GEOLOGY OF THE PROMONTORY RANGE,
BOX ELDER COUNTY, UTAH

by

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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>i</td>
</tr>
<tr>
<td>ACKNOWLEDGMENT</td>
<td>iii</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>Location</td>
<td>1</td>
</tr>
<tr>
<td>Accessibility</td>
<td>3</td>
</tr>
<tr>
<td>Purpose of the Investigation</td>
<td>6</td>
</tr>
<tr>
<td>Method of Study and Mapping</td>
<td>8</td>
</tr>
<tr>
<td>Laboratory Work</td>
<td>13</td>
</tr>
<tr>
<td>Previous Work</td>
<td>13</td>
</tr>
<tr>
<td>Land Utilization</td>
<td>15</td>
</tr>
<tr>
<td>Geography</td>
<td>15</td>
</tr>
<tr>
<td>Physiographic Setting</td>
<td>15</td>
</tr>
<tr>
<td>Topographic Features</td>
<td>17</td>
</tr>
<tr>
<td>Drainage</td>
<td>18</td>
</tr>
<tr>
<td>Climate and Vegetation</td>
<td>19</td>
</tr>
<tr>
<td>STRATIGRAPHY</td>
<td>22</td>
</tr>
<tr>
<td>PRECAMBRIAN STRATIGRAPHY</td>
<td>24</td>
</tr>
<tr>
<td>General Statement</td>
<td>24</td>
</tr>
<tr>
<td>Oldest Sequence</td>
<td>25</td>
</tr>
<tr>
<td>Intermediate Sequence</td>
<td>28</td>
</tr>
<tr>
<td>Youngest Sequence</td>
<td>30</td>
</tr>
<tr>
<td>Age and Correlation</td>
<td>35</td>
</tr>
<tr>
<td>CAMBRIAN STRATIGRAPHY</td>
<td>38</td>
</tr>
<tr>
<td>General Statement</td>
<td>38</td>
</tr>
<tr>
<td>Prospect Mountain Quartzite</td>
<td>39</td>
</tr>
<tr>
<td>Pioche &quot;Shale&quot;</td>
<td>43</td>
</tr>
<tr>
<td>&quot;Undifferentiated Middle Cambrian&quot;</td>
<td>46</td>
</tr>
<tr>
<td>Busby Quartzite</td>
<td>48</td>
</tr>
<tr>
<td>Millard Limestone</td>
<td>50</td>
</tr>
<tr>
<td>Burrows Limestone</td>
<td>53</td>
</tr>
<tr>
<td>Burnt Canyon Limestone</td>
<td>56</td>
</tr>
<tr>
<td>Dome Limestone</td>
<td>58</td>
</tr>
<tr>
<td>Swasey Limestone</td>
<td>59</td>
</tr>
<tr>
<td>Wheeler Formation</td>
<td>61</td>
</tr>
<tr>
<td>Marjum Limestone</td>
<td>64</td>
</tr>
<tr>
<td>Nounan Formation</td>
<td>71</td>
</tr>
<tr>
<td>St. Charles Dolomite</td>
<td>74</td>
</tr>
<tr>
<td>Stratigraphic Correlation and Terminology</td>
<td>77</td>
</tr>
<tr>
<td>Stratiographic Period</td>
<td>Page</td>
</tr>
<tr>
<td>---------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>Ordovician Stratigraphy</td>
<td>79</td>
</tr>
<tr>
<td>General Statement</td>
<td>79</td>
</tr>
<tr>
<td>Garden City Formation</td>
<td>80</td>
</tr>
<tr>
<td>Swan Peak Formation</td>
<td>86</td>
</tr>
<tr>
<td>Fish Haven Dolomite</td>
<td>90</td>
</tr>
<tr>
<td>Stratigraphic Correlation and Terminology</td>
<td>96</td>
</tr>
<tr>
<td>Silurian Stratigraphy</td>
<td>97</td>
</tr>
<tr>
<td>General Statement</td>
<td>97</td>
</tr>
<tr>
<td>Laketown Dolomite</td>
<td>97</td>
</tr>
<tr>
<td>Devonian Stratigraphy</td>
<td>102</td>
</tr>
<tr>
<td>General Statement</td>
<td>102</td>
</tr>
<tr>
<td>Water Canyon Dolomite</td>
<td>103</td>
</tr>
<tr>
<td>Jefferson Formation</td>
<td>107</td>
</tr>
<tr>
<td>Stratigraphic Correlation and Terminology</td>
<td>111</td>
</tr>
<tr>
<td>Undifferentiated Middle (?) Paleozoic</td>
<td>112</td>
</tr>
<tr>
<td>Undifferentiated Silurian-Devonian</td>
<td>112</td>
</tr>
<tr>
<td>Lower Plate of the Overthrust Fault</td>
<td>113</td>
</tr>
<tr>
<td>Mississippian Stratigraphy</td>
<td>115</td>
</tr>
<tr>
<td>General Statement</td>
<td>115</td>
</tr>
<tr>
<td>Madison Limestone</td>
<td>116</td>
</tr>
<tr>
<td>Deseret Limestone</td>
<td>120</td>
</tr>
<tr>
<td>Humbug Formation</td>
<td>124</td>
</tr>
<tr>
<td>Great Blue (?) Limestone</td>
<td>127</td>
</tr>
<tr>
<td>Stratigraphic Correlation and Terminology</td>
<td>131</td>
</tr>
<tr>
<td>Mississippian-Pennsylvanian Stratigraphy</td>
<td>132</td>
</tr>
<tr>
<td>General Statement</td>
<td>132</td>
</tr>
<tr>
<td>Manning Canyon Shale</td>
<td>132</td>
</tr>
<tr>
<td>Pennsylvanian-Permian Stratigraphy</td>
<td>138</td>
</tr>
<tr>
<td>General Statement</td>
<td>138</td>
</tr>
<tr>
<td>Oquirrh Formation</td>
<td>138</td>
</tr>
<tr>
<td>Mesozoic and Tertiary Stratigraphy</td>
<td>150</td>
</tr>
<tr>
<td>Quaternary Stratigraphy</td>
<td>151</td>
</tr>
<tr>
<td>Topic</td>
<td>Page</td>
</tr>
<tr>
<td>------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>Northern Structural Block</td>
<td>220</td>
</tr>
<tr>
<td>Western District</td>
<td>220</td>
</tr>
<tr>
<td>Eastern District</td>
<td>221</td>
</tr>
<tr>
<td>Lake Bonneville</td>
<td>224</td>
</tr>
<tr>
<td>Shorelines and Sea Cliffs</td>
<td>226</td>
</tr>
<tr>
<td>Lake Terraces</td>
<td>228</td>
</tr>
<tr>
<td>Bars</td>
<td>230</td>
</tr>
<tr>
<td>Guspate Forelands</td>
<td>230</td>
</tr>
<tr>
<td>Spits and Hooks</td>
<td>231</td>
</tr>
<tr>
<td>Lake Levels</td>
<td>232</td>
</tr>
<tr>
<td>ECONOMIC GEOLOGY</td>
<td>233</td>
</tr>
<tr>
<td>Lead-Zinc Deposits</td>
<td>233</td>
</tr>
<tr>
<td>Copper</td>
<td>236</td>
</tr>
<tr>
<td>Other Economic Commodities</td>
<td>237</td>
</tr>
<tr>
<td>Potential Economic Commodities</td>
<td>238</td>
</tr>
<tr>
<td>GEOLOGIC HISTORY</td>
<td>240</td>
</tr>
<tr>
<td>General Statement</td>
<td>240</td>
</tr>
<tr>
<td>Precambrian</td>
<td>240</td>
</tr>
<tr>
<td>Cambrian</td>
<td>241</td>
</tr>
<tr>
<td>Ordovician</td>
<td>242</td>
</tr>
<tr>
<td>Silurian</td>
<td>242</td>
</tr>
<tr>
<td>Devonian</td>
<td>243</td>
</tr>
<tr>
<td>Mississippian</td>
<td>244</td>
</tr>
<tr>
<td>Pennsylvanian</td>
<td>244</td>
</tr>
<tr>
<td>Permian</td>
<td>244</td>
</tr>
<tr>
<td>Mesozoic and Tertiary</td>
<td>244</td>
</tr>
<tr>
<td>Quaternary</td>
<td>245</td>
</tr>
<tr>
<td>SUMMARY AND CONCLUSIONS</td>
<td>246</td>
</tr>
<tr>
<td>BIBLIOGRAPHY</td>
<td>249</td>
</tr>
<tr>
<td>APPENDIX</td>
<td>255</td>
</tr>
<tr>
<td>Figure</td>
<td>Illustration Description</td>
</tr>
<tr>
<td>--------</td>
<td>-------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>1</td>
<td>Index map of north-central Utah</td>
</tr>
<tr>
<td>2</td>
<td>Portions of the Promontory Range covered by aerial photo mosaics and by radial line assembly method</td>
</tr>
<tr>
<td>3</td>
<td>Uppermost lithologic unit of the Marjum limestone</td>
</tr>
<tr>
<td>4</td>
<td>Oblique aerial photograph of Mt. Baldy</td>
</tr>
<tr>
<td>5</td>
<td>Lowermost lithologic unit of the Garden City formation</td>
</tr>
<tr>
<td>6</td>
<td>Southwest face of Mt. Baldy</td>
</tr>
<tr>
<td>7</td>
<td>Oblique aerial photograph of the western flank of the Promontory Range east of Staples Flat</td>
</tr>
<tr>
<td>8</td>
<td>Oquirrh formation of Wolfcamp (?) age showing interbedded calcareous orthoquartzite and arenaceous limestone</td>
</tr>
<tr>
<td>9</td>
<td>Tufa (Lake Bonneville origin) deposited as a concentric shell around Precambrian quartzite outliers</td>
</tr>
<tr>
<td>10</td>
<td>View westward along the trace of the Little Valley fault</td>
</tr>
<tr>
<td>11</td>
<td>View of the Long Canyon fault from the mouth of Maple Canyon</td>
</tr>
<tr>
<td>12</td>
<td>Vertical aerial photograph of the Bert horst</td>
</tr>
<tr>
<td>13</td>
<td>Structural evolution of the Bert horst</td>
</tr>
<tr>
<td>14</td>
<td>The Indian Caves overthrust fault in Miller Canyon</td>
</tr>
<tr>
<td>15</td>
<td>Small chevron fold on the western flank of Mt. Tarpey</td>
</tr>
<tr>
<td>16</td>
<td>Structural evolution of Larsen Ridge</td>
</tr>
<tr>
<td>17</td>
<td>Block faulting in Little Valley</td>
</tr>
<tr>
<td>18</td>
<td>Vertical aerial photograph of the Little Valley fault</td>
</tr>
<tr>
<td>19</td>
<td>Vertical aerial photograph of the Wildcat fault</td>
</tr>
<tr>
<td>20</td>
<td>Vertical aerial photograph of the Coldwater fault</td>
</tr>
</tbody>
</table>
Figure

21. Vertical aerial photograph of the northern portion of the Promontory Bar. ........................................... 227

22. Vertical aerial photograph of the extreme northern tip of the Promontory Range. .......................... 229

Plate

1. Geologic map of the Promontory Range, Box Elder County, Utah. ............................................. (in pocket)

Table

1. Sedimentary rocks of the Promontory Range. ................................. 23
ABSTRACT

The Promontory Range, Box Elder County, Utah, is the first mountain range west of the north-central Wasatch Mountains.

An almost complete stratigraphic record from early Late Precambrian to Early Permian is present. No Mesozoic or Tertiary strata have been noted, but the Late Pleistocene is very well represented by the deposits of Lake Bonneville.

Systemic lithologies and thicknesses are as follows: Precambrian (phyllite, shale, mafic extrusives, quartzite) 7,443\(+\) feet; Cambrian (quartzite, calcareous siltstone, limestone, dolomite) 10,762\(+\) feet; Ordovician (limestone, shale, quartzite, dolomite) 2,992\(+\) feet; Silurian (dolomite) 757 feet; Devonian (predominantly dolomite) 1,576\(+\) feet; Mississippian (limestone, calcareous orthoquartzite, sandstone, shale) 2,619\(+\) feet; Mississippian-Pennsylvanian (quartzite, shale) 1,088\(+\) feet; Pennsylvanian-Permian (limestone, calcareous orthoquartzite, shale) 3,213\(+\) feet; and Pleistocene (gravel, sand, silt, clay) 1,000\(+\) feet. The Precambrian and Pleistocene sequences are undifferentiated; 24 Paleozoic formations are recognized but no new formational names are introduced.

Three major unconformities have been recognized: (1) at the base of the Upper Ordovician, (2) at the base of the Lower Mississippian, and (3) at the base of the Pleistocene.

With the exception of a sill in the Middle Cambrian sequence, igneous rocks are confined to the Precambrian and are largely extrusive.

Metamorphism of higher grade than that of the greenschist facies has not
been recognized. The Precambrian stratigraphic sequence, carbonate strata in the lower plate of an overthrust fault, and argillaceous Mississippian-Pennsylvanian strata in the northern portion of the range have been subjected to pervasive low-grade metamorphism; but on the whole metamorphism is relatively unimportant in the rocks of the Promontory Range.

Structurally the Promontory Range is typical of the mountain ranges of the Basin and Range province. The range is elongate north-south (approximately 30 miles long) and averages six miles wide. A northeast-southwest high-angle fault divides the Promontory Range into northern and southern structural blocks. The characteristic structural features are large fault blocks bounded by high-angle faults. Folding is minor, except in the northern portion of the range. One overthrust fault has been recognized in the west-central portion of the area. It is the oldest structural feature in the Promontory Range.

The Laramide orogeny is represented by (1) evidences of overthrusting, presumably from the west, by (2) tight, locally overturned folds which trend approximately north-south, and by (3) minor high-angle reverse faults and major high-angle normal faults. This later faulting has an approximate north-south and east-west pattern and has formed large tilted fault blocks, mostly without strong topographic expression. Gravity surveys indicate that border faults exist below the alluvium along the western and eastern sides of the range, but their topographic expression is not clear. These would belong to the Basin and Range system.
ACKNOWLEDGMENT

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Finally, I express deep appreciation to my wife, Peggy, for her secretarial work on the manuscript and for the encouragement she has freely given throughout the project.
INTRODUCTION

Location

The Promontory Range, a peninsula projecting southward into the Great Salt Lake from its north shore, is located in Box Elder County, Utah (see Figure 1). It is separated from the North Promontory Range to the northwest by a topographic pass in which the Golden Spike Monument is situated (see geologic map, Plate 1). The highest point on this pass is termed Promontory Summit and is renowned for the difficulties which were encountered in constructing the first transcontinental railroad across it. The North Promontory Range continues northward and slightly eastward through northeastern Box Elder County and into Idaho. It is composed of low-lying rounded hills which contrast strongly with the moderately high Promontory Range.

The Promontory Range extends from Promontory Point at the southermost extension of the peninsula to the pass in which the Golden Spike Monument is situated.

The Promontory Range is the easternmost mountain range of the Basin and Range System in northern Utah. This elongate north-south trending mountain range is 30 miles long and ranges from four to eight miles in width. The area mapped comprises approximately 180 square miles of bedrock and is located entirely within T.6 N. - T.9 N., R.5 W.; T.6 N. - T.10 N., R.6 W.; and T.9 N. - T.10 N., R.7 W; Salt Lake Base and Meridian.
Figure 1. Index map of north-central Utah. Area of report is stippled.
No part of the area is covered by published U.S.G.S. topographic quadrangle maps, and therefore quadrangle names have not yet been established.

Accessibility

The following discussion describes the conditions of accessibility as they existed in early 1957, the last time the writer visited the area. These conditions have been extensively altered in conjunction with the Morrison-Knudson railroad dike project across the northwestern arm of the Great Salt Lake.

The Promontory area may be readily reached by hard-surfaced road from either Brigham City or Tremonton. These are all-weather roads but for the sporadic clearing of snow done by the county west of Connors Spring.

The following road log is from Brigham City to the intersection with the gravel road leading to Promontory Point. This intersection is shown in the northeastern corner of the geologic map (see Plate 1).


7.0 Junction at Corinne of U.S. Highways 30S, 191 and Utah Highway 83. Turn left on Utah Highway 83.

21.4 Junction with hard-surfaced road from Tremonton on north side of highway. Continue along Utah Highway 83.
24.8 Junction with northward-trending gravel road to Howell. Continue left along Utah Highway 83.

