5-1958

Geology of the Southern Part of Wellsville Mountain, Wasatch Range, Utah

Ronald H. Gelnett
Utah State University

GEOLOGY OF THE SOUTHERN PART OF WELLSVILLE MOUNTAIN, WASATCH RANGE, UTAH

by

Ronald H. Gelnett

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

of

MASTER OF SCIENCE

in

Geology

UTAH STATE UNIVERSITY
Logan, Utah

1958

73 p.

ACKNOWLEDGMENT

The project was carried out under the able direction of Dr. J. Stewart Williams. The writer is indeed grateful to Dr. Williams for his advice and criticism in preparation of the manuscript and for the identification of fossil collections. The writer also wishes to express a debt of gratitude to Dr. Clyde T. Hardy for helpful suggestions on structural problems and for criticism in preparation of the plates. Sincere appreciation is extended to Mr. Donald R. Olsen for his helpful advice on field problems and for suggestions in preparation of the geologic map.

Ronald H. Gelnett

TABLE OF CONTENTS

	Page
Abstract	1
Introduction	2
Purpose and scope	2
Location and extent of the area	2
Previous investigations	4
Field work	5
Physiography	6
Stratigraphy	10
Pre-Cambrian rocks	10
Cambrian system	12
Brigham formation	14
Langston formation	15
Ute formation	16
Blacksmith formation	18
Bloomington formation	18
Nounan formation	19
St. Charles formation	20
Ordovician system	21
Garden City limestone	23
Swan Peak quartzite	26
Fish Haven dolomite	29
Silurian system	31
Laketown dolomite	31
Devonian system	35
Water Canyon formation	35
Jefferson formation	38
Mississippian system	42
Lodgepole limestone	42
Brazer formation	46

TABLE OF CONTENTS (cont.)

	Page
Pennsylvanian system.	49
Oquirrh formation	50
Quaternary deposits	54
Structural geology	55
Regional structural relations	55
Geologic structure	57
General features	57
Northwest-trending faults	59
Wasatch fault zone	59
Mt. Hughes fault	59
Northeast-trending faults	61
Major transverse fault	61
Antimony Canyon fault	62
Age of structure	62
Ore deposits	67
Bibliography	69

ILLUSTRATIONS

Figure | Page

1. Index map of northeastern Utah showing the location of Wellsville Mountain and area studied. 3

2. Diagramatic sections of the Brazer formation at Deweyville, Dry Lake, and Leatham Hollow showing variation in thickness 43

3. Structure map of north-central Utah. 56

Plate

1. Aerial view of the southern part of Wellsville Mountain showing attitude of strata and the location of the Wasatch fault zone 8

2. View, looking down into cirque in Pine Canyon from the crest, showing moraines 9

3. Transverse fault in Antimony Canyon, showing its trace on the west and east sides of the southern part of Wellsville Mountain 13

4. Vertical columnar structures in the Langston formation, just above mine dump in Antimony Canyon 17

5. Aerial view of the west-facing front, looking east, showing high-angle transverse faults, strike-slip fault in Baker Canyon, and lower Paleozoic stratigraphy 22

6. Contact between the Fish Haven dolomite and the Swan Peak quartzite in Precipice Canyon showing the Fish Haven pushed over the Swan Peak 30

7. Dark and light beds at the base of the Laketown dolomite in Cottonwood Canyon. 33

ILLUSTRATIONS (cont.)

Plate		Page
8.	Middle Paleozoic section on the north side of Calls Fort Canyon. Close-up view showing Jefferson-Lodgepole-Brazer contacts	36
9.	Aerial view of major transverse fault showing its trace on east and west side of the mountain . .	60
10.	Aerial view of west-facing front, north of Brigham City, showing transverse faults in Hanson, Kotter, and Water Fall canyons	63
11.	View of east-facing front, near north end of the mountain, showing Mt. Hughes fault with slickensided surface	65
12.	Aerial oblique view, east side of southern part of the mountain, showing Fish Haven pushed over Swan Peak	66

ABSTRACT

Wellsville Mountain is 10 miles west of Logan, Utah, at the northern extremity of the Wasatch Range. Paleozoic rocks form a northeast-dipping homocline bounded in part by northwest-trending high-angle faults and cut by a series of northeast-trending high-angle faults. A major transverse fault, with a stratigraphic displacement of 4,500 feet, divides the mountain into two distinct blocks.

The rock units of the area are comparable to those of the Logan quadrangle immediately to the east. Pre-Cambrian rocks crop out in Box Elder Canyon, just east of Brigham City, and are overlain by at least 20,000 feet of northeast-dipping Paleozoic rocks of every period except possibly the Permian. The Beirdneau sandstone member of the Jefferson formation of Devonian age and the Leatham formation of Lower Mississippian age are not recognized in the area. A new fauna, in the Jefferson formation, is tentatively correlated with that of the upper Devils Gate limestone of central Nevada. About 6,600 feet of the Oquirrh formation of Pennsylvanian age is exposed near the northern end of Wellsville Mountain. The presence of Desmoinesian fusulinids at the base of the Oquirrh and upper Virgilian fusulinids throughout the interval from 1,000 to 2,000 feet above its base indicates an absence of Lower Pennsylvanian rocks and suggests that the upper 4,400 feet may be in part Permian. Mesozoic rocks are not found in the area. The Wasatch formation and Salt Lake group of Tertiary age crop out in the foothills at the northern end of Wellsville Mountain.

Two fault systems are recognized in the area. The northeast-trending high-angle transverse faults of Laramide age and the northwest-trending high-angle bordering faults are Basin and Range age.

INTRODUCTION

Purpose and Scope

Wellsville Mountain occupies the extreme northern tip of the Wasatch Range, Utah. The range is part of the Rocky Mountain system referred to as the Middle Rocky Mountains and bounds the southwest portion of the province (Figure 1). The geology of the Wasatch Range and vicinity is rather complete from previous geologic investigations. Almost all areas in the range have been mapped, excepting the northern most extremity, Wellsville Mountain. Heretofore only reconnaissance study and mapping of the area has been attempted.

The purpose of this study is twofold. First, to map and describe the structure and stratigraphy of the area. Secondly, to describe and correlate structural and stratigraphic relationships in Wellsville Mountain to that of the surrounding area.

Location and Extent of the Area

The western boundary of the Wasatch Range forms the southwestern boundary of the Middle Rocky Mountain physiographic province (Figure 1). The northernmost extremity of the Wasatch Range, Wellsville Mountain, is bordered by Cache Valley on the east, Bear River Valley on the west, and the Junction Hills area and Malad Range on the north. All of these areas are Basin and Range in structure. The southern boundary is U.S. Highway 89-91 from Brigham City to Logan. Wellsville Mountain is a narrow, rugged fault-mountain that trends north-northwest with a length of nearly 20 miles and an average width of 3 to 5 miles.

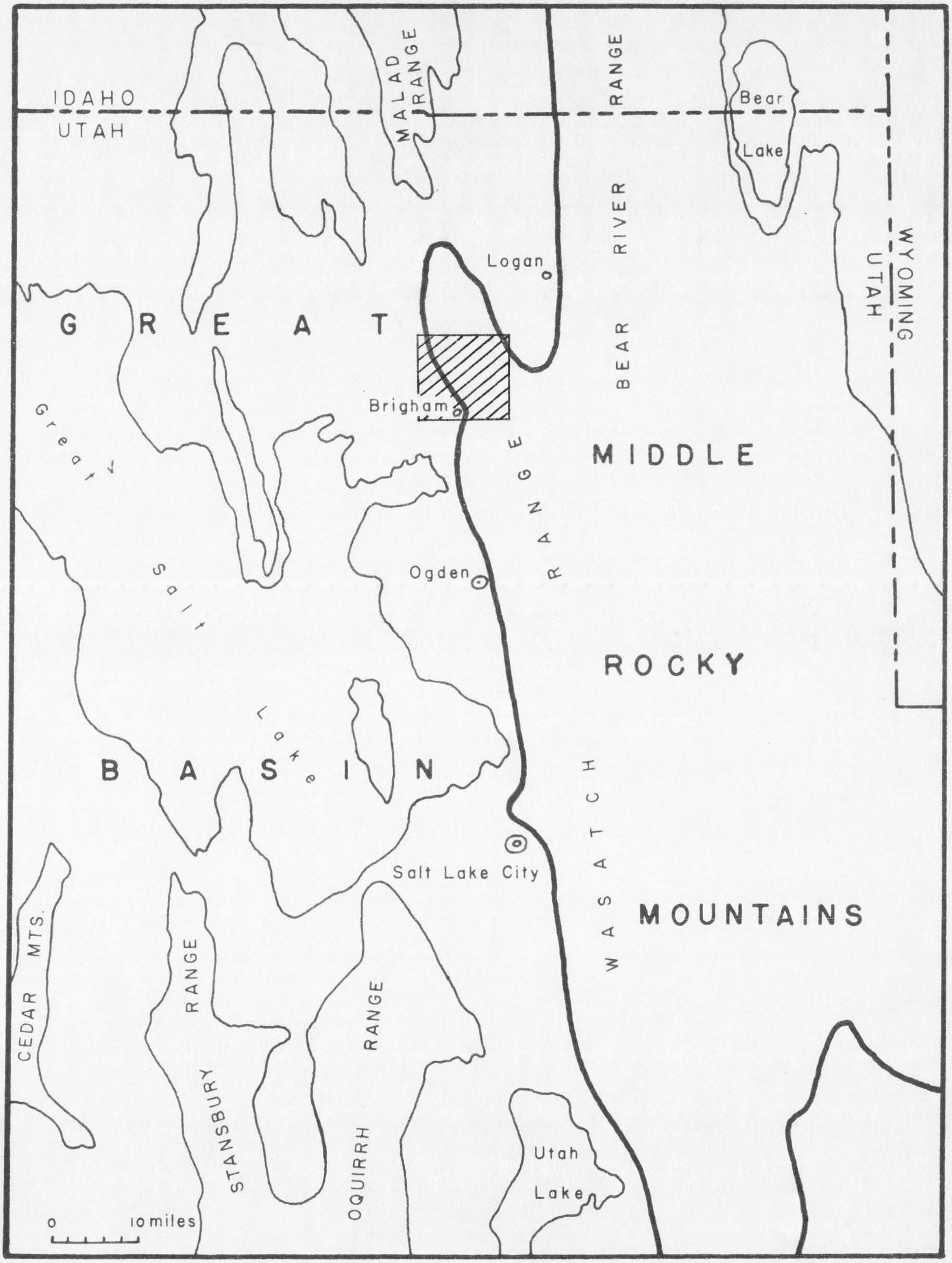


Figure 1. Index map of northeastern Utah showing the location of Wellsville Mountain and area studied.

The approximate geographical location of Wellsville Mountain is at west longitude 112°00' and north latitude 41°35'. The geologic map of this area includes 48 square miles and parts of four Utah quadrangles, the western half of Mt. Pisgah quadrangle, eastern half of Brigham City quadrangle, and the north-central parts of Willard and Mantua quadrangles.

Previous Investigations

The Fortieth Parallel Survey led by King (1867-1877) made the earliest geologic exploration in this general area. In 1871 the Hayden Survey party made geologic observations while traveling through Cache Valley on its way to Yellowstone Park (Hayden, 1872). Bradley (1872, p. 189-271) observed and described the western face of Wellsville Mountain and examied the "Gates of the Bear River" enroute from Ogden to Malad, Idaho. Geologists of the Green River Division under Peale (1879, pp. 509-646), while studying the area from Logan Canyon northward, described briefly the geology of the "Western Base of the Wasatch" in 1877. Gilbert (1890, p. 159) described the Lake Bonneville shore features on both sides of Wellsville Mountain and noted the Tertiary deposits as being derived from a lake older than Lake Bonneville in the southern part of Cache Valley (1890, p.99). The Cambrian rocks of the area were first studied and named by Walcott. In 1908 he published his original Blacksmith Fork section (Walcott, 1908a). Later, Richardson (1913) published the first complete Paleozoic section from his work in the Randolph Quadrangle, Utah. He named and described several new formations including the Garden City limestone, Swan Peak quartzite, Fish Haven dolomite, Laketown dolomite, and the Brazer formation. Gilbert (1928), in his study of Basin and

Range structures, described the spurs on the west side of Wellsville Mountain and the "back valleys" which includes Dry Lake and Mantua valleys. Gilbert describes them as graben structures. Eardley and Hatch (1940, p. 811) measured and described a section of Brigham quartzite in Baker Canyon (Antimony Canyon) in Wellsville Mountain and studied the pre-Cambrian series in Box Elder Canyon. A complete and detailed Cambrian section was measured by Maxey (1941) in Calls Fort Canyon near the northwest corner of the map area. The structure and physiography of the north-central Wasatch Range was published by Eardley (1944). An extensive study of the geology in the area just north of Wellsville Mountain, the Malad Range, was made by Hanson (1949) and Prammani (1957).

Field Work

The field work for this paper was done during the summer of 1957. United States Forest Service aerial photographs (scale 1:20,000) were carried in the field and the structural and stratigraphic detail was plotted on them. For a base, the information was then transferred to United States Geological Sruvey topographic quadrangle maps (scale 1:24,000). This eliminated errors due to distortion and parallax of the photographs. The data were then traced on an overlay of the same scale to complete the final map.

All formations in the succession from Ordovician to Pennsylvanian inclusive were measured with the aid of a 100 foot steel tape and a Brunton compass. True stratigraphic thicknesses of the sections were calculated with the aid of Mertie's chart (1947). Rock samples and fossils were collected for study and identification in the laboratory. Descriptive colors or rock samples were determined in the laboratory with the rock color chart of the National Research Council.

PHYSIOGRAPHY

Wellsville Mountain is a long, narrow, simple crested mountain bordered by two broad, flat valleys -- Cache Valley on the east and Bear River Valley, a northern arm of Great Salt Lake Valley, on the west. The mountain is, essentially, a typical fault-block Basin and Range type structure (Plate 1B). It has a length of over 20 miles and an average width of 3 to 5 miles, increasing from south to north. A major high-angle transverse fault divides the mountain into two distinct blocks and crest levels (Plate 1A). The average relief of the southern block is approximately 3,500 feet and the northern block 4,500 feet. The two highest peaks on the mountain, Wellsville Cone and Willards Peak, rise to an elevation 9,300 feet and 9,355 feet respectively directly west of the town of Wellsville, Utah.

The "Back Valleys", as described by Gilbert in 1928 as graben type structures, include Dry Lake and Mantua valleys. Dry Lake Valley is located between the southern part of Wellsville Mountain and the Pisgah Hills (Plate 1A). Mantua Valley is to the south, just out of the picture.

The rocks in the area are predominently limestone and dolomite, with quartzite, shale, calcareous sandstone, and conglomerate. The slopes on the west side of the mountain are considerably steeper and more rugged than those of the east face and the vegetation is sparser. The west side of the mountain is a sheer, rugged, cliff-like face with almost no mantle (Plate 1B). This face is fundamentally controlled by the Wasatch fault zone that forms the eastern confine of the Basin and Range Province and extends along the base of the mountain. It has many deep and precipitous canyons which are, for the most part, marked by high-angle transverse faults that dissect the mountain. The east side of the mountain is marked, essentially, by the dip of the strata. Vegetation is more abundant there because of the increased volume of mantle. Vegetation on both sides of the mountain consists of sage brush at lower elevations and on the foothills, and fir, mountain mahogany, and juniper at higher elevations.

