The Geology of a Part of the Bear River Range and Some Relationships that it Bears with the Rest of the Range

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THE GEOLOGY OF A PART OF THE BEAR RIVER RANGE AND SOME RELATIONSHIPS THAT IT BEARS WITH THE REST OF THE RANGE

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In Partial Fulfillment of the requirements for the Degree Master of Science in the School of Arts and Science Department of Geology

By
Vic E. Peterson
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CHAPTER I

INTRODUCTION

PURPOSE AND SCOPE OF INVESTIGATION -

The structure of the western three or four miles of the Bear River range east of Logan, Utah, has many times been alluded to in papers written locally on Cache Valley and the related ranges. There has not however, ever been, to the author's knowledge, an investigation made of this portion of the range for the express purpose of determining its exact structure. Although the area specifically covered by this present investigation is greatly inadequate to base the whole west range structure on, the author believes that the facts brought to light by the specific study of this area, added to the facts already known of the rest of the range, will give a clearer and more comprehensive interpretation of the whole western Bear River range front. It was with this purpose in mind that the present investigation was made.

The original outline for the study included an investigation of the paleontology of the section. It was found however, after a few weeks study in the field, that the fossils in the local section are far too scarce for any comprehensive study in the present investigation. The study herein described then
will be found to refer to paleontology only where it is necessary or where fossil horizons were found advantageous over lithologic units for mapping of formations. The section represented here has several times been studied in part. With a study of these investigations, it was found that there was enough lithologic difference in most of the sections to make possible local correlation and mapping on that basis.

In order to make the present paper more thorough and complete it seemed advisable to branch out from the specific area in a few cases and investigate other parts of the valley and range for further insight into some of the problems confronted on the area. It was also found necessary to make a rather complete study of the literature of related areas.

LOCATION AND EXTENT OF THE AREA

The area specifically studied comprises approximately 13 square miles lying between Providence canyon and Logan canyon in the Bear River range east of Cache Valley, Utah. It extends 2½ miles east of the west front of the range into the mountains and about one mile from the same point into the valley. Specifically it covers the following sections:

Sections 1, 2, 11, 12 N 3/4 14 R. 1 E.T. 11 N. S.B.M.
Sections 6, 7 W4 3, NW4 17, N3/4 18, R. 2 E.T. 11 N.S.B.M.
Sections 35 and 36, R. 1 E. T. 12 N. S.B.M.
Sections 31 and W4 32, R 2 E. T 12 N. S.B.M.

The locations of these sections are shown on the included quadrangle map. (Plate 1.)
EARLIER INVESTIGATIONS -

Hague (1) was probably the first investigator of the region of which this area is a part. His main observations were conducted in Logan canyon, Blacksmith Fork canyon and East Fork canyon. It was Hague who described Cache Valley as a syncline. Peale,(2) at about the same time described the structure of the west limb of the Bear River range. Following soon after this, Gilbert (3) described the Bonneville terraces in Cache Valley and made some allusions to the structure of the Bear River range front. Walcott (4) measured a section of the Cambrian in Blacksmith Fork canyon. Kindle (5) conducted a reconnaissance investigation of the Devonian of the west face of the range. Cooley (6) in a more recent investigation has written a paper on the Devonian of Logan and Blacksmith Fork canyons. Owen (7) has presented a detailed discussion of the Swan Peak quartzite, and a map of its outcrops in the area covered by the Logan quadrangle map. The west front of the range and the Bear River fault have been described by Bailey (8). Bailey's views have been rejected.

(3) Gilbert, G.K., U.S.G.S. Mon. 1. pp. 159-163 (1890).
by Blackwelder, (9) who attempts to show that the west face of the range is a resequent fault-line scarp rather than a fault scarp as contended by Bailey and others.

FIELD WORK -

The field work for this investigation was conducted during the fall and spring of 1935 and 1936. The maps used were tracings of photographic enlargements of the Logan quadrangle map which covers the area.(Plate 1) Mapping of the formations was done with the aid of an aneroid barometer and the recognition of topographic forms shown on the map. It must be stated therefore, that the accuracy of mapping is only within/inherent to these methods. Unfortunately, the accuracy was not great enough to show many of the minor features in their true aspect. For this reason some of the more minor features were left off the map. On the other hand, some minor features which have considerable bearing on the major features of the area were drawn with a slight exaggeration on the map to make more clear their true aspects. All the major features were mapped as nearly accurate as the methods used would permit.

CHAPTER II
GEOGRAPHY AND PHYSIOGRAPHY

As given above, the area here discussed in detail forms a part of the Bear River Range and of Cache Valley. Any geographic or physiographic study of this area thus becomes a study of the two larger areas of which it is a part, and the features which are apparent on this area are representative of the larger features displayed in the Valley and Range. Consequently a brief discussion will be given of the geographic and physiographic features of the two larger areas.

Cache Valley—

Cache Valley is situated in the northern most part of Utah and extends into Idaho. In shape it is roughly elliptical, with its long axis north and south. The Valley attains its maximum width, approximately 19½ miles, at the Utah-Idaho boundary. From this point the Valley tapers both ways. The segment which lies in Utah is about 44 miles long and that which extends into Idaho is about half that length.

Cache Valley is one of the many subsidiary valleys which are included in the Great Basin. Twice in its history it has been occupied by great lakes, namely, the unnamed lake in which the Salt Lake formation was deposited and Lake Bonneville, a Quaternary lake which covered an extensive area in the Great Basin. During the time that Lake Bonneville occupied parts of the Great Basin, water covered Cache Valley to a depth of 800 feet at the
highest level of the lake and hundreds of feet of sediments were deposited at the mouths of the larger canyons which enter the valley. The disappearance of the Lake exposed a very gently undulating surface which is now known as Cache Valley.

On the east side, the valley is bordered by the high deeply furrowed Bear River Range. This range comprises a large catchment basin for the excellent supply of pure water which enters Cache Valley.

On the west, the valley is separated from Box Elder Valley by a narrow but high extension of the Wasatch known as the Wellsville range. The eastern front of this range is very steep with many precipitous cliffs protruding from its face. This steep face is cut into by narrow gorge-like canyons which head high up against the north-south ridge.

The average elevation of the valley is about 4400 feet above sea level. In between this and the highest level of Bonneville, elevation 5200 feet, are a number of terraces, which mark the different stages of the lake. These vary in width from a few tens of feet to nearly a mile. The three most prominent of these have been named by Gilbert, (10), proceeding from highest to lowest, the Bonneville, Provo, and Stansbury levels.

The most important streams enter the valley from the north and east. The entire drainage of the valley is received by Bear River. The two most important streams which enter the valley from the east are Blacksmith Fork and Logan Rivers. The

(10) Gilbert, G. K., U.S.G.S. Monograph I pp 159-163 (1890)
average annual flow of these two streams is $160,000$ and $270,000$ acre feet respectively. The drainage leaves the valley in what is known as Bear River Narrows, a narrow gorge which is cut through the northern extension of the Wellsville range just south of Newton Hill.

Bear River Range—

As originally defined by the United States Geographic Board, (11) the Northern Wasatch consists of two distinct parallel ranges separated by depressions 4 to 10 miles in width. The range to the west is the Wellsville range; the range on the east is the Bear River Range; and the depressions separating the two ranges are part of the great structural trough which Gilbert (12) termed the Back Valleys. The Bear River Range extends from a latitude of approximately $41^\circ 15'$ or in the vicinity of Huntsville, Utah, in a nearly north-south direction between Cache Valley and Bear Lake Valley to terminate at a latitude of approximately $42^\circ 45'$. The range terminates in what is known as Sheep Rock, just south of the sharp bend of Bear River, near Alexander, Idaho. It has a maximum length of 95 miles with a width varying from 2 to 22 miles. Its maximum width is attained on a line between townships 15 and 16 south in southern Idaho.

The range itself is divisible into three parts, namely, a high plateau-like ridge which lies on the east; a higher and

(12) Gilbert, G. K., U.S.G.S. Prof. Paper 153 p. 53-54 (1928)
broader plateau-like ridge which lies on the west; and a trough-like valley which separates the two ridges. Both the east and west ridges are dissected by steep gorge-like canyons and are in an early mature state of erosion. The lower area in between however, is farther along in the erosion cycle and has attained a topography symbolic of late maturity or old age.

As seen from the top of the Wellsville Range the Bear River Range appears nearly flat on top except for a few high peaks which rise slightly above the general terrain. These peaks seem also to be about the same elevation. From that distance the relief of the front of the range is softened so that it does not appear as steep as it actually is. (Plates 6 and 7 show this relationship.)

Roughly, the profile of the west ridge can be divided into three segments. Up to an elevation of approximately 7000 feet the face of the range is composed of steep-dipping narrow ridges which are truncated on their western extensions to form a line of facets. Separating these ridges are a number of small and a few large canyons which are persistently gorge-like at their mouths. Between seven and nine thousand feet the profiles have a marked tendency to flatten out. Possibly this is structurally controlled though as will be shown it more likely represents a stage of erosional development in the range. It is up against these flat ridges that the afore named small canyons head. Between 9000 and 10,000 feet the profiles have a tendency to steepen slightly before they terminate in the highest peaks.
On the north and east sides of many of the higher peaks are found small cirque basins which were formed during the Pleistocene (Wisconsin) glacial epoch. These still collect large amounts of snow which lasts well into the summer months.