26.9 Junction of Utah Highway 83 and gravel road to Promontory Point (marked and labelled on geologic map).

The Promontory Range is almost completely encircled by secondary gravel roads. Were it not for a five-mile gap, along the western shoreline of the Great Salt Lake immediately north of the Indian Caves, the entire range would be encircled by an access road. The gravel road along the eastern side of the range and its northward extension from Promontory Point along the western side of the range up to the Indian Caves may be readily traveled by ordinary sedan-type automobile, but the surface is extremely rough.

Utah Highway 83 continues hard-surfaced to the Golden Spike Monument from its junction with the gravel road to Promontory Point. West and south of the monument the road is gravelled and in good condition to a point about three miles southeast of the Old Fort Ranch (see geologic map). From here to its termination this road is poorly defined and local inquiries should be made before attempting travel in a conventional vehicle, particularly when the ground may be wet or in case of threatening weather. The cattle guard and gate on this main road near the northwest corner of Mt. Baldy are kept locked the year around, but permission to enter is readily granted by Mr. Claude Staples, Brigham City, Utah, who manages the Old Fort Ranch.

Within this network of primary access roads there are few roads which offer access to the mountains themselves, and only four of these extend appreciably farther upslope than the highest elevation attained
by Lake Bonneville. All access roads shown on the geologic map with solid lines may be negotiated by conventional vehicle.

Although there are several comparatively low passes along the range crest, no road serves to connect the eastern and western flanks. A road was started over Keller Pass from the eastern side of the range north of Mount Tarpey but was not completed. A fire road was constructed in recent years over Whitaker Pass but has not been maintained. This road could be traversed in its present condition from the west up Middle Canyon and down the steep east side of the pass, but it is extremely doubtful if even a four-wheel drive vehicle could ascend the east side or Whitaker Pass. The North Fork of Little Valley and Maple Canyon has not been maintained and is now obliterated. A road could be built over the pass due east of the South Fork of Little Valley, but this has not yet been attempted.

The huge multi-million dollar project presently being conducted by the Morrison-Knudsen Company has resulted in the construction of several new roads between The Narrows and Promontory Point and Little Valley. These new roads are not shown on the geologic map (Plate 1); but the old roads, those present in 1952 and 1953 at the time of the latest aerial photography, are shown instead.

The Southern Pacific railroad line between Ogden, Utah and San Francisco, California passes across the southern edge of the peninsula between two stations on the line; Promontory Point and Saline. Although these stations are not regular stops, any passenger train may be stopped at these stations by giving sufficient notice to the train personnel.
The old railroad (now abandoned) over Promontory Summit, the first transcontinental railroad, became only a branch line in 1904 because of extreme costs in negotiating the steep grades and the sinuous course which was many miles longer than the present route, the famous Lucin cut-off.

Two landing strips afford ready access by airplane to the southern portion of the Promontory Range. The CAA emergency landing strip at Promontory Point is illuminated at night by landing lights and a rotating beacon which automatically go on shortly before sunset and go off shortly after dawn. The Morrison-Knudsen Company has built a longer, wider landing strip along the west edge of its temporary camp at the mouth of Little Valley. Both of these strips are capable of serving any small light plane. Mr. Keller of Ogden, who runs a sheep camp in Coldwater Canyon, lands his light plane on an improvised strip due west of his ranch buildings. Aerial visitors to Shamrock Shanty, north of The narrows, utilize the dry lake bed of an inlet in Bear River Bay for a landing strip.

Purpose of the Investigation

The area was chosen because of the opportunity it afforded of combining a structural and stratigraphic study. The Promontory Range is the easternmost large structural unit of the Basin and Range geologic province in northern Utah and its study may be expected to yield information on the relationship between the Great Basin and the Rocky Mountain geologic provinces, with respect to both stratigraphic and structural
Although little has been published on the geology of the mountain ranges to the west of the Promontory Range in northwestern Utah, the north-central Wasatch Mountains to the east have been studied in detail by Eardley (1944). Several hypotheses were set forth by Eardley (1944, 1951) concerning thrust faulting and other structural features, and a detailed study of the Promontory Range, about 25 miles to the west, was believed necessary in order to prove or to modify the existing theories.

The area has been considered by all recent writers to be located within the miogeosyncline of the Cordilleran orthogeosyncline during most, if not all, of the Paleozoic era. Very little has been published on the area and none of this published material has dealt in detail with other than local geologic problems. Therefore, it was believed that a study of this range would add to the ever increasing accumulation of understanding of the paleogeography of the region.

The Promontory Range occupies a key position between two areas where the Paleozoic systems have received considerable study; the Oquirrh Mountains and the Logan quadrangle. Correlations between these two widely separated areas will naturally be enhanced by a knowledge of the stratigraphic geology of the Promontory Range. As the Paleozoic strata of the north-central Wasatch Mountains constitute a shelf facies and those of the Great Basin are miogeosynclinal, a knowledge of the sedimentary rocks of the Promontory Range will be helpful in determining the nature of the transition between the two types.

In the monographic study made by Gilbert (1890) of the features of
Lake Bonneville, little mention was made of those features present in the Promontory Range. It was thought that even a cursory study of these features by the present author would be beneficial and possibly encourage further study of some of these well-displayed geomorphological features.

Method of Study and Mapping

Field work was done intermittently during the periods June-October of 1955 and June-October of 1956, during which a total of 113 days was spent in the field. The first season was spent primarily in reconnaissance and search for fossils. During the second season 46 stratigraphic sections were measured and geologic mapping on aerial photographs was completed. The stratigraphic sections were measured by Brunton compass.

Paleontological work was done only insofar as necessary to determine the age of the individual formations. More than 100 fossil collections were made, mostly from the Middle Cambrian succession and the Oquirrh formation.

Many strike and dip readings were taken but joint systems were seldom measured.

No portion of the Promontory Range is covered by published topographic quadrangle maps having a larger scale than 1:250,000. A topographic quadrangle map at 1:24,000 scale of Fremont Island to the south has been published by the U. S. Geological Survey which has also released maps of several similar quadrangles situated immediately east of
the range; but personal communication with this agency reveals that they plan no topographic work at 1:24,000 scale in the Promontory Range in the near future.

Geologic mapping was done on individual contact prints (9" x 9") of aerial photographs made by the Western Aerial Photographic Laboratory of the Commodity Stabilization Service (167 West Second South, Salt Lake City, Utah). The photography was done in 1952 and 1953 and the prints have a scale of approximately 1:20,000. The geologic mapping was confined as closely as possible to the central portion of each photo in order to diminish distortion. The entire area of the geologic map (Plate 1) has aerial photograph coverage under this recent project.

Prior to the 1952-1953 project three federal agencies photographed parts or all of the range. The Production Marketing Administration photographed portions of the range in 1937 and 1946 at a scale of 1:20,000. In 1940 the Soil Conservation Service also photographed part of the range at the same scale. The Corps of Engineers, U. S. Army, photographed the entire range at a scale of 1:32,000 in 1944. The Soil Conservation Service compiled semiconrolled mosaics in 1944 from existing aerial photographs. These mosaics cover approximately 75 percent of the area of the geologic map (Plate 1) and may be obtained in scales of 1" = 1 mile and 2" = 1 mile or in any desired enlargement of the former scale. Figure 2 shows the approximate coverage of the mapped area furnished by these aerial mosaics (SCS designation: Utah 18, 19, and 31).

For the area covered by the mosaics, geologic information was
transferred from the contact prints to acetate overlays upon which drainage and cultural features had been previously traced directly from the mosaics.

For the portion of the area not covered by the mosaics a base map was prepared from the contact prints. This was done by the slotted-templet method of radial-line assembly and in the process the scale was reduced from the approximate 1:20,000 of the aerial photographs to 2" = 1 mile, in order to conform to the scale of the aerial mosaics. The geology, drainage, and culture mapped on the individual contact prints was then transferred to this base map by the use of an Abrams Vertical Sketchmaster. This method of compiling the geology from the aerial photographs to the base map was satisfactory, except in areas of high topographic relief where frequent small adjustments were necessary. As far as possible such adjustments were made in the drainage patterns between geologic contacts, so that the drainage patterns may be locally slightly distorted but the geology is much more accurately plotted.

The geology plotted on the radial-line assembly base map was then matched with that plotted on the mosaic overlays. Only minor adjustments were necessary and these were made where the geology is relatively simple or completely concealed.

Good planimetric control was furnished by four triangulation stations established by the U. S. Coast and Geodetic Survey. These stations are located on the geologic map (Plate 1) and are, from north to south; North Promontory, Middle Promontory, South Promontory, and
Promontory. Unfortunately these stations lie almost in a straight line, but this is unavoidable because of the elongate narrow shape of the range and its almost linear drainage divide. The plotting of these four stations, which lie fairly close to the boundary of the two areas shown on Figure 2, on both the aerial mosaics and the radial-line assembly base map enabled an accurate tie between the two.

The resulting geologic map (Plate 1) has a scale of approximately 1:31,680 or 2" = 1 mile.

Over the 180 square miles of the mapped area only two original section corner markers were recovered. These are the NE and SE corners of Sec. 14, T. 7 N, R. 6 W. The original land survey was made in 1885 and small rock cairns were erected to mark the section corners. The original field notes of this survey show that pipes or metal caps were not used to locate the corners. The only markings on these section corner stones were a crude set of horizontal and vertical scratches denoting the number of sections south and west from the NE corner of the township. No further official land net surveying has been done during the subsequent 74 years and in this interval almost all of the section corners have been destroyed, a misfortune for which the sheep men and cattle men vociferously blame each other.

The pattern of farmland on the aerial photographs, along with roads and fence intersections, has enabled the construction of a partial land net, even though the original corner markings have been destroyed.

The writer last visited the area in the spring of 1957 and therefore has not had the opportunity to inspect the numerous large excavations
Figure 2. Portions of the Promontory Range covered by aerial photo mosaics and by radial line assembly method.
made by the Morrison-Knudsen Construction Company. It is possible that such a study might significantly change some of the writer's conclusions concerning certain areas in the vicinity of Promontory Point and Little Valley.

Laboratory Work

Fossils were collected at more than 100 localities. These collections were sent to various paleontological experts for identification.

Over 50 petrographic thin sections were prepared, mostly from Precambrian rock specimens. The primary objective of this phase of the study was to determine the metamorphic grade and whether the lithologies concerned were originally igneous or sedimentary rocks.

During the measurement of stratigraphic sections over 700 representative lithologic samples were collected for inspection with binocular microscope. All carbonate samples were etched with concentrated HCl in order to determine the true clastic content. The results of this microscopic study were incorporated with field notes in order to compile the detailed stratigraphic sections of the Appendix.

Previous Work

The first geologic work in the area was done by Captain Howard Stansbury (1853) during the year 1849, when a reconnaissance of the area around the shore of the Great Salt Lake was made by U. S. Army troops under his command. His diary of the expedition is a geologic classic in
distinctive, vivid literary style. Over a century after the publication of this account, one familiar with the country may follow the progress of the expedition and discover exact localities mentioned by Stansbury, thanks to his accurate descriptions. The next workers were Hague and Emmons (1877) and King (1878), who of necessity dealt with generalities, mapping rocks of different geologic ages as single units. Some paleontology was done in the northern part of the area by Hague and Emmons, but the stratigraphic investigations were cursory. Gilbert (1890) mentioned the Promontory Range several times in his classic study of Lake Bonneville, but did not discuss any of the features within the area. Butler and Heikes (1916) studied the Promontory mining district which has copper and lead-zinc ores in Proterozoic (?) and Middle Cambrian strata, respectively. Butler, et. al. (1920) made a comprehensive study of the ore deposits of Utah in which the Promontory District is mentioned, but this is essentially a condensation of the earlier work (Butler and Heikes, 1916). Siegfus (1924, 1925) also studied the ore deposits north of Promontory Point, but in greater detail. The Proterozoic (?) strata in the vicinity of Promontory Point were measured and described by Eardley and Hatch (1940). Hintze (1951) and Webb (1956) measured stratigraphic sections in the Ordovician on the northwest flank of the range. The writer (Olson, 1956) described the general geology of the range in what was essentially a progress report. Several corrections and additions are made in this thesis, for field work continued for more than two months after the writing of the aforementioned report.
Land Utilization

Dry farming, cattle raising, and sheep grazing are the principal uses to which the land is put in the Promontory Range. There are approximately 20 active ranches in the area; with the exception of maintenance personnel of the Southern Pacific Railroad the inhabitants of these ranches comprise the total permanent residents of the area.

The main agricultural crops are wheat and alfalfa. Cattle are grazed and fed the year round in the Promontory Range but sheep are grazed primarily in the fall and spring.

Geography

**Physiographic Setting:** - The Promontory Range is a typical mountain range of the Basin and Range System. The structural characteristics of this system are summarized by Eardley (1951, pp. 475-485). The largest physiographic province included in the Basin and Range System is the Great Basin Province which is characterized by internal drainage; the Promontory Range lies within the Great Basin Province.

The Promontory Range stands up boldly above the relatively flat topography which surrounds it on all sides save the north. Bear River Bay, an arm of the Great Salt Lake, and its mud flats, alkali flats, and marshes furnish a sharp contrast between the Promontory Range on the west and the steep Wasatch Range on the east. The southern and western margins of the Promontory Range are bounded by the shores of the Great Salt Lake and its mud and alkali flats, except for the northern half of the western margin where the range is bounded by extensive blankets of
alluvium and marshy areas. Owing to the extreme shallowness of the Great Salt Lake, relatively small increments or decreases in its volume greatly alter the position of the shoreline. This, of course, also holds true for Bear River Bay, which at the present time is periodically extremely dessicated. On viewing this partially restricted arm of the Great Salt Lake from the peaks of the Promontory Range, the writer estimates that the area presently covered by its waters during the summer is far less than one-fifth that accorded to it by the 1922 U. S. Geological Survey planimetric map of the state of Utah. Conversely, the area given to the northwestern arm of the Great Salt Lake by this map is essentially the same as at the present time, even during the dry, hot summer season.

The extreme topographic contrast between the mountains and the surrounding "flats" on the eastern, southern, and western sides of the Promontory Range is absent on the northern end of the range where its main mass is separated from the Northern Promontory Range by a high pass. The highest point in this pass is named Promontory Summit and is renowned for the difficulties encountered in constructing the first transcontinental railroad across it. The eastern slope of the pass is steep and necessitated extensive "contouring" by the old railroad. After the summit is reached from the east the pass is relatively flat and its western descent is very gradual. The pass is about 750 feet above the present level of the Great Salt Lake and it is here that the least amount of relief between the Promontory Range and its flanking alluvial deposits may be found. The pass is broad and flat and its soil supports the relatively fertile wheat fields of the Cedar Springs area.
**Topographic Features:** - The Promontory Range, for the most part, consists of a single north-south ridge with strata of uniform dip forming a homocline. This portrayal, although locally idealized, is valid for most of the range north of The Narrows or, essentially, the area of the northern structural block.

South of The Narrows the large fault blocks of the southern structural block have determined the formation of isolated major ridges with diversified trends and have complicated the otherwise simple drainage of the Promontory Range.

Black Mountain, the ridge east of Maple Canyon and the North Fork of Little Valley, and the ridge between Little Valley and South Canyon are the major topographic features of the southern structural block and have all been carved out of large fault blocks.

In contrast to this the northern structural block has one dominant topographic feature; the main ridge or backbone of the range. Mt. Tarpey, or the North Promontory triangulation station, is the highest peak in the Promontory Range, with an elevation of 7,425 feet above sea level or about 3,225 feet above the present level of the Great Salt Lake. This represents a pronounced local increase in the elevation of the drainage divide. Mt. Baldy, to the west of Mt. Tarpey, is a fault block and is the main departure from the homoclinal nature of the main ridge. Larsen Ridge along the extreme north end of the range is homoclinal but with a northwesterly dip rather than the eastern dips of the main ridge. Along the western side of the range from Middle Canyon northward to
Staples Flat (an extensive embayment of Lake Bonneville), long ridges or spurs of carbonate rock descend gradually toward the Great Salt Lake. The strata here dip gently westward, being separated from the easterly dipping strata of the homoclinal main ridge by the Promontory fault. The abrupt truncation of these spurs in a gently curving north-south line lends credence to the possibility of a border fault along the western side of the range.