Wellsville Mountain boasts of no perennial streams. Some 20 springs have been piped into the surrounding communities for culinary water supplies. In this respect the mountain plays an important role in the lives of the inhabitants of these communities. Larger communities thus served are, Brigham City, Honeyville, Deweyville, Collinston, Cutler Dam, Mendon, and Wellsville. None of these springs, however, affords a large enough discharge for irrigation purposes. The mountain is high enough to support a substantial quantity of snow well into the summer months to afford late season recharge to the springs.

Terraces of the Pleistocene Lake Bonneville are extremely well developed and occur along both sides of the mountain in every locality, except in the southeast margin of the map area where the topography was well above the highest lake level. The terraces on the northern end and east side of the mountain are under cultivation, producing grain without irrigation.

Conspicuous glacial cirques are formed at higher elevations, north of the map area, in four major canyons: Pine, Brush, Shumway, and Coldwater Canyons (Beus, 1958). Glacial features found in Pine Canyon suggests at least two stages of glaciation (Plate 2).

PLATE 2

View, looking down into cirque in Pine Canyon from the east showing moraines. The town of Wellsville is at the mouth of the canyon, top center.

STRATIGRAPHY

A spectacular and well-exposed Paleozoic stratigraphic section crops out in the west-facing front of Wellsville Mountain. The rocks range in age from pre-Cambrian to possibly Permian. The pre-Cambrian rocks crop out on the southern end of the mountain in Box Elder Canyon and are unmeasured in that area. The greater mass of the mountain consists of a complete succession of Paleozoic rocks comprising formations from every period except possibly the Permian-- an estimated stratigraphic thickness of over 21,000 feet. There are no Mesozoic sediments in Wellsville Mountain. Tertiary sediments are represented by the Salt Lake group and Wasatch group, which crop out in the northern extremity and north-east side of the mountain. The Tertiary formations were not measured and are, therefore, not included in the stratigraphic thickness figure. However, these formations were remapped and briefly described by Beus (1958). Tertiary deposits were not recognized in the southern part of Wellsville Mountain.

Pre-Cambrian Rocks

The pre-Cambrian rocks found in Wellsville Mountain are believed to be part of the Big Cottonwood series of the Wasatch, Uintah, Oquirrh, and other ranges of northern Utah as defined by Hinds (1936, p. 53-136). The single pre-Cambrian unit in this area crops out in Box Elder Canyon, just east of Brigham City, and passes beneath the alluvium northward in a short distance. The outcrop was described by Eardley and Hatch (1940, p. 811). They reported two major series of pre-Cambrian strata-- an older series of gneisses, shists, metaquartzites, granites, and pegmatites, and a younger less metamorphosed series of quartzites and phyllites that are either Lower Cambrian or Upper Proterozoic (p. 840). Granger and Sharp (1952) tried to solve the pre-Cambrian series mystery with their studies in the City Creek to Parleys Canyon area. Their findings are the most up-to-date. They proposed four new terms to be used in distinguishing units of the pre-Cambrian rocks in that area. The new term "Little Willow" series was proposed for the strongly folded gneissic quartzites by Granger and Sharp (1952, pp. 3-6) to be probably the equivalent to the Farmington Canyon Complex (Eardley and Hatch, 1940, and Bell 1952), but they differ from it in containing abundant basic igneous rocks and no potash pegmatites. The intense metamorphism of this sequence in contrast to the upper weakly metamorphosed formations suggests an age of older pre-Cambrian. The upper pre-Cambrian is divided into three new units. The lower unit of pinkish quartzites and blue-purple shales, which rest unconformably on the Little Willow series, is given the name "Big Cottonwood" series. The new term "Mutual Formation" was proposed to designate the youngest upper pre-Cambrian rocks. The intervening member was given the term "Mineral Fork Tillite." Granger and Sharp state that if it were not for the presence of this tillite member it would be almost impossible to distinguish between the lower Big Cottonwood series and upper Mutual formation because they were deposited in like environments.

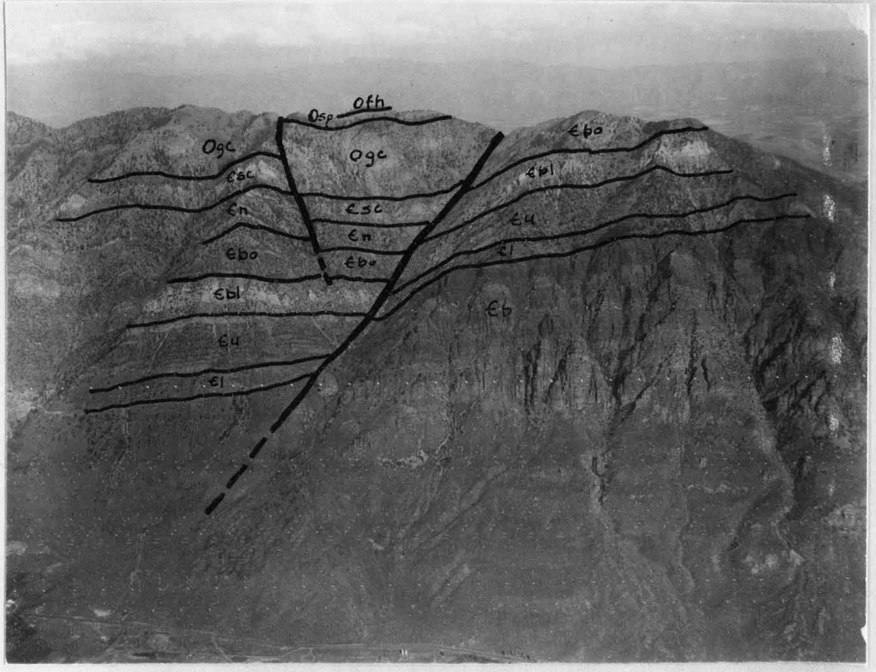
It is believed by the writer that the outcrop in Box Elder Canyon may possibly be the equivalent of the upper most pre-Cambrian, the Mutual formation, because of the abundance of quartzites and phyllites. However, the contact between the Brigham quartzite and the underlying pre-Cambrian series has been in question and is as yet, unmarked. No new evidence has been found by the writer to reveal such a division between the two units. The dashed line representing the contact between the Brigham quartzite and the pre-Cambrian series (geologic map in the envelope) is only an arbitrary one and an approximation of that boundary.

Cambrian System

The rocks of the Cambrian system on Wellsville Mountain have excellent exposures and probably constitute one of the most complete sections anywhere in Utah. The following Cambrian formations are exposed in the area: Brigham, Langston, Ute, Blacksmith, Bloomington, Nounan, and St. Charles. The white dolomites of the Blacksmith and St. Charles formations afford excellent stratigraphic markers for easy recognition of the other Cambrian formations. The observer, driving north from Brigham City on Highway 69, can easily identify the Cambrian stratigraphy by using the geologic map (in envelope) in conjunction with Plates 3, 5, and 8.

In 1908 Walcott named the Cambrian formations and published his original Blacksmith Fork section (Walcott, 1908b). In a later paper of that same year he defined the new formations and their type localities (Walcott, 1908a). Richardson in 1913 studied the Cambrian stratigraphy in the Randolph Quadrangle and published a measured section (1913, p. 406-408). He retained Walcott's original Blacksmith Fork formational names in his section. In addition, he defined two new members and gave them names. The basal shale member of the Bloomington formation he named the "Hodges Shale," and the basal quartzite member of the St. Charles formation he called the "Worm Creek" quartzite.

PLATE 3



(A) Transverse fault in Antimony Canyon, west side of mountain. €b, Brigham Qtz.; €l, Langston; €u, Ute; €bl, Blacksmith; €bo, Bloomington; €n, Nounan; €sc, St. Charles; Ogc, Garden City; Osp, Swan Peak; and Ofh, Fish Haven

(B) Antimony Canyon transverse fault on east side of the mountain passing through Dry Lake in right foreground.

Maxey (1941) made a thorough and detailed study of the Cambrian stratigraphy in this area and measured a section 6,500 feet thick in Calls Fort Canyon on the west side of Wellsville Mountain. Because of his thorough and up-to-date work on the Cambrian stratigraphy the formations therein were not remeasured and will only be described briefly in the following paragraphs.

Brigham Formation

Walcott (1908a, p. 8) defined the Brigham quartzite in the west face of Wellsville Mountain as the type locality of that formation. He described the Brigham as massive quartzitic sandstone. The Brigham quartzite in his original Blacksmith Fork Canyon section was also described as greenish quartzitic sandstone. Eardley and Hatch (1940, p. 811) measured the most complete section of Brigham Quartzite in what they called Baker Canyon in Wellsville Mountain (p. 809). However, the Brigham quartzite does not crop out in the canyon designated as Baker Canyon on the latest U.S.G.S. Brigham City quadrangle map. It is believed that Eardley and Hatch measured their section in one of the canyons south of Baker Canyon, either Antimony Canyon or Hanson Canyon, as the exposures there are excellent. They described 1,775 feet of the formation as consisting of gray, pink, brown, and greenish-brown quartzites. The base of the succession is not exposed and the contact between the underlying pre-Cambrian phyllites and the Brigham quartzite in Box Elder Canyon is, therefore, undefined. The total thickness of the Brigham quartzite is not known.

Williams (1948, p. 1132) in his study of the Logan quadrangle, suggests that the age of the Brigham quartzite is older than earliest Middle Cambrian. This determination is based upon the age of the fauna collected from the overlying Langston formation (Williams and

Maxey, 1941). Williams suggests Early Cambrian (Waucobian) for the age of the Brigham quartzite. The Tintic quartzite of the central Wasatch Range and east Tintic Mountains, south of the Oquirrh Range, is reported to be the equivalent of the Brigham quartzite in this area (Crittenden-Sharp-Calkins, 1952).

The upper 250 feet of the Brigham quartzite is a conspicuous reddish-brown to maroon color and is easily distinguished in the field from the lighter quartzites of the lower succession (Plate 3A).

Langston Formation

The Langston formation also was named by Walcott (1908a, p. 8). The type locality is Blacksmith Fork Canyon, Bear River Range, Utah. He described the formation as consisting of two units, a lower massive, bluish-gray limestone and an upper massive, dark arenaceous limestone with calcareous gray sandstone in the basal portion. The Spence shale was then included as the basal member of the Ute formation. Diess (1938, p. 1116) studied the type locality of the Langston formation and found that the shale beds of the Ute formation could not be correlated with the Spence shale of Idaho; Walcott's type section of the Spence shale (Walcott, 1908a, p. 8). Later, in 1939, Resser at Two Mile Canyon near Malad, Idaho, described Walcott's section of the Cambrian just above the Brigham quartzite as consisting of 6 feet of limestone containing the distinctive Ptarmigania fauna with 155 feet of dark gray limestone and dark argillaceous shale containing the characteristic Spence shale fauna (Resser, 1939, p. 10).

Maxey (1941) measured and defined 310 feet of the Langston formation in Calls Fort Canyon as consisting of three members. The lower member comprising 50 feet of the Ptarmigania limestone, the middle 175 feet of silty limestone and shale as the Spence shale member, and the upper 110 foot member as buff-brown dolomite and silty limestone. The age of the formation, as stated above, is earliest Middle Cambrian.

A characteristic feature of the Langston formation is the occurrence of columnar structures in the basal 20 feet of the upper 110 foot member which can be traced northward at this same horizon through several canyons (Plate 4). They can be observed on the north side of Antimony Canyon, just east of the mine dump, three miles north of Brigham City on Highway 69. The columns are six to eight inches in diameter and the larger ones are three to four feet in length composed almost entirely of gray limestone.

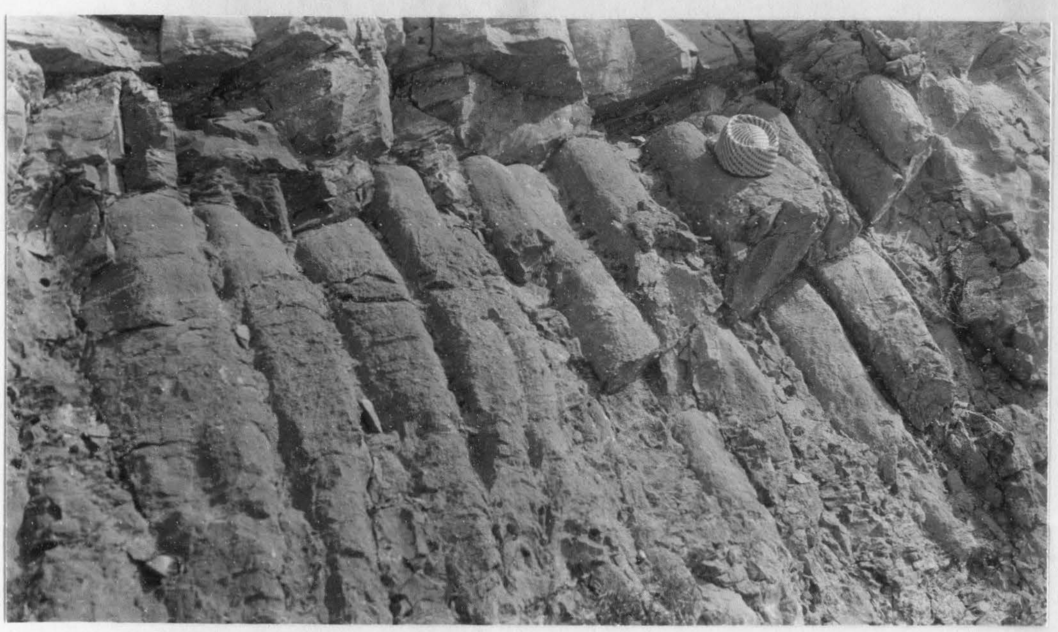
According to Clyde T. Hardy and J. Stewart Williams (personal communication) the columnar structures are a type of contemporaneous deformation. The interpretation by Hardy and Williams is as follows:

> Strata overlying groups of columns are arched upward slightly and those over the intervening undisturbed areas are depressed slightly. This relationship suggests that downward movement in the intervening areas may have caused material of the basal mobile layer to rise at numerous loci in such a way that the immediately overlying silty layer was thinned above each. As this effect extended upward, successive overlying limy layers were forced together and columnar structures resulted.

Ute Formation

The type locality of the Ute formation is in Blacksmith Fork Canyon, Cache Valley, Utah, defined by Walcott (1908). Maxey (1941) studied and measured the Ute formation in Calls Fort Canyon in Wellsville Mountain describing 645 feet of thin-bedded alternating sandy limestone and shale beds, the sand content increasing upward until the uppermost unit becomes a calcareous sandstone. The average thickness of the limestone layers is 50 feet and the shale layers 15 feet. The Ute formation consists of light- to dark-gray limestone, gray calcareous sandstone and tea-green shale.

PLATE 4



Vertical columnar structures in the Langston formation, just above mine dump in Antimony Canyon.

Conspicuous laminae of fine sand and silt separate the limestone layers. The partings weather in relief in colors of brown to orange-tan.