Physiographic Development-

Studies of the physiographic development of the regions immediately adjacent to Cache Valley and the Bear River Range, have already been made. Mansfield (13) has made a rather thorough study of the physiographic development of southeastern Idaho. A number of investigators have touched on the physiographic development of the Wasatch range. Unfortunately, none of these investigators are in full agreement with each other. There is also some disagreement in southeastern Idaho, though this disagreement is in the relation of the physiographic development of Western Wyoming and Southeastern Idaho. As will be shown, the physiographic interpretation given by Mansfield and students of the Wasatch range are not in agreement. In any event, the discussion here given, will be an interpretation of local features in the light of those found in the two adjacent territories.

Pre-Wasatch Erosion Surface-

Lying between the east and west ridges of the Bear River range, and forming part of that surface, there occurs occasional outcrops of Wasatch conglomerate (Eocene). The contacts

between this deposit, and the underlying Paleozoic, are not in many places observable, but where apparent, they are seen lying unconformably on the rocks below. Only a little work has been done on this deposit. However, a few rough conclusions can be drawn from observations made on the formation.

Outcrops of the Wasatch conglomerate are known to occur in the central Bear River Range, from an altitude of 6500 feet to 9000 feet, or through a vertical distribution of 2500 feet. At no place, to the author's knowledge, does such a thickness of the Wasatch conglomerate appear in the Bear River Range. Usually the deposits are not more than a few hundred feet, at the most. There is, therefore, an indication of rather an extensive warping of the central Bear River Range, subsequent to the deposition of the Wasatch conglomerate, or following some time after the Eocene epoch.

Unfortunately, sufficient work has not been done on the Tertiary deposit of the central Bear River Range to determine the relief of the surface on which it was deposited. Mansfield (13) has studied this surface in Southeastern Idaho and has found the relief to be about 1350 feet with individual valleys, ranging from 400-100 feet in depth. He has called this surface, where exposed, the pre-Wasatch erosion surface, and attributes it to the Pre-Eocene erosion, following the Laramide Revolution. No account is given of this surface in the Wasatch.

Mansfield does not give any account of the erosion surface developed during the epoch of the formation of this conglomerate. However, from what has already been said of this region, some indication of the relief can be gained. The highest deposit of the Wasatch conglomerate known in the Bear River range is at an elevation of near 9000 feet, and is located just south of Tony Grove Lake. The highest peak in the range is but a few miles to the north and has an elevation of 9880 feet. This gives an interval of near 1000 feet between the highest known peak, and the highest known deposit of the Wasatch conglomerate. It is probably reasonable then to say, that the minimum relief was near 1000 feet at the time of the Wasatch deposition, though it may have been more, as will be shown.

On Mt. Nebo, in the southern Wasatch, Eadley (14) in measuring the displacement of the Wasatch fault, found a difference of 3000 feet between the total displacement and the total relief between the bottom of the valley and the top of Mt. Nebo. He inferred from this that the Wasatch must have had a relief of between 2000 and 3000 feet before uplift. This is in contrast to Gilbert (15) and others, who have postulated that the Wasatch was an uplifted peneplane. A similar mature surface is seen surmounting the Wasatch in a number of other places, and where found probably corresponds with the mature surface which Eardley has postulated for the southern Wasatch. This mature

surface, in all probability, represents the erosion surface formed during the Eocene deposition.

As has been given above the ridges of the west face of the Bear River range flatten out at an elevation of about 7000 feet and taper back gradually to the high peaks which surmount the range. It was this flattening which suggested the presence of an erosion surface. To verify this suggestion two lines of recourse were followed, namely a comparison of ridge profiles, and a frequency chart of the occurrence of certain elevations as bench lands and peaks. Both methods proved to be in strong support of an erosion surface lying between 7000 and 9000 feet on the Bear River Range.

The ridge profiles were taken only on the Logan quadrangle. Here there seemed to be a marked harmony in the profiles throughout most of the area though some few ridges in the northern portion did not correspond completely.

The frequency charts of the elevations occurring as bench lands or peaks were taken for three quadrangles, namely, Preston, Logan, and Randolph. The curves which were obtained were surprisingly consistent, so much so that it is difficult to interpret their meaning other than that which is given below. It was found that for these three quadrangles there were three distinct elevations at which bench lands and peaks most commonly occur. These are:

7000 feet
8100 feet
8600 feet
The interpretation of these observations is of course highly hypothetical, but they seem to point to only one recourse, that of successive uplift of the range. Whether this uplift took place along the Bear River fault, or whether it was of a broad epeirogenic nature it is impossible to say. It is possible that the three elevations have no meaning by themselves. However, it does seem very likely that at least one erosion surface is represented by the distance between 7000 and 9000 feet. It is possible that this erosion surface represents part of the Wasatch erosion surface. If it does, the mature erosion surface developed here would correspond more closely with the mature surface of Bardley, having a relief of near 3000 feet.

The Tertiary history subsequent to the Eocene period is as equally opaque to view as the Eocene and pre-Eocene history. At the present time, views of that history are but a matter of conjecture. As cited above, the physiographic histories worked out for either of the adjacent regions are open to debate.

Mansfield (16) in southeastern Idaho, postulates a long period of erosion following the deposition of the Eocene conglomerate. This period of erosion extended from the end of Eocene to the latter part of Miocene time and he thinks that the time involved was doubtless sufficient to reduce the whole region to a peneplane. He has observed this surface in a few places, cutting the Pre-Eocene erosion surface, and has called it the Snowdrift

peneplane. Mansfield believes the epoch during which this peneplane developed to have been essentially free from any extensive diastrophic activity.

Gilbert (17) on the other hand postulates a great epeirogenic movement following the deposition of the Eocene conglomerate. This epeirogenic movement caused the change in the direction of the drainage which had up to this time flowed from west to east, to flow from east to west. There is considerable evidence to substantiate this view. Concordantly with this movement there occurred intensive orogenic activity with the development of a series of north-south ranges of which the Wasatch is one. About this same time the great structural trough which Gilbert (18) has termed the Back Valleys is supposed to have been formed.

It is obvious that these two histories are out of harmony with each other. The regions are too close to each other to have had such diverse physiographic development.

Snowdrift Peneplane-

Mansfield has observed this peneplane north of the Bear River Plateau. The surface is not well developed but is preserved only in scattered remnants and its presence is inferred by the relationship which these remnants bear to each other.

Mansfield in speaking of the post Eocene development says,

"Erosion interrupted by deformation appears to have prevailed until Pliocene time but no deformation of note occurred until about the middle of Miocene. This long erosion interval which covered most of Eocene, Oligocene, and perhaps more than half of Miocene time, was doubtless sufficient to reduce the country approximately to base level. The erosion surface developed on the Wasatch beds may thus have truncated the pre-Wasatch erosion surface as above suggested or have merged from that surface beyond the area of deposition".

Locally, there is evidence of a peneplane having existed over the Bear River Range, though this evidence is highly conjectural. As has been mentioned above, the high peaks approach the same elevation within a few hundred feet, varying from 9700 to 10,000 feet in elevation. This regularity of elevations could easily be accounted for by a peneplane having existed before uplift.

As cited above, Eardley (20) has shown that a mature surface of nearly 3000 feet in relief existed on the Wasatch before uplift. There is also very good evidence that the same surface existed in the Bear River Range before it was uplifted. In order, then, to correlate these observations with Mansfield's views they must be placed at a later date in origin, or probably deferred to the end of Miocene time. Also epeirogenic movement which Gilbert postulates for the change in direction of drainage,

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would have had to been a gentle one. The orogenic movements which he postulated, would have to be deferred to the late Miocene. Rather than arbitrate these observations from their original form, it seems more justified not to recognize Mansfield's Snowdrift peneplane, at least locally, and to assume that if such a surface existed that it was localized in Southeastern Idaho and not wide spread as Mansfield has suggested.

Post Eocene Development-

As Gilbert (21) postulated, soon after the Eocene epoch the development of the Back Valleys was begun. This uplift was probably not a continual one but one of broken sequence. This is indicated by the frequency charts given above. However, at least for the greater part of the uplift, the movement was rather rapid, hesitating no place long enough to allow an erosion surface to advance far enough to be preserved in the present topography. This movement continued throughout the Oligocene and probably most of Miocene time. The erosion surface which was developed must have locally been in a very youthful stage. Mansfield (22) in southeastern Idaho describes the surface on which the Salt Lake formation was deposited as of mature relief. This surface is not observable in Cache Valley.

Some time in late Miocene or early Pliocene the orogenic movements which brought about the formation of the series of north-south ranges became greatly retarded. At this same time

there was developed in the Back Valleys a great fresh-water lake in which the Salt Lake formation sediments were deposited. This lake remained fixed in position long enough to allow the development of a mature erosion surface surrounding its edges. The mountain mass, however, was not entirely free from uplift. The succession of sediments given in the included section of the Salt Lake formation suggests that the mountain mass was probably uplifted several times during the presence of the lake in the Back Valleys and surrounding regions. This erosion surface is represented in Cache Valley and the Bear River Range by high terraces in a few of the canyons and by the maturely dissected upland at the south end of the valley. The terraces stand from 200 to 300 feet above the highest level of Bonneville. In southeastern Idaho, Mansfield (23) called this erosion surface the Gannett erosion surface and the period during which it was developed the Gannett cycle. This surface is not described west of the Wasatch. Likely the more active movement along the Wasatch fault kept an erosion surface from developing to such a state that it could be recognized in the present topography.