The large valleys of the range have been determined, for the most part, by the major faults. This is particularly true of the southern structural block where every major drainage save one has been carved along a large fault, but less true of the northern structural block where many major drainages display only a loose association with faults.

The rough topography of the range above the highest shoreline of Lake Bonneville is in sharp contrast to the subdued, smooth topography below this level; especially on the eastern side of the range. Along the western side of the range this contrast is not as clear owing to the predominance of lithologies which do not weather to fine debris. Thus, Lake Bonneville generally had more rock debris and alluvium to rework along the eastern side than on the western side of the range.

**Drainage:** All drainages within the mapped area have their ultimate termination in the Great Salt Lake. There are no perennial streams in the Promontory Range, which has virtually a complete lack of running water. Large valleys and canyons have been excavated in the Promontory Range but their beds are now completely dry.
The main drainages of the southern structural block are Little Valley, Maple Canyon, Long Canyon, Brushy Canyon, South Canyon, and Middle Canyon. All are fault-line valleys, either in part or wholly, with the exception of Brushy Canyon. They are almost linear and thus differ slightly from their counterparts in the northern structural block which have more irregular courses. The drainage pattern is variable owing to the variations in bedding attitudes of fault blocks and the directions of the major faults; but conforms closely to what Thornbury (1954, pg. 123) terms an angulate pattern, which is a variant of rectangular drainage.

In the northern structural block the major drainages are more a result of the slope of the flanks of the range, rather than being dependent upon faults and the attitude of the strata. Some canyons, such as Chokecherry Canyon, owe only a minor portion of their courses to the presence of faults. The drainage pattern is dendritic, and Thornbury (1954, pg. 121) in discussing dendritic drainage patterns says that "they develop upon rocks of uniform resistance and imply a notable lack of structural control". This description fits the geology of the northern structural block very well.

**Climate and Vegetation:** - On generalized climatological maps the Promontory Range is referred to as having a dry climate of the "middle latitude steppe" variety. The Weather Bureau of the U. S. Department of Commerce maintains no weather stations within the mapped area, but the Lakeside Station is about 25 miles west of Promontory Point and the Bear
River Refuge is about 15 miles east of the middle of the range. Official records for the period 1953-1955 at Lakeside showed an average annual temperature of 53.3° and an average annual precipitation of 7.1 inches. For the period 1937-1952 the Bear River Refuge had an average annual temperature of 50.6° and an average annual precipitation of 12.6 inches. A straight interpolation between the two stations would give an average annual temperature of 52.3° and an average annual precipitation total of 10.5 inches for the Promontory Range, but it is not reasonable to assume that such computations are necessarily valid.

Three other weather stations, not in use today, gave a similar picture concerning precipitation totals. Records kept at Promontory for the periods 1870-1905 and 1908-1913 show an average annual precipitation of 8.5 inches. Blue Creek, about 12 miles east of Promontory, showed an average annual precipitation of 8.2 inches over the period 1878-1904 and 15.1 inches over the period 1941-1952. Midlake, which is about halfway along the Southern Pacific trestle between Promontory Point and Lakeside, averaged 6.3 inches of precipitation annually between 1911 and 1929.

Vegetation varies considerably throughout the Promontory Range. There is generally a fairly close correlation between the type and density of vegetation and the underlying formation. Trees are characteristically absent on the Precambrian section and the Prospect Mountain quartzite; sagebrush and grass are prevalent over these formations. The Middle Cambrian through Lower Ordovician section at high elevations supports a heavy growth of junipers, with minor stands of maple, oak,
and mahogany as scrub brush. The Manning Canyon shale and the Oquirrh formation generally do not support trees, but have a dense low-lying vegetative cover of sagebrush and dock weeds. The latter seems to be wholly restricted to these two formations. At scattered localities, e.g. the crest of the range near the head of Chokecherry Canyon and all of Larsen Ridge, the Oquirrh formation supports a dense growth of junipers, but this is unusual. Striking examples of this change in the vegetative cover associated with different formations may be seen where large faults place these formations in juxtaposition. Probably the best example of this is the Little Valley fault at the head of the South Fork of Little Valley (see Figure 10). Alluviated areas above the Bonneville level do not, of course, comply to this pattern of association between bedrock and the type of vegetation. The vegetative cover associated with formations other than those previously discussed varies considerably and cannot be as easily classified.

There is a general absence of trees, locally a total absence, beneath the uppermost level attained by Lake Bonneville, and this is far more conspicuous along the eastern side of the range than along the western side. Dense grass grows on much of the soil developed on the deposits of Lake Bonneville and this lush growth is extensively utilized for the grazing of sheep. The best example is on the flats north of Promontory Point, where the conspicuous change between the grassy flat and the dense growth of junipers on the slopes of Black Mountain perfectly delineates the uppermost level attained by Lake Bonneville.
STRATIGRAPHY

Sedimentary formations exposed in the Promontory Range have an aggregate thickness of approximately 36,000 feet (refer to Table 1), of which 28,940 feet were measured and the remainder was estimated by careful calculation.

In addition to Precambrian rocks, the systems represented include the Cambrian, Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, Permian, and Quaternary.

The Precambrian rocks consist of at least 7,500 feet of interbedded continental and marine deposits, with the former by far predominant. These strata have been subjected to low-grade regional metamorphism.

The Paleozoic Era is represented by more than 27,000 feet of strata ranging in age from Lower Cambrian to Lower Permian. Of this total more than 80 percent is of marine origin, while the remainder is of continental or shoreline origin. The stratigraphic section in the Promontory Range from the early portion of the Upper (?) Precambrian through the Lower Permian is incomplete due to structural breaks and subsequent erosion. Nevertheless, it is reasonable to assume that the area was the site of practically continuous sedimentation during this long interval of time.

The Cenozoic Era is represented by an estimated 1,000 feet of unconsolidated debris of terrestrial origin which are assigned to the Pleistocene Lake Bonneville.
<table>
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<td>Sincler Formation</td>
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<td>Paleozoic</td>
<td>Devonian</td>
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<td>Grant Bluff (?). limestone</td>
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Most reliable thicknesses:

TOTAL STRATIGRAPHIC SECTION: 35,723²
The Precambrian rocks of northern Utah have been divided into two large units; an older complex which is strongly metamorphosed and a younger unit which has been only slightly metamorphosed compared to the overlying basal Paleozoic sedimentary strata (Blackwelder, 1949, pg. 25). The older complex, as described by Blackwelder, is not present in the Promontory Range; however there is reason to believe, as will be explained below, that the contact between the "older" and "younger" Precambrian is probably not more than a few hundred feet stratigraphically below the lowermost exposed Precambrian strata in the Promontory Range.

Precambrian rocks are exposed only at the southernmost tip of the peninsula of the Promontory Range and along the western flank of the range immediately north of Little Valley along the spurs trending westward toward the shore of the Great Salt Lake. Butler et. al. (1920) mapped a small area in the northwestern portion of the range as Precambrian. This error and the probable reasons for it are discussed under "Metamorphic Geology".

The Precambrian sequence is displayed in three structurally separate blocks. The oldest sequence is exposed from the abandoned sheep-loading pier at Promontory Point northwesterly to the Southern Pacific railroad cut immediately south of the CAA emergency airstrip buildings. The intermediate sequence is exposed from a point due east of the CAA airstrip northerly toward the steep-facing terrace fronts of Lake
Bonneville. The youngest and thickest sequence is exposed along two westward-trending spurs between Brushy Canyon and Little Valley on the western side of the range about ten miles north and west by dirt road from Promontory Point. The last-named locality is the best for studying the Precambrian because of the excellent exposures and the great thickness of uninterrupted section.

It is very doubtful that these three sequences can ever be tied together to give a complete, uninterrupted Precambrian stratigraphic section because of the lack of marker beds. Judging from lithology alone there is no stratigraphic repetition or duplication between the stratigraphically adjacent portions of these three structurally separated sequences. Assuming that there are no large-scale facies changes in this "younger" Precambrian, therefore validating lithologic correlation, a minimum thickness of 7,443 feet is obtained by combining the thickness of the three sequences. A complete section would doubtless be much thicker.

Oldest Sequence

*Distribution and Thickness:* The oldest rocks in the Promontory Range are exposed at the sheep-loading pier at Promontory Point. The outcrop is but a few acres in area and there are no stratigraphic equivalents anywhere else within the mapped area. Between the pier and the railroad cut, where a northeasterly trending fault truncates the section, 229 feet of strata have been measured. This portion of the Precambrian sequence has no characteristic topographic expression in the
Lithology: - The "oldest sequence" of the Precambrian contains widely varied lithologies. Most of the sequence is composed of quartzite, but there are relatively minor amounts of metamorphosed mafic extrusives, shale, argillite, silicified dolomite, and limestone (see Stratigraphic Section PC-1, Appendix). The presence of well-defined carbonate strata distinguishes this portion of the Precambrian stratigraphic section. The key bed in this oldest sequence is a 25 feet thick pink to light brown, silicified dolomite unit whose base lies approximately 50 feet above the base of the sequence. The dolomite weathers to a distinctive cream color with a slight pinkish tint and is deeply furrowed by solution etching along regular, closely spaced microfractures.

The quartzites are "dirty" compared to overlying quartzites, particularly the Lower Cambrian Prospect Mountain quartzite. Petrographic examination shows that approximately 25 per cent of the quartzite is composed of interstitial material, predominantly muscovite, chlorite, and calcite. Petrographic analysis further shows that in some quartzite specimens at least 10 per cent of the detrital grains are feldspars, particularly microcline and plagioclase (generally oligoclase). This type of lithology has been referred to by Pettijohn (1957, pg. 316) as "quartzose subgraywacke" or "protoquartzite". As the stratigraphic section is ascended it becomes apparent that the quartzites become "cleaner" and the amount of detrital quartz grains increases at the expense of detrital feldspar grains. When the Prospect Mountain quartzite...
is reached the detrital grains are all quartz and the presence of even minor amounts of detrital material in interstitial cavities extremely rare.

The limestone which is present at the top of this sequence is peculiar in that it has been little metamorphosed, while the other lithologies in the sequence have been subjected to pervasive low-grade regional metamorphism.

**Age and Correlation:** - The "oldest sequence" is the only portion of the Precambrian sequence in the Promontory Range which may be correlated with certainty with nearby Precambrian outcrops. The dolomite previously described is correlated with the "dolomite unit" described by Larsen (1957, pp. 72-73) on Antelope Island, about 15 miles south and east of Promontory Point. Dr. Larsen kindly showed the writer this dolomite unit, which on Antelope Island is locally thicker than 20 feet and is underlain by either tillite or a "dark-purple quartzite" where the tillite is absent.

Petrographic thin sections of the dolomite from Antelope Island and Promontory Point are identical, as are their X-ray diffraction patterns. This evidence, plus the fact that outcrops at the two localities are very similar megascopically, has led Larsen and the writer to correlate these beds. No tillite has been found at Promontory Point, but a bluish-purple quartzite which underlies the dolomite at this locality strengthens the correlation.

Larsen states that either the tillite or the dark-purple quartzite
overlies the much older Farmington Canyon complex of schists, metaqartzites, and amphibolites with high angular unconformity. Eardley and Hatch (1940) recognized this angular unconformity on Antelope Island but not on Fremont Island, only five miles east and south of Promontory Point. The Farmington Canyon complex is not present in the Promontory Range, but is probably present not far south of the sheep-loading pier at Promontory Point under the floor of the Great Salt Lake. This statement is made with assurance because of the correlation of the dolomite units; however, it must be realized that if the erosional surface developed on the Farmington Canyon complex prior to the deposition of the dolomite unit was characterized by great regional relief, then the angular unconformity between the two in the vicinity of Promontory Point could be much lower in the stratigraphic section than it is on Antelope Island.

The youngest strata on Antelope Island are correlated directly with the oldest strata in the Promontory Range and it seems certain that almost all of the Precambrian history subsequent to the original deformation and truncation of the Farmington Canyon complex is recorded in the Precambrian stratigraphic sequence of the southern portion of the Promontory Range.

Intermediate Sequence

Distribution and Thickness: - The "intermediate" Precambrian stratigraphic sequence is exposed only in the black cliffs which run north-easterly from the CAA airport along the main line of the Southern Pacific
Railroad. These cliffs, and consequently the exposures, are man made and are a result of excavation by the railroad for track ballast. The "intermediate sequence" is doubtless present in a wide belt along the southernmost margin of the Promontory Range peninsula, but is almost completely concealed by alluvial deposits which have been reworked by Lake Bonneville. If it were not for excavation by the railroad, we would have little or no information on the intermediate sequence; for its resistance to erosion is very low and its topographic position near the shore of the Great Salt Lake affords little chance for distinct outcrops.

Between the fault which separates this sequence from the "oldest sequence" and its sedimentary contact with the quartzites of the "youngest sequence" on the steep-facing fronts of the Lake Bonneville terraces, 1,801 feet of strata have been measured. The true complete thickness of this intermediate sequence cannot be determined from the available outcrop data.

Lithology: - The intermediate sequence of the Precambrian of the Promontory Range consists primarily of a distinctive black phyllite, with relatively minor amounts of interbedded shale, metamorphosed mafic extrusives, and metamorphosed calcareous strata. As may be seen in Stratigraphic Section PC-2 (Appendix) this stratigraphic interval, exclusive of its uppermost unit, is composed of more than 95 per cent black phyllite.

The calcareous strata have been subjected to low-grade regional metamorphism and are composed almost completely of microcrystalline calcite with minor amounts of chlorite. Euhedral pyrite cubes are locally
abundant in the fresh rock.

The metamorphosed mafic extrusives are characterized by well defined, euhedral phenocrysts of amphibole or pyroxene which have generally been completely replaced by microcrystalline calcite and albite. The groundmass is composed of chlorite, microcrystalline albite, and abundant calcite. The texture is clearly porphyritic and the fresh surfaces are light gray or tan with pale green phenocrysts. These extrusive units have been extremely susceptible to alteration, particularly replacement by limonite. It is admittedly possible that these concordant igneous units could be sills, but all of the field evidence, poor though it is, argues for an extrusive origin.

The uppermost unit of the "intermediate sequence" is transitional between the characteristic lithologies of the underlying portion of the intermediate sequence and the overlying "youngest sequence". Shale is the predominant constituent and differs from the underlying phyllite in its texture and lack of slaty cleavage. Quartzite is present in minor quantities but is distinctively different than the overlying blocky quartzite because of its "shaly" bedding habit. No interbedded basic extrusives or calcareous beds have been noted in this uppermost unit.

Youngest Sequence

Distribution and Thickness: - The "youngest sequence" in the Precambrian stratigraphic interval is best exposed along the western flank of the Promontory Range between Little Valley and Middle Canyon, particularly along the walls of Long Canyon. It is also present on the Lake
Bonneville "flats" immediately south of Black Mountain, but due to its widespread concealment by Lake Bonneville sediments little can be learned from these scattered outcrops.

Along the south wall of Long Canyon the youngest sequence is 5,413 feet thick. At this locality the upper contact with the overlying Prospect Mountain quartzite is well exposed but the base of the youngest sequence is concealed by the Great Salt Lake; consequently this measurement, although the greatest possible in the Promontory Range, does not embrace a complete exposure of the youngest sequence. In the lowermost portion of this measured section care must be exercised to remain south of the Long Canyon fault.

**Topographic Expression:** - The youngest Precambrian sequence is a ledge-and-slope former on a small scale. For the most part its topographic expression is very similar to that of the Prospect Mountain quartzite; except that the presence of different and heterogeneous lithologies results in less uniform slopes due to the formation of prominent cliffs and ledges upon the more resistant strata.

**Lithology:** - The youngest sequence (see Stratigraphic Section PC-3, Appendix for detailed description) can be divided into four major stratigraphic units. The lowermost of these major units and the one beneath the uppermost unit are characterized by varied and heterogeneous lithologies including interbedded metamorphosed basic sills and extrusive flows, while the other two units consist entirely of quartzite.