The Ute formation is conformable with the Langston formation below and the Blacksmith sandy dolomite beds above (Maxey, 1941). It contains an early Middle Cambrian fauna (Williams and Maxey, 1941). The Ute is the oldest formation outcropping in the southern Malad Range, just north of Wellsville Mountain.

Blacksmith Formation

The Blacksmith formation is a uniform lithologic unit. Walcott (1908a) first named and described the formation in his original Blacksmith Fork section, its type locality. On the west-facing front of Wellsville Mountain, where the Cambrian section is so spectacularly exposed, the Blacksmith formation is an excellent stratigraphic marker with its high cliffs characteristically banded in two shades of gray, weathering light-gray, almost white. The Blacksmith formation is almost everywhere a bold cliff-maker which is easily distinguished from the less resistant Ute formation below and the Hodges shale member of the basal Bloomington formation above.

The Blacksmith dolomite is only 450 feet thick at its type locality in Blacksmith Fork Canyon. It is 805 feet thick in Maxey's (1941) Calls Fort Canyon section where it consists of massive dolomite and dolomitic limestone. The dolomite is light neutral gray to dark neutral gray, compact to medium crystalline, with some oolitic layers. The dolomitic limestone layers exist in the upper one-fourth of the formation. No fossils have been found in the Blacksmith formation, but it must be of Middle Cambrian age since it occurs between units containing Middle Cambrian fossils.

Bloomington Formation

Walcott (1908a) named the Bloomington formation for exposures near the town of Bloomington, Bear Lake County, Idaho. He described it as consisting of "bluish-gray, more or less thin-bedded limestones and argillaceous shales." Richardson (1913, p. 406) differentiated the lower shale unit of the formation, designating it the Hodges shale member, after Hodges Creek which enters Bear Lake south of Garden City, Utah. Maxey (1941), in his Calls Fort section, reported the Bloomington formation as consisting of 1,055 feet of thin-bedded gray limestones and tawny-olive shales. It includes three units as follows: (1) a 300 foot basal shale unit (Hodges shale) consisting of tawny-olive shale with a few interbedded layers of light- to dark-gray limestone, (2) a 500 foot middle limestone unit of thin- to thick-bedded, light- to dark-gray limestone which weathers to thin light gray plates, partly arenaceous, and (3) a 165 foot upper unit strikingly similar to the Hodges shale member except for an increased proportion of shale. The Bloomington formation is characteristically a slope former.

A conspicuous marker in the middle limestone unit is a thinly laminated limestone bed. The laminae are very fine and alternate in color from light- to dark-gray on weathered surfaces, which gives the limestone a banded appearance.

The Bloomington formation is conformable with the underlying Blacksmith formation. There is a sharp boundary that separates the upper Bloomington limestone from the lower Nounan dolomite. Richardson and Walcott both report Middle Cambrian fossils from the Bloomington formation in the Randolph Quadrangle, Utah.

Nounan Formation

The Nounan formation was named by Walcott (1908a) for its occurrence west of the town of Nounan, Bear Lake County, Idaho. He assigned it to the Middle Cambrian. At the type locality the Nounan is 950 feet thick.

Maxey (1941) measured a section on the north side of Calls Fort Canyon in Wellsville Mountain and reported the Nounan formation as consisting of 825 feet of mostly light-gray, finely crystalline, compact, thin-bedded dolomite. The upper third of the formation consists of light-gray dolomite interbedded with thick layers of dark-gray, argillaceous, thin-bedded limestone. The Nounan is predominantly a cliff-maker in the area. A prominent, massive ledge crops out on the north side of Calls Fort Canyon.

The confines of the Nounan formation are easily recognized with the upper medium-gray limestone member against the buff colored basal quartzite of the St. Charles formation (Worm Creek) and the sharp contact of limestone against dolomite at the base. Hanson (1949) measured 1,408 feet of the Nounan formation in Clarkston Mountain, southern Malad Range, Utah. Hanson reports the upper part of the Nounan formation in Clarkston Mountain is early Late Cambrian and the lower dolomite member is thought to be latest Middle Cambrian or earliest Late Cambrian.

St. Charles Formation

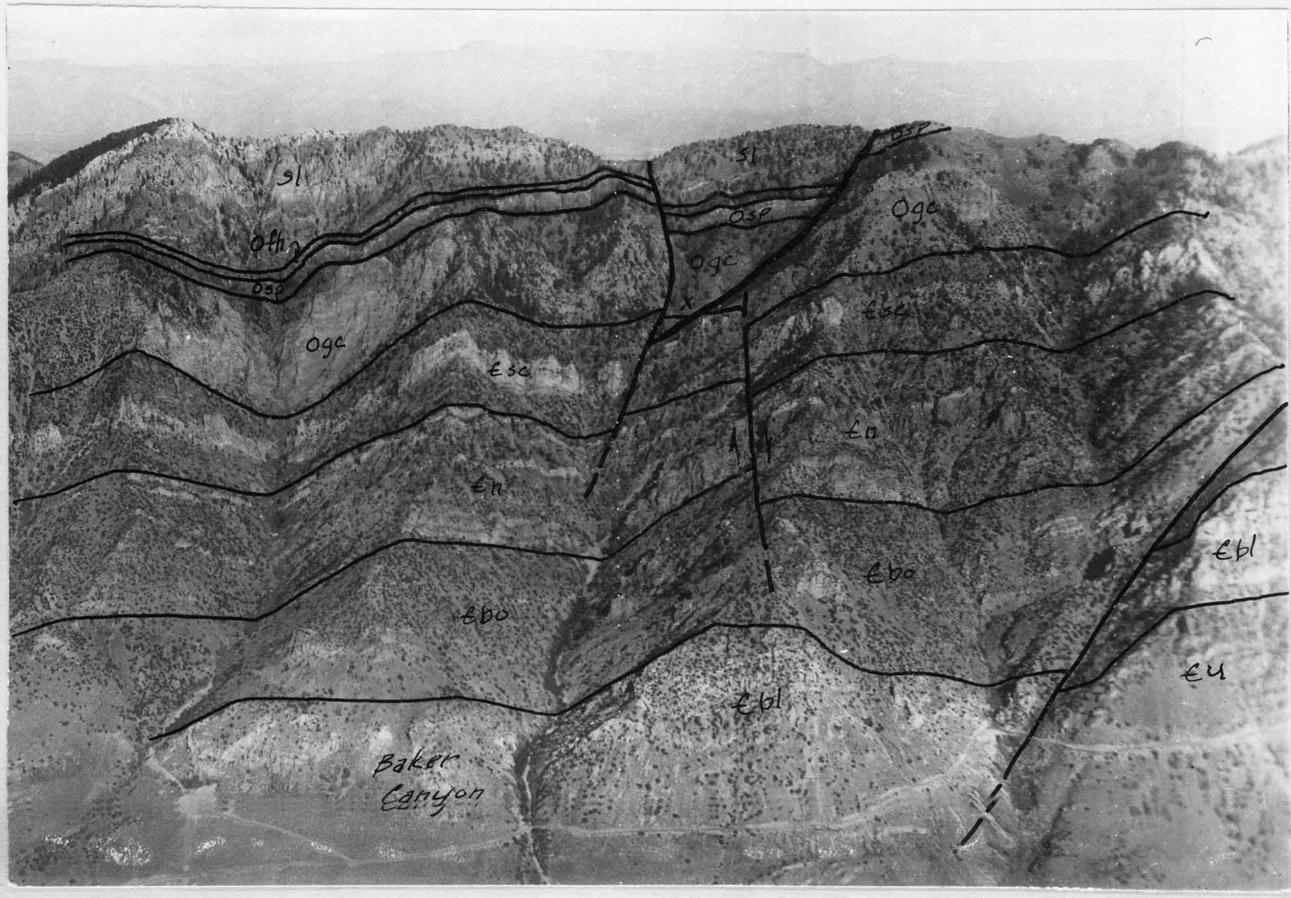
The uppermost Cambrian formation was named by Walcott (1908a) for its occurrence west of the town of St. Charles, Bear Lake County, Idaho, but the published section was measured in Blacksmith Fork Canyon and found to be 1,225 feet thick. He described the formation as "bluish-gray to gray arenaceous limestone, with some cherty and concretionary layers, passing at the base into thin-bedded gray to brown sandstones." Richardson (1913, p. 408) differentiated the basal quartzite member as the Worm Creek quartzite. The St. Charles formation is a conspicuous light-gray (white) stratigraphic marker in the west-facing front of Wellsville Mountain. It can be traced northward from the south side of Antimony Canyon, second large canyon north of Brigham City, to Coldwater Canyon east of Honeyville (Plate 5).

The St. Charles formation (Maxey, 1941) consists of a basal quartzite member, the Worm Creek, a middle member of thin-bedded limestones, and an upper member of massive dark-gray dolomite that weathers almost white and forms impassable cliffs and ledges. The middle 105 foot limestone member is a distinct and characteristic marker of the St. Charles with its rhythmic bands of siltstone that weather in relief. Haynie (1957) describes this member as the "crinkly" limestones. It consists of calcareous siltstone or sandy limestone with some cross-bedding. The siltstone partings are approximately 5 mm. thick and are spaced from 1 to 2 cm. apart. The laminations give the limestone a crinkly appearance. The upper dolomite member of the St. Charles formation is characterized by the presence of elongate chert nodules 1 inch to 1 foot in length and 1 inch thick aligned with the bedding-planes. This dolomite member is banded darker and lighter shades of gray near the top. Maxey reported the St. Charles formation to be 1,130 feet thick in Calls Fort Canyon, and the fauna of the St. Charles formation as upper Cambrian (Croixian) in age.

Ordovician System

The Ordovician system in Wellsville Mountain is represented by three formations with a stratigraphic thickness of 2,225 feet. Richardson (1913, p. 408) named and described these formations in his study of the Randolph quadrangle, Idaho. The oldest of these formations is the Garden City limestone containing a Beekmantown fauna. The age of this fauna ranges from earliest Ordovician to early Chazyan. The overlying Swan Peak formation is composed of a lower shaly, sandy, and in part calcareous member succeeded by vitreous quartzite. This formation

PLATE 5



Aerial view of west-facing front looking east. Shows high-angle transverse faults and strike-slip fault in Baker Canyon with the Bear River Range in the background. €bl, Blacksmith; €bo, Bloomington; €n, Nounan; €sc, St. Charles; Ogc, Garden City; Osp, Swan Peak; Ofn, Fish Haven; Sl, Laketown, and X mine dump.

contains the Chazyan fauna which is early Middle Ordovician. The uppermost of the three formations is the Fish Haven dolomite consisting of massive, dark-gray, coarsely crystalline dolomite with abundant corals. According to Richardson the Fish Haven is characterized by the Richmond fauna which is upper Ordovician (Cincinnatian) age. A more detailed study of the Garden City limestone in northeastern Utah was made by Ross in 1951. He divided the formation into two members as follows: (1) a lower member of intraformational limestone conglomerate, crystalline limestone, and muddy limestone, and (2) an upper member of dolomitic limestone containing nodules and layers of chert. Ross described 12 trilobite faunal zones within the Garden City formation.

The three members of the Ordovician system were measured and described in Wellsville Mountain by the writer and his companion, Stanley S. Beus. The Ordovician system is well-exposed in this area (Plate 5). The resistant, vitreous quartzites of the Swan Peak formation afford an excellent stratigraphic marker. The system crops out in the south wall of Coldwater Canyon east of Honeyville, and extends southward transversing the range at the head of Baker Canyon, through the Dry Lake area, Pisgah Hills, and Mantua Valley.

Garden City Limestone

Richardson (1913, p. 408) named the Garden City limestone from Garden City Canyon, a tributary of Bear Lake, in Bear Lake County, Idaho. He characterized the formation as consisting of thick- to thin-bedded gray limestone with a conspicuous limestone conglomerate or breccia. Deiss (1938, p. 1123) described the Garden City formation in a remeasured section of Walcott's, in Blacksmith Fork Canyon, in 1937. On a faunal basis, Deiss found that 777 feet of the basal limestone of the Garden

City formation was mistakenly assigned to the lower St. Charles formation by Walcott. The exact boundary between the Ordovician Garden City and the Upper Cambrian St. Charles is not known, but is arbitrarily drawn at the base of the lowest limestone unit of the Garden City which contains Fenestrellids (Deiss, 1938, p. 1123).

Williams (1948, p. 1135) in his study of the Logan quadrangle, measured 1,400 feet of the Garden City in Green Canyon, Cache Valley, Utah. Hanson (1949) described 1,805 feet of the Garden City limestone in the southern Malad Range, just north of Wellsville Mountain. In 1951 (p. 7-9), Ross studied the Garden City limestone and divided it into two members, the lower two-thirds consisting of numerous alternations of interbedded intraformational limestone conglomerate, crystalline, aphanitic, and muddy limestones with some siltstones. The upper member is recognized by the abundance of black chert nodules and stringers that are roughly parallel to the laminae of the cryptocrystalline limestones and dolomites. The discovery of a remarkably well-preserved silicified trilobite fauna permitted Ross to establish 12 faunal zones within the formation. This made possible the correlation of the Garden City limestone with the Pogonip limestone of Nevada. The age of most of the Garden City limestone was found to be lower Ordovician with the uppermost beds earliest Middle Ordovician.

The Garden City formation in Wellsville Mountain almost everywhere forms colossal cliffs of medium-gray limestone. It has a thickness of 1,698 feet consisting of mostly medium-gray, finely crystalline, thick- to medium-bedded limestone and dolomitic limestone with intraformational conglomerates and muddy limestone and silt partings that weather in relief at the base of the formation. Black chert nodules and stringers, from one to ten inches thick, comprise almost 50 percent of the rock approximately 175 feet from the top of the formation. The upper 150 feet grades into dark-gray, coarsely crystalline dolomite and dolomitic limestone. The lower segment of the Garden City limestone is characterized by a strikingly rhythmic unit of alternating 18-inch layers of finely crystalline, medium-gray limestone and shaly limestone containing silt partings or laminae. The silt partings weather in relief and measure one-eighth to one-half inch thick. Some chert stringers are present in this unit. In this area, the Garden City formation is easily differentiated from the dolomite of the St. Charles formation below and the fuscous black shales and red quartzites of the Swan Peak formation above.

A complete section of the Ordovician system including the Garden City limestone, Swan Peak quartzite, and Fish Haven dolomite was measured on the major ridge between Cottonwood and Precipice Canyons, 1 mile south and 1½ miles east of Honeyville, Utah, in section 3, Township 10 north, Range 2 west. This ridge affords the single accessible section of the Garden City limestone in this area.