Following the deposition of the Salt Lake formation, diastrophic movements which caused the faulting of the Salt Lake sediments caused the drainage of the lake and the lowering of the base level of erosion. This was succeeded by a period of erosion which gutted out most of the Salt Lake formation from

the center of the valley leaving only remnants of that formation high on the valleys edge. Mansfield (24) has discussed several cycles following the Gannett cycle, but these are of local occurrence and cannot be correlated here.

Following the movement which caused the drainage of the lake and the dissection of the Salt Lake sediments which were deposited in it another diastrophic movement caused a rise in the base level of the drainage of Cache Valley, possibly tilting as Eardley has suggested of the mountain mass caused by movement of the Wasatch fault. This movement is shown by the large accumulation of sediments which formed in the valley subsequent to the post Gannett erosion. Toward the latter part of Pliestocene time, a large fresh water lake, Lake Bonneville, occupied the eastern portion of the Great Basin. An arm of this lake occupied Cache Valley during this epoch.

While the lake was present in the valley, it formed a number of terraces which indicate the successive levels at which the lake stood. At least 10 of these levels are very conspicuous.

After the lake withdrew from the valley the rivers entrenched their way into the lake sediments. Two epochs of entrenchment are recognized.

CHAPTER III

STRATIGRAPHIC GEOLOGY

GENERAL FEATURES

The section exposed on this area forms a part of the remarkably full section of sedimentary rocks exposed in the north part of Utah. It forms a part of approximately 45,000 feet of sediments, representing calcareous muds, sands, and gravels, which were deposited in this and neighboring regions to be consolidated into rocks. The later sediments are found to be made up to a great extent of the fragments of the earlier sediments, indicating a progressive formation.

The many changes in the lithology indicate diverse, sometimes rapid, sometimes very progressive, changes in geographic conditions. Other studies have shown that the changes were reflected into the evolutionary progress of the organisms, the remains of which now form so significant a record. Many horizons in the older and marine sediments are found to be abundantly fossiliferous, these making correlations of the sediments possible. However, these fossiliferous horizons constitute a very minor part of the total section, there being a far greater amount of rock present which cannot be placed as yet in its true stratigraphic position. The few fossils that are found in the non-marine later sediments do not have a great deal of value in correlation. Consequently their position stratigraphically can only be approximated.
The old paleozoic beds are found in the eastern two-thirds of the area and comprising the greater part of the Bear River range in which the area lies. The beds have been profoundly contorted from their original nearly horizontal position into warped, folded and faulted uplands. Lying unconformably up against these beds from the west are the unconsolidated Quaternary sediments. These form the whole western part of the area.

On the south, west, and north are portions of the valleys edge which are composed of Pliocene beds.

The general relations of the above beds may be seen on the included map. (Plate 3.)

ORDOVICIAN SYSTEM

The Ordovician system forms the oldest rock series found in the area. The system consists of light colored limestones, shales, quartzites, dolomitic cherty limestones, and dolomites which have been divided by Richardson (25) into the following three formations: from the oldest to the youngest - Garden City limestone which contains a Beekmantown fauna, Swan Peak quartzite, which contains a Chanzy fauna, and Fish Haven dolomite which contains a Richmond fauna.

Rocks of this age skirt the whole western front of the area. In Logan canyon they are found as the basal system dipping at a moderate angle to the east to pass out of sight about in the vicinity of the Legion camp. But on the west front the

rocks of this system are found invariably on edge or overturned to the east.

The best section exposed on the area is found in Logan canyon from its mouth to the vicinity of the Legion camp. All of the Swan Peak quartzite, the Fish Haven dolomite and by far the greater part if not all of the Garden City limestone, are here exposed in a noble fashion.

GARDEN CITY LIMESTONE

Name - The Garden City limestone was named from Garden City on the west side of Bear Lake, approximately 4 miles south of the Utah-Idaho boundary line.

Distribution and Character - Logan canyon is the only place on the whole area where the Garden City limestone is seen entire and in its true aspects. Here it appears as a massive thin and thick bedded light colored limestone between the mouth of the canyon and the Second Bridge. It emerges from the canyon to the west in a rapidly increasing dip to become overturned by the time it reaches the western face of the range on the area. Along the western edge of the range the formation has suffered great fracturing as the result of the folding. In many places the fracturing has left the rocks open to the action of percolating waters which have discolored the formation from its natural hue. The formation does not form a persistent outcrop across the front to the range like the Swan Peak quartzite above but is in most places covered by surface mantle. It
is, however, present all across the front.

Age and Correlation - An extensive fauna has been collected by Mansfield (26) from the Garden City limestone in southeastern Idaho. The fauna was identified by Kirk as of Beekmantown age and corresponds in part to that certain portions of the Pognip limestone of the Eureka district of Nevada. Some correlations of this section with surrounding districts are given in Figure 1.

SWAN PEAK QUARTZITE

Name - The Swan Peak quartzite was named from Swan Peak at the head of Swan Creek canyon west of Lakota, Utah.

Character and Distribution - The formation forms a narrow band which traverses the north and west portion of the area. It first appears in Logan canyon at the mouth of Jackies hollow as a conspicuous cliff dipping to the east 25°. Followed west the dip rapidly increases until where the formation rises out of the canyon it is overturned and dipping to the west about 70°. In the last quarter of a mile of its emergence from the canyon it is crossed by two small thrust faults which displace the formations continuity by about half its thickness. On the west face of the range the formation is not entire, a portion of the shaly member at the bottom of the formation having been pinched out in the process of folding. Across the face of the range the harder quartzitic member outcrops as a conspicuous

light colored band. This band except for one large off-set just north of Dry canyon rises and falls across the canyons and hollows with little deviation to the right or left. At the south end of the range the formation is crossed by a number of small east-west faults. At the extreme south portion the formation is covered by mantle and its exact position is not discernible. One small wedge of the upper 40 feet of the formation occurs on the north side of the mouth of Providence canyon.

The Swan Peak quartzite consists locally of approximately 30 feet of thin shales and quartzites overlain by about the same amount of massive light colored quartzite. The following section was measured on the south side of Logan canyon:

Forty feet of alternate layers of shale and quartzite with a predominance of quartzite. Contains some beds of very thin black paper shale. These beds alternate with beds of light tan quartzite. The shale beds vary from $\frac{1}{4}$ inch to 4 inches in thickness. The quartzite is gray to brown finely crystalline rock and weathers to light brown. Both shales and quartzites are crossed by worm track-like configurations from 1/8 to 1/4 inch in diameter and 1 to 2 inches long.

Forty feet of purple to white medium grained quartzite sandstone. Weathers to purple-pink. Strata are massive in structure and vary in thickness from 3 inches to 4 inches in thickness. The beds are separated by a thick medium to light colored paper shale with the thinner beds more predominant toward the bottom. Abundance of fucoides.

Four feet of light brown shale and quartzite in thin beds. Beds vary in thickness from 1 inch to 5 inches with an average of about 3 inches. Weathers to light brown.

Ten feet of light gray to white quartzite sandstone, massive in structure. Weathers to light brown to light gray. Abundance of fucoides.
One foot of steel gray paper shale. Weathers to light brown to light gray.

Sixty-seven feet of whitish gray massive bedded quartzite. Weathers to a light grayish brown. Beds vary in thickness from 6 inches to 10 feet with an average thickness of 4 feet. Abundance of fucoides.

Age and Correlation - Fossils are not abundant but a sufficient number have been found to prove the formation to be Ordovician. The fauna which occurs is related to that which occurs in the Simpson formation in Oklahoma and has been tentatively referred to the Chazy by Ulrich and Kirk (27).

Figure 1 gives some correlations of the Swan Peak with other regions. Peterson (28) has shown that a close relation exists between the Morehouse quartzite of the San Francisco range in Central Utah with the Swan Peak quartzite of this region if they are not equivalent. Richardson considered the Blue Bell dolomite of the Tintic district to be equivalent to the Fish Haven dolomite of Southeastern Idaho. The Ajax limestone and Ophohongo formation are then probably of the same deposition period as the Garden City limestone and the Swan Peak quartzite.

**FISH HAVEN DOLOMITE**

Name - The Fish Haven dolomite was named from Fish Haven creek which enters Bear Lake just north of Fish Haven bathing resort in Idaho.

Distribution and Character - Although Richardson (29)

described the Fish Haven dolomite in its type section as being 500 feet thick he did not recognize any definite dividing line between it and the overlying Laketown dolomite. If such a dividing line does exist, it is not marked lithologically and consequently becomes unmappable in the present investigation. There are several lithologic units in the great thickness of rocks between the base of the Devonian and the top of the Swan Peak quartzite which might be used as a basis for mapping. It is possible to make a rough approximation of the position of the top of the Fish Haven dolomite by lithologic units. However, it is better to present the whole section between the Swan Peak quartzite and the base of the Devonian as one unit under the Laketown dolomite, since it has been contended that there is no break between the two formations and that they both belong to the Silurian. The section as studied will therefore be presented in conjunction with the section of the Laketown dolomite.