The lowermost major stratigraphic unit is at least 1,991 feet thick
(base not exposed) and consists predominantly of quartzite. This quartzite, however, is not all massive. A large portion of the unit consists of quartzitic shale or "shaly" quartzite. The blocky, massive quartzite and the shaly quartzite are intimately interbedded in individual sets of strata generally less than one foot thick. The shaly quartzite is generally light greenish-gray, silt-sized to very fine-grained, and has individual laminae \( \frac{1}{4} \) inch or less thick which commonly display low-angle cross-bedding. The interbedded blocky, massive quartzite is generally greenish-gray, very fine-grained to fine-grained, and stands out as "ribs" between the recessed, less resistant shaly quartzite units. Interbedded blocky, massive quartzite and shaly quartzite, constitutes approximately 67 per cent of the lowermost major stratigraphic unit. Massive quartzite, tan to light gray, very fine-grained to fine-grained, constitutes approximately 30 per cent and the remainder is composed of metamorphosed basic extrusives and sills and a one-foot thick bed of metamorphosed limestone (?). The metamorphosed concordant igneous bodies have pronounced porphyritic texture with euhedral amphibole or pyroxene phenocrysts replaced by abundant calcite, minor albite, epidote, and muscovite, and with the groundmass composed largely of calcite, with generally lesser amounts of albite, chlorite, and muscovite. The extrusive flows generally have a "chilled" or "baked" zone at the base. The sills have similar zones at their bases and at their upper contacts, with the upper zone almost always considerably thinner than the lower zone. This entire lowermost major stratigraphic unit is dark-weathering, generally to dark shades of green or brown.
The next highest major stratigraphic unit is massive quartzite 1,424 feet thick. The basal 990 feet and the uppermost 170 feet are not conglomeratic and are predominantly grayish-white on both fresh and weathered surfaces. The interval between the quartzite members is almost entirely conglomeratic quartzite which weathers much darker, generally dark brown, due primarily to intense staining by iron oxides. Pebbles of clear quartz up to one inch in diameter are present throughout this poorly sorted, greenish conglomeratic quartzite. The matrix of the conglomeratic quartzite is medium-grained to very coarse-grained, while the non-conglomeratic quartzite has fine-grained to medium-grained texture. The unit, taken as a whole, is lighter colored than the major stratigraphic units above and below. Another factor which makes this unit stand out prominently is the almost complete absence of bedding surfaces.

The next highest major stratigraphic unit is a heterogeneous assemblage of interbedded quartzite, shale, and metamorphosed basic extrusives which is 588 feet thick. The basal 112 feet are completely concealed and the remainder is at best only fairly well exposed. The quartzite weathers very dark due to intense surficial staining by iron oxides, crops out in thick ledges, and is by far the most predominant lithology in the entire unit. The shale which is found only near the base and top of the exposed portion of the unit, is olive-drab on fresh surfaces, slightly silty, and weathers tan except where heavily stained reddish-brown by iron oxides along fractures. The extrusives are confined to the basal 115 feet of the exposed portion of the unit and have
been subjected to low-grade regional metamorphism in which phenocrysts of unknown composition have been replaced with abundant epidote, common calcite and muscovite, and rare albite. The groundmass is largely quartz with some calcite and muscovite. As is generally the case with these concordant igneous units in the Precambrian stratigraphic section of the Promontory Range, there is pronounced prophyritic texture and the igneous units are much darker than the sedimentary strata with which they are interbedded. Both the lower and upper contacts of this major stratigraphic unit are concealed or arbitrarily chosen, but because of the dark weathered colors it stands out prominently from the lighter-colored rocks above and below.

The uppermost of the four major stratigraphic units of the "youngest sequence" is 1,410 feet thick and consists entirely of massive quartzite, portions of which are conglomeratic. This unit cannot be satisfactorily subdivided despite its great thickness. In the lower half of the unit conglomeratic streaks or lenses are sporadically present, but these are not laterally persistent. Conglomerate beds are present in the upper half of this unit, particularly in the uppermost 360 feet. The uppermost 70 feet of the unit are very conglomeratic with well-rounded pebbles of white quartz averaging one inch in diameter. Most of the pebbles are of quartz and not reworked quartzite, probably indicating at least temporary proximity to a highland. In the 290 feet immediately below the uppermost 70 feet the conglomerate pebbles are commonly 1/8 inch in diameter. Bedding surfaces are very rare throughout this entire 1,410 feet thick unit and in the uppermost 90 feet the quartzite becomes
extremely massive with bedding either totally absent or indiscernible. Taken as a whole this massive quartzite unit is generally coarser than the lower massive quartzite unit previously described (1,424 feet thick).

At every locality where the contact between the undifferentiated Precambrian and the overlying Prospect Mountain quartzite has been studied in the Promontory Range, complete conformity is the rule. Bedding attitudes are similar above and below the contact. Although the lithologic change is abrupt, the contact is conformable and detailed study disclosed no visible channeling. The quartzites of the Precambrian are distinguished from the Prospect Mountain quartzite chiefly by their lack of bedding surfaces and the relative abundance of conglomeratic layers which are comparatively rare in the latter. Homogeneous lithology, a characteristic of the entire Prospect Mountain quartzite, is present only in short stratigraphic intervals in the underlying Precambrian strata.

Age and Correlation

Eardley and Hatch (1940 b) refer to the Precambrian sequence of the Promontory Range as "Proterozoic (?)" and the Farmington Canyon complex as Archean. Subsequent workers have modified this dating, as will be discussed below.

Only by radioactive age determinations can an age be given for the Precambrian sequence, and thus correlation with nearby areas may be made, at present, solely on the basis of aggregate lithologic similarities. The areas which will be considered are the Northern Farmington Mountains.
of the Wasatch Range (Bell, 1952), the Wasatch Mountains east of Salt Lake City (Crittenden et. al., 1952), and Antelope Island (Larsen, 1957).

Larsen recognizes two major divisions of Precambrian time in the stratigraphic section of Antelope Island; Middle (?) Precambrian represented by the Farmington Canyon complex, and Upper Precambrian represented by the Mineral Fork tillite and the Mutual (?) formation. The correlation is based on the tillite as a datum plane, but tillite is not present in the Promontory Range. As previously stated, however, there is reason to believe that the entire Precambrian sequence in the Promontory Range lies stratigraphically above the tillite.

Therefore, if Larsen's correlation with the Precambrian sequence in the Wasatch Mountains described by Crittenden et. al. (1952) is correct, the entire Precambrian sequence of the Promontory Range, greater than 7,500 feet thick, must be ascribed to the Mutual formation. The greatest thickness given to the Mutual formation by Crittenden et. al. (1952) is 1,200 feet; however, the wedging characteristics of the Mutual formation, the pronounced unconformities at the base and upper contact of the Mineral Fork tillite, and the possibility that the tillite owes its origin to mountain or alpine glaciation make it appear possible that such seemingly great changes in the stratigraphic thickness of a formation could occur within a distance of 60 miles.

Nevertheless, the writer prefers to assign no formational names to the Precambrian sequence in the Promontory Range, primarily because a study of nearby Precambrian sequences was not within the scope of this paper. In the light of present knowledge of the problem it would seem
necessary to restudy the sequences at Little Mountain near the southeast corner of Bear River Bay, Fremont Island, and the other small islands of the Great Salt Lake. Only then could a work of regional scope competently correlate these sequences and arrive at a comprehensive knowledge of the Precambrian history of northwestern Utah.
CAMBRIAN STRATIGRAPHY

General Statement

The Cambrian system in the Promontory Range consists of twelve formations; the Prospect Mountain quartzite, the Pioche "shale", the Bushy quartzite, the Millard limestone, the Burrows limestone, the Burnt Canyon limestone, the Dome limestone, the Swasey limestone, the Wheeler formation, the Marjum formation, the Nounan formation, and the St. Charles formation (listed in ascending order). The stratigraphic interval from the base of the Busby quartzite to the top of the Swasey limestone is mapped as "undifferentiated Middle Cambrian", mainly for cartographic reasons.

The system is not completely exposed at any one locality, but a composite section may be established from exposures at three localities. The Prospect Mountain quartzite and the Pioche "shale" are exposed along the south ridge of Long Canyon. The interval from the top of the Pioche "shale" to the base of the Nounan formation is well exposed on the southwest face of Black Mountain (see Plate 1). Along the east ridge of Maple Canyon the Nounan formation and the St. Charles formation are exposed, although the former is probably complicated by faulting and its measured thickness is unreliable. A composite of measured thicknesses at these three localities gives a total minimum thickness for the Cambrian system of 10,762 feet (assuming that the Prospect Mountain quartzite is entirely Lower Cambrian).

With the exception of the upper plate of the Indian Caves overthrust
fault and the south end of Little Mountain, no Cambrian strata occur north of the Middle Canyon fault. The upper plate of the Indian Caves overthrust is composed of the Marjum formation and the Nounan formation and has been thrust upon younger dolomites. The southern end of Little Mountain is presumed by the writer to be essentially composed of St. Charles dolomite.

The Cambrian system constitutes a very large portion of the exposed bedrock of the Promontory Range; only the combined Pennsylvanian-Permian systems exceed the Cambrian in total area of exposure. No system approaches the Cambrian in thickness and only the Proterozoic (?) and Ordovician systems are as well exposed and represented.

Prospect Mountain Quartzite

Distribution and Thickness: - The Prospect Mountain quartzite is widely distributed in the southern one-third of the Promontory Range. The only complete and structurally uninterrupted exposures are present in a virtually continuous outcrop extending from Little Valley to the Middle Canyon fault along the west side of the range, a distance of about 5 miles. Throughout the length of this belt the formation and its contacts are well exposed. Along the south ridge of Long Canyon and the knife-like ridge between Long Canyon and Little Valley, 3,884 feet of

1. There are three prominent topographical features named "Little Mountain" nearby the Promontory Range. One is northwest of Corinne and another is situated at the southeast corner of Bear River Bay. The third is located approximately midway along the eastern side of the Promontory Range; and, unless otherwise noted, all further references to "Little Mountain" will concern the last-named.
the Prospect Mountain quartzite were measured, this being the only complete measured section.

Another excellent exposure is present between the North Fork and South Fork of Little Valley but the lower contact is not present and faulting has complicated the upper portions of the section. Nevertheless, 2,830 feet of the Prospect Mountain quartzite were measured here, so it is probable that this section embraces approximately the upper three-quarters of the formation.

Other scattered, incomplete exposures of the Prospect Mountain quartzite are present along the base of Black Mountain on its south and west faces. These are unfortunately just below the Bonneville level and are almost totally obscured by the widespread surficial lacustrine deposits; therefore, no appreciable stratigraphic sequence can be established.

**Topographic Expression:** - The Prospect Mountain quartzite forms smooth, even slopes. Wherever extensively present in the Promontory Range it is dipping at fairly high angles and therefore the best exposures are found along ridge crests. The formation is extremely homogeneous and differential resistance to erosion is not a determinant affecting the degree of concealment of any stratigraphic horizon. Between Little Valley and Middle Canyon along the west side of the range this

1. In an earlier publication (Olson, 1956, pg. 44) the thickness of this section was given as 5,215 feet. This was caused by an unfortunate error in computation which was not discovered until after the publication of the article.
quartzite forms extremely rugged topography. Steep bare slopes and
craggy ledges are common. The Prospect Mountain quartzite supports
remarkably little vegetation compared to the overlying Cambrian for­
mations. While only sagebrush is supported upon the quartzite, the
overlying shales and carbonate sediments are characterized by extensive
growths of cedars, maples, etc. This abrupt change in both quantity and
character of vegetative cover plus the extreme color change between the
Prospect Mountain quartzite and the overlying Pioche "shale" enable this
lithologic contact to be easily traced on aerial photographs. It is
perhaps the best exposed formational contact in the Promontory Range.

Lithology: - The Prospect Mountain quartzite has an extremely homo­
geneous lithology; with the exception of some minor shale units near the
top, the formation is entirely composed of quartzite. The texture of
the quartzite ranges from very fine-grained to very coarse-grained, but
the fine-grained to medium-grained textures predominate. The color
varies greatly both on fresh and weathered surfaces. On fresh surfaces
the bulk of the quartzite is tan to white; with brown, pink, and light
green in minor amounts. The weathered colors are much darker due to
oxide staining; dark reddish-brown predominates, with dark brown, dark
tan, and purple relatively minor.

At one locality, along the south ridge of Long Canyon, some shale
partings were noted at the base of the uppermost 89 feet, but this
presence of shale is unusual for the Prospect Mountain quartzite. The
shale is dark tan to olive-drab, silty, micaceous along bedding surfaces,
and weathers the same color as fresh surfaces. Although these shales resemble those in the overlying Pioche "shale", the quartzites with which they are interbedded are similar to the Prospect Mountain quartzite. The Prospect Mountain quartzite - Pioche"shale" contact is based on both lithology and color, but the color change is more prominent and is the feature employed in mapping the units on aerial photographs.

When measuring stratigraphic sections in the Prospect Mountain quartzite, as many as nine lithologic units may be differentiated, mainly by color, and although these units may persist laterally for short distances, it is extremely doubtful that they have any regional validity. The bedding habit of the Prospect Mountain quartzite is diagnostic and enables the drawing of a clear-cut contact between it and the underlying Precambrian quartzites. Parallel bedding surfaces clearly define beds averaging one to two feet thick throughout the extent of the Prospect Mountain quartzite, and this persistent presence of well defined parallel beds contrasts sharply with the almost totally massive Precambrian quartzite beneath. Low-angle cross-bedding is locally displayed between the parallel bedding surfaces in the basal half of the formation, but is by no means common. Conglomeratic beds are scattered throughout the Prospect Mountain quartzite, but they are volumetrically unimportant and nowhere characterize this formation as strongly as they do some of the underlying Precambrian quartzite.

The Prospect Mountain quartzite is differentiated from the overlying Pioche "shale" by a much lighter color and an almost complete absence of shale, and from the underlying quartzite of the Precambrian by well
defined parallel bedding and a somewhat lighter color. There is complete conformity between the Precambrian and the Lower Cambrian as judged from a study of the basal contact of the Prospect Mountain quartzite. The upper contact of the formation is a sharp line of color change, but the lithologic change is gradual.

**Age and Correlation:** - No fossils have been found in the Prospect Mountain quartzite of the Promontory Range, but it is arbitrarily assumed to be entirely Lower Cambrian.

Correlation is made directly with the Prospect Mountain quartzite of the House Range. The type locality is at Eureka, Nevada. The Tintic quartzite to the south and the Brigham quartzite to the east and northeast are stratigraphic equivalents of the Prospect Mountain quartzite.

**Pioche "Shale"**

**Distribution and Thickness:** - The Pioche "shale" rests directly upon the Prospect Mountain quartzite and is well exposed at all three localities mentioned for the latter formation.

The best exposures of the Pioche "shale" extend in a virtually continuous belt from the north wall of Little Valley (just west of the junction of the North Fork and South Fork of Little Valley) northward to the head of Middle Canyon where it is terminated by the Promontory fault. Along the north rim of Little Valley the Pioche "shale" is 307 feet thick, this being the most reliable measured section. Approximately two-thirds of the way up South Canyon a good, but incomplete, exposure of
the Pioche "shale" crops out just north of the South Canyon fault.

Good exposures are also present along the east wall of the North Fork of Little Valley, but the proximity to major faults and the resulting pervasive minor brecciation of the area render measurements unreliable. One measured section, where faulting was not very intense, is 194 feet thick, while another measured section, a scant mile away where faulting is intense, is greater than 314 feet thick with neither bottom nor top contact exposed. The latter measurement cannot be trusted due to the extensive faulting.

Along the south and west faces of Black Mountain the Pioche "shale" is spottily exposed, but is above the Bonneville level for the most part and hence is more susceptible to study than in the underlying Prospect Mountain quartzite. The bottom contact of the Pioche "shale" however, is seldom present here.

All of the exposures mentioned are readily accessible by field vehicle with little climbing necessary.

**Topographic Expression:** - Due to its shaly members, the Pioche "shale" is less resistant than the underlying Prospect Mountain quartzite and consequently is more of a slope-former. Where exposed along ridges it commonly forms a modified dip slope between the relatively more resistant cliff-forming formations above and below it. Along the south-west face of Black Mountain it forms "sea cliffs" with extensive talus slopes extending down to the Bonneville level.
Lithology: - The Pioche "shale" is mostly quartzite and shale is very minor. The writer estimates that the maximum amount of shale present at any locality within the Promontory Range would not exceed 10 per cent.