<u>Garden City Limestone</u>

Unit		Thickness (feet)
6.	Dolomite and dolomitic limestone, dark gray, medium- to thick-bedded, weathers dark gray to olive gray. Upper part coarsely crystalline . . .	149
5.	Limestone, medium gray, finely crystalline, thick-bedded. Contains black chert nodules and stringers from one to ten inches thick comprising 50 percent of the rock in the lower half	157

4.	Limestone, medium gray, finely crystalline, interbedded with muddy limestone containing silt partings which weather in relief to a light yellow-brown; beds six inches to two feet thick. Chert nodules rare; forms blocky outcrops	334
3.	Limestone and intraformational conglomerate, medium gray, finely crystalline. Alternating beds of muddy and silty limestone in beds one to five feet thick. Muddy limestone beds weather medium light gray to grayish-yellow. One-eighth to one-half inch silt partings weather in relief, some chert nodules one to two inches thick.	1005
2.	Limestone, medium gray, finely crystalline, medium-bedded. Alternating 18 inch beds of limestone and shaly or silty limestone with $\frac{1}{2}$ inch silt partings that stand in relief; some chert nodules one to two inches in diameter	50
1.	Muddy limestone, medium gray, one to two inch beds, weathers grayish-yellow.	3
	Total	1,698

Swan Peak Quartzite

Richardson (1913, p. 409) described and named the Swan Peak quartzite for its exposures on Swan Peak in the Bear River Range, Utah, $1\frac{1}{2}$ miles south of the Idaho boundary. He reports 500 feet of the formation consisting of "fine-textured, massive- to thin-bedded, white-to-gray quartzite, which is apparently conformable with the Garden City limestone below." Williams (1948, p. 1136) was the first to recognize the existence of three characteristic units within the formation in his study of the Logan quadrangle. The lower unit consists of fuscous black shales with widely interspersed beds of bluish-brown sandy limestone; the middle unit consists of brown quartzite with strongly marked beds of fucoidal structures; and the upper unit is composed of thick-bedded buff quartzite. Williams section in Green Canyon measured 339 feet thick. Hanson (1949, p. 44) measured 606 feet of the Swan Peak formation in the Malad Range, north of Wellsville Mountain. The upper massive quartzites are absent in Blacksmith Fork Canyon, only the basal shales and sandy members are present. This suggests a thickening of the formation westward and a pronounced unconformity between the Swan Peak quartzite and the overlying Fish Haven dolomite.

The sequence of the three separate units, found by Williams in Green Canyon, was recognized in Wellsville Mountain. The Swan Peak quartzite is 427 feet thick in this area. The lower unit consists of fuscous black shales and quartzitic sandstone, silty in part; the middle unit displays brown to grayish-green quartzite with abundant fucoidal markings; and the uppermost unit consisting of massive, vitreous orange-pink quartzite containing ripple marks. The Swan Peak quartzite is assigned to Middle Ordovician (Champlainian) age (Williams, 1948).

The Swan Peak formation, with its characteristic reddish-brown color and well-indurated resistant beds of quartzite, affords an excellent stratigraphic marker that can be easily identified and traced along the west-facing front of Wellsville Mountain.

The Swan Peak quartzite was measured immediately above the Garden City limestone at the same locality described above on the ridge between Cottonwood and Precipice Canyons.

Swan Peak Quartzite

Unit	Thickness (feet)
7. Quartzite, white to grayish-orange-pink, finely crystalline, vitreous luster, thick-bedded. Forms rugged blocky outcrops, abundant ripple marks . . .	191

6.	Quartzite, grayish-red-purple to dusky-red, finely crystalline, forms blocky outcrops of one to two foot beds marked with white bands one to two inches thick. Contains four beds of grayish-green shale about three inches thick at intervals. Abundant fucoidal markings.	26
5.	Quartzite, brown to grayish-green with white bands and abundant fucoidal markings	11
4.	Quartzite, light brown, finely crystalline, interbedded with one foot beds of very fine black flakey shale	43
3.	Shale, dark gray, weathers light olive-brown to green, some beds weather grayish-black. Contains stringers and nodules of limestone which weather in relief.	72
2.	Shale, weak, greenish-black to fuscous black, forms even slopes, weathers brown	15
1.	Quartzitic sandstone, silty in part, olive brown to grayish-green to dusky red, finely crystalline, thin-bedded, crumbly, some banding and cross-bedding in sandy members. The basal ten feet contains beds of fuscous black flakey shale; fossiliferous . . .	78
	Total	436

The lower 78 feet of quartzitic sandstone and shale contain well-preserved fossils. The writer collected the following from the formation in the measured section area:

Unidentified trilobites

Gastropods

Orthis sp.

Didymograptus sp.

Orthambonites *swanensis* Ulrich and Copper

Orthambonites *michaelis* Clark

Elutherocentrus *petersoni* Clark

Fish Haven Dolomite

The name, Fish Haven dolomite, was derived from Fish Haven Creek which enters Bear Lake, Idaho, about 2 miles north of the Utah State line, by Richardson (1913, p. 410). He defined it as a fine-textured, medium-bedded, dark-gray to blue-black dolomite 500 feet thick, which contains the widespread Richmond fauna. The Fish Haven dolomite unconformably overlies the Swan Peak quartzite and contrasts sharply with the latter in both composition and color (Plate 6). The Fish Haven dolomite is a uniform and consistent lithic unit throughout northern Utah, consisting of thick-bedded, dark-gray, medium crystalline dolomite.

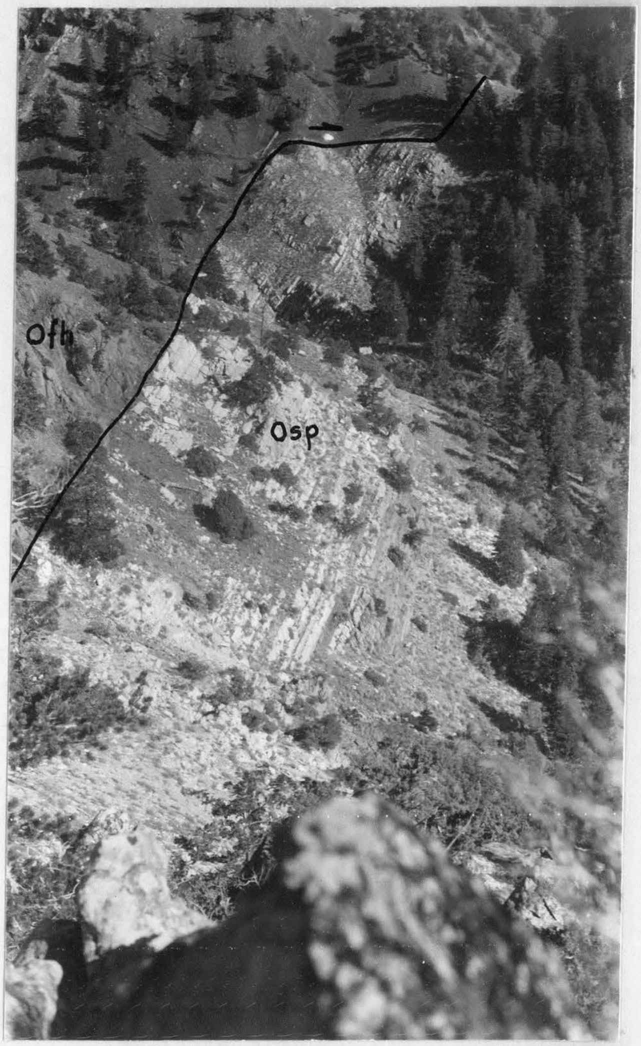
West of Richardson's 500 foot section near Bear Lake, Idaho, Williams measured 140 feet of the Fish Haven dolomite in Green Canyon (1948, p. 1137). In the southern Malad Range it has a thickness of only 50 feet (Hanson, 1949). The Fish Haven formation in Wellsville Mountain is also 140 feet thick and consists of a fetid, dark-gray, coarsely crystalline, fossiliferous, massive dolomite which has been assigned to middle Upper Ordovician age (Cincinnatian or Richmondian). The Bighorn dolomite of Montana and Wyoming is similar in lithology and is believed to be the equivalent of the Fish Haven dolomite in this area.

The Fish Haven dolomite was measured immediately above the Swan Peak quartzite at the same locality described above on the ridge between Cottonwood and Precipice Canyons.

Fish Haven Dolomite

Unit	Thickness (feet)
1. Dolomite, dark gray, coarsely crystalline, massive, contains abundant corals; fetid	140
Total	140

PLATE 6



Sharp contact between Fish Haven (Ofh), upper left-hand corner, and Swan Peak quartzite (Osp) in Precipice Canyon. Fish Haven dolomite pushed over Swan Peak quartzite, top center.

The following fossils were collected from the Fish Haven dolomite in Wellsville Mountain in the measured section locality:

sponges

rugose corals

Paleofavosities prolificus Billings

Calapoecia cf. O. canadensis Billings

Halysites sp.

Silurian System

The single Silurian formation in Wellsville Mountain is the Laketown dolomite, named by Richardson (1913, p. 410). The formation was named for exposures in Laketown Canyon, 4 miles southeast of Laketown in the Randolph quadrangle, Bear Lake County, Idaho. Richardson describes the formation as consisting of a massive light-gray to whitish dolomite, containing lenses of calcareous sandstone and having a thickness of over 1,000 feet. Williams (1948, p. 1138) recognized three members of the Laketown in Green Canyon as follows: (1) a lower light-gray dolomite, (2) the middle dark-gray dolomite, and (3) the upper light-gray dolomite. The formation is 1,510 feet thick at this locality. Hanson (1949, p. 49) reports an estimated thickness of over 2,000 feet for the Laketown in the southern Malad range.

Laketown Dolomite

The Laketown dolomite in Wellsville Mountain overlies the Fish Haven dolomite with no conspicuous lithologic change. Williams (1948, p. 1137) suggests that even though there is no noticeable angular discordance between the Fish Haven and Laketown dolomites, there is obviously a hiatus representing considerable time. No new evidence has been found by the writer to determine the exact contact, but a tentative boundary was approximated in the well-exposed outcrop in Cottonwood Canyon where the section was measured (Plate 7). The Laketown formation has been established as Niagaran (Middle Silurian) in age on the basis of fossils. No identifiable fossils were found in the Laketown dolomite in Wellsville Mountain.

The Laketown dolomite, from the lower tentative boundary to the disconformable contact between the top of the formation and the Water Canyon formation of Lower Devonian age, was measured and found to be 1,600 feet thick in this area. It consists of a lower alternating light and dark-gray dolomite member and an upper massive, medium-gray dolomite member. The Laketown is massive to medium-bedded, coarse to finely crystalline dolomite with characteristic dolomite crystals on weathered surfaces. The alternating light and dark-gray dolomites of the lower member are conspicuous and affords a minor stratigraphic marker (Plate 7).

A well-exposed section of the Laketown formation was measured in Cottonwood Canyon along the major spur forming the north wall of the canyon. Cottonwood Canyon is located 1½ miles east of Honeyville, Utah, and the section was measured in section 3, Township 10 North, Range 2 West. Measurements began with the lower tentative contact between the Fish Haven and Laketown formations and continued up the crest to the contact of the overlying Water Canyon formation.

<u>Laketown Dolomite</u>

Unit	Thickness (feet)
11. Dolomite, medium gray, weathers very light gray, medium-bedded, thin sandy laminae form on weathered surfaces; upper 50 feet includes some medium gray weathering beds containing calcite nodules	369
10. Dolomite, medium dark gray, medium-bedded, finely crystalline, weathers with dolomite crystals on surfaces; contains some white chert nodules. . . .	37

PLATE 7

Dark and light beds at the base of the Laketown dolomite in Cottonwood Canyon. Tentative boundary between Laketown and Fish Haven formations in lower right corner.

9.	Dolomite, medium light gray, thick-bedded to massive, weathers medium dark gray, coarsely crystalline, dolomite crystals on weathered surfaces.	34
8.	Dolomite, dark gray, medium-to thick-bedded, weathers medium dark gray, contains fine threads and flecks of white dolomite	104
7.	Dolomite, medium light gray, massive, weathers light gray, coarsely crystalline, weathers with dolomite crystals on the surfaces; contains some chert nodules, forms steep rugged cliffs	367
6.	Dolomite, dark gray, medium- to thick-bedded becomes massive at the top, weathers medium gray, coarse to finely crystalline, dolomite crystals on weathered surfaces, corals abundant in lower 20 feet	513
5.	Dolomite, medium beds of alternating light and dark gray color giving a distinct banded appearance, coarse to finely crystalline, dolomite crystals on weathered surfaces, contains some rugose corals. . .	42
4.	Dolomite, light gray, crystalline, massive	31
3.	Dolomite, alternating beds of dark and light gray one to three feet thick thining near the top gives a banded appearance, crystalline, dolomite crystals on weathered surfaces.	83
2.	Dolomite, dark gray, massive, crystalline, contains some chert nodules one- to two-inches thick . . .	17
1.	Dolomite, medium light gray, crystalline, dolomite crystals on weathered surfaces, a single thick bed sharply defined by darker colored beds and planes of deposition at the top and bottom	7.5

	Total	1,604.5

Devonian System

The Devonian rocks in Wellsville Mountain are well-exposed and represented by 1,400 feet of lower and upper Devonian formations consisting of mostly dark-gray dolomites, limestones, and sandstones. The Water Canyon formation is Lower Devonian age and the Jefferson formation is Upper Devonian age. In the Logan quadrangle, immediately to the east studied by J. Stewart Williams (1948, p. 1138), the Devonian strata are reported to be 2,000 feet thick. In central Idaho, Ross (1934, pp. 960-966) reported the Upper Devonian alone as being over 3,000 feet thick and divisible into three members as follows: (1) The Jefferson dolomite below, (2) the Grand View dolomite in the middle, and (3) the Three Forks limestone at the top. In Western Utah and Nevada, limestones and dolomites of Middle and Upper Devonian age are several thousand feet thick. Merriam (1940), in central Nevada, divides the Devonian age and the Devils Gate formation of Upper Devonian age.

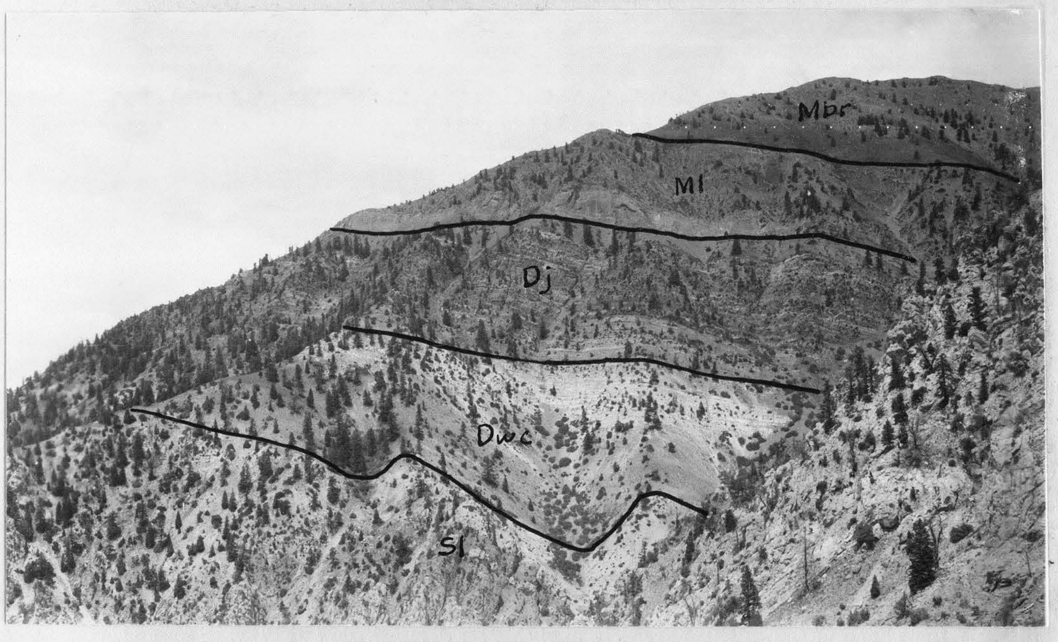
The Lower Devonian Water Canyon formation, with its upper member of white dolomite, affords a conspicuous stratigraphic marker that can easily be traced on both sides of Wellsville Mountain (Plate 8). The Upper Devonian Jefferson formation is difficult to distinguish from the overlying Lodgepole limestone, of Mississippian age, other than by field examination. The Jefferson is 850 feet thick, two miles north of the map area in Coldwater Canyon, directly east of Honeyville, Utah, and thins rapidly southward.