Age and Correlation - Richardson and Mansfield have both noted a rather extensive Richmond fauna in the Fish Haven dolomite in northern Utah and southeastern Idaho. The Richmond fauna is generally believed to be indicative of upper Ordovician but it has been regarded by Ulrich (30) as of lower Silurian. It may be noted here that the strata of Richmond age are overlying the strata of Chazy age. According to the eastern series this would leave a large interval between the Swan Peak

Figure 1

CORRELATION OF LOCAL ORDOVICIAN SERIES WITH OTHER REGIONS
quartzite and the Fish Haven dolomite though no very conspicuous unconformity is apparent between the two formations.

Figure 1 gives some correlations of the local section with neighboring regions. No equivalent of the Fish Haven dolomite exists in the San Francisco range but in the Tintic district, Richards has considered the Blue Bell dolomite to be of the same age as the Fish Haven dolomite of northern Utah.
SILURIAN SYSTEM

The Silurian system as originally defined for Northern Utah consists of only one formation, the Laketown dolomite. No definite line can be drawn between this system and the underlying Ordovician. It has been suggested that such a division does not exist and that the time between the upper Ordovician and the lower Silurian is represented by an uninterrupted period of sedimentation. That there was few geographic changes throughout the most of the period is borne out by an examination of the lithology of the section. The local section is distinct for having such great thickness of dolomite with such a few changes in its lithology.

Richardson found in the upper two thirds of this great thickness of dolomite a fauna which he ascribed as of Niagaran age. In the lower one third of the section fossils have been found which determine it to be of Richmond age.

Name - The Laketown dolomite was named from Laketown canyon four miles southeast of Laketown, Utah. There it includes the light colored sandy and calcareous beds that lie apparently conformably above the Fish Haven dolomite and immediately beneath another dolomitic series which is correlated by Richardson with the Jefferson limestone of Montana.

Distribution and Character - The great dolomitic series including the Laketown and Fish Haven dolomites first appears on the area in Logan canyon between Steam Mill hollow and
Jackie's Hollow. Here it plunges into the canyon as massive, precipitous ledges dipping to the east at an angle of 25°. Viewed as a whole it has a shelved appearance resulting from more extensive development of vertical jointing and a relatively less resistance to erosion in some beds. Followed westward, the formation maintains its precipitous and shelved appearance but the dip rapidly increases. Where it approaches the top of Jackie's hollow the dark coral bearing bed at the top of the formation is crossed and recrossed by an east-west fault. A quarter of a mile farther west this same fault cuts off the whole formation, displacing it to the west by just about its full thickness to the west. On top of the ridge the dip attains an angle of 65° to the east. As the outcrop is followed southward the dip rapidly increases until on the south side of Dry canyon the upper part of the formation is overturned and dipping to the west at an angle of 65°. Erosion has removed the overturned portion of the lower part of the section. Further south the beds become more overturned until when they reach the vicinity of Magpie hollow the entire section is overturned and dipping to the west at an angle of 35°. This is approximately the apparent dip of the same overturned section in the bottom of Providence canyon.

The following is a section of the Ordovician-Silurian series measured on the south side of Logan canyon:

115 feet of dark bluish-gray finely crystalline dolomite. Weathers to a deep blue-gray. Contains an abundance of Halsites.
Probably Halysites gracilis. Grades to lighter color toward the top.

27 feet of dark bluish-gray dolomite, well developed system of joints. Weathers to a medium gray. Contains numerous small calcite inclusions toward top.

27 feet of bluish-gray dolomite containing a profusion of small calcite inclusions. Tends toward a more massive structure than preceding bed. Weathers to a medium gray. Streaked by dark bands.

65 feet of fine grained, crystalline, medium-bluish-gray dolomite. Weathers to a medium gray. Well developed vertical jointing.

58 feet of fine grained light gray dolomite containing a few thin layers of very light gray dolomite containing calcite inclusions. Weathers to medium light-gray.

5½ feet of medium-gray fine grained dolomite containing lenses of dark gray dolomite.

6 feet of fine grained light gray dolomite containing a few thin layers of very light gray dolomite containing calcite inclusions. Weathers to medium light-gray.

7 feet of dark bluish-gray dolomite, fine grained, weathers to a dark gray. In beds 3" to 4" thick.

31 feet medium gray fine grained dolomite. Beds 3' to 4' thick. Contains numerous small calcite inclusions. Weathers to light gray.

2½ feet dark bluish-gray dolomite. Weathers to a light gray.

18 feet of medium-gray fine grained dolomite. Weathers to light gray. Thin bedded; highly jointed.

21 feet dark bluish-gray fine-grained dolomite containing cherty concretions. Weathers to a dark gray.

27 feet of light-gray, fine grained dolomite. Weathers to a medium gray.

8 feet of dark blue-gray dolomite; fine grained. Contains a few cherty concretions toward bottom. Contains lense of lighter colored chert in upper 2 feet.
19 feet of medium gray, fine grained dolomite. Weathers to a light gray. Fades to a deep bluish-gray toward top.

13 feet of very light gray arenaceous dolomite or limestone. Fine grained; banded with lighter streaks. Weathers to a very light gray; massive bedded.

2 ½ feet dark blue-gray dolomite. Fine grained. Weathers to a dark bluish-gray.

17 feet of very light gray, fine grained, thin bedded dolomite. Weathers to light gray.

22 feet dark-gray dolomite, fine grained. Contains lenses of lighter dolomite near top. Weathers to a medium gray.

200 feet of medium dark-gray, fine grained, massive bedded dolomite. Weathers to dark gray.

112 feet light gray, fine grained dolomite. Fractured surface has pinkish tinge. Weathers to a medium-gray.

308 feet of medium coarse crystalline, light gray dolomite. Fractured surface has pinkish tinge. Weathers to medium gray with streaks of tan.
Age and correlation - Fossils collected by Mansfield (32) from the Laketown dolomite in southeastern Idaho were identified by Kirk as belonging Niagrian fauna, and the formation was referred by him to the Niagrian fauna, and the formation was referred by him to the Niagrian epoch of the Silurian period. Kindle (33) reported a similar fauna from green canyon, 3 miles north of the area. Some correlations of the local silurian section with neighboring areas is shown in Figure 2.

DEVONIAN SYSTEM

Richardson (34) and Mansfield (35) have reported the presence of the Devonian system in Randolph quadrangle and on four small areas in the vicinity of Montpelier, Idaho. In the occurrences throughout the district they distinguished two formations, the Jefferson limestone below and the Three Forks limestone above. Kindle (36) reported the presence of Jefferson limestone extending along the east side of Cache Valley, but found no Devonian present which would correspond with the Three Forks limestone of the afore mentioned districts. Cooley (37) in a later study on the Devonian of this region substantiated Kindle's findings and measured a section in Logan and Blacksmith Fork canyons of the Jefferson limestone.

(36) Kindle, E. M. Same as (33) above.
Name - The name Jefferson limestone was given to this formation in Montana where it was studied by Kindle and where the type sections occur. The latter part of the name implies that the section is made up entirely or largely of limestone. This is certainly not true of the local section. The local sections has a very diversified lithology. Consequently the local section will be spoken of as the Jefferson formation rather than the Jefferson limestone.

Character and Distribution - On this area the Jefferson formation comprises more than 2/3 of the total rock section exposed. This is due in part to the formations great thickness, but is due mostly to the effect of the overturned fold on the west side of the range which doubles the section. Except for an area of nearly a square mile of Carboniferous rock on the east central part of the map the Jefferson formation occupies the whole belt between the top of the Silurian and the east edge of the area. See plate 3. Aerial Geol. map.

A more diversified topography is found where the Jefferson formation outcrops than on any of the other formations present on this area. The remarkable changes in lithology create a topography varying from mantle covered smooth slopes to some of the most precipitous cliffs exposed on the area.
Age and Correlation - The formation apparently lies with conformity on the Silurian beds below and is overlain conformably by the Mississippian beds above. There seems locally at least to be only the middle Devonian represented. Kindle (38) has shown the local section to be associated with the type section in Montana. From fossils gathered at the type section Kirk (39) ascribed the formation as belonging to the middle Devonian or Hamilton. Figure 3 gives some correlations of the local section with neighboring regions.

MISSISSIPPIAN

The Mississippian series includes two formations, the Madison limestone below and the Brazer limestone above. Both formations are characterized by their rather pure limestones. Locally they are quarried for use in the processing of Sugar.

THE MADISON LIMESTONE

Name - The Madison limestone was named by Peale from the Madison range in south central Montana where it occurs along the east and west flanks of the range.

Distribution and Character - Only in the very highest reaches in the east central portion of the area does the Madison limestone occur on the area of this investigation. It first appears high up on the south side of the right hand fork of Dry canyon. Here it is marked by a great massive dark gray cliff separated from a small but persistent cliff below. The large cliff on the China Wall as it is called is very resistant to erosion and
persistently forms a terrace or shelf wherever it outcrops.