The quartzite is most commonly green, fine-grained, and weathers purple to dark brown. Other colors are purple, greenish-tan, and greenish-gray and weathered colors include dark reddish-brown, dark tan, and rare bluish-purple. Although the texture ranges from very fine-grained to medium-grained, the predominant texture is fine-grained.

The shale is dull green to olive drab, micaceous, quartzitic, and weathers greenish-tan to green. Biotite is abundant on bedding surfaces, but is rarely present in the internal portions of the shale which are markedly quartzitic. The bedding surfaces are extremely undulatory and irregular, possibly due to differential compaction on a minute scale, and have a pronounced phyllitic sheen. Imposed upon these coarse undulations are almost microscopic "ruffles" which resemble microscopic ripple marks. These shales are diagnostic of the Pioche "shale" in the Promontory Range.

Locally the quartzite has abundant white quartz veins, averaging one inch thick, which either cut or are parallel to bedding. Large fucoidal markings up to six inches long are present on the bedding surfaces of the quartzite.

The Pioche "shale" stands out prominently from the underlying Prospect Mountain quartzite and the overlying "undifferentiated Middle Cambrian" sequence because of its very dark weathered color.
Age and Correlation: - No fossils have been found in the Pioche "shale" of the Promontory Range, but it is arbitrarily assumed to be Middle Cambrian. Wheeler and Steele (1951) found Olenellus in the Pioche "shale" of the House Range and consider this formation to be almost entirely Lower Cambrian. The writer and Mr. Robert C. Bright found Taxioura approximately midway in the overlying Busby quartzite. It is possible that, because of its time-transgressive behavior, the Pioche "shale" in the Promontory Range may be entirely Middle Cambrian.

Correlation is made directly with the Pioche "shale" of the House Range. The type locality is near Pioche, Nevada. No attempt is made to correlate the Pioche "shale" of the Promontory Range with stratigraphic units to the east and northeast, but it is likely that its stratigraphic equivalent is present in the uppermost portion of the Brigham quartzite. It is unlikely that the Pioche "shale" will ever be found much further north than the southern part of the Promontory Range.

Wheeler (1943, pg. 1815) states that "If the Spence and Pioche shales are distinct the northern limit of the latter in north-central Utah is somewhere between Ogden and Blacksmith Fork, and somewhere south of Promontory Point." The writer believes that both of these units are present at Promontory Point and that they are definitely distinct. The existence of the Pioche "shale" is unquestionable, but much further work is needed to definitely prove the existence of the Spence shale.

"Undifferentiated Middle Cambrian"

A succession of carbonate and clastic strata occupying a stratigraphic position between the Pioche "shale" and the Wheeler formation is
mapped as "undifferentiated Middle Cambrian" for the following reasons: (1) the mapping of these individual formations as separate units would necessitate the employment of a map scale which would be too large; (2) this stratigraphic interval is commonly poorly exposed and formational contacts would be largely speculative; and (3) the writer believes that facies changes which are severe over relatively short lateral distances render the mapping of these individual formations highly impracticable in the present investigation.

This succession contains units which are correlated with the following formations recognized in the House Range by Wheeler and Steele (1951): Busby quartzite, Millard limestone, Burrows limestone, Burnt Canyon limestone, Dome limestone, and the Swasey limestone (with the Condor member at the base). At the southwest corner of Black Mountain this succession is 1,172 feet thick. Near the head of South Canyon and on its south wall 620 feet of this sequence were measured, but this section is incomplete because the Busby quartzite, Millard limestone, and most of the Burrows limestone are concealed. An aggregate thickness of 544 feet for the Burnt Canyon limestone, Dome limestone, and Swasey limestone at this locality contrasts with a 624 foot thickness for the same interval at the southwest corner of Black Mountain. Near the head of Long Canyon and on its south wall the total thickness of the interval was estimated by Brunton-and-pace method to be 1,075 feet, compared to the measured thickness of 1,172 feet at the southwest corner of Black Mountain.

It is readily apparent from an inspection of Stratigraphic Sections
C-7 through C-11 (Appendix) that the lithology of this stratigraphic interval (Busby quartzite through Swasey limestone) changes laterally, but all of the formations within it may be commonly recognized at different localities.

Both the Pioche "shale" and the Wheeler formation stand out prominently as "marker beds" and thus facilitate the mapping of this "undifferentiated Middle Cambrian" succession.

**Busby Quartzite**

*Distribution and Thickness:* - The Busby quartzite lies upon the Pioche "shale" and is overlain by the Millard limestone, both contacts being conformable.

The Busby quartzite has a very limited areal extent. The only exposures known to the writer are along the base of Black Mountain on its south and west faces. Even over this small area the thickness varies considerably, with a 45 foot thickness and a 72 foot thickness measured within half a mile at the southwest corner of Black Mountain. The Busby quartzite is absent at the southeast corner of Black Mountain and its total extent, along strike, is approximately three miles.

The maximum measured thickness of the Busby quartzite is 72 feet on the west face of Lead Hill. This thickness gradually tapers off to the east and north west. On Lakeview Ridge the Busby quartzite is 45 feet thick and this is the figure used in obtaining the thickness of 1,172 feet for the "undifferentiated Middle Cambrian".
**Topographic Expression:** - The calcareous portion of the Busby quartzite commonly forms the capping of the cliff of Pioche "shale" along the base of the southwest face of Black Mountain. The uppermost unit forms a slope between this cliff and the overlying steep cliff of the basal Millard limestone. It stands out from the green-weathering Pioche "shale" below by its brown to tan weathered color and from the overlying Millard limestone by its lack of orange-brown siltstone partings which give the Millard limestone outcrops their characteristic "ruled" appearance.

**Lithology:** - The Busby quartzite is made up of three lithologic units which vary considerably in distribution and thickness. The basal unit is a fine-grained calcareous orthoquartzite which weathers tan to light brown. Both contacts of this basal unit are distinct and sharp.

Above the orthoquartzite is a pearly dark gray, medium crystalline limestone which weathers tan to brown. Bedding is completely absent and the limestone is susceptible to local alteration.

The uppermost unit is a gray, silty, micaceous shale which is commonly concealed by limestone debris or hillwash. The thickness of this shale varies greatly from 5 feet on the west face of Lakeview Ridge to a maximum observed thickness of 47 feet on the west face of Lead Hill and thins rapidly toward the east.

**Age and Correlation:** - The Busby quartzite is definitely established as Middle Cambrian and is thus the oldest positively dated formation in the Promontory Range. Mr. Robert C. Bright has identified the following from the Busby quartzite of the Promontory Range:
**Taxioura sp. undet.**

Correlation is made directly with the Busby quartzite of the House Range. The type locality is Gold Hill, Utah. Mr. Robert C. Bright who has investigated the Spence shale member of the Langston formation at its type locality near Liberty, Idaho and other nearby occurrences stated that the uppermost shale unit of the Busby quartzite in the Promontory Range could be the Spence shale. However, further work will be required for a definite correlation. At some localities the basal portion of the Busby quartzite (exclusive of the shale) somewhat resembles the Langston formation of the Logan area. It is possible that the Busby quartzite of the Promontory Range is the stratigraphic equivalent of the Langston formation and its Spence shale member of the Logan area, but any definite correlation must await further work.

**Millard Limestone**

**Distribution and Thickness:** - The Millard limestone is prominently exposed along the southwest and south faces of Black Mountain, particularly along Lakeview Ridge and Lead Hill. This formation is recognized at all localities where the "undifferentiated Middle Cambrian" succession was studied. Other localities where the Millard limestone is well exposed are the east and west walls of the North Fork of Little Valley and near the heads of Long Canyon and South Canyon on the western side of the range.

The areal distribution of the Millard limestone is nearly the same as that of the Pioche "shale", but the best exposures are along the
southwest face of Black Mountain.

On Lakeview Ridge the Millard limestone is 202 feet thick and is very well exposed. To the east on Lead Hill the Millard limestone is also well exposed, but this section was not measured. Along the south wall of Long Canyon near its head, the thickness of the Millard limestone is estimated at 200 feet. An abnormally thin section of the Millard limestone is present along the east wall of the North Fork of Little Valley, where only 43 feet are present. Since this exposure is close to two major faults, this anomalous thickness may be in large part due to structural complications.

Topographic Expression: - The Millard limestone is commonly a slope-former, but there are prominent local exceptions to this outcrop habit. Prolonged wave action at the Bonneville level resulted in the formation of several wave-cut sea cliffs along the west and south faces of Black Mountain. The undercutting of formations beneath the Millard limestone has resulted in the basal portion of the Millard limestone cropping out as a prominent ledge above the less resistant shale unit of the underlying Busby quartzite. This phenomenon occurs on the southern ends of Lakeview Ridge, Lead Hill, and ridges to the northwest and southeast.

Lithology: - The Millard limestone is a dark gray, very finely crystalline, silty limestone which weathers dull gray. The formation is characterized almost throughout its entire extent by orange to tan siltstone laminae, generally less than 1/16 inch thick and parallel to bedding. These partings weather deeper than the intervening limestone and give to
the outcrops a "banded" or "ruled" appearance. The lithology of the Millard limestone is distinctive; stratigraphic intervals devoid of the siltstone partings are seldom greater than 6 inches thick. The basal contact of the Millard limestone is sharp, but the upper contact with the overlying Burrows limestone is transitional.

**Age and Correlation:** The Millard limestone is known to be Middle Cambrian. Dr. C. L. Balk has identified a fauna from the area as follows:

25 feet above base of Millard limestone - "top of Albertella zone - biofacies equivalent of the *Ptarmigania* assemblage from the Is. at the base of the Langston, Logan quad."

*Ptarmigania* sp. undet.

100 feet above base of Millard limestone - "top of Albertella zone - also biofacies equivalent of *Ptarmigania* assemblage"

*Ptarmigania* sp. undet.

The Millard limestone is correlated directly with the Millard limestone of the House Range, described by Wheeler (1948), and Wheeler and Steele (1951). Wheeler (1948, pg. 36) states that "On physical stratigraphic evidence the basal portion of this formation (Millard limestone - R.H.O.) is assigned to the Albertella zone, -." With the present evidence, however, no attempt is made to correlate the Millard limestone of the Promontory Range with the Middle Cambrian sequence at Blacksmith Fork in the Logan quadrangle, Utah. Nor will any such attempt be made with the
Burrows limestone, Burnt Canyon limestone, Dome limestone, Swasey limestone, and the Wheeler formation. Definite correlation of any portion of this interval with the well-established Logan section must await more detailed, painstaking paleontological field work and research.

**Burrows Limestone**

**Distribution and Thickness:** The Burrows limestone is recognized at all localities where the "undifferentiated Middle Cambrian" succession has been studied. The areal distribution is the same as that of the underlying Millard limestone.

The best exposures of the Burrows limestone are along the southwest and south faces of Black Mountain, particularly along Lakeview Ridge where the formation is 301 feet thick. Along the south wall of Long Canyon near its head, the thickness of the Burrows limestone is estimated at 275 feet. On the east wall of the North Fork of Little Valley there are 163 feet of Burrows limestone, but this anomalously thin section may be due in large part to its proximity to two major faults.

**Topographic Expression:** The Burrows limestone is generally a slope-former, but several of the limestone units may stand out as prominent ledges. On Lakeview Ridge the basal and uppermost limestone units crop out as very prominent cliffs. Elsewhere the uppermost unit of the Burrows limestone commonly forms a massive ledge while the topographic expression of the remainder of the formation is comparatively subdued.
**Lithology:** - The Burrows limestone consists largely of dolomite and limestone with minor amounts of shale. The dolomite is pearly gray, medium to coarsely crystalline, and weathers uniformly brown to dark brown. This dolomite is a very distinctive unit; there is no lithology similar to it in the "undifferentiated Middle Cambrian" succession. There is strong evidence that the dolomitization is epigenetic. On Lakeview Ridge no dolomite is present in the Burrows limestone and at all other localities the amounts of dolomite vary greatly. The coarse crystallinity, massive bedding habit, and brown weathered color of the dolomite are in sharp contrast with the limestone units of the Burrows limestone. Wheeler (1940, 1948) noted similar dolomitization in the region around Pioche, Nevada.

The limestone is microcrystalline, slightly silty, and weathers light gray to gray. Much of the limestone has scattered "blebs" of coarsely crystalline calcite which are intensely stained orange to orange-brown by limonite. Along Lakeview Ridge the limestone ledges are very susceptible to marbleization and most of the lead-zinc ore in the Promontory mining district was mined from the Burrows limestone.

A green, slightly micaceous shale below the uppermost dolomite ledge of the Burrows limestone on the south face of Black Mountain is the only clastic unit observed in the formation. This shale contains a large trilobite fauna.

**Age and Correlation:** - The Burrows limestone is known to be Middle Cambrian. Dr. C. L. Balk has identified the following fauna from the Burrows limestone:
85 feet above base of Burrows limestone - "the Glossopleura zone -"

Glossopleura cf. G. bion or G. belesis Walcott
Alokistocarella sp. undet.

125 feet below top of Burrows limestone - "the Glossopleura zone - this group is the same as the Spence shale assemblage"

Glossopleura cf. G. producta (Hall and Whitfield)
Zacanthoides cf. Z. idahoensis (Resser)
Athabaskia cf. A. wasatchensis (Resser)
Ehmaniella quadrans (Hall and Whitfield)
Alokistocare cf. A. idahoense (Resser)
from another locality at approximately the same horizon -
"also the Glossopleura zone"

Zacanthoides cf. Z. holopygus (Resser)
Inglefieldia cf. I. imperfecta (Lockman)

The Burrows limestone is correlated directly with the Burrows limestone of the House Range, described by Wheeler (1948) and Wheeler and Steele (1951). Wheeler (1948, pg. 36) states that "The Burrows has nowhere yielded fossils. Nevertheless, its regional occurrence between the Glossopleura - Kootenia faunas of both underlying and overlying rocks demands that it be assigned to the same zone." In the light of present knowledge no attempt is made to correlate the Burrows limestone of the Promontory Range with the Middle Cambrian sequence at Blacksmith Fork in the Logan quadrangle, Utah.
Burnt Canyon Limestone

**Distribution and Thickness:** The Burnt Canyon limestone has about the same areal distribution as the underlying Burrows limestone and is recognized at all localities where the "undifferentiated Middle Cambrian" sequence has been studied. The best exposures of the Burnt Canyon limestone are along the southwest and south faces of Black Mountain, particularly along Lakeview Ridge where the formation is 91 feet thick. Along the south wall of South Canyon, near its head, the Burnt Canyon limestone is 80 feet thick. On the east wall of the North Fork of Little Valley the formation was measured as 70 feet thick, but the proximity of this exposure to two major faults may render this thickness unreliable. The Burnt Canyon limestone is estimated to be 260 feet thick along the south wall of Long Canyon, but this section was not measured. This anomalous thickness is not considered representative of the Burnt Canyon limestone.

**Topographic Expression:** The Burnt Canyon limestone, wherever exposed, is a gentle slope-forming unit between the uppermost massive ledge of the Burrows limestone and the cliff-forming Dome limestone. Of all the formations in the "undifferentiated Middle Cambrian," the Burnt Canyon limestone is probably the least well exposed and represented.

**Lithology:** The Burnt Canyon limestone consists of interbedded limestone and shale. The limestone is gray to dark gray, generally very finely crystalline, and weathers gray to bluish-gray. The shale is pale greenish-
tan to olive-drab, micaceous, and on the whole constitutes a relatively minor portion of the entire formation. The Burnt Canyon limestone is similar to the Swasey limestone and if it were not for the overlying Dome limestone the Burnt Canyon limestone - Swasey limestone stratigraphic interval would doubtless be considered a single formation. A basal shale unit along the southwest and south faces of Black Mountain has yielded an abundant trilobite fauna.