Water Canyon Formation

Williams (1948, p. 1139) named the Lower Devonian Water Canyon formation from a tributary of Green Canyon, two miles north of Logan

PLATE 8

(A) Middle Paleozoic section on the north side of Calls Fort Canyon. Ogc, Garden City; Osp, Swan Peak; Ofh, Fish Haven; Sl, Laketown; Dwc, Water Canyon; Dj, Jefferson; Ml, Lodgepole; and Mb, Brazer.



(B) Middle Paleozoic section in same canyon showing close-up of Jefferson-Lodgepole-Brazer contacts. Explanation same as above.

in the Bear River Range. He reports the formation as consisting of two members as follows: (1) a lower member of thin-bedded silty and sandy dolomite that weathers buff, and (2) an upper member of sandy dolomite, dolomitic sandstone, and sandstone intraformational breccia. The upper member, as described by Williams, is not recognized in Wellsville Mountain.

The Water Canyon formation was found to be 555 feet thick in a measured section in this area. It consists of two distinct units, according to color and sand content, as follows: (1) a lower 290 feet unit of medium-gray dolomitic sandstone that weathers yellowish-gray to fawn, and (2) an upper 265 foot unit of medium-dark-gray, medium-bedded colomite that weathers light gray to white (Plate 8). The Upper Devonian Jefferson formation overlies the Water Canyon formation without angular discordance; however, the intraformational breccia member reported by Williams is absent in this area suggesting an unconformity. Unidentified fossil fish fragments were taken from both units of the Water Canyon formation on a dip-slope 2 miles north of Dry Lake on the south side of Stoddard Canyon.

Bryant (1932) compared the fish fauna of the Water Canyon in northeastern Utah to that of the Bear Tooth Butte formation of Wyoming and concluded that both are early Devonian age. Denison (1952, 1953), in his studies of the Devonian fossil fish, reports the same age.

A complete section of the Devonian strata was measured on the south side of Coldwater Canyon, just east of Honeyville, Utah, in section 34, Township 11 North, Range 2 West. The Water Canyon and Jefferson formations were measured along a small ridge north of the south wall of Coldwater Canyon.

4.	Dolomite, medium gray, medium- to thick-bedded, sandy and silty, sand and silt partings prominent in some beds.	86
3.	Dolomite, dark gray, thin-bedded, silty, with fine silt bands prominent, some beds medium dark gray	88
2.	Dolomite, medium dark gray, weathers yellowish-gray to fawn, thin- to medium-bedded, silty, slightly darker gray above first ten feet	32
1.	Dolomitic sandstone, medium light gray, weathers yellowish-gray to fawn, medium-bedded, fine-grained . .	60
	Total	555

Jefferson Formation

Upper Devonian rocks are widely distributed throughout the Cordilleran geosyncline. Equivalents of the Jefferson occur from Canada southward to California. Peale (1895, p. 27) described the type locality of the Jefferson formation for exposures at Three Forks, Montana. Williams (1948, p. 1139) divides the Jefferson into two members and names them as follows: (1) the lower Hyrum dolomite, and (2) the upper Beirdneau sandstone. The Hyrum member which consists of black dolomite and limestone was named for exposures near Hyrum, Utah, in Blacksmith Fork Canyon. The Beirdneau sandstone member was named for exposures around Beirdneau Peak, north of Logan Canyon. It consists of buff-weathering sandstone and is probably the equivalent of the Three Forks formation in Montana.

The Hyrum dolomite member or its equivalent, as described by Williams, is present in Wellsville Mountain. However, the Beirdneau sandstone member was not recognized and is believed to be absent. The Leatham formation, described by Holland (1952), is also absent. In this area the Jefferson formation thins southward from 850 feet in

Coldwater Canyon east of Honeyville, to approximately 50 feet at the head of Moss Rock Canyon. The Jefferson was not identified on the east side of the mountain. There the overlying Lodgepole limestone, of Mississippian age, rests unconformably on the Lower Devonian Water Canyon formation. The Jefferson-Lodgepole contact is without angular discordance and appears to be gradational. However, it suggests an erosional unconformity of considerable time lapse because of the great variation in thickness in a short distance.

The Jefferson formation on the west side of Wellsville Mountain consists of dark-gray dolomite, sandy dolomite, quartzite, and limestone. A viterous, pale-orange quartzite appears at two horizons in the formation. The upper 165 feet of the Jefferson consists of a cherty, highly fossiliferous limestone (Plate 8B). This upper unit contains a fauna new for the Jefferson in northeastern Utah. This fauna affords a tentative correlation with that of the uppermost Cyrtospirifer zone of the Devils Gate formation in central Nevada, as described by Merrian (1940, p. 62). Heretofore, the uppermost Devonian fauna in this area was correlated with the Argentarius zone of middle Upper Devonian age. Several species of brachipods, including a well-preserved Cyrtospirifer, characterize this fauna.

In Logan Canyon, Cache Valley, Utah, Halysites catenulatus is reported by Kindle (1908, pp. 16-23) to occur above beds containing the Martinia maia fauna, which is Middle Devonian, Nevada formation, age. However, Halysites catenulatus is common in the upper beds of the Silurian Laketown dolomite and has never been found above this horizon (Williams, 1948, p. 1141, and Merriam, 1940, p. 70). Kindle, obviously through some structural element, mistakenly identified the

Laketown dolomite as part of the Jefferson formation. Merriam (1940, p. 68) made the correlation between the Hyrum dolomite and Devils Gate formation. Williams (1948, p. 1140), in his study of the Logan quadrangle, Utah, collected fossils from the Hyrum member of the Jefferson comparable to those of the Spirifer argentarius zone of Merriam's Devils Gate formation, Middle Devonian age, in central Nevada. No fossils have been identified in the Beirdneau sandstone member in the Logan quadrangle, reported by Williams.

The Jefferson formation was measured at the same locality, described above, with the Water Canyon formation.

Jefferson formation.

Unit		Thickness (feet)
8.	Limestone, dark gray to grayish-black, weathers light gray, thin- to medium-bedded, compact, finely crystalline. The lower 60 feet contains black chert nodules as much as four inches in diameter. The upper part contains conspicuous layers of black chert about one inch thick and varying from six to ten inches apart and is highly fossiliferous. Forms a smooth slope below the Lodgepole cliffs.	165.0
7.	Dolomite, dark gray, upper part is limy and contains few thin limestone beds one- to two-inches thick . .	158.0
6.	Quartzite, very pale orange, fresh surface appears as if lightly sprinkled with fine black pepper	2.8
5.	Dolomite, dark gray, contains fine nodules and stringers of chert	93.0
4.	Dolomite, dark gray and medium gray beds alternating, medium- to thick-bedded, sandy, darker beds contain an abundance of microscopic white dolomite crystals giving a speckled black and white appearance; upper 50 feet mostly medium gray	196.0

3.	Dolomite, medium dark gray to medium gray, weathers light gray, thick-bedded to massive, cliff former, some beds alternating medium gray to light gray, upper part contains some chert in fine stringers . .	215.0
2.	Quartzite, same as unit 6 above.	11.0
1.	Sandy dolomite, medium dark gray, coarsely crystalline .	9.0
	Total	849.0

No fossils were found in the lower portion of the Jefferson formation in Wellsville Mountain, however, in unit 8 several species of Brachiopods have been identified and one unidentified Crynoid. The fossils collected from the Jefferson are as follows:

Rugose corals

Crinoid

Ostracodes

Fenestrellids

Spirifer sp.

Cyrtospirifer sp. A

Cyrtospirifer sp. B

Chonetes sp.

Leptaena sp.

Cyrtina sp.

Martinia sp.

Camarotoechia sp.

Schuchertella sp.

Productella sp.

Mississippian System

Mississippian rocks of the Cordilleran region are widespread and relatively uniform in thickness and lithology. In northeastern Utah they are represented by two separate formation, the Lodgepole limestone below and the Brazer formation above, with no angular discordance between them (Williams, 1943, p. 611). The Mississippian rocks of this area are equivalents to the Madison group of Montana. Heretofore, the Lodgepole has been referred to as the Madison limestone in this area, but it is actually the equivalent of the lower member of the Madison group. The Lodgepole limestone is Lower Mississippian and the Brazer is Upper Mississippian (Meramacian and Chesterian) age.

Mississippian rocks crop out near Deweyville, Utah, in the west-facing front of the mountain and extend continuously southward, transversing the crest at the head of Moss Rock Canyon, through the Dry Lake area. The upper Mississippian Brazer formation crops out in the road cut near the southeastern edge of Dry Lake and passes through the Pisgah Hills and Mantua Valley. The lower Mississippian Lodgepole limestone does not crop out at Dry Lake due to Quaternary alluvial cover. A complete measured section of the Lodgepole in the area shows a thickness of 843 feet. The Brazer formation thins rapidly northward from a thickness of 3,700 feet at Dry Lake (Williams, 1948, p. 1142), to 1,800 feet in the measured section just east of Deweyville, Utah, 12 miles northwest of Dry Lake (Figure 2).

Lodgepole Limestone

Lower Mississippian rocks have heretofore been referred to as the Madison limestone in this area. In this report the Madison will be called

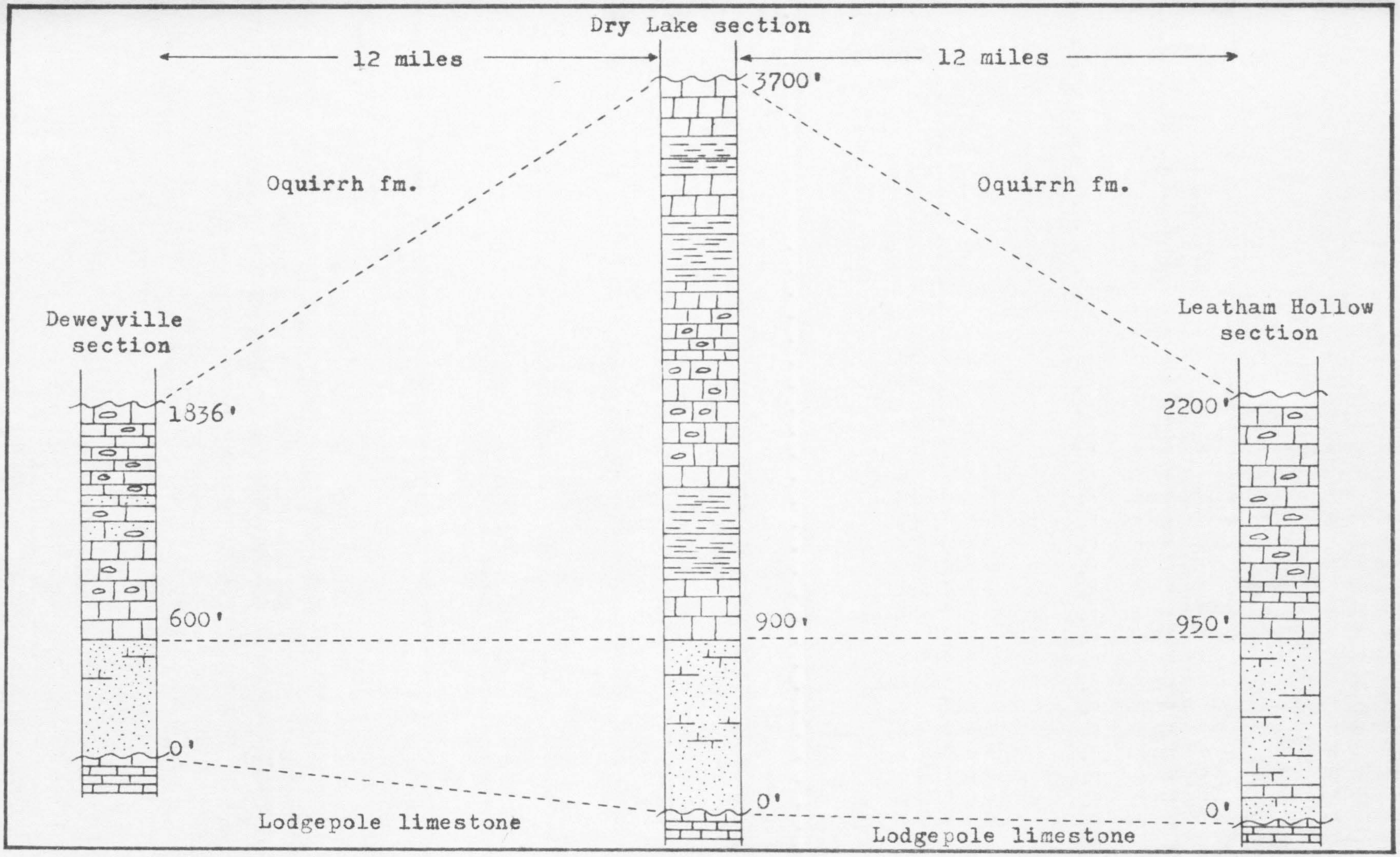


Figure 2. Diagramatic sections of the Brazer formation at Deweyville, Dry Lake and Leatham Hollow, showing variation in thickness. Dry Lake section from Williams and Yolton (1945); Leatham Hollow section from Parks (1951).

the Lodgepole limestone because of a later study of Madison nomenclature by Collier and Cathcart (1922) and Holland (1952). The name Madison was given to the Lower Mississippian rocks that crop out at Three Forks, Montana, by Peale in 1893. He sub-divided the Madison into three parts as follows: (1) lower "Laminated limestones," (2) middle "Massive limestones," and (3) upper "Jaspery limestones." In 1922 Collier and cathcart named Peale's sub-divisions of the Madison the Madison group. They termed the "Laminated limestones" the Lodgepole and the "Massive limestones" the Mission Canyon. The upper "Jaspery limestones" being stripped by erosion in that area, however, the term Madison limestone is retained for the upper limestones of the Madison group. These terms have been adopted ever since by workers throughout Wyoming. Holland (1952) studied the Lower Mississippian strata in Montana and Utah. He found that the Madison limestone of northeastern Utah was strikingly similar to the Lodgepole limestone of Montana. Also, the faunal assemblages of the Madison in Utah was remarkably similar to that of the Lodgepole in Montana. Holland concluded that the Madison of northeastern Utah was equivalent to the Lodgepole limestone in Montana. In 1952, Holland named and differentiated the Leatham formation from the overlying Lodgepole in its type locality, Leatham Hollow in Blacksmith Fork Canyon, 8 miles east of the map area. The Leatham formation has not been recognized in the map area. The absence of the Leatham in Wellsville Mountain suggests an erosional unconformity between the underlying Jefferson dolomite and the Lodgepole limestone.