The Madison limestone is characterized by its exceedingly pure limestone beds which contain a profusion of fossils. The limestone is generally coarsely crystalline and weather to a medium gray color. The thickest of the beds, the China Wall as it is called, forms one of the most conspicuous cliffs of the local section. In places this bed is inclined to be cherty.

Age and Correlation - An abundance of fossils occur in this formation and it has been possible accurately to date it as belonging to the lower Mississippian. Figure 4 shows some correlations of the formation with neighboring regions.

SOME CORRELATIONS OF THE MADISON LIMESTONE WITH OTHER REGIONS
TERTIARY SYSTEM

General Features - The youngest consolidated sediments recognized in the immediate vicinity of this area are Tertiary in age. There are two systems of rocks in the close proximity of the Bear River range which have been definitely identified as being of Tertiary age. The oldest of these two lies in the down warped trough which forms the central part of the range about 10 miles east of this area. This deposit has been correlated as belonging to the Wasatch Conglomerate of Eocene age. The other and the one which will receive consideration here is the Salt Lake formation of Pliocene age. This is found skirting the valley in a few places.

Name - In 1869 the name Salt Lake group was introduced by Hayden (40) in the following words:

"In the valley of the Weber River, from Morgan City to Devil's Gate, there is a thickness of 1,000 to 1,200 feet of sands, sandstone, and marls of a light color for the most part, which I regard as of upper Tertiary age. These newer beds must have not only occupied this expansion of the Weber Valley but also all of Salt Lake Valley, for remnants of it are seen all along the margins of the mountains inclosing Salt Lake Valley... I found this series of beds so widely extended and so largely developed in Weber Valley and Salt Lake Valley that I regard it as worthy of a distinct name and in consequence have called it the Salt Lake Group."

Character and Distribution - As shown on the map published by the Hayden Survey, the Salt Lake formation is distributed over portions of Salt Lake Valley, Box Elder Valley, Malad

Valley, Morgan Valley, Ogden Valley, Cache Valley and Bear Lake Valley. Of all these places, probably the best exposures are found in Cache Valley. In Cache Valley this formation is found in a number of places skirting the Valley. The best exposure is found near Cove which is nearly on the Utah-Idaho boundary line. Next best to this is probably the outcrop which is found on the south end of the valley where the included section was measured.

The character of the formation is variable to a degree with each locality where it is found. What outcrops which have been observed in juxtaposition with the sides of the valley are found to be usually coarse, and contain a considerable amount of angular material. That which is found near the valley's center is found to be generally finer though a considerable amount of coarse material is present. This coarse material is composed of well-rounded river-worn pebbles and boulders. Throughout the whole formation there is an abundance of volcanic ash. Of some 30 samples gathered through a section of the Salt Lake formation only 2 failed to show the presence of volcanic ash. These two were gathered very near to the contact between the formation and the old Paleozoics which underlie the formation. As well the formation consists of light-colored marles, sandstones, sands, clays, and conglomerates. The formation is characterized by its great amount of calcareous material. All the consolidated sediments contain large amounts of calcareous material which serve as the chief adhesive.
A section of the Salt Lake formation follows:

4 feet of light colored, tightly cemented sandstone; beds 2 to 6 inches thick alternating with beds of light colored clay. Both clay and sandstone contain an abundance of volcanic ash. Finest clay contains a fresh water diatome of the genus (Hyndmanii).

1 foot of loosely consolidated, light tan, medium-coarse grained sandstone.

3 feet of unconsolidated, light tan to gray, medium grained sandstone.

1 foot of well consolidated fine grained, light colored sandstone. Contains abundance of volcanic ash. Cemented by white calcareous material.

5 feet unconsolidated, fine grained, light colored sand. Some concretionary forms appear near the top just below the soil line.

50 feet of section covered by mantle. One or two outcrops indicate that the section is composed of material much like that below but contains a few beds of conglomerate.

4 feet of well cemented conglomerate. Pebbles composed of well rounded, blue-gray limestone and cherts varying in size from 3 mm to 4 inches in diameter. Cementing material calcareous.

10 feet of conglomerate. Like preceding bed in type of material but generally much finer grained.

1 foot of fine grained, well consolidated, light colored limestone, containing a few disseminated limestone pebbles.

4 feet of coarse grained, light colored, loosely cemented sandstone. Grains predominantly of chert. Cementing material calcareous.

3 feet of fine grained, cryptocrystalline, light colored, well consolidated limestone.

3 feet of fine, clean, unconsolidated clay. Contains diatome of genus (Hyndmanii).

2 feet of light colored, well consolidated limestone containing numerous small high spired snails.

2 feet of medium coarse conglomerate.

50 feet of unexposed section. Seemingly it is composed of generally fine material.
12 feet of alternate layers of well consolidated, fine grained, light colored sandstone with few layers of unconsolidated sand of a medium texture.

13 feet of tightly cemented conglomerate composed of well rounded, blue gray limestone pebbles ranging in size from 2 inches to six inches in diameter. Cemented with white calcareous material.

5 feet of medium grained, light colored sandstone which contains numerous oolites disseminated through the bed.

30 feet of fine to coarse grained, light colored sandstone with small pebbles distributed sparingly through the beds. Beds 3 inches to 2 feet thick. Two beds of conglomerate a little over a foot thick occur near the center of the section. A fossiliferous limestone appears 8 feet from the top; contains numerous high spired snails.

10 feet of light colored, fine grained limestone. Contains volcanic ash.

40 feet of partially covered up sands, sandstones, conglomerates, limestone, and clay. Clay contains an abundance of volcanic ash (40-60 percent).
Age and Correlation - As mentioned above the fossils which are found in the formation do not have much value in correlation. An extensive fauna is present but little work has been done on it. The fauna consist of a number of freshwater gastropods and pelecypods. In many of the finer beds there is found a diatome of the genus The only correlation which has been suggested for the Salt Lake formation found in Cache Valley was made by Hague. This was done on lithologic comparison only and is of little or no value.
CHAPTER IV

STRUCTURAL GEOLOGY

The structural features which are apparent on this area are representative of the complex structure of the West Bear River Range. The area is not large enough to adequately cover the structure of the whole West Bear River Range front but some inferences can be made of its general structure. It will therefore be the writer's intentions not to draw any conclusion as to the West Bear River Range structure, but to merely make a few suggestions of that structure as interpreted in the light of the structural features found on this area.

Geologist of the Hayden Survey concluded that the general structure of the West Bear River Range was synclinal. (42) Richards and Mansfield (43) have shown the presence of a thrust fault (Bannock Overthrust) on the east edge of the range. A number of observers have recognized the gravity fault on the west side of the range.

The present writer's observations were mostly confined to the area here discussed in detail but some conclusions can be drawn about the general structure of the whole range.

The general trend of the structure of the west limb of the range is between 10 and 15 degrees east of north. As Peal (44)

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(43) Mansfield, G. R., cit. p. 155. (1927)
and others have shown the general structure of this portion of the range is synclinal. (Plate 8.) The axis of the fold forms the highest part of the range while the limbs are badly dissected by canyons. In general shape the northern portion of the range is trough-like in form. Owen (45) has shown this very well on a map which he made of the outcrops of the Swan Peak quartzite in the Logan quadrangle. Cooley (46) and others have shown the west limb of this fold to be overturned on the west edge of the range. Southward the folded structure is truncated by the great fault which traverses the valley from the vicinity of Sardine Canyon and passes up Blacksmith Fork Canyon.

The relation between the trend of this fold and the Bear River fault which truncates its western face accounts largely for the distribution of the different ages of rock represented on the valleyward side of the range. Passing north from Logan Canyon the rocks outcropping on the face of the range become successively older in age.

This portion of the range is not free from faulting but is traversed in a number of places by faults trending in about the same direction as the fold.

The central low-lying portion of the range has suffered much greater fracture than either of the adjacent portions. In general structure it is a greatly fractured anticline, traversed by numerous north south faults. At least two of these faults are of

considerable size, namely those which separate this portion of
the range from the other two limbs.

Richards (47) has described the east limb of the range as
a great overthrust block. The thrust fault can be traced for
the full length of the range and beyond. No account is given of
the structure of the block itself.

As seen on the map the general distribution of the rock
outcrops over the area runs in a direction about north 10 degree
east. Two sections have been prepared across the map to show
the general structure which is apparent on this portion of the
range. These sections both show the approximate position of a
fault, if such does exist, in the central part of the area. As
will be shown this structure might be accounted for either by
faulting or folding.

DRY CANYON-
The rocks which first appear at the mouth of Dry Canyon are
overturned Ordovician strata dipping to the west at an angle of
50°. The western most of this series is Garden City limestone.
As cited above the Garden City limestone does not possess its
normal characteristics on the face of the range but has been
altered from its original features by the faulting and breccia-
tion in connection with the folding. All well leaching ground-
waters have changed its general hue.

