the Hillyards Canyon fault.

A third transverse fault emerges from beneath the alluvium at the northern end of Willow Flat. It strikes N. 60° W. and brings the Nounan formation into contact with the Brigham formation with a stratigraphic displacement of approximately 2,500 feet. At several localities along this fault there are mineralized zones with fissure fillings of barite and specular hematite. This is the only fault showing this type of mineralization within the area.

A fourth transverse fault enters the present area north of Paris Peak and disappears beneath the alluvium in the valley of the north fork of Bloomington Creek. It strikes N. 40° E. and appears to be of considerable linear extent north of this area.

The longitudinal faults within the area are of sufficient similarity to warrant their assignment to a single period of faulting. The offset of the Litz Basin fault by the Hillyards Canyon fault, and its abrupt termination against the Eagan Basin fault, would appear to indicate relative contemporaniety of all three faults. This temporal relationship is probably also true of the other transverse faults in the area. Since the longitudinal faults in this region have been shown by Mansfield to postdate the Bannock fault by a considerable interval of time, it is believed that the transverse faults also postdate the Bannock fault and thus can bear no genetic relationship to it.

RESUME' OF STRUCTURAL EVOLUTION IN ADJACENT AREAS

This resume' represents a condensation of material from the work of Mansfield (1927), Williams (1948), and Eardley (1938, 1944, 1949) plus additional details from the present area.

It is probable that correlatives of most of the late Paleozoic, Mesozoic, and early Cenozoic deposits found in adjacent areas were deposited within the area under consideration and were removed by subsequent erosion. (See Eardley 1949, Fig. 2 & 3) The presence of thick deposits representing each of the Paleozoic systems within this general area indicates proximity to the axial zone of the Cordilleran geosyncline, and nearby Mesozoic and Cenozoic deposits indicate it was within the zone of deposition of the Rocky Mountain geosyncline. Temporary cessation of deposition is by disconformities, Cessation of deposition plus some degree of attendant warping is recorded by unconformities as shown on Figure 2.

Eardley (1949, pp. 12-23), distinguished six post-Paleozoic orogenic pulses in the Wasatch area which may be summarized as follows:

1. Cedar Hills orogeny (Mid-Cretaceous); early east-west folding and north-south faulting.
2. Early Laramide orogeny (Late Cretaceous); extensive system of divergently trending folds which affected the earlier fault pattern.
3. Middle Laramide orogeny (Early Paleocene); formed the great overthrusts.
4. Late Laramide orogeny (Eocene); system of broad gentle north-south folds.
5. Absarokan orogeny (Oligocene); volcanic activity plus minor refolding along Late Laramide axes.
6. Basin and Range Orogeny (Late Tertiary): high-angle north-south fault system.

Relation of Local Structures to Regional Pattern

Of the diverse deformational patterns recorded in adjacent areas the sole representatives within the Preston area appear to be the broad gentle folding involved in the formation of the Logan Peak syncline and the high-angle faulting, which, although it cannot be closely dated, certainly partakes of the nature of Basin and Range faulting. On the basis of nature, magnitude, and orientation, the folding in the Bear River Range is herein tentatively correlated with the Late Laramide orogeny of Eardley.

Whether or not this correlation is correct the attempted correlation raises a significant question; i.e., how can one explain the existence of an area of relatively simple structure within a zone of extreme structural complexity? The absence of Cenozoic and Mesozoic deposits does not answer the question since elsewhere divergent trends are recorded within the Paleozoic sequence as well as within the later deposits. It is believed that the ultimate answer to this question lies in the nature of the sedimentary prism in this area and its spatial relationship to resistant bosses of Pre-Cambrian basement rock. The Paleozoic formations in this area are very thick and relatively competent. Thinning of the Paleozoic rocks to the east and the presence within the eastern stratigraphic column of thick, less competent Mesozoic rocks give a much different character to the eastern sedimentary prism in regard to possible reaction to diastrophic forces than that of the western prism. To the South the Paleozoic prism is also somewhat thinner, in addition to which closely grouped bosses of Pre-Cambrian basement rocks probably imparted diverse trends to regional tangential stresses which in this area resulted only in broad gentle uplift. The hypothesis that regional diastrophic forces which elsewhere imposed diverse structural patterns resulted only in gentle folding and uplift in this area is supported to some extent by the relatively great depth of the general stratigraphic level of erosion within this area.

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