**Age and Correlation:** - The Burnt Canyon limestone is known to be Middle Cambrian. Dr. C. L. Balk has identified the following forms from this formation:

- from base to 10 feet above base of Burnt Canyon limestone -
  - "the *Glossopleura* zone - A Spence shale assemblage"
  - *Glossopleura similaris* Resser
  - *Glossopleura* cf. *G. bion* Walcott
  - *Zacanthoides* cf. *Z. idahoensis* Resser
  - *Obolus (Westonia) ella* (Hall and Whitfield)
  - *Athabaskia* cf. *A. wasatchensis* (Resser)
  - *Ehmaniella* cf. *E. quadrans* (Hall and Whitfield)
  - cf. *Kootenia idahoensis* Resser

- from another locality in 2 to 4 foot interval above base of Burnt Canyon limestone - "*Bathyuriscus - Elrathina* zone - somewhere in lower half"
  - *Iphidella* cf. *I. pannula* (White)
  - *Ehmaniella* cf. *E. burgessensis* Rasetti
The Burnt Canyon limestone is correlated directly with the Burnt Canyon limestone of the House Range, described by Wheeler (1948) and Wheeler and Steele (1951). No attempt is made by the writer to correlate the Burnt Canyon limestone of the Promontory Range with the Middle Cambrian succession at Blacksmith Fork in the Logan quadrangle, Utah.

Dome Limestone

**Distribution and Thickness:** - The Dome limestone has approximately the same areal distribution as the underlying Burnt Canyon limestone and is recognized at all localities where the "undifferentiated Middle Cambrian" succession has been studied.

The best exposures of the Dome limestone are along the southwest and south faces of Black Mountain. On Lakeview Ridge the Dome limestone forms the uppermost of three limestone cliffs between the Pioche "shale" and the prominent dip slope developed upon the top of the Swasey limestone. The Dome limestone at this locality is 39 feet thick, but is seen to thicken rapidly to the southeast to at least twice this amount. A thickness of 97 feet is assigned to the Dome (?) limestone on the east wall of the North Fork of Little Valley. Along the south wall of Long Canyon near its head, the Dome limestone is estimated to be 15 feet thick. On the south wall of South Canyon the Dome (?) limestone is 47 feet thick.

**Topographic Expression:** - The Dome limestone is a cliff-former wherever it is well exposed. The best example of this is on the southeast face of Lakeview Ridge. There are no interbedded clastic sediments and the
formation generally forms a single massive ledge standing out in sharp contrast with the Burnt Canyon limestone and the Condor member of the Swasey limestone, both of which are slope-formers.

**Lithology:** - The Dome limestone, unlike the formations above and below it, has no interbedded clastics. The limestone is dark gray, microcrystalline to very finely crystalline, and weathers blue-gray to dull dark gray. It is locally oolitic throughout its stratigraphic extent and the weathered surfaces are characteristically extremely rough (spires, ridges, and furrows, etc.) Beds average one to two feet in thickness and the bedding planes are markedly uneven.

**Age and Correlation:** - No fossils were found in the Dome limestone, but because of its stratigraphic position between formations of known Middle Cambrian age it is certainly Middle Cambrian.

The Dome limestone is correlated directly with the Dome limestone of the House Range, described by Walcott (1908a, 1908b), Deiss (1938), Wheeler (1948), and Wheeler and Steele (1951). No correlation is attempted between the Dome limestone of the Promontory Range and the Middle Cambrian sequence at Blacksmith Fork in the Logan quadrangle, Utah.

**Swasey Limestone**

**Distribution and Thickness:** - The Swasey limestone has about the same areal distribution as the underlying Dome limestone and is recognized at all localities where the "undifferentiated Middle Cambrian" has been studied.

This formation is generally better exposed than most of the
"undifferentiated Middle Cambrian" sequence. Along Lakeview Ridge the Swasey limestone is 494 feet thick and the Condor member constitutes the basal 322 feet. Along the south wall of Long Canyon and the west wall of the North Fork of Little Valley, the Swasey limestone is estimated to be 325 feet thick. On the south wall of South Canyon the Swasey (?) limestone is 417 feet thick. Along the east wall of the North Fork of Little Valley, the Swasey (?) limestone was measured as greater than 600 feet thick, but the section was terminated by a major fault and structural complications have certainly affected these strata.

**Topographic Expression:** - The Swasey limestone appears topographically in two contrasting manners. The Condor member, at the base of the Swasey limestone, is a slope-former much like the Buntt Canyon limestone. The remainder of the Swasey limestone makes up a very prominent landform along ridges; a steep limestone cliff with the uppermost beds forming a flatiron dip slope down to the bottom of a V-shaped notch which has its apex on the contact of the Swasey limestone with the overlying Wheeler formation.

**Lithology:** - The Condor member of the Swasey limestone differs from the remainder of the formation mainly in having interbedded shales. This member occurs at the base of the Swasey limestone and is generally well concealed. Only on Lakeview Ridge is the Condor member well exposed. At this locality it consists of interbedded units of shale and limestone with the individual units generally at least 20 feet thick. The shale is silvery tan to pale greenish-gray, talcose, and weathers the same as the fresh colors. Most of the shale is completely argillaceous with no included sand or silt grains.
Bedding is generally paper-thin and surfaces have a pronounced phyllitic sheen. The interbedded limestone is gray to dark gray, microcrystalline to finely crystalline, and weathers gray to light bluish-gray. The limestone is characteristically very thin-bedded and commonly has orange, argillaceous siltstone partings along bedding surfaces.

The remainder of the Swasey limestone, exclusive of the basal Condor member, has no interbedded shale. This limestone is very similar to the interbedded limestone of the Condor member except that the upper portion becomes thick-bedded and the orange siltstone partings steadily decrease upward until they are totally absent in the upper one-half.

Age and Correlation: - No fossils have been found in the Swasey limestone, but its Middle Cambrian age is well established by the presence of Middle Cambrian fossils in formations above and below.

The Swasey limestone is correlated directly with the Swasey limestone of the House Range, as described by Walcott (1908a, 1908b), Deiss (1938), Wheeler (1948), and Wheeler and Steele (1951). With present evidence no attempt is made to correlate the Swasey limestone of the Promontory Range with the Middle Cambrian succession at Blacksmith Fork in the Logan quadrangle, Utah.

Wheeler Formation

Distribution and Thickness: - The Wheeler formation is recognized at almost all localities where the underlying "undifferentiated Middle Cambrian" sequence and the overlying Marjum formation have been studied.
Its best exposures are on Black Mountain where it is present as a continuous band extending from the northwest corner of this mountain mass almost to the southeast corner. On Lakeview Ridge the Wheeler formation is 181 feet thick and on Lead Hill, to the southeast, is 85 feet thick.

The Wheeler formation on the west wall of the North Fork of Little Valley is 130 feet thick and may be traced northward toward the Long Canyon fault. Its presence on the south wall of South Canyon has not been detected, but it may be represented by all or part of a concealed interval 151 feet thick at the base of the Marjum formation. Along the north wall of South Canyon south of the Promontory fault the Wheeler formation has not been detected.

The sporadic occurrence of the Wheeler formation is difficult to explain. It has not been observed north of Long Canyon nor on the southeast portion of Black Mountain, although it may be represented by concealed intervals at some of these localities. The Wheeler formation, almost entirely shale, is doubtless extremely susceptible to deformative forces. It is possible that in close proximity to large faults this formation may have been thinned at the expense of other Cambrian strata. This seems more likely than ascribing the seemingly total local absence of the formation entirely to stratigraphic thinning and pinching out.

**Topographic Expression: -** The Wheeler formation has an extremely characteristic topographic expression. Its resistance to erosion is almost negligible, but it lies between two formations which are extremely resistant. Along ridges the Wheeler formation forms a very prominent V-shaped notch,
one side of which is a dip slope developed on the uppermost Swasey limestone and the other is hillwash developed on the Wheeler formation. The abundant clay minerals in the calcareous shale have formed a residual regolith due to the dissolution and removal of the carbonate cement. This regolith is light gray, but its weathered color is white, and the unit thus stands out prominently between dark-weathering limestones.

**Lithology:** The Wheeler formation is almost entirely shale, but there are minor limestone and calcite "beds". The shale is blackish-gray to whitish-gray, generally extremely silty and calcareous, and weathers to a dirty light gray, although diffuse local concentrations of iron oxides may impart a brown or tan color to weathered surfaces. The shale is extremely fissile and it is common to have indistinct laminae 1/16 inch thick or less coalesced into distinct "beds" up to 1/4 inch thick.

The calcite "beds" are undoubtedly the result of extensive recrystallization. The calcite is white, very coarsely crystalline, and weathers cream-colored. Both the shale and the calcite "beds" may stand out as thin (six inches to two feet thick) laterally persistent "ribs" above the pervasive hillwash derived from the regolith of the Wheeler formation.

The limestone is dark gray, medium crystalline, and weathers drab tan. It has a pronounced shaly habit and limonite flecks are scattered throughout.

The characteristic regolith developed upon the Wheeler formation is described above. Samples were gathered to be tested for possible utilization in the brick industry, but an excessive calcareous content renders the material useless for this purpose.
Age and Correlation: - No identifiable fossils have been found in the Wheeler formation. Its presence between formations of established Middle Cambrian age, however, proves that it is Middle Cambrian.

Poorly preserved trilobite thoracic segments were collected at two localities. Dr. C. L. Balk inspected both of these collections and states that nothing from them can be identified.

Correlation is made directly with the Wheeler formation of the House Range. A concerted attempt to find recognizable fossils in the Wheeler formation of the Promontory Range might be successful and would certainly be worth the effort. Shearing, tight folding, and extensive recrystallization would render paleontological research very difficult indeed. In the light of present knowledge no attempt is made to correlate the Wheeler formation of the Promontory Range with the Middle Cambrian sequence at Blacksmith Fork in the Logan quadrangle, Utah.

Marjum Limestone

Distribution and Thickness: - The Marjum limestone is best exposed on Black Mountain where it makes up the major portion of this mountainous mass. It is 1,878 feet thick at this locality¹ and is totally uncomplicated by faulting for the most part with both lower and upper contacts well exposed.

The Marjum limestone is present along the east wall of the North Fork of Little Valley and Maple Canyon where it is in fault contact with the

¹ In an earlier article (Olson, 1956, pp. 47-48) the writer described a unit which he named the Dunderberg shale. This unit is now incorporated into the Marjum limestone and the name "Dunderberg shale" is recognized as having no validity in the Promontory Range.
"undifferentiated Middle Cambrian" sequence. At this locality only the upper half of the formation is present.

From the west wall of the North Fork of Little Valley to the north wall of South Canyon on the western side of the range the Marjum limestone crops out as a continuous band with both upper and lower contacts generally well exposed. In contrast with its exposures on Black Mountain, however, the Marjum limestone is locally complexly faulted.

Along the western side of the range from Middle Canyon north to Broadmouth Canyon, the Marjum limestone is present as the major portion of the upper plate of the Indian Caves overthrust fault. At no locality within this thrust sheet is the Marjum limestone present in its entirety and it is probable that very little of the lower half of the formation is present in the upper plate.

Topographic Expression: - The various portions of the Marjum limestone vary greatly in their topographic expression, but as a general rule the basal half of the formation is a slope-former and the upper half crops out as massive, almost vertical cliffs. The best example of this outcrop habit is found along the south face of Black Mountain. The massive cliffs near the top of this south face are the uppermost limestone units of the Marjum limestone and the contact with the overlying Nounan formation is generally exposed near the top of the dip slope which forms the north face of Black Mountain.

The cliff-forming habit of the upper half of the Marjum limestone is also well displayed along the east wall of Maple Canyon due east of the pass between the North Fork of Little Valley and Maple Canyon.
Elsewhere the Marjum limestone does not conform too closely to the topographic pattern of long slopes beneath massive, almost vertical cliffs; however, there is one topographic characteristic which is almost omnipresent in the Marjum limestone - a well-defined dip slope developed on its uppermost lithologic unit. This feature is well displayed north of the Long Canyon fault on the west wall of Maple Canyon (see Figure 11).

**Lithology:** The Marjum limestone has a heterogeneous lithology consisting of limestone, shale, "concretionary limestone in shale", siltstone, and dolomite. Limestone constitutes by far the major portion of the Marjum limestone and is black to dark gray, mostly microcrystalline, and weathers dark gray to light bluish-gray. Much of the limestone throughout the Marjum limestone is consistently very thin-bedded with spotty argillaceous siltstone "blotches" present along bedding surfaces. The siltstone in the Marjum limestone differs from that in the remainder of the Cambrian section in that it is seldom present as laterally persistent partings, but rather as isolated patches seeming to fill depressions on the limestone bedding surfaces. In the basal portion of the formation these siltstone "blotches" contain abundant trilobite remains while the limestone itself is barren of fossils.

The "concretionary limestone in shale" is a peculiar lithology found only in the Marjum limestone. At most localities this unit is uppermost in the Marjum limestone. It is 145 feet thick at the crest of Black Mountain where it forms the brown-weathering steep slope above the massive limestone cliffs. On the north wall of North Canyon where it is exposed in the upper plate of the Indian Caves overthrust fault this unit is 156 feet thick and
thus appears to have a uniform thickness within the Promontory Range. This unit has limestone nodules or "stringers" encased in a shale matrix (see Figure 3) with both the nodules and the "stringers" elongate parallel to bedding. The limestone is pale green, extremely microcrystalline, and weathers light greenish-gray. The shale weathers brown to tan and high-angle fracture cleavage is pervasive in the shale. The limestone, however, has not been sheared, which would suggest that it had an epigenetic concretionary origin; but the nodules when broken show no evidence of a nucleus.

Figure 3. Uppermost lithologic unit of the Marjum limestone long the south side of Miller Canyon. Limestone modules are encased in a shale matrix.
Mr. Robert C. Bright (personal communication) has found a tribolite fauna in limestone nodules at this horizon in the Bear River Range of Idaho, but they have proved totally barren in the Promontory Range. The field evidence seems to indicate that the nodules are concretionary and were formed later than the shearing of the shale. This peculiar lithology is found elsewhere than at the top of the Marjum limestone, but at these lower horizons is present as much thinner units and is not as well developed.

A search of the literature shows that this type of lithology at the same approximate horizon (uppermost Middle Cambrian or lowermost Upper Cambrian) has a widespread occurrence in the Great Basin and in the Rocky Mountains. Nolan, Merriam, and Williams (1956 pg. 18) have described identical lithology in the Dunderberg shale of Upper Cambrian age in the vicinity of Eureka, Nevada. Calkins and Butler (1943, pg. 17) noted a similar lithology in the middle member of the Maxfield limestone, assumed to be Middle Cambrian, in the Cottonwood-American Fork area of the Wasatch Mountains, Utah. Young (1955, pg. 17) has described an identical lithologic unit at the top of the Bowman (?) limestone in the Southern Lakeside mountains, Utah. The occurrence of this unit directly below the Lynch (?) dolomite suggests a direct correlation with the "concretionary limestone in shale" unit which lies directly below the basal dolomites of the Nounan formation in the Promontory Range. This lithology, however, was not described in the Stockton and Fairfield quadrangles, Utah (Gilluly, 1932) at the type locality of the Bowman limestone. Walcott (1908 b) described a similar lithology near the top of the Bloomington formation, of Middle Cambrian age, at Blacksmith Fork east of Hyrum, Utah.
To the writer's knowledge this peculiar "concretionary limestone in shale" unit occurs nowhere else in the Paleozoic section than near the Middle Cambrian-Upper Cambrian boundary. This may prove to be a useful marker bed in areas which lack recognizable fossils.

The shale in the Marjum limestone probably constitutes less than five percent of the volume of the formation, and is green to light green, talcose, very thinly laminated, and extremely fissile.

Siltstone is present as paper-thin partings along the bedding surfaces of very thin-bedded limestones. These argillaceous, micaceous siltstone partings stand out sharply in relief along weathered surfaces and are intensely stained by iron oxides while the limestone is comparatively free of such staining. The "banded limestones" are distinctive but not diagnostic of the Marjum limestone, for very similar units are present in the overlying Nounan formation. The Lower Ordovician Garden City formation has "banded limestones" which are also similar, but the overall outcrop appearance of the "banded limestones" of the Garden City formation is generally diagnostic.

The dolomite in the Marjum limestone is considered to be epigenetic for several reasons. The most compelling reason is the sporadic lateral distribution of the dolomite; when a dolomite unit is traced laterally it soon grades into limestone. The contacts of the dolomite with the limestone undulate sharply over stratigraphic intervals as great as five feet, a phenomenon to which a sedimentary origin can hardly be ascribed. The overall physical appearance of the dolomite also resembles the dolomitized portions of the "undifferentiated Middle Cambrian" sequence far more than it does the dolomites of the Upper Cambrian, Upper Ordovician, Silurian, and Devonian.
The Marjum limestone is more than 80 per cent limestone, but the remainder is extremely heterogeneous.