Next up the canyon and lying underneath the Garden City lime-
stone is the Swan Peak quartzite. This formation has about the

(47) Richards, R.W., Lead and Copper in Bear River Range, Idaho
and Utah. U.S.G.S. Bull. 470, pp. 177-181, (1910)
same dip as the Garden City limestone. It is noticeable that on the west face of the range where the Swan Peak outcrops it is markedly thinned, there being only the upper quartzite member present. This member is usually highly jointed. The base of the lower limb of the overturned fold, of which this bed is a part, does not appear until considerably farther up in the section. The base of this limb of the fold first appears in Dry Canyon in the massive dolomites which comprise the Fish Haven and Laketown dolomites. The massive structure which these beds have, along with the extensive development of jointing, makes the exact position of the base difficult to discern. Beyond the base of this fold the rocks dip steadily to the eastward at an angle of about 25°.

The structural relationships for the south side of Dry Canyon which are shown on section A-A, Plate 4., are most apparent when seen from the high ridge on the north of the canyon. As is common to the great dolomitic series of the local section, the extensive development of jointing plains in the more massive beds makes it very difficult to delineate between these fractures and true bedding. This feature can be eliminated however, by an actual examination of the beds.

The highest portion of the overturned beds is seen to have been overturned again to dip to the east at an angle of 65°. Possibly this point marks the major axis of the overturned fold which forms the western part of the range. Immediately east
of these overturned beds there occurs a narrow zone in which the rocks are only scatteringly observable. Where they can be seen they are usually very broken up and bedding and dip are not ascertainable.

Immediately east of this zone there is a thick massive ledge which is dipping to the east at an angle of 30 degrees on the ridge but changes to 24 degrees in a short distance. The age of this bed is not accurately known but it probably belongs to the top of the Jefferson or lower Madison. As shown on the section the overturned beds can be traced throughout the fold and to the east to possess the apparent dip of the above described bed and to lay in apparent stratigraphic order with it. There is not, however, an exposed succession of beds between the two outcrops and their association is but an inference. What rocks that are exposed are thin bedded limestones like those found in the upper Jefferson section in Logan canyon. Associated with these outcrops are beds of breccia probably formed by slipping between the beds.

PROVIDENCE CANYON-

The same general relationships between the beds are maintained in Providence canyon that are found in Dry canyon. The bed which forms the eastern-most overturned strata in Dry canyon is synonymous with the eastern-most overturned bed found in Providence canyon and the same relationship is maintained through the whole distance between the two localities. In Providence canyon, however, the folding is of a great magnitude.
The base of the east limb of the fold cannot be seen in Providence canyon. It probably lies some hundreds of feet below the bottom of the canyon.

As seen by the section, Plate 5, the first beds in the canyon are badly fractured by numerous small faults which were probably associated with one large north-south fault, possibly the Bear River fault though more likely with a fault of an earlier age. No attempt was made to work this structure out other than the recognition of this relationship. The beds throughout the rest of the overturned series are dipping to the west. The section represented corresponds to the section between the Swan Peak quartzite and the heavy dolomite bed in the middle Devonian. The beds are not as thick as they are in undisturbed areas but are markedly thinned. The beds are not changed substantially as far as lithology is concerned but seem to possess all the features characteristic of this section wherever it has been observed on the west Bear River Range by the writer.

The contact between the overturned beds and the east dipping beds here is in many respects shown much better than in Dry canyon even though the lower limb of the fold cannot be seen. Here it is clearly apparent the contact is extensively brecciated and that a fault is present. This fault may not penetrate deeply but at least it is present through the section exposed. The east dipping beds, east of this brecciated zone, resemble those in Dry canyon though they may possibly be farther up in the
section. A fauna collected just above the massive ledge east of the overturned strata indicates that that bed is of Mississippian age, Madison limestone. This bed is not more than 200 to 300 feet above the massive bed spoken of.

Inasmuch as the structural relationships between the overturned beds on the west and the east dipping beds on the east is of utmost importance in the determination of the structure on the West Bear River Range, it seems well to summarize the facts observed of this relationship in the two areas and present a correlation between the two. The correlation here presented will not be conclusive but will be only by way of suggestion.

Facts Observed—

1. The same bed is found as the eastern-most overturned bed in both localities and throughout the interval between them.

2. In both localities a broken zone is found between the east dipping and the overturned beds. This zone is not well-developed in Dry Canyon but is very well developed in Providence canyon.

3. In neither place is this zone wide between the heavy dolomite or limestone bed which forms part of the east dipping beds and the overturned dolomite which forms the overturned bed on the west; possibly not more than 200 yards.

4. The folding is on a much grander scale in Providence canyon and becomes greater when traced south into Millville canyon.
5. No fault is apparent on the contact between the beds in Dry canyon though one seems clearly present in Providence canyon.

6. In neither place do the east-dipping beds seem to have been involved in the folding. If they have been, a marked change (one very unlikely) in the position of the axis of the fold must be postulated.

7. The whole structure is plunging to the south.

8. The stratigraphic contact between the two parts of the structure is not exactly known in either place.

It is not the author's intention to propound a theory to account for these facts but to merely suggest some possible origins which might account for the relationships on the structure.

A- The Structure was Formed By Folding-

As cited above the relationships between the two parts of the structure do not suggest an origin merely by folding. It is possible, however, to postulate a type of folding which would create such a structure. The steps in formation would be as follows:

1. A fold of the type shown in Figure (5) was formed where the West Bear River Range is now situated.

![Figure 5](image_url)
2. This fold was subsequently planed off along plane B-B'.

Neither in Dry canyon or Providence Canyon does the structure suggest such an origin as this, but in Millville canyon beds which would seem to correspond to those marked 'x' in Figure (6) seem to be present.

B- The Structure Was Caused By A High Angle Thrust Fault-

At least in Dry Canyon and Providence Canyon where the sections were prepared the structure does not suggest an origin by folding alone. The contact between the two portions of the structure is not of the type that would normally be expected of such an origin. A more fitting explanation is to assume the presence of a fault. If this fault were a high angle thrust fault, the characteristics which are seen in Providence canyon could easily be produced. The succession of events would be as follows:

1. An overturned fold was developed where the west limb of the Bear River Range is now situated. Figure (6).

2. Some time after the development of this fold a high angle thrust fault along plane A-A' lifted the Carboniferous
beds up to be opposite the overturned Devonian beds as in Figure (7).

3. Subsequent erosion plain B-B'.

Such a movement would produce the structure which is formed in Providence canyon. However, does such a movement fit the conditions at other places on the area?

As given above, no fault seems to be present in Dry canyon though the presence of one is not denied. In Logan canyon a high angle thrust fault, as above, though it would not have to be large, ought to be evidenced. No such a fault has been seen by the writer nor has anything which would suggest such a fault been found. It was mentioned above that the structure occurred on a grander scale as followed southward. It is possible, though not probable, then that such a fault as given above would die out before it reached Logan canyon.

C- The Structure Was Determined by Gravity Faulting-

For the structure to be determined by gravity faulting implies little deviation from the explanation given for B. It is only a case of which block moved up. There is the difference
however of the direction which the fault would have. The succession of events would be about as follows:

1. An overturned fold was formed where the Bear River Range front is now situated. Figure (6)

2. Subsequent to the formation of this fold a gravity fault which parted the strata along plain Z-Z' Figure (8) developed dropping the overturned Devonian strata down to be in juxtaposition with the Upper Jefferson and Lower Carboniferous strata.

3. This was followed by a period of erosion which truncated the structure along plain B-B'. Figure (8).

D- The Structure was Formed by a Low Angle Overthrust

As noted above a fault seems to be present between the east and west portions of the structure in Providence canyon and such a fault can be inferred to exist in Dry canyon. In neither case, however, is the fault surface actually observable. The low angle overthrust has the advantage here that low angle thrusts which cut the bedding at low angles are not easily detected and can easily be overlooked.
If the structure was developed by a low angle overthrust, the succession of events would be about as follows:

1. An overturned fold was formed where the west limb of the Bear River Range is now situated. Figure (6).

2. Subsequent to the development of this fold a low angle overthrust formed along plain C-C' Figure (9), thrusting beds of Devonian and Carboniferous age up against the overturned Devonian Beds. C'

3. This was subsequently eroded down to the position of Plain B-B'. Figure (9).

Like B and C, this mode of origin requires the recognition of a fault in Logan canyon or the implication that such a fault as developed in the southern part of the area dies out before it reaches Logan canyon. As has been mentioned, there is a wide zone of breccination near the base of the Jefferson Formation. This portion of the section shows extensive slipping along the beds. The plain which would be formed by a projection of the postulated low angle thrust fault would pass directly into this zone of brecciation. It can be implied that the thrust passes into this broken zone of the Jefferson in Logan canyon without
any evidence of displacement in the stratigraphic sequence.

OTHER FAULTING -

In a number of places on the area small east west faults occur. Some of these have been shown on the map but many are too small to be plotted with any accuracy by the methods used and have consequently been left off the map and will be excluded from any discussion.

At least four epochs of faulting are apparent on the area and a series of faults is represented by each. They will be discussed in their order of occurrence from oldest to youngest.

THRUST FAULT-

The first faulting which occurred on the area was compresssionary in origin. The nature of the greatest of these structures has already been described. A small thrust fault which has already been alluded to exists on the Swan Peak quartzite in Logan canyon just south of the Utah Power and Light Plant. These faults probably occurred contemporaneous with the folding and antidate the thrust above described. However, the time of origin is not far different from the epoch of faulting which caused the development of the thrust fault.