The Lodgepole limestone in Wellsville Mountain is 843 feet thick consisting of largely thin- to medium-bedded, dark-gray, fossiliferous limestone. Chert nodules and calcite veinlets occur at intervals throughout the formation. The lower bold cliffs of the Lodgepole are called the "Chinese Wall" and they are very prominent in the area (Plate 8B). A long steep slope rises to the base of a second cliff of the Lodgepole, which is called the "Upper Chinese Wall." This upper wall is less conspicuous in the area. The contact between the overlying Brazer formation and the Lodgepole limestone is well marked by contrasting gray limestone cliffs of the Lodgepole and the brown weathering, slope forming, calcareous sandstone of the Brazer.

The Lodgepole limestone was measured directly up the mountain face on the lower west-facing front of Wellsville Mountain, approximately 3 miles north and ½ mile east of Honeyville, Utah. The measured section is located at Township 11 North, Range 2 West, in section 21, just north of the area in this report.

Lodgepole limestone

Unit	Thickness (feet)
8. Limestone, dark gray, weathers medium light gray, very finely crystalline, thin-bedded, upper part contains abundant black chert stringers one to three inches in diameter and aligned with the bedding plane; lower 50 feet covered	92
7. Limestone, medium gray, coarse and granular, largely composed of crinoid stems	18
6. Limestone, medium gray, thin- to medium-bedded, coarsely crystalline, lower part has three-foot limestone beds separated by black chert stringers one to seven inches thick; in the upper part the beds become thinner and the chert stringers increase in abundance. This unit forms most of the prominent upper cliffs of the formation	124
5. Limestone, dark gray, weathers medium gray, finely crystalline, thin-bedded, contains black chert stringers one to three inches in diameter and one to three feet in length aligned with the bedding plane, the chert increases in abundance upward; fossiliferous . .	56

4.	Limestone, medium dark gray, weathers medium gray, finely crystalline, thin-bedded, sandy on weathered surfaces, fossiliferous, less resistant than unit 5 above	159
3.	Limestone, dark gray, weathers medium gray, finely crystalline, beds six inches to two feet thick, sandy on weathered surfaces, cliff forming	65
2.	Limestone, dark gray, weathers medium gray, finely crystalline to granular, thin-bedded, sandy on weathered surfaces; slope forming.	254
1.	Limestone, medium dark gray, weathers medium light gray, thin-bedded, granular, lower 25 feet contains abundant black chert nodules one to three inches in diameter, crinoid stems, brachiopods, and corals are most abundant fossils; forms conspicuous steep cliffs at the base of the formation	95
	Total	843

Brazer Formation

The Brazer formation was named by Richardson (1913, p. 413) for exposures in Brazer Canyon, in the Crawford Mountains, 6 miles northeast of Randolph, Utah. Here the Brazer formation attains a thickness of 600 feet. Williams (1943) redescribed the type section and measured several additional sections in the Wasatch Mountains. In the Pisgah Hills, adjoining the southern flank of Wellsville Mountain, he described 3,700 feet of the strata which he assigned to the Brazer. According to Williams the upper 2,370 feet of Chester age is not present in the type locality. Williams and Yelton (1945) divide the Brazer formation into five separate members on a faunal basis as follows: (1) the lowermost A member consisting of calcareous, brown weathering sandstone, (2) the B member of thick-bedded dark-gray limestone, (3) the C member of argillaceous limestone, (4) the D member of dark cherty limestone, and (5) the uppermost E member of silty limestone and black shale. The lettered members of this paper correspond to the five numerical members redescribed by Williams (1948). The uppermost of the five members probably correlates with the Manning Canyon shale of the Oquirrh Mountains, southwest of Salt Lake City.

There is no evidence for a hiatus between the Brazer formation and the underlying Lodgepole limestone member (Williams, 1943, p. 611); however, the phosphatic shale horizon at the base of the Brazer in the Bear River Range is not recognized in Wellsville Mountain. The thickness and lithology of the Brazer suggests that all of the E member and part, if not all of the D member is missing in the measured section area near Deweyville, Utah. The writer measured a complete section of the Brazer formation near Deweyville, Utah, and found it to be 1,876 feet thick; considerably thinner than the 3,700 foot section measured by Williams and Yelton 12 miles to the south in Dry Lake (Figure 6). All five members crop out on the south side of the major transverse fault in the locality of Rattlesnake Canyon (north-center part of map in the envelope). Here the Brazer is complete and possibly as thick as that in the Dry Lake section.

The Brazer formation in Wellsville Mountain consists of a basal thin-bedded, brown weathering, slope forming, calcareous sandstone. Overlying this sandstone unit the rocks consist largely of limestone, sandy limestone, and shale with increasing amounts of chert near the top of the formation.

The Brazer formation crops out in the lower slopes of the northern west-facing front of Wellsville Mountain. The section was measured 1 mile southeast of Deweyville, Utah, on the south side of the first major canyon; Township 11 North, Range 2 West, section 16.

Brazer formation

Unit		Thickness (feet)
5.	Limestone, medium dark gray, weathers light gray, finely crystalline, medium-bedded, includes a few beds of light brown sandy limestone one to three feet thick, some smoke-gray chert nodules. . . .	237
4.	Sandy limestone, medium gray, weathers medium gray to light brown, interbedded with thin medium-gray crystalline limestone beds containing black chert nodules; slope forming	276
3.	Limestone, dark gray, weathers medium gray with a rough sandy surface, medium-bedded, contains nodules and stringers of black chert aligned with the bedding planes, chert increases in abundance upwards, includes an eight inch bed of greenish-gray shale at the base. Silicified corals and Brachiopods abundant . . .	320
2.	Limestone, medium gray, weathers medium light gray, coarsely crystalline, grades into colitic limestone near the top, medium-bedded, cliff forming, contains corals and crinoid stems	398
1.	Calcareous sandstone, fine- to medium-grained, medium gray, weathers pale yellowish-brown, thin- to medium-bedded, becomes more calcareous upward, slope forming.	605
	Total	1,836

Pennsylvanian System

Rocks of Pennsylvanian age are widely distributed throughout the Cordilleran region and attain a remarkable thickness of 26,000 feet in the Oquirrh Range west of Salt Lake City. The Pennsylvanian rocks in Wellsville Mountain are represented by a thick succession of the Oquirrh formation. The Oquirrh formation crops out in Rattlesnake and Wellsville Canyons in this area and makes up the major portion of the northern half of Wellsville Mountain. At the northern end of the mountain the Oquirrh formation is 6,643 feet thick.

Richards and Mansfield (1912) named the Pennsylvanian rocks, in southeastern Idaho and northeastern Utah, the "Wells" formation. In 1932, Gilluly named the Pennsylvanian rocks the Oquirrh formation from exposures in the Oquirrh Range; however, a detailed section was never published. Bissell (1936), in his study of the Pennsylvanian rocks of the southern Wasatch Mountains used the name "Oquirrh" formation and proposed to raise it to a series. He then subdivided it into two formations, the Hobble formation above and the Kelly formation below. Williams and Yolton (1945) restudied the Pennsylvanian rocks in the Dry Lake area of the Logan quadrangle with particular interest to the assignment of Marrowan age to a faunal assemblage of the Wells formation. Williams (1948) questioned the use of the term "Wells" formation in his discussion of the Paleozoic rocks of the Logan quadrangle. Later, in 1953, he clarified the Pennsylvanian terminology in the Logan area and applied the name Oquirrh to rocks previously referred to as Wells. The Oquirrh formation lies onconformably upon the underlying Brazer formation of Mississippian age.

Oquirrh Formation

The Oquirrh formation, in a measured section in Wellsville Mountain described by Williams (1943, p. 594), consists of two members as follows: (1) a lower member 2,300 feet thick, and (2) an upper member 2,700 feet thick. The lower member consists of gray sandstone and sandy limestone interbedded with thick-bedded gray limestone and the upper member consists of thin- to medium-bedded sandstone that weathers brown or buff.

Williams (1948, p. 1143) described a Desmoinesian fauna, Wedekindellina, 200 feet above the base of the Oquirrh, dating the lower 450 feet of the formation as earliest Pennsylvanian (Bendian) age. In this same section a Triticites faunal zone was recognized from 1,000 to 2,000 feet above the Wedekindellina zone. He assigned this zone to late Missourian age. Williams concluded that the uppermost part of the section be, at least in part, Virgilian age. Nygreen (1955) restudied the lower Oquirrh formation of the Logan area and reported an error in the dating of the formation by Williams and Yelton (1945). He found that the Wedekindellina zone, described by Williams and Yelton as being 200 feet above the base of the formation, was not Marrowan age, but instead Desmoinesian age. Nygreen proposed a new name, "West Canyon" limestone member, to the base of the Oquirrh formation in its type locality and recognized it in Sardine Canyon, two miles east of Dry Lake. The West Canyon limestone member is 1,456 feet thick at its type locality in the Oquirrh Range and 510 feet thick at Sardine Canyon. The formation consists of bioclastic limestone with interbedded sandstone or siltstone. Fusulina and Wedekindellina fossils found in this member by Nygreen indicate Desmoinesian age for the West Canyon limestone. The Fusulina zone is located 1,000 feet above its base and the Wedekindellina zone 300 feet above the base.

The writer measured a complete section of the Oquirrh formation near Williams measured section at Deweyville, Utah, (1943, p. 594). Here the Oquirrh formation is 6,643 feet thick. In this section the Wedekindellina zone was identified 85 feet above its base (unit 3 in the measured section), which is middle lower Desmoinesian age. Suggesting that all but the lower 200 feet of the West Canyon limestone member, described by Nygreen at Sardine Canyon, may possibly be present in this area. The upper Triticites zone was identified 1,100 feet above the base of the formation (unit 9 in the measured section) corresponding to that described by Williams (1943, p. 617), which he suggested may be in part Missourian age and the upper part Virgilian age. Another Triticites faunal zone was located 2,200 feet above the base (unit 11 of the Deweyville section) and identified as uppermost Pennsylvanian (Upper Virgilian) age. Thus, fossils of the Oquirrh in this area show that the Lower Pennsylvanian rocks are absent and that the upper remaining 4,400 feet of the formation may possibly be, at least in part, Permian.

A complete section of the Oquirrh formation, that may be in part Permian, was measured 1 mile southeast of Deweyville, Utah, in sections 9, 10, 11, and 12, Township 11 North, Range 2 West. This section was measured across the northern end of Wellsville Mountain, beginning at a point 1 mile southeast of Deweyville above a high prominent cliff of the Lodgepole limestone, and ended 2 miles west of the town of Mendon on the east side.

Oquirrh formation

Unit	Thickness (feet)
16. Calcareous sandstone, pale brown to grayish-red,	

	weathers pale reddish-brown, fine-grained, includes some medium gray beds above the first 1,000 feet; covered in part.	1,868
15.	Calcareous sandstone, thin-bedded, grayish-brown, weathers pale yellowish-brown, interbedded with thin beds of medium-gray, sandy, finely crystalline limestone	332
14.	Sandy limestone, dark gray, weathers medium gray, many beds $\frac{1}{4}$ to $\frac{1}{2}$ inch thick, includes some thin beds of grayish-pink, calcareous sandstone	92
13.	Calcareous sandstone, medium gray, weathers dark yellowish-orange, thin-bedded, very fine-grained, contains some beds of medium-gray, sandy, finely crystalline limestone	636
12.	Calcareous sandstone and sandy limestone, middle part mostly sandstone, in beds six inches to one foot thick, weathering pale yellowish-brown, limestone and sandstone interbedded throughout	1,204
11.	Calcareous sandstone, quartzitic in part, medium gray, weathers yellowish-gray, contains thin beds of blue-gray sandy limestone throughout; forms blocky and platy outcrops	353
10.	Sandy limestone, medium dark gray, weathers medium gray, thin-bedded, very fine sand on weathered surfaces, some beds weather pale yellowish-brown, becomes more sandy upward, more resistant than the unit below, forms slopes and ledges	586
9.	Calcareous sandstone, fine-grained, weathers pale yellowish-brown, contains some thick beds of dark-gray, coarsely crystalline, sandy limestone, forms ledges and slopes, contains abundant fusilines at the top and bottom	495
8.	Calcareous sandstone and sandy limestone, medium gray, weathered surface is in alternating bands of gray and brown with the brown bands being more sandy, contains some intraformational conglomerate	38
7.	Calcareous sandstone, medium gray, weathers pale yellowish-brown, fine-grained, contains some beds of medium-gray sandy limestone	582

6.	Limestone, medium blue gray, finely crystalline, thin-bedded.	73
5.	Sandy limestone, crystalline, light gray, weathers light brown.	88
4.	Sandy limestone, medium gray, thin-bedded, light brown sand laminae stand in relief on weathered surfaces	116
3.	Calcareous sandstone and sandy limestone; limestone, medium gray, thin-bedded and finely crystalline; the sandstone is olive and weathers pale yellowish-brown, forms slopes in contrast to the unit below. Abundant Fusilines, Brachiopods, Crinoids, and Bryozoans. . .	92
2.	Limestone, medium gray, coarsely crystalline, highly fossiliferous, contains brownish-black chert nodules; forms ledges	35
1.	Sandy limestone, light olive gray, crystalline, thin-bedded, weathers pale yellowish-brown; forms slopes. .	53
	Total	6,643

The most important fossils found in the Oquirrh formation were Fusilines as described above. The identity and age determinations of the Fusilines were made by paleontologists of the Carter Oil Company; they are as follows:

Fenestrellid bryozoans

Triticites sp. A

Triticites sp. B

Wedekindellina sp.

Quaternary Deposits

Quaternary deposits in this area consist of lacustrine sediments from Lake Bonneville and alluvium. The Bonneville Lake terraces are well-exposed along the west side of Wellsville Mountain. There are no lake terraces on the east margin of the mapped area because the relief was too high for the invasion of the lake waters. Quaternary alluvium skirts the east flank of the area and exposures of Paleozoic rocks are sometimes covered, making it difficult to determine the formation boundaries.

Lake Bonneville Group

The Lake Bonneville shoreline can easily be traced along the west-facing front of Wellsville Mountain and it is represented by a dotted-line on the geologic map in the envelope. The shoreline is also recobnized south of Wellsville, Utah (upper right-hand corner of the map in the envelope). The highest level of the lake reached an elevation of approximately 5,100 feet. Bonneville sediments consist of well-sorted gravel, silt, and clay. Three conspicuous intermediate lake level stages are represented by terraces along the west-facing front of the mountain near Deweyville, Utah.

Lenses of a well-cemented conglomerate are exposed east of Honeyville, Utah, in the Lake Bonneville sediments. Cementation of the gravels may be the result of downward circulating Bonneville lake water.

STRUCTURAL GEOLOGY

Regional Structural Relations

The area of this study is in a region of north-south Laramide folds and thrusts (Figure 3). Paleozoic rocks of the Bear River Range to the east of the area are folded into a broad north-trending syncline and anticline. Paleozoic and Mesozoic rocks in the Salt Lake City area are folded into north-south and east-west folds. The Bannock overthrust is approximately 30 miles to the east of Wellsville Mountain and the Willard overthrust is about five miles to the south. Small scale thrusting, the overriding block moved in an eastward direction, in the Promontory Range about six miles west of this area was reported by Olson (1956). The folds and thrust faults of the Ogden area were produced by the buttress effect of a pre-Cambrian crystalline stable mass to the west called the "Northern Utah Highland" (Eardley, 1939, 1944). Eardley reports that all transverse faults in the central Wasatch Range are older than Basin and Range faulting and some may be due to vertical forces that acted during folding or to differential release of pressure after folding (1939, p. 1285).