**Age and Correlation:** - The Marjum limestone is Middle Cambrian. Fossils have been found at only a few horizons and all of those forms which are identifiable have proved to be Middle Cambrian.

Dr. Allison R. Palmer has identified the following from a collection made approximately 200 feet above the base of the Marjum limestone:

- **Bolaspidella** sp.
- **Marjumia** ? sp.
- **Glyphaspis** ? sp.

Dr. C. L. Balk has identified a specimen as:

- **Elrathia** - may be **Elrathia kingi**

Unfortunately the stratigraphic position of this specimen cannot be determined, but it is certainly from the Marjum limestone.

Dr. W. C. Bell has identified a small collection of inarticulate brachiopods from the Marjum limestone.

- approximately 600 feet above base - **Nisuria**
- approximately 200 feet below top - "suppose that these are brachial valves of **Acrathela**, but can't prove it."

A single pygidium of **Kootenia** was collected approximately 750 feet below the top of the Marjum limestone along the east ridge of Maple Canyon.

Although faunal control of the Marjum limestone is relatively poor, especially for its upper portion, it seems safe to state that the Marjum limestone is entirely Middle Cambrian.
Correlation is made directly with the Marjum limestone of the House Range. The Marjum limestone of the Promontory Range is tentatively correlated with the upper portion of the Blacksmith dolomite and the Bloomington formation of the Logan quadrangle, Utah. Just how much of the Blacksmith dolomite is represented by the Marjum limestone of the Promontory Range is not known, but it seems safe to say that the entire Bloomington formation has its stratigraphic equivalent in the Marjum limestone of the Promontory Range. Mr. Robert C. Bright inspected the 1,878 foot thick section of the Marjum limestone exposed on the south face of Black Mountain (see Stratigraphic Section C-15, Appendix) and reports that the basal 398 feet resembles Blacksmith lithology, while the uppermost 1,480 feet resembles Bloomington lithology.

Nounan Formation

**Distribution and Thickness:** - The Nounan formation is abundantly exposed in the southern one-third of the Promontory Range. Only one complete section is present, however, along the east ridge of Maple Canyon south of the Narrows where complex, small-scale faulting renders any measurement questionable. Here, between a poor and highly questionable basal contact and a good upper contact, 2,180 feet were measured.

More extensive exposures are present along the west wall of Maple Canyon which is made up almost entirely of the Nounan formation. Here it is much better exposed than anywhere in the Promontory Range, but unfortunately the top is nowhere exposed. This outcrop runs from the head of the North Fork of Little Valley northward with minor faulting to the Promontory fault in
Whitaker Pass and is believed very nearly to represent a complete section of the Nounan formation.

The Nounan formation also constitutes most of the north side of Black Mountain; but here incompletely understood faulting and excessive tree cover render its study difficult and this is the poorest of the three major outcrops.

Along the ridge crest between Miller and North Canyons east of the Indian Caves, a small outcrop of the Nounan formation occurs in the upper plate of a large overthrust fault. Less than a 200-foot stratigraphic interval is present here due to erosion, but its presence and distinctive lithology were very important in determining the structural geology of the area because of a dearth of fossils in the upper plate of the thrust fault.

**Topographic Expression:** - The Nounan formation is typically a ledge-former wherever present, but locally forms well-defined dip slopes such as on the north slope of Black Mountain and the west wall of Maple Canyon. It is characterized by many covered intervals between the massive ledges of dolomite and limestone which represent shale members or carbonate rock with abundant argillaceous intercalations. The massive ledges may form fairly precipitous cliffs but these are rarely very thick, as are for example, the cliffs of Laketown dolomite on Mt. Baldy.

**Lithology:** - The Nounan formation has an extremely heterogeneous lithologic composition, consisting of limestone and dolomite with relatively minor amounts of siltstone and mudstone.

Dolomite as distinguished by acid tests, is by far more abundant than
any other lithology in the Nounan formation. Of the total amount of carbonate strata in the Nounan formation, dolomite constitutes over 70 per cent and limestone makes up the remainder. The texture of the dolomite varies greatly, but the color is fairly consistent; most of the dolomite is silvery gray to gray and weathers light gray to gray, locally light bluish-gray. The light colors of the dolomites of the Nounan formation distinguish it from the underlying Marjum formation and overlying St. Charles formation, both of which weather considerably darker.

The limestone of the Nounan formation is generally microcrystalline to finely crystalline. Its color ranges from gray to dark gray and the weathered surfaces are much darker than those of the dolomite. Much of the limestone strongly resembles dolomite and an acid test is necessary to distinguish between them.

Siltstone and mudstone constitute at the most 10 percent of the Nounan formation. They are generally represented by concealed intervals which betray the buried lithology only through the presence of scattered flakes or chips of siltstone and mudstone. A "banded limestone" unit about 150 feet thick has its upper contact 520 feet below the top of the Nounan formation along the east wall of Maple Canyon. Siltstone laminae with maximum thickness of one-fourth inch are parallel to bedding and separated by one inch thick limestone beds. These laminae are more resistant to erosion than the intervening limestone beds and stand out in sharp relief as "ribs" along weathered surfaces. This "banded limestone" unit strongly resembles similar units in the basal half of the Marjum formation.
Age and Correlation: - The Nounan formation is probably almost entirely Upper Cambrian. No identifiable fossils have been found in the basal 795 feet of the Nounan formation in the Promontory Range, and the Upper Cambrian - Middle Cambrian boundary is arbitrarily placed at the Nounan-Marjum contact. It is realized, however, that some of the basal 795 feet of the Marjum formation may be of Middle Cambrian age. The lithology of the Nounan formation in the Promontory Range seems to preclude the discovery of good faunas, but detailed paleontological field work may be able to date the basal portion of the formation.

The Nounan formation of the Promontory Range is correlated directly with the Nounan formation of the Logan quadrangle, Utah. The strength of this correlation, however, lies mainly on lithology and stratigraphic position, rather than on faunal evidence. With present evidence no attempt is made to correlate to the southwest; such correlation would require an extremely detailed regional study.

St. Charles Dolomite

Distribution and Thickness: - The St. Charles dolomite, referred to elsewhere in northern Utah as the St. Charles formation, is well exposed in the Promontory Range at only one locality, along the east ridge of Maple Canyon south of The Narrows, where it is 1,160 feet thick. This includes its basal member, the 80-foot thick Worm Creek quartzite member which has not been found elsewhere in the Promontory Range. This is the only complete section of the St. Charles dolomite known in the range, and the accuracy of stratigraphic measurement is affected slightly by some small faults and the
necessity of frequently offsetting the line of section.

Other exposures of the St. Charles dolomite are on the south end of Little Mountain and at the head of Middle Canyon east of the Promontory fault, with the latter by far the poorest having only the uppermost 360 feet present. At both of these localities the upper contact is present but concealed and the lower contact has been eroded or faulted out. The St. Charles dolomite is easily the worst exposed and most poorly represented Cambrian formation in the Promontory Range.

Topographic Expression: - The St. Charles dolomite commonly crops out as a series of prominent hogback- or cuesta-forming ledges separated by relatively minor concealed intervals. On the south end of Little Mountain an extensive exposure of what is thought to be the St. Charles dolomite is very well exposed, but alteration and brecciation have altered its appearance and rendered it extremely atypical.

Lithology: - The St. Charles dolomite is composed entirely of dolomite except for the basal Worm Creek quartzite member and a 75 foot thick limestone interval which rests directly on the Worm Creek quartzite member. The Worm Creek quartzite member consists of quartzite, calcareous orthoquartzite, sandstone and shale. The basal 11 feet has interbedded quartzite and quartzitic sandstone; both are white and very fine-grained, but the quartzite weathers white and the quartzitic sandstone, which is largely cemented by calcareous material, weathers tan to light brown. The two lithologies are intimately interbedded and the white-weathering quartzite stands out in sharp contrast with the dark-weathering quartzitic sandstone.
Above this are 18 feet of white, very fine-grained calcareous orthoquartzite, which weathers tan to light brown and on outward appearance resembles dolomite. This grades into a 31-foot thick sequence of alternating quartzitic sandstone and quartzite which are fine-grained and intensely limonitic on both fresh and weathered surfaces. The uppermost unit is a 20 foot thick shale with one thin quartzite bed in it. The shale is dark tan, highly argillaceous and only slightly silty, extremely fissile, and has pronounced platy bedding.

Above the Worm Creek quartzite member are two limestone units which form a prominent cuesta and dip slope. The weathered color of these limestones is lighter than most of the overlying dolomite in the St. Charles dolomite.

The uppermost 1,005 feet of the St. Charles dolomite are entirely dolomite, which occurs as interbedded light gray and dark gray weathering units. Most of the dolomite is finely crystalline and has a "silvery" appearance on fresh surfaces. The weathered surfaces commonly have a "sandy" texture which is caused by differential solution of the crystalline texture; there are no included clastic grains in the dolomite. The dolomite is very thick-bedded; beds less than two feet thick are rare.

Age and Correlation: - The St. Charles dolomite is known to be Upper Cambrian, because the underlying Nounan formation is Upper Cambrian and the overlying Garden City formation is well established as Lower Orodovician. In the Promontory Range fossils have been found only in the basal 130 feet of the St. Charles dolomite in the limestone interval which lies between
the basal Worm Creek quartzite member and the lowermost massive dolomite.

Correlation is made directly with the St. Charles formation of the Logan quadrangle, Utah. Whereas considerable doubt is connected with the correlation of the underlying Nounan formation, the correlation of the St. Charles dolomite is confidently established due to the presence of the basal Worm Creek quartzite member and the overlying Garden City formation. With present evidence no attempt is made to correlate the St. Charles dolomite of the Promontory Range with stratigraphic units to the southwest; such correlation would require an extremely detailed regional study.

Stratigraphic Correlation and Terminology

The Promontory Point area has long been believed to hold the key to the relationships between the Cambrian of the Great Basin and the Cambrian of the classic Logan-Blacksmith Fork area. The current study has indicated that there is more likely an interfingering of the formations of these two areas in the vicinity of Promontory Point, rather than a zone of northeasterly progressive lithologic transition.

The Lower Cambrian offers no problems in correlation for there are similar formations to the west, south, and east. The main problem lies in definitely establishing a Lower Cambrian age by faunal evidence, but the writer was unable to do this.

The Middle Cambrian is correlated directly with the House Range section, which is probably the most complete Cambrian section in the Great Basin. The correlation of all Middle Cambrian formations seems well established, with the exception of the uppermost formation, the Marjum limestone. This
unit, particularly in its upper portion, strongly resembles the Bloomington formation of the Logan quadrangle. The writer would not debate the choice of the name "Marjum limestone" for this formation with those who wished to use "Bloomington formation", except to point out that the two shale members which are so well developed in the Bloomington formation of the Logan quadrangle are here completely absent.

The Upper Cambrian is correlated directly with the Logan quadrangle. The name "St. Charles dolomite" is applied with much more certainty than "Nounan formation", but both designations are certainly valid.

To the writer's knowledge this is the only instance in which the Cambrian stratigraphic terminologies of the House Range and the Logan quadrangle have been extensively combined and utilized in one area. Clearly, the final solution will hinge upon regional work both from northeastern Utah and from the eastern Great Basin embracing a detailed study of the Promontory Point area.
The Ordovician system in the Promontory Range consists of three formations; the Garden City formation, the Swan Peak formation, and the Fish Haven dolomite (in ascending order). The system is best exposed on the western side of the outlying mountain\(^1\) north of the Old Fort Ranch where a thickness of 2,992 feet was measured (see Figure 4). Here, the base of the Garden City formation is not exposed; thus the aforementioned thickness is a minimum for this specific locality. Elsewhere in the range Ordovician strata are thinner and, although some of this thinning may be due to the intense brecciation associated with these poorer exposures, it is postulated that Middle and Upper Ordovician beds gradually thinned toward the south (see "Middle Paleozoic Tectonics"). Ordovician formations are found on Mt. Baldy, at the head of Owens Canyon, in a small fault sliver west of Sandy Pass between Miller Canyon and Middle Canyon, on the outlying Little Mountain along the eastern side of the range, at the head of Middle Canyon and at The Narrows northeast of Maple Canyon. The Ordovician system constitutes only a small portion of the exposed bedrock of the Promontory Range and nowhere is it entirely present at any one locality.

1. This mountain which has previously been unnamed, is here named "Mt. Baldy" by the writer.
Garden City Formation

Distribution and Thickness: - The Garden City formation is best exposed on the western slopes of Mt. Baldy and at The Narrows about 10 miles north of Promontory Point on the eastern side of the range, with the former being the better or more complete exposure. At no one place within the Promontory Range is the Garden City formation present in its entirety. On the north side of Middle Canyon, just east of the Promontory fault, both the lower
and upper contacts of the Garden City formation are probably present, but the rocks are so brecciated due to their proximity to a major fault that measurements are not reliable; for large portions of the formation may be absent due to widespread small-scale block faulting. This locality is unique in the Promontory Range in that both the lower and upper contacts of the Garden City formation are present.

Along the westward trending spurs at the base of the western slope of Mt. Baldy, the Garden City formation was measured as 1,169 feet thick. This is the maximum development of the Garden City formation within the Promontory Range. Hintze (1951) measured 1,472 feet nearby, but the difference between these figures may probably be ascribed to the choice of a lower limit for each of the stratigraphic sections, where poorly exposed strata and float blocks are almost completely blanketed by sediments of Lake Bonneville. At this locality, and nowhere else in the range, the contact with the overlying Swan Peak formation is generally very well exposed.

The Garden City formation is also present on Little Mountain, at The Narrows, and in a small fault block west of Sandy Pass between Miller Canyon and Middle Canyon. Nowhere in the Promontory Range is the basal contact with the underlying St. Charles dolomite well exposed, although it is present at several localities. A considerable covered interval is everywhere present between the uppermost ledges of the St. Charles dolomite and the lowest limestone beds of the Garden City formation.

**Topographic Expression:** - The Garden City formation is a consistent, gentle slope-former. It does not form undulating topography. Locally,
resistant beds of the upper two lithologic members may form prominent cuestas or hogbacks, such as those at The Narrows.

**Lithology:** The Garden City formation may be subdivided into three distinct lithologic units which persist throughout its known extent in the Promontory Range.

The basal unit ranges in thickness from 560 feet at The Narrows to between 635 and 750 feet on Mt. Baldy and consists of a light bluish-gray weathering limestone with very thin light brown seams of well indurated muddy limestone (see Figure 5). The limestone is uniformly finely crystalline and has very homogenous lithology throughout. The argillaceous seams weather dull light brown to tan and are accentuated on weathered surfaces due to differential resistance. They stand out in bas-relief fashion from the less resistant limestone at depths up to \( \frac{1}{4} \) inch and are characterized by uniform limonite staining whereas the non-argillaceous limestone is free of such stain. Along joint surfaces the argillaceous seams have planar surfaces while the intervening limestone has been dissolved to very uneven surfaces. On fresh surfaces the argillaceous seams are relatively inconspicuous and only slightly limonite-stained; thus indicating that their prominent surficial expression is due to differential resistance to weathering processes. Although generally parallel to bedding, many of the seams diverge from this attitude. At several localities the argillaceous seams display planar cracks at high angles to bedding and these are interpreted to be shear surfaces. The occurrence of the argillaceous seams is sporadic at best. Individual seams are from 1/8 inch to

- 82 -
1/4 inch thick and may occur singly or as clusters. Generally this lowermost lithologic member is characterized by approximately equal thicknesses of limestone with intercalated argillaceous seams and limestone free of such intercalations. Intervals within this member up to 50 feet thick have none of these partings, but generally they are more or less omnipresent. This gives the entire member a very prominent "banded" appearance. Its lithology and appearance are everywhere the same and there is no other similar

Figure 5. Lowermost lithologic unit of the Garden City formation. Dark argillaceous seams stand out in bas-relief fashion from the less resistant, lighter-colored limestone.
lithologic unit in the Promontory Range.