The next series of faults formed on the area was a series of north south faults. These faults were normal gravity faults and probably owe their time of origin to the orogenic movements subsequent to the Eocene deposition. The broken up zone at the mouth of Providence canyon very likely belongs to this epoch of faulting. The best exposed fault of this series is exposed
on the northern edge of the area on the north side of Logan canyon, Plate 9. Here, like in Providence canyon there is a wide zone of fracture.

EAST WEST FAULTS-

Of all the faults found on the area here studied, the series of east west faults are the most easily recognized. They are seen cutting the Swan Peak quartzite a number of places, offsetting it either to the east or west. These faults are invariably high angle gravity faults. The largest of the series has a displacement of near 1300 feet. This fault occurs just north of Dry canyon and passes into Logan canyon on the high ridge separating Dry canyon from the head of Jackies hollow. It has only been traced across this hollow to the east but is inferred to continue in that same direction, as shown on the map. Plate 3.

Over that portion of the range exposed at the south end of the area, as shown on the map, there occurs a number of small east west faults which displace the Swan Peak quartzite to the east or west. No attempt has been made to trace these through the dolomite beds to the east. Very likely they die out before they extend into the underlying series. At least no account of them was found at the top of the Silurian.

THE BEAR RIVER FAULT-

The last epoch of faulting which effected the Bear River Range was the development of the north south gravity fault which truncated the structure on the west face of the range.
Gilbert (48) has placed the age of this fault as belonging to the orogenic movements which occurred at the end of Eocene time. Like the Wasatch fault it received its greatest displacement during tertiary time; the valley was a deep trough by Pliocene time when the Salt Lake sediments were deposited on the downthrow block of the fault. Movement did not cease on the fault during the Salt Lake deposition though it was probably much less rapid. The repetition of the secession of sediments in the Salt Lake formation seems best explained by the renewed movement of the Bear River fault. The last movement along the fault is of comparatively recent date. Probably toward the latter part of the Provo epoch or very soon after.

The last movement of the Bear River fault is shown by a small scarplet which is seen in a few places crossing the Bonneville terraces west of the range. This scarplet is best shown where it crosses the Logan delta on the Golf course. Here a road cut has been made which exposed a section through the scarplet. The total displacement is not measurable but can be seen to be greater than 16 feet. Plate 10. The scarplet has been truncated on the top by later erosion and a layer of boulders and gravel have been laid down on its surface. The topographic expression of the scarplet has not been lost however, though it has been considerably defaced. The scarplet can be traced from this point of the delta in a north easterly direction to Green canyon. The scarplet has not been traced north of Green

canyon though it can well be assumed to occur there.

Southward the scarplet can be traced well beyond Dry canyon. Across the front of Dry canyon it is lost under the alluvial fan which has developed in front of that canyon. South of Dry canyon it is seen as a series of terraces which truncate the spurs developed in the Bonneville terraces. Beyond these terraces it is lost in the recent fan material lying close to the range front, but some suggestions of it are seen as far south as Blacksmith Fork canyon. The fact that the scarplet can be traced off the delta and into alluvial material lying close to the mountain front far removed from the edges of the delta seems quite conclusive evidence that the movement seen in the Provo beds is not due to slumping but is due to relatively recent movement on the Bear River fault.

The fact that the movement on the Bear River fault is of comparatively recent date define the scarp on the west face of the Bear River range as a fault scarp as Bailey (49) has concluded rather than as a resequent fault-line scarp as Blackwelder (50) contended.


CHAPTER V
HISTORICAL GEOLOGY

Though the area here discussed is greatly inadequate to give any comprehensive interpretation of the historical geology of the region, it does have many potent factors which hinge tightly on to the history of the Bear River range. Most of these factors have to do with the latter part of the region's history. However, there are a few features which are revealed even in the earliest section exposed which have had some relationship to the formation of the range or sediments which comprise it. The writer will therefore present a brief summary of geologic history of the whole region with an attempt to correlate the local history with the regional history.

Proterozoic Era -

There are no rocks of proterozoic age found in this immediate vicinity but the history of that age can be inferred from other places close at hand where they do occur. A broad view of the evidence thus obtained indicates that the land during that remote period had about the same proportions to the sea as today. Erosion intervals, glaciation, and diastrophic movements seem to have all played a part in the history of the period. Walcott (51) believes that even at that early period the Cordillerian geosyncline was well fixed in position. However, he is inclined to believe that the sediments of this

(51) Walcott, C.D. Cambrian Geol. and Paleo. III Smithsonian Misc. Coll., Vol. 64, pp. 80-81 (1914)
period were predominantly terrestrial.

Schuchert (52) on the other hand is inclined to believe that the sea occupied the Cordilleran geosyncline for long periods during the epoch. Before the era ended the whole western Cordillerian region was uplifted and peneplaned nearly to base level. Little warping was necessary to cause the sea to transgress over the area occupied by the Cordillerian geosyncline.

Paleozoic Era -

The paleozoic sediments of this region are dominantly marine in origin, indicating the progressive subsidence of the Rocky Mountain geosyncline which was already formed in Pre-Cambrian time. This progressive subsidence was not, however, free from Fluctuation. A study of the lithology indicates that not only did many minor fluctuations take place but that several times during the era that the region was actually uplifted out of the sea and erosion took place, removing some of the sediments. None of the uplifts were great nor did they involve crumpling of the earth's crust. Broad gentle uplifts which again subsided to form no perceptable angularity between the beds subsequently formed on top of their eroded surfaces was the type of diastrophic movements that took place.

Cambrian -

Either in the latter part of lower Cambrian or early part of Middle Cambrian, sediments, perhaps to begin with terrestrial in origin, were laid down in this district. Through the major part of the middle Cambrian the sea was transgressing over the land to the north and the resulting sediments here were predominantly calcareous. With the oncoming of the upper Cambrian the sea began its regression from the land. This inferred from the more sandy and shaley deposits of the Upper Cambrian. Before the end of the Cambrian period, however, the sea again inundated the land even greater than preceding transgressions forming the calcareous sediments which form the top of the local Cambrian section.

Ordovician -

The Ordovician sediments lie unconformably on the Cambrian sediments below. A broad gentle upwarping of the Cambrian sediments above the sea with a brief erosion interval breaks the continuity of the two formations. Locally this unconformity is not evidenced by any lithological change but Mansfield (53) reports that in southeastern Idaho a calcareous bed with a large amount of intraformational breccia marks the top of the Cambrian. The sedimentation at the beginning of the Lower Ordovician was largely calcareous in nature though many thin beds of clastic material occur interbedded with the more abundant calcareous layers. The great

amount of intraformational breccia and intraformational conglomerates found in the lower part of the local Ordovician probably indicate that the seas were not excessively deep in this area. The shallowing which took place during the formations of these breccia and conglomerates probably account for the additions of small amounts of clastic materials which are so often found associated with the conglomeritic and brecciated layers. In the early part of Middle Ordovician a reversal of subsidence took place which caused the sea to withdraw from the north. During this epoch the clastic sediments of the Swan Peak Quartzite were formed. This withdrawal of the sea continued until at least the vicinity around Northern Utah was lifted out of the water to form land. This condition persisted until the Upper Ordovician when the sea again transgressed over this area to lay down the Fish Haven dolomite. During the beginning of this period of sedimentation the sea rose and fell many times as shown by the marked changes in lithology at the base of this formation.

Silurian -

Not enough is known of the Silurian of this district to tell much of the history of this region during that period. Separation of the one formation represented from the Ordovician below is difficult because of the lack of fossils. Though no conspicuous disconformity is observ-
able between the two periods, there may be a disconformity of quite some size. On the other hand, the local section may represent a period of continuous deposition as has been shown. The Silurian is wide-spread throughout the west but toward the end of the period the water withdrew from the geosyncline and the entire district became land. The whole period is marked by a remarkably great accumulation of dolomitic limestone with very few changes in lithology.

Devonian -

The whole area remained land until Middle Devonian time when the sea again transgressed the land. No apparent discordance is evident between the dip of the beds of the two periods, the beds of the Devonian lying almost if not parallel with the Silurian beds below. The land mass previous to this inundation must have been nearly flat as the first sediments of the Devonian were calcareous in nature with hardly any clastic sediments represented. In Southeastern Idaho, Mansfield (54) describes the sea as having become increasingly deeper with several minor fluctuations. The local section conforms closely to this order of events but must have experienced many diastrophic disturbances at various epochs in the period. This is indicated by the many lithologic variations in the local section. At various times the sea must have become rather shallow as shown by the presence of coarse sandstones and numerous ripple marks.

However, the neighboring land must have been of comparatively low relief. Many of the ripple marks are found in thin-bedded limestones and in a few cases crossed bedding was noted in limestone beds. As has been shown, no marked unconformity exists between the Devonian and the Mississippian of this area though Mansfield believes that a disconformity does exist between the two periods in Southeastern Idaho. Locally, Cooley (55) has shown that the transition between the two periods, though marked lithologically, is not one of unconformable relationship. At least in this area then, the period between the Devonian and the Carboniferous is probably one of uninterrupted sedimentation.