The southern Malad Range is a horst with northeast dipping beds. Hanson (1949) postulates two theories for the origin of structure in that area as follows: (1) the range being an eastern limb of a Laramide anticline, the axis of which has been faulted down to the west, and (2) possibly the rocks of the range may be part of a large

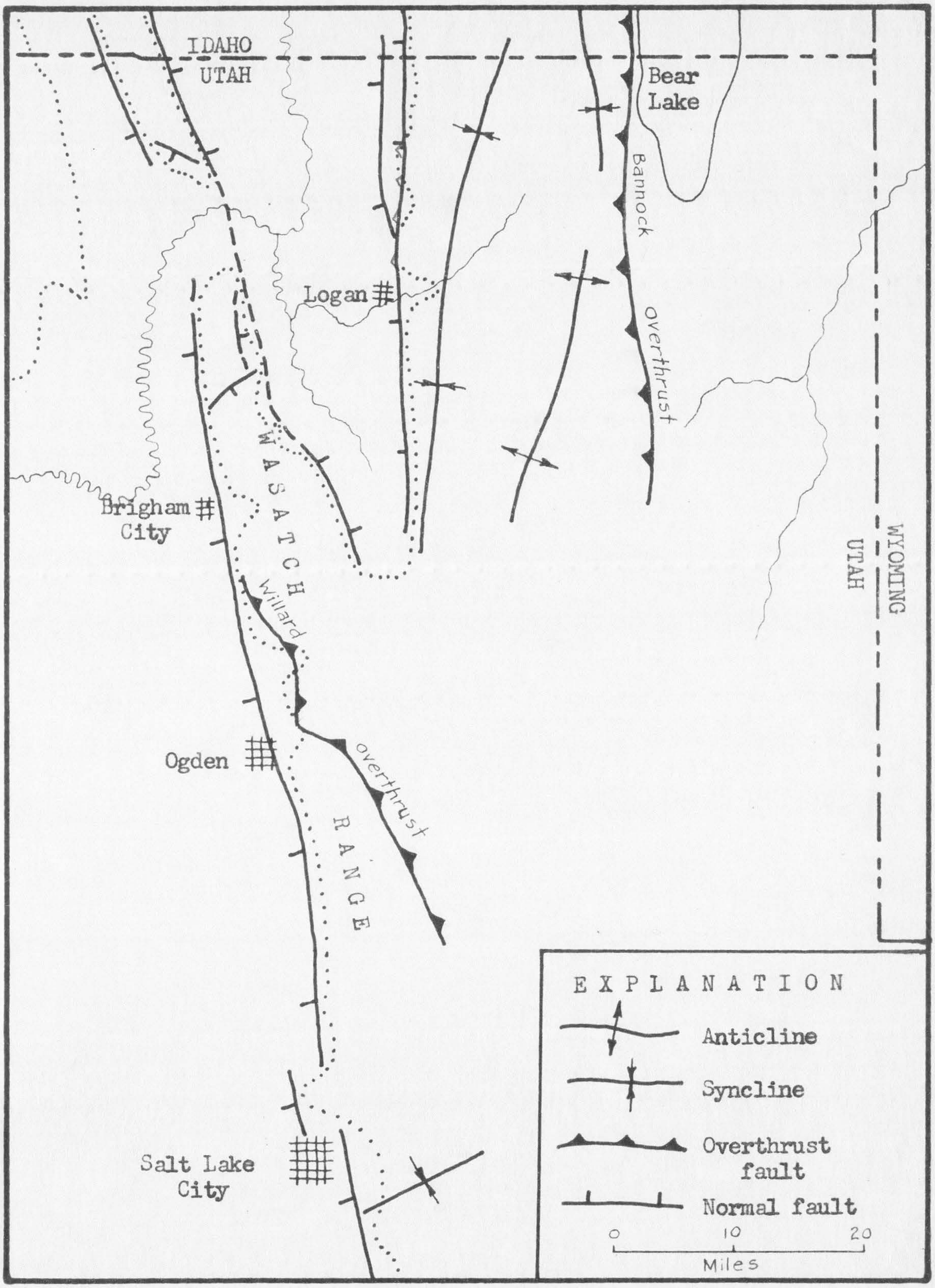


Figure 3. Structure map of north-central Utah after Eardley (1939) and Hanson (1949).

overthrust sheet, the footwall of which is exposed in the area to the south. However, evidence for these theories is not conclusive.

The area between the southern Malad Range on the north and Wellsville Mountain on the south is named by Williams as the Junction Hills. The Paleozoic rocks of the Junction Hills have westerly dips while those of the southern Malad Range and Wellsville Mountain have northeasterly dips. The relationship of the Junction Hills to the southern Malad Range and Wellsville Mountain presents a problem which cannot be conclusively solved on the basis of the existing information. Williams (1948, pp. 1151-1153, Figure 2) has described this difficulty at length and has suggested five working hypotheses for the origin of these structural relationships involving high-angle faulting and thrust faulting with the overriding block moving eastward. These hypotheses are based on the anomalous structural relationships of the Junction Hills to the southern Malad Range and Wellsville Mountain. The brecciated and mashed condition of the Paleozoic rocks within the Junction Hills area supports his thrust fault hypothesis.

Williams (1948, p. 1155) described Wellsville Mountain as a homocline cut by numerous high-angle transverse faults which he interpreted as tear faults produced when the homocline was tilted northeastward and thrust to the east. These tear faults are associated with the change in trend of the beds from a north-south strike in Mantua Valley, three miles east of Brigham City, to an east-west strike at the northern end of the mountain.

Geologic Structure

General Features

The major structure of Wellsville Mountain is a northeast-dipping fault-block bounded in part by northwest-trending high-angle faults and cut by numerous northeast-trending transverse faults. The rugged west-facing front is marked by the Wasatch fault zone and the east-facing front is marked primarily by the dip of the Paleozoic rocks. Basin and Range high-angle faulting is found on the northeast side of the mountain (Plate 11). The entire mountain is characterized by abundant faulting. No intense folding, overturning of beds, or direct evidence of thrusting is displayed in this area. Many high-angle transverse faults of relatively large displacement are concentrated in the southern half of the mountain and the resulting tilted fault-blocks are by far the predominant structural features. The major faults, with but few exceptions, may be grouped into a northwest and northeast system. They are nearly vertical high-angle faults produced in two different epochs-- the northeast-trending transverse faults which are associated with Laramide deformation (Plates 3, 5, 10) and the northwest-trending bordering faults which are of Basin and Range age (Plates 1B,11A).

A major transverse fault, starting at the mouth of Moss Rock Canyon 4½ miles north of Brigham City, Utah, cuts diagonally across the west-facing front and effectively divides the mountain into two fault-blocks. This fault is the largest transverse fault in the area (north-center part of map in the envelope) having a stratigraphic displacement of about 4,500 feet (Plate 9). The downdropped block is to the south. The southern block contains numerous high-angle transverse faults having stratigraphic displacements ranging from a few hundred feet to 2,000 feet. The intervening tilted fault-blocks of the southern block have the downdropped side to the north. The Paleozoic rocks of the southern block strike N 35° W and dip 35° to 40° NE. The northern block consists mostly of Mississippian and Pennsylvanian rocks having approximately the same strike and dip as the southern block. Major transverse faults are lacking in the northern block.

Northwest-trending Faults

Wasatch fault zone. --The Wasatch fault zone bounds the west-facing front of Wellsville Mountain and exhibits remarkable lineation along its southern part (Plate 1B). The fault zone extends for approximately 115 miles from central Utah northward to the Utah-Idaho state line (Eardley, 1939, p. 1305). Gilbert (1928) described the fault zone as hugging the western base of the Wasatch Range and is so recent that the original fault scarp still remained in various places. These observations are especially applicable to the west-facing front of Wellsville Mountain. Recent movement along the Wasatch fault zone is manifest by a fault scarp in the alluvium at the mouth of Coldwater Canyon east of Honeyville, Utah, one mile north of the mapped area.

The steep west-facing front (Plate 1B) affords reasonable certainty that the Wasatch fault exists in this area. A recent gravity study by K. L. Cook and J. W. Berg Jr., of the University of Utah, clearly marks the Wasatch fault bordering the western base of the mountain. The age of the fault zone has been well established in the literature as Basin and Range age with continuing movements up to the recent.

Mt. Hughes fault.-- The Mt. Hughes fault is a newly discovered high-angle fault on the northeast side of the mountain of Basin and

PLATE 9

(A) Major transverse fault on west side of mountain. Stratigraphic displacement of Swan Peak (Osp) is 3,700 feet.

(B) Major transverse fault on east side of mountain through Pine Canyon. Landslide on Leatham Hill right foreground. Glacial cirques in upper right-hand corner.

Range, or younger, age (Plate 11A). The fault strikes approximately N 30° W and swings northward out into Cache Valley west of Mendon, Utah. It separates two conspicuous hills, Leatham Hill to the south and Mt. Hughes on the north, from the east-facing front of the mountain between Wellsville and Mendon, Utah. The hills represent the down-dropped side. Several slickensided surfaces along the fault plane locate the fault and reveals a dip of 75° NE (Plate 11B). The fault together with the Wasatch fault suggests a horst type structure for the northern block of Wellsville Mountain (Beus, 1958).

Lake Bonneville terraces and alluvium obscure any direct evidence for a bordering fault between Cache Valley and the northeast side of Wellsville Mountain; however, there is no doubt a fault or faults exist in that zone. Evidences for the existence of a fault along the northeast side of the mountain is manifest by the abrupt relief between the valley floor and the crest, linear trend, and the many truncated spurs.

Northeast-trending Faults

The northeast-trending transverse faults in this area are too numerous to describe. Therefore, only two typical examples will be discussed as follows: (1) a major transverse fault and (2) the fault in Antimony Canyon. The general trend of the transverse faults is nearly at right-angles to the strike of the strata. All of the major canyons in this area are produced by erosion along the trace of these faults.

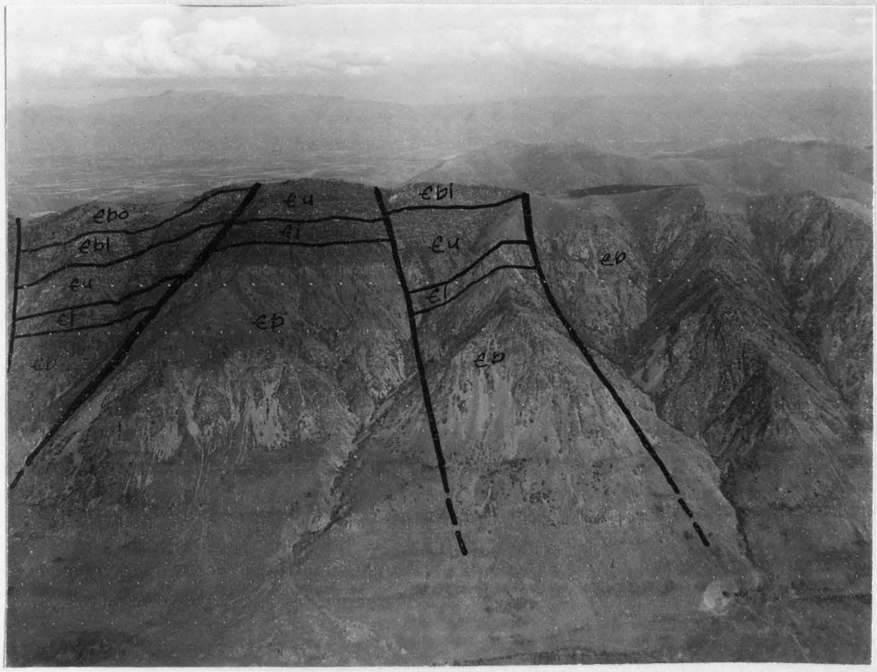
Major transverse fault.-- A major transverse fault divides the mountain into two distinct fault-blocks with the downdropped side to the south. It has a stratigraphic displacement of about 4,500 feet with the Ordovician Swan Peak quartzite against the Cambrian Bloomington formation at the mouth of Moss Rock Canyon about 4½ miles north of Brigham City, Utah (Plate 9A). The fault strikes more northerly than the main transverse faults in this area and cuts diagonally across the west-facing front of the mountain. It crosses the crest (north-central margin of the map in the envelope) and extends down Pine Canyon on the east side of the mountain (Plate 12B).

Antimony Canyon fault.--The Antimony Canyon fault is one of the most conspicuous transverse faults in the area (Plate 3A). It is easily recognized from the highway in the second major canyon two miles north of Brigham City, Utah. The fault has a stratigraphic displacement of about 1,000 feet with the base of the Ute formation against the Blacksmith formation near the mouth of the canyon. The fault strikes approximately east-west and the attitude of the fault plane is obscured by debris along its trace. Almost all of the northeast-trending faults of the area completely traverse the mountain. The Antimony Canyon fault extends through Dry Lake on the east side of the mountain (Plate 3B).

Age of Structure

The structural evidence in Wellsville Mountain affords two plausible hypotheses for its origin as follows: (1) overthrusting with the overriding block to the east, as suggested by Williams, with Basin and Range high-angle faulting superimposed on the older Laramide structures, and (2) normal and strike-slip faulting of Paleozoic rocks during Laramide folding and uplift, with Basin and Range high-angle faulting superimposed on them. No significant evidence was found in the mapped area to support the first hypothesis.

PLATE 10



Aerial view of west-facing front, north of Brigham City, showing transverse faults in (from left to right) Hanson, Kotter, and Water Fall Canyons.

The second hypothesis seems more reasonable in view of the structural evidence exposed in the area. Evidence for strike-slip movement along transverse faults was found in the south wall of Baker Canyon three miles north of Brigham City (Plate 5). The exposed slickensides in the fault plane of this fault clearly shows horizontal movement. Possibly all of the transverse faults had strike-slip components during Laramide time and later vertical movements along the same fault planes during Basin and Range time to produce the stratigraphic displacement.

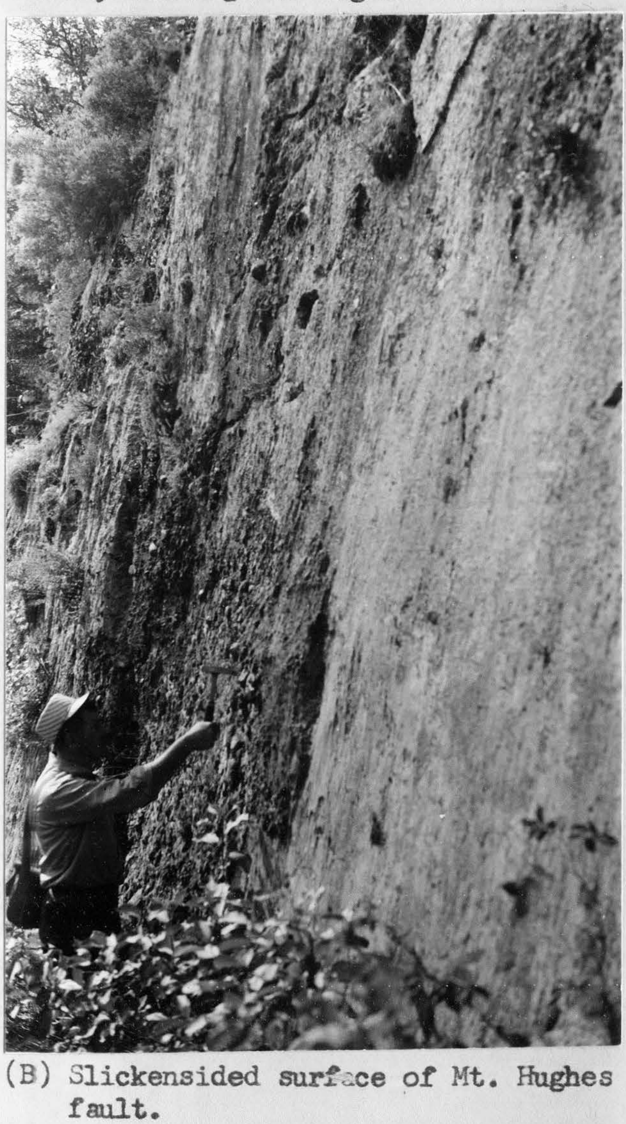
Local folds in Ordovician rocks, at the crest of the mountain west of Dry Lake on the east side of the southern block and in Precipice Canyon 4½ miles north of Brigham City, show the Fish Haven black dolomite pushed over the orange-pink quartzites of the Swan Peak (Plates 3A,6, 12.)

It seems reasonable that the transverse faults, folding and tilting of the beds occurred during the Laramide orogeny (late Mesozoic and early Tertiary). Basin and Range high-angle faulting followed, elevating the mountain (late Tertiary). The recent fault scarp in the alluvium at the mouth of Coldwater Canyon near Honeyville, Utah, and the recent faulting in Tertiary sediments on the northeast side of the mountain, described by Williams (1945), affords evidence for continued uplift of the area after Basin and Range time.

It is not meant to imply, in the foregoing discussion, that all faulting was restricted to two relatively short periods of time separated by a period of stability. It is very likely that faulting was more or less continuous or intermittent throughout the latter half of the Cenozoic era to the recent.

PLATE 11

(A) View of east-facing front, near north end of the mountain, showing Mt. Hughes fault



(B) Slickensided surface of Mt. Hughes fault.

PLATE 12

Aerial oblique view, east side of southern part of the Wellsville Mountain, showing Fish Haven (Ofh) pushed over Swan Peak (Osp.).

ORE DEPOSITS

Wellsville Mountain is almost entirely devoid of mineralization except for small ore deposits in Antimony Canyon and Baker Canyon. Both mines have been abandoned since World War II. The mineralization is an epithermal type deposit which is manifest by the ores--stibnite (antimony sulfide) in Antimony Canyon and copper carbonates in Baker Canyon. Mineral deposits are located along transverse fault planes associated with Cambrian carbonate rocks. There are no igneous rocks in the area to the writers knowledge. This suggests that the mineralization is associated with hydrothermal solutions from depth.

The Box Elder District, was organized October 2, 1889, near Bakers, Utah--a station on the railroad two miles north of Brigham City (Butler, 1920, p. 222). One property, known as Mineral Ridge, was worked intermittently for years under different names. It is located in Baker Canyon, four miles north of Brigham City, and has an aerial tramway, mill and other improvements. The mine consists of three short tunnels and a few shallow pits along a crushed zone which strikes N 60° E and dips 50° SE (transverse fault on the left in Baker Canyon, Plate 5). The crushed zone is 25 to 30 feet wide and stained yellowish brown. A small production of gold-copper ore was reported from the Box Elder District in 1908 as having been sold to the Independent Smelting Company in Ogden, Utah. Again in 1943 a small shipment of gold-copper ore was reported sold to the Garfield Smelter in Garfield, Utah (Woodward, 1943, p. 472).

With the aid of a Reconstruction Finance Corporation mine loan the Dry Lake Mining Company was able to produce 6 tons of ore averaging 50 percent antimony. This mine, in Hunsaker Canyon (Antimony Canyon) two miles north of Brigham City, was the only active antimony mine in the state. The mine consists of one tunnel and a shaft that penetrates a crushed zone at the apex of two transverse faults (Plate 3A). Mineralization occurs along the fault planes in the Cambrian carbonate rocks. The small production of ore that was taken from this mine was an antimony sulfide (Stibnite) ore. The mine operated only for a short time during the war in 1943 and 1944.

BIBLIOGRAPHY

Agatston, Robert S. (1954) Pennsylvanian and lower Permian of northern and eastern Wyoming: Amer. Assoc. Petrol. Geol., Bull., vol. 38, Pt. 2, pp. 508-583.

Beus, Stanley S. (1958) Geology of the northern part of Wellsville Mountain, northern Wasatch Range, Utah: Utah State University, Logan. Thesis.

Bissell, H.V. (1936) Pennsylvanian stratigraphy in the southern Wasatch Mountains, Utah: Iowa Acad. Sci. Proc., vol. 43, pp. 239-243.

Blackwelder, Eliot (1935) Summary of the pre-Cambrian rocks of Utah and Wyoming: Utah Acad. Sci. Proc., vol. 12, pp. 153-157.

Bostwick, David A. (1955) Stratigraphy of the Wood River formation, south-central Idaho: Jour. Paleon., vol. 29, no. 6, pp. 941-951.

Bradley, Frank H. (1873) Report of the Snake River region: U.S. Geol. Survey Terr. (Hayden). Ann. Rept. no. 6, pp. 189-271.

Branson, E.B. and Mehl, M.G. (1931) Fishes of the Jefferson formation of Utah: Jour. Geol., vol. 39, pp. 509-531.

Brooks, James E. and Andrichuk, John M. (1953) Regional stratigraphy of the Devonian system in northeastern Utah, southeastern Idaho and western Wyoming: Intermountain Assoc. Petrol. Geol., Guide to the Geology of Northeastern Utah and Southeastern Idaho, 4th Ann. Field Conf., pp. 28-31.

Bryant, W.L. (1932) Lower Devonian fishes of Bear Tooth Butte, Wyoming: Amer. Philos. Soc., paper, vol. 71, pp. 225-254.

Butler, B.S., Loughlin, G.F., and Heikes, V.C. (1920) The ore deposits of Utah: U.S. Geol. Survey, Prof. Paper 111.

Church, Victor (1943-44) Pleistocene glaciation of Wellsville Mountain, Utah: Utah Acad. Sci. Proc., vol. 21, pp. 8-9.

Collier, A.J. and Cathcart, S.H. (1922) Possibility of finding oil in laccolithic domes south of the Little Rocky Mountains: U.S. Geol. Survey, Bull. 736, pp. 171-178.

Copper, G.H., et. al. (1942) Correlation of the Devonian sedimentary formations of North America: Geol. Soc. Amer. Bull., vol. 53, pp. 1729-1794.

Crittenden, M.D., et. al. (1952) Geology of the Wasatch Mountains east of Salt Lake City: Guidebook to the Geology of Utah, no. 8, pp. 1-37.

Deiss, Charles (1938) Cambrian formation and sections in part of the Cordilleran trough: Geol. Soc. Amer. Bull., vol. 49, pp. 1067-1168.

Denison, Robert H. (1952) Early Devonian fishes from Utah, Part 1, Osteostraci: Chicago Mus. Nat. Hist., Fieldiana, Geology, vol. 11, no. 6.

_______ (1952) Early Devonian fishes from Utah, Part 2, Heterostraci: Chicago Mus. Nat. Hist., Fieldiana, Geology, vol. 2, no. 7.

Eardley, A.J. (1939) Structure of the Wasatch-Great Basin region: Geol. Soc. Amer. Bull., vol. 50, pp. 1277-1310.

_______ and Hatch, R.A. (1940) Proterozoic (?) rocks in Utah: Geol. Soc. Amer. Bull., vol. 51, pp. 795-844.

Eardley, A.J. (1944) Geology of the north-central Wasatch mountains: Geol. Soc. Amer. Bull., vol. 55, pp. 819-894.

_______ (1951) Structural geology of north America: Harper and Bros., New York.

_______, Hatch, R.A., and Bell, G.L. (1952) Geology of the central Wasatch mountains, Utah: Utah Geol. Soc., Guidebook to the Geology of Utah, no. 8.

Eardley, A.J. (1955) Tertiary history of north-central Utah: Utah Geol. Soc., Guidebook to the Geology of Utah, no. 10, pp. 37-44.

Ezell, Robert L. (1953) Geology of the Rendezvous Peak area, Cache and Box Elder counties, Utah: Utah State University, Logan. Thesis.

Gilbert, G.K. (1890) Lake Bonneville: U.S. Geol. Survey, Mon. 1.

_______ (1928) Studies of Basin-Range structure: U.S. Geol. Survey, Prof. Paper 153.

Gilluly, James (1932) Geology and ore deposits of the Stockton and Fairfield quadrangles, Utah: U.S. Geol. Survey, Prof. Paper 173.

Granger, A.E. and Sharp, B.J. (1952) Geology of the Wasatch mountains east of Salt Lake City: Utah Geol. Soc., Guidebook to the Geology of Utah, no. 8, pp. 1-37

Hanson, Alvin M. (1949) Geology of the southern Malad Range and vicinity in northern Utah: University of Wisconsin, Madison. Thesis.

_______ (1953) Upper Cambrian formations in northern Utah and southeastern Idaho: Intermountain Assoc. Petrol. Geol., Guide to the Geology of Northern Utah and Southeastern Idaho, 4th Ann. Field Conf., pp. 19-21.

Hayden, F.V. (1872) Preliminary report of the U.S. Geological Survey of Montana and portions of adjacent territories: U.S. Geol. Survey, 5th Ann. Rept., pp. 11-165.

Haynie, Anthon V. Jr. (1957) The Worm Creek member of the St. Charles formation, Utah-Idaho: Utah State University, Logan. Thesis.

Holland, F.D. Jr. (1952) Stratigraphic details of lower Mississippian rocks of northeastern Utah and southwestern Montana: Amer. Assoc. Petrol. Geol., Bull., vol. 36, pp. 1697-1734.

Kindle, E.M. (1908) Occurrence of the Silurian fauna in western America: Amer. Jour. Sci., 4th series, vol. 25, pp. 125-128.

King, Clarence (1878) U.S. Geol. Expl., 40th Par. Rept., vol. 1.

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

Maxey, George Burke (1941) Cambrian stratigraphy in the northern Wasatch region: Utah State University, Logan. Thesis.

Mc Kee, Edwin, et. al. (1956) Paleotectonic maps of the Jurassic system: U.S. Geol. Survey, Map I-175.

Merriam, C.W. (1940) Devonian stratigraphy and paleontology of the Roberts mountain region, Nevada: Geol. Soc. Amer. Special Paper, no. 25.

Mertie, J.B., Jr. (1947) Graphic and mechanical computation of strata and distance to a stratum: U.S. Geol. Survey, Prof. Paper 129-c, pp. 39-52.

Moore, R.C. and Thompson, M.L. (1949) Main divisions of Pennsylvanian period and system: Amer. Assoc. Petrol. Geol., Bull., vol. 33, pp. 275-302.

Moritz, Carl A. (1953) Summary of the Cretaceous stratigraphy of southeastern Idaho and western Wyoming: Intermountain Assoc. Petrol. Geol., Guide to the Geology of Northeastern Utah and Southeastern Idaho, 4th Ann. Field Conf., pp. 63-72.

Nolan, T.B. (1943) The Basin and Range province in Utah, Nevada, and California: U.S. Geol. Survey, Prof. Paper 197-D, pp. 141-196.

Nygreen, Paul W. (1955) Stratigraphy of the lower Oquirrh formation in the type area and near Logan, Utah: University of Nebraska, Lincoln. Thesis.

Olson, R.H. (1956) Geology of the Promontory Range: Utah Geol. Soc., Guidebook to the Geology of Utah, no. 11, pp. 41-75.

Parks, James M. (1951) Corals from the Brazer formation (Mississippian) of northern Utah: Jour. Paleon., vol. 25, pp. 171-186.

Peale, A.C. (1879) Report of the geology of the Green River district, Wyoming: U.S. Geol. and Geog. Survey Terr. (Hayden), 11th Ann. Rept. (for 1877), pp. 509-646.

_______ (1893) The Paleozoic section in the vicinity of Three Forks, Montana: U.S. Geol. Survey, Bull. 110.

Prammani, Prapath (1957) Geology of the east-central part of the Malad Range, Idaho: Utah State University, Logan. Thesis.

Resser, C.E. (1939) The Ptarmigania strata of the northern Wasatch mountains: Smithson. Misc. Coll., vol. 98, no. 24, p. 72.

Richards, R.W. and Mansfield, G.R. (1912) The Bannock overthrust, a major fault in southeastern Idaho and northeastern Utah: Jour. Geol., vol. 20, pp. 681-709.

Richardson, G.B. (1913) The Paleozoic section in northern Utah: Amer. Jour. Sci., 4th series, vol. 36, pp. 406-413.

_______ (1941) Geology and mineral resources of the Randolph quadrangle, Utah-Wyoming: U.S. Geol. Survey, Bull. 923.

Ross, Reuben James, Jr. (1954) Correlation and interpretation of Paleozoic stratigraphy in south-central Idaho: Geol. Soc. Amer. Bull., vol. 45, pp. 937-1000.

_______ (1951) Stratigraphy of the Garden City formation in northeastern Utah and its trilobite faunas: Yale Peabody Mus. Nat. Hist., Bull. 6.

Sadlick, Walter (1955) Carboniferous formations of northeastern Uintah Mountains: Wyo. Geol. Assoc. Guidebook, 10th Ann. Field Conf., pp. 49-59.

Schaum, J.H. (1943) U.S. Dept. Int., Bureau of Mines Minerals Yearbook, p. 780.

Strickland, J.W. (1956) Mississippian stratigraphy, western Wyoming: Wyo. Geol. Assoc. Guidebook, 11th Ann. Field Conf., pp. 51-54.

Walcott, Charles D. (1908a) Nomenclature of some Cambrian Cordilleran formations: Smithson. Misc. Coll., vol. 53, no. 1, pp. 1-12.

_______ (1908b) Cambrian sections of the Cordilleran area: Smithson. Misc. Coll., vol. 53, no. 5, pp. 167-230.

Williams, J. Stewart and Maxey, G.B. (1941) Cambrian section in the Logan quadrangle, Utah and vicinity: Amer. Jour. Sci., vol. 239, pp. 276-285.

Williams, J. Stewart (1943) Carboniferous formations of the Uinta and northern Wasatch mountains: Geol. Soc. Amer. Bull., vol. 54, pp. 591-624.

Williams, J. Stewart and Yolton, James S. (1945) Brazer (Mississippian) section of Dry Lake, Logan quadrangle, Utah: Amer. Assoc. Petrol. Geol. Bull., vol. 29, pp. 1143-1155.

Williams, J. Stewart (1948) Geology of the Paleozoic rocks of the Logan quadrangle, Utah: Geol. Soc. Amer. Bull., vol. 59, pp. 1121-1164.

Woodward, G.E. and Luff, Paul (1943) U.S. Dept. Int., Bureau of Mines Minerals Yearbook, p. 472.