Carboniferous -

Here the change between the Devonian and the Mississippian is one of Faunal relationships but in Southeastern Idaho the change is believed to have been caused by mild diastrophic action. The relation is well shown in the Portneuf quadrangle of Idaho. Evidence has been shown that a small stratigraphic break exists between the two periods. The more sandy beds of the Pennsylvanian indicate a distrophic movement which separates it from the Mississippian. In both epochs the subsidence was intermittent. The Permian is separated from the Pennsylvanian by an unconformity.

Mesozoic Era -

The nearest Mesozoic sediments to this locality are situated about 30 miles to the east, namely on the east side of Bear Lake. Unlike the Mesozoic sediments of the east, the Mesozoic sediments here lie with no marked angular unconformity on the Paleozoic sediments beneath. The great change comes in the complete alteration of fauna and the contrast between marine and non-marine sediments. During the latter part of the era enormous amounts of terrestrial sediments accumulated.

Most of North America was land throughout the Early Mesozoic. However, an arm of the sea did come in from the Pacific during the lower Triassic from the southwest which caused the deposition of the Triassic marine sediments in Southeastern Idaho. This sea fluctuated from time to time causing intercalation of the marine with the terrestrial sediments. At the end of the period the sea withdrew and the land was above water long enough to become quite extensively eroded. No great changes took place in the earlier Jurassic. Probably only minor warping took place in the geosyncline. During the lower and first part of the Middle Jurassic accumulations of desert sands were spread over the area. In the later part of the Middle Jurassic the sea extended into Southwestern Wyoming and Southeastern Idaho from the north through the great Jurassic Valley. Here it remained a long time and a characteristic marine fauna and sediments mark its stay. The sea withdrew and
again inundated the land before the end of the period though the second inundation was rather short.

After the close of the Jurassic, the interpretation of the historical geology of this region becomes disputable. Gilbert (56) in speaking of the formation of the Wasatch says: "The Jurassic deposition was followed by a diastrophic revolution. The formations were folded and faulted on a grand scale, and among the faults were extensive over-thrusts." And in another place the same writer says: "The topography created by (this) dislocation was so far reduced by erosion in Cretaceous time that a transgression by the sea spread sands of Dakota age over worn edges of Jurassic, Triassic and Upper Carboniferous strata."

On the other hand Mansfield (57) in speaking of the effects of the Sierra Nevada disturbance on southeastern Idaho says: "In Southeastern Idaho this diastrophic activity is recorded in a marked change in type of sedimentation rather than in dislocation of the strata or in igneous activity."

Butler (58) in describing the origin of the Wasatch and associated ranges is in harmony with Mansfield in that he records no extensive folding or faulting at the end of the Jurassic but rather defers this period of great

(58) Butler, B.S., Ore Deposits of Utah, U.S.G.S. Prof. Pp. 111, p. 67, (1920)
diastrophic activity to the latter part of the Cretaceous or Early Eocene. Schuchert and Dumbar (59) as well, in their "Textbook of Historical Geology" record no extensive folding or faulting in the vicinity of the Wasatch until post-Cretaceous time.

Gilbert's paper followed both Butler's and Mansfield's in publication, though Schuchert and Dumbar's writings are of a much later date. It would seem then that, though Gilbert lists evidence of the great diastrophic movement taking place at the end of Jurassic time, Schuchert and Dumbar disregard this evidence and place the movement as of Late Cretaceous in age.

As Mansfield has worked it out, the Cretaceous history in Southeastern Idaho is about as follows: (60)

The Lower Cretaceous was marked by the accumulation of an enormous amount of fluvial sediments which had their origin to the west. This condition continued until the beginning of the Upper Cretaceous when minor diastrophic movements caused the uplift and erosion of the geosyncline. This erosion continued until the end of the period. At the end of the period came the Laramid Revolution which through broad epirogenic movements caused the uplift, folding and faulting of the region. Among the later features over-thrusts were of common occurrence.

As Gilbert (61) describes the history of the Cretaceous in the vicinity of the Wasatch, the following events took place:

At the end of the Jurassic and the very early part of the Lower Cretaceous, extensive epirogenic movements caused the faulting, folding of the region. During this epoch the great anticlines, synclines, and overthrust faults were formed in the Wasatch. The same date of folding and overthrusting can be attached to the Bear River Range. Throughout the remainder of the period and up to the end of the Eocene the Western region at least, underwent extensive erosion, the eroded debris being transported to the east.

Cenozoic Era -

Like the Mesozoic the Tertiary of this district is not clear but is open to debate. The difficulty in accurately dating many of the formations, periods of volcanic activity, and diastrophic movements makes the interpretation of the time and order of events difficult to discern. The general history is about as follows:

Incedent to the folding and faulting that occurred during the Larmide Revolution, the area which now corresponds to that of the Great Basin was uplifted to such a height that the consequent streams which developed on its surface flowed to the east to enter into a fresh water lake.

which existed over what is now the eastern part of Utah. This condition persisted throughout most of the Eocene period with the consequent lowering of the western highland surface to a mature relief or peneplain. The lake which existed to the east gradually rose until its sediments were deposited over the truncated folds and faulted surface of the pre-Tertiary rocks. In Southeastern Idaho the erosion surface on which the Wasatch conglomerate was deposited has been named by Mansfield (62) the pre-Wasatch Erosion Surface. He calculated that this surface had a maximum relief of 1350 feet with individual valleys as much as 1000 feet deep. Mansfield does not account for the erosion surface which was developed beyond the area of deposition during this epoch. The mature erosion surface which Eardley (63) has postulated on the Southern Wasatch before uplift, probably corresponds to this latter named surface. According to Mansfield there was developed in Southeastern Idaho and including the northern part of the Bear River Range a peneplain following the deposition of the Wasatch conglomerate which eroded to a very low relief the whole region. As has been shown it seems better not to recognize this peneplain in this area in as much as it is in great opposition to the physiographic history of the Wasatch Range and the apparent history of the Bear

(63) Eardley
River Range.

Following soon after the deposition of the Wasatch conglomerate, a broad epeirogenic movement uplifted the area east of the Wasatch Range so that the streams reversed their course and flowed westward. Concordent with this movement there was associated orogenic activity. It was likely during this period that development of the Wasatch and Bear River Ranges began. The uplift which caused the development of the Bear River Range must have been rather rapid and continued without hesitation up until late Miocene or early Pliocene time. At least on the Bear River Range there is no erosion surface which marks a hesitation in the uplift.

Some time late in Miocene or early Pliocene the orogenic movements which brought about the formation of the series of north-south ranges, of which the Bear River and Wasatch ranges are a part, became greatly retarded. At this time there was developed in the Back Valleys a great fresh-water lake in which the Salt Lake formation sediments were deposited. This lake remained fixed in position long enough to allow the development of a mature erosion surface surrounding its edges. The mountain masses were not however free from uplift. During the presence of the lake in Cache Valley the Bear River Range was probably uplifted several times. The movement of the Wasatch block was not retarded sufficiently to allow
the formation of an erosion surface corresponding to that which was developed in Cache Valley.

Following the deposition of the Salt Lake formation, diastrophic movements caused the drainage of the lake in which they were deposited. This was succeeded by a period of erosion which gutted out most of the Salt Lake formation from the center of the valley.

Following the movement which caused the drainage of the lake and the dissection of the Salt Lake sediments which were deposited in it another diastrophic movement caused a raise in the base level of the drainage of Cache Valley. This might have been tilting as Eardley (64) has suggested of the mountain mass, caused by movement on the Wasatch fault. This movement is shown by the large accumulation of sediments which formed in the valley subsequent to the post Gannett erosion. Toward the latter part of Pliocene time, a large fresh-water lake, Lake Bonneville, occupied Cache Valley. While the lake was present in the valley it formed the terraces which are conspicuously seen surrounding the valley's edge. It was during this epoch also that the great thicknesses of Bonneville sediments were formed.

Probably at the end of Pleistocene time or corresponding to the end of the Glacian epoch, climatic changes caused this lake to dry up, leaving the valley essentially as we see it today.

(64) Eardley
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PLATE 4

CARBONIFEROUS

BONNEVILLE

ORDOVICIAN - SILURIAN

DEVONIAN
PLATE 6. A view along the face of the Bear River range. Note the steep ridges separated by the narrow gorge-like canyons. Dry canyon is on the extreme left.

PLATE 7. A view of the area studied which shows the flatening of the ridge profiles. Logan canyon is on the extreme left. Providence canyon is seen to the extreme right.
PLATE 8. The synclinal structure of the west limb of the Bear River range as seen on the north side of Logan canyon. The high peak, which is situated about on the axis of the syncline is Mt. Beirdneau. The dark line marks the top of the 'China Wall' (Madison).

PLATE 9. Partially overturned strata on the north side of the mouth of Logan canyon. The broken line marks the position of a fault which truncates the structure.
PLATE 10. Crosssection through small scarplet on the Provo delta at the mouth of Logan Canyon. The block to the left dropped down about 16 feet.
PLATE 11. A typical outcrop of the brecciated beds near the base of the Jefferson formation.

PLATE 12. The north side of Providence canyon showing a slump developed in the thin-bedded Jefferson strata near the contact with the Madison limestone.
PLATE 13. The eastern-most overturned beds on the south side of Providence canyon. X marks the zone of brecciation. To the left or east of this the beds dip to the east.