The middle lithologic unit of the Garden City formation consists of massive limestone beds, which stand out as massive ledges separated by covered intervals. The thickness of this unit does not vary as greatly as that of the lowermost unit, being 317 feet thick at The Narrows and between 230 and 345 feet thick on Mt. Baldy. The limestone weathers dark blue-gray and is generally about the same color on fresh surfaces. Although the color of this massive limestone varies considerably, it is everywhere much darker than the underlying basal lithologic unit. Black chert is present as nodules elongated parallel to bedding up to three inches thick and five feet long, but generally much smaller. The limestone is more coarsely crystalline than that of the lowermost unit and is characterized by locally abundant disseminated concentrations of hematite. Although the entire unit tends toward massiveness, some ledges display parallel beds one to two feet thick. This middle unit differs from the lowermost unit of the Garden City formation in its massive to thick-bedded habit, a complete lack of the light brown argillaceous seams, presence of disseminated hematite and abundant black chert, and its tendency to form cliffs.

The uppermost lithologic unit of the Garden City formation is about 200 feet thick and is entirely present only on the southwestern slopes of Mt. Baldy. It consists of massive, dark gray to dark bluish-gray, finely crystalline dolomite which weathers dirty gray or grayish-tan. There is commonly a pronounced color change between fresh and weathered surfaces. The upper 10 to 20 feet are commonly thick-bedded, parallel beds ranging six inches to two feet thick, but below this there is seldom a trace of bedding.
surfaces. Hematite grains are locally abundant, but no chert has been observed in this unit. Ross (1951, pp. 8-9) states that a zone of "rather coarsely crystalline dolomite was found at the very top of the formation at all localities studied -" and has proved that this is due to secondary dolomitization, generally in close proximity to zones of faulting. This may also be true in the Promontory Range, but nowhere has the author found limestone at the top of the Garden City formation. If there has been secondary dolomitization, this replacement is quite complete.

Age and Correlation: - The lowermost lithologic unit contains a prolific trilobite fauna with well-preserved forms found throughout most of its stratigraphic interval. Hintze (1951, pp. 94-96, and 1952) has studied and described this fauna in great detail and the writer has not attempted any further work along these lines. Hintze (1951, pg. 93) further states that on Mt. Baldy "the upper half of the Garden City formation is well displayed", but from a study of all other outcrops of this formation in the Promontory Range, it seems to the writer that nearly all of the Garden City formation is displayed at this locality.

Aside from the abundant trilobite fauna, the only fossils found in the lowermost lithologic unit are rare, questionable graptolite remains which are not identifiable. The upper two lithologic units of the Garden City formation have yielded no fossils.

The Lower Ordovician age assigned to the lowermost lithologic unit by Hintze is tentatively assigned by the present writer to the entire formation. Ross (1951, pg. 6) found that the lithologic boundary between the
uppermost dolomite of the St. Charles formation and the lowest limestone beds of the Garden City formation in the Logan quadrangle coincides with the fossil evidence for the Cambrian-Ordovician systemic boundary. A paucity of fossils in the St. Charles dolomite of the Promontory Range makes such a determination extremely difficult, but the close proximity to the Logan quadrangle suggests that a similar age relationship may exist in the Promontory Range.

The Garden City formation is conformable with the underlying St. Charles dolomite and the overlying Swan Peak formation at all localities studied by the author. It may be confidently correlated with the Garden City formation to the northeast and southwest and is the lithologic and stratigraphic equivalent of the Pogonip group, which is widespread in eastern Nevada and western Utah.

Swan Peak Formation

**Distribution and Thickness:** The Swan Peak formation is best exposed on the western slopes of Mt. Baldy where it is 804 feet thick. Webb (1956, pg. 68) measured 711 feet nearby. This is by far the maximum development of the Swan Peak formation within the Promontory Range and is the only exposure with well defined lower and upper contacts; all other exposures are very incomplete.

Near the head of Middle Canyon and east of the Promontory fault 275 feet of the Swan Peak formation are exposed, but the intense brecciation and lack of a definite bottom contact render this measurement somewhat questionable. This exposure, however, along with others, clearly shows
that the Swan Peak formation thins noticeably southward and eastward from the exposure at Mt. Baldy.

Other less complete exposures of the Swan Peak formation are found near the head of Owens Canyon, near the mouths of Middle Canyon and North Canyon, and on Little Mountain. The last-mentioned occurrence is in the intensely brecciated region and is extremely atypical.

The Swan Peak formation is very susceptible to brecciation and in structurally complex areas measurements of its thickness are unreliable.

**Topographic Expression:** The Swan Peak formation varies considerably in topographic expression. On Mt. Baldy the quartzite forms towering, almost vertical cliffs above the gently flaring aprons formed by the underlying shale unit. Elsewhere in the Promontory Range the Swan Peak formation has a more suppressed topography, generally forming rounded ledges and where intensely brecciated may even form depressions, probably due to wind and water action on weakly cemented rock. An example of such a depression is the saddle in Whitaker Pass just north of the Promontory fault.

**Lithology:** The Swan Peak formation may be divided into two distinct lithologic units - a lower shale unit and an upper quartzite unit. The shale has been found only on Mt. Baldy; at all other localities in the Promontory Range where the Swan Peak formation has been noted only the quartzite unit is present or exposed. The shale unit may be as thick as 295 feet, of which the uppermost 200 feet are commonly completely concealed by huge talus blocks of quartzite derived from the upper member.
The basal bed of the shale unit is a 15-foot thick ledge of calcareous orthoquartzite, which is dark gray to gray, very fine-grained, and weathers to an extremely prominent dark brown or reddish-brown. It is slightly calcareous on fresh surfaces, but the weathered surfaces have had the calcareous material etched out and removed and are intensely stained by iron oxides which form a 1/16 inch thick "rind" around the fresh unaltered rock. This blocky-weathering, prominent unit stands out distinctly between slopes above and below and serves as an excellent marker for mapping the Garden City formation - Swan Peak formation contact on aerial photographs.

The remainder of the shale unit is not very well exposed, particularly the uppermost 200 feet which are generally completely concealed by huge quartzite talus blocks up to six feet long on a side. The basal 75 feet of this shale unit have little argillaceous shale except near the top, but this interval is characterized by a pervasive shaly habit. Most of the unit consists of platy, impure limestone beds approximately ½ inch thick which undulate markedly in thickness. This limestone is dark bluish-gray, finely to medium crystalline, weathers dirty gray to light brown, and commonly has a "sandy" texture on weathered surfaces. This basal 75 foot interval has yielded the only fossils found in the Swan Peak formation of the Promontory Range.

The quartzite unit was measured by Webb (1956, pg. 68) as 525 feet thick and by the writer as 509 feet thick. This is excellent agreement in view of the obscuring of the basal contact by large talus piles. The quartzite is white to tan or light brown, but may be locally varicolored, and the texture is uniformly very fine-grained to fine-grained. The
weathered color is generally reddish-brown to orange, although locally the uppermost two-fifths of the quartzite weathers white and is distinguished from the quartzite below by its complete massiveness. Cross-bedding was rarely observed in the quartzite of the Swan Peak formation. Fortunately, wherever the Swan Peak formation is exposed in the Promontory Range it is a recognizable part of a well established Ordovician sequence and can be readily identified by its lithology and stratigraphic position combined; otherwise there might be some confusion with the Prospect Mountain quartzite and certain quartzites of the Precambrian.

**Age and Correlation:** - The age of the Swan Peak formation is known to be Middle Ordovician. In the Promontory Range fossils have been found only in the basal 75 feet or so of the shale unit. Dr. G. Arthur Cooper has identified the following from this brief stratigraphic interval,

- *Anomalorthis utahensis*
- *Orthambonites michaelis*
- *Orthambonites* sp.
- *Orthidiella* ? sp.
- *Receptaculites* sp.

The basal contact with the Garden City formation is not exposed and the upper contact with the Fish Haven dolomite is extremely unusual. This latter contact will be discussed under the heading "Fish Haven dolomite".

Correlation is made directly with the Swan Peak formation of the Logan quadrangle, Utah. This formation has also been recognized to the southeast, south, southwest and west of the Promontory Range. The writer doubts that
the Eureka quartzite is present in the Promontory Range.

Fish Haven Dolomite

**Distribution and Thickness:** The Fish Haven dolomite is best exposed on the western and southeastern slopes of Mt. Baldy. The former exposure has been measured as 984 feet thick, but it is extremely probable that the Fish Haven dolomite is in fault contact with the underlying Swan Peak formation at this locality because of the local absence of the "reworked zone" which is generally present at the base of the Fish Haven dolomite and because of the brecciation of the uppermost portion of the Swan Peak formation. The displacements of these minor strike faults are generally very small, probably nowhere exceeding 50 feet, and as there is no discordance in bedding attitude on opposite sides of the fault, they would scarcely be detectable except for the absence of the "reworked zone" and the attending brecciation. A composite stratigraphic section arrived at by combining the above mentioned section minus its lowermost stratigraphic unit with the lowermost stratigraphic unit measured on the southeastern slope of Mt. Baldy results in a thickness of 1,019 feet. It is safe to state that the maximum thickness of the Fish Haven dolomite in the Promontory Range is somewhere between 984 feet and 1,019 feet.

Near the head of Middle Canyon and east of the Promontory fault 168 feet of the Fish Haven dolomite have been measured. The formation is well displayed with a clearly exposed lower contact and an arbitrarily placed upper contact. It has not been as intensely brecciated as the underlying Swan Peak formation and thus, if the upper contact is correctly placed,
this is probably a reliable measurement.

The Fish Haven dolomite also crops out extensively near the head of Owens Canyon, to a lesser degree on Little Mountain, and in a small fault block between Miller Canyon and Middle Canyon on the western side of the Promontory Range.

The large discrepancies in thicknesses of measured stratigraphic sections of the Fish Haven dolomite in the Promontory Range are doubtless due in large part to the arbitrary placement of the upper contact. It is doubtful that this contact as chosen on Mt. Baldy represents the same datum plane timewise as that contact as chosen near the head of Middle Canyon.

The placement of the Fish Haven dolomite - Laketown dolomite contact is a major problem throughout the northern Utah - southeastern Idaho area. If Richardson's original lithologic descriptions (1913, pg. 410) were to be followed, this formational contact should be placed at the top of unit #2 of Stratigraphic Section 0-8 (see Appendix); consequently the Fish Haven dolomite would be 158 feet thick and the overlying Laketown dolomite would be 1,618 feet thick. This agrees well with respective thicknesses of 140 feet and 1,500 feet in the Logan (Utah) quadrangle as given by Williams (1948, pg. 1137) and with thicknesses for the Laketown dolomite ranging 1,150 - 2,000 feet in northern Utah and southeastern Idaho as given by Stokes (1953). However, coralline fossils collected approximately 100 feet stratigraphically above the top of unit #2 have been determined by Miss Jean Berdan as Upper Ordovician in age. Richardson (1913, pg. 410) "proposed to restrict the name Laketown dolomite to beds
of Silurian age." It is generally thought that the Fish Haven dolomite represents a portion of Late Ordovician time and the Laketown dolomite was deposited completely within the Middle Silurian. Within the 1,776 feet thick stratigraphic interval represented by the combined Fish Haven dolomite - Laketown dolomite there are only two mappable lithologic breaks: (1) the one previously described at the top of unit #2 (Stratigraphic Section 0-8), and (2) the one situated at the top of unit #8 of Stratigraphic Section 0-9 as well as at the base of unit #1 of Stratigraphic Section S-1.

The first possible contact is at a color change with a uniform dark gray to blackish-gray dolomite below and alternating light gray and dark gray dolomite above. This color break is not accompanied by a visible disconformity and it seems improbable to assume that it could represent a period of cessation of deposition of millions of years. The second possibility seems more plausible, for it not only separates an underlying predominantly dark gray dolomite sequence from an overlying predominantly light gray dolomite sequence, but is a visible disconformity. At every locality where it was studied, this clear-cut color break consists of a gently undulate surface with six inches to one foot of local stratigraphic relief.

Clearly, an accurate well-substantiated placement of the Fish Haven dolomite-Laketown dolomite contact will require more complete paleontological evidence and regional study.

Topographic Expression: - On Mt. Baldy the Fish Haven dolomite forms gentle to steep ledges above the cliff-forming Swan Peak formation. Its
topographic expression is subdued compared to the generally precipitous cliffs of the underlying Swan Peak formation and the somewhat more rugged cliff-and-ledge topography of the overlying Laketown dolomite. Elsewhere, the Fish Haven dolomite forms even more subdued topography, characterized by thin ledges separated by completely concealed intervals.

**Lithology:** - The Fish Haven dolomite is a fairly homogeneous formation except for the local presence of a thin zone of reworked sand at its base. This sandstone, found only on Mt. Baldy, ranges from 3 feet to 7 feet in thickness, is very fine-grained, well sorted, composed largely of well rounded quartz grains, and is strongly cemented by dolomite. Weathered and fresh surfaces are dull greenish-gray and argillaceous partings less than 1/2 inch thick, parallel to bedding, are locally common. The sandstone probably represents reworked quartzites or sands of the immediately subjacent Swan Peak formation (with very angular grains) and its contacts with the underlying quartzite and overlying dolomite are exceedingly sharp, showing no gradation or transition whatsoever. Traces of dolomite cement in the underlying quartzite or quartz grains in the overlying dolomite are completely absent. The entire sandstone unit is commonly recessed between the more resistant lithologies above and below. It is seldom exposed on cliffs or along the crests of ridges and spurs, for it is generally well concealed by debris; but on dip slopes, where the debris can be washed off the uppermost ledge of the Swan Peak formation by intermittent stream action, the sandstone is very well exposed.

Because of the controversy over the placement of the Fish Haven
dolomite-Laketown dolomite (see above), the basal carbonate unit of the Fish Haven dolomite will be described separately. This unit is an extremely homogeneous, dark gray to blackish-gray, very finely crystalline, spangly dolomite. Characteristic of this unit is the color of its weathered surfaces. This dolomite weathers to a uniform blackish-gray or somewhat similar to the color of gun steel. From the distance the color of this unit is very dark (black to blue-black) compared to the underlying quartzites of the Swan Peak formation and the overlying alternating light gray and dark gray dolomite units, and is generally noticeably darker than any portion of the overlying Fish Haven and Laketown dolomites. This dolomite is commonly characterized by closely spaced furrows normal to bedding, probably caused by solution along microfractures. It is denser than and not as vuggy as the overlying dolomite, although rare vugs partially lined with inward-projecting euhedral limonite-stained quartz crystals are locally present in the lower half of the unit. The upper half of the unit has locally abundant black chert, weathering dark brown, which is present mostly as "plastered" masses along bedding surfaces. This dolomite unit as a whole, however, contains little chert and vugs are rare. Bedding is poorly developed and, where present, beds are generally greater than two feet thick, although some beds are as thin as two to six inches.

The remainder of the Fish Haven dolomite above the basal dolomite unit consists of alternating light gray and dark gray dolomite, with the darker color predominating (see Stratigraphic Section 0-9, Appendix). This portion of the Fish Haven dolomite is characteristically either massive or blocky very thick-bedded and the lithology may vary laterally unlike the basal unit
described above. The thicknesses of the seven light gray, dark gray, and "banded" dolomite units range from a minimum of 31 feet to a maximum of 438 feet. The seven recognizable lithologic units consist of light gray and dark gray dolomite units interbedded with "banded" dolomite units in which thin bands of light gray and dark gray dolomite alternate; no limestone was observed. The texture of the dolomite varies from microcrystalline to finely crystalline and all color shades of the dolomite tend to weather somewhat lighter than their actual color. Except for local concentrations, chert is only sparsely present in the Fish Haven dolomite and vugs, particularly those filled with quartz crystals, are rare compared with the overlying Laketown dolomite. The "sandy" texture of weathered surfaces, so common in the Laketown dolomite, is very rare in the Fish Haven dolomite. The individual lithologic units of the Fish Haven dolomite are on the whole more persistent laterally than those of the Laketown dolomite.

**Age and Correlation:** The Fish Haven dolomite has been dated throughout northern Utah and southeastern Idaho as Upper Ordovician. The following fossils have been collected, mostly from the basal portion of the formation, and have been identified by Miss Jean Berdan.

- *Calapoecia* ? sp.
- *Catenipora* sp.
- *Heliolites* ? sp.
- *Palaeophyllum* ? sp.
- *Streptelasma* ? sp.
Pervasive dolomitization has rendered almost all of these forms indeterminate and little hope is held by the writer for definite paleontological dating of the Fish Haven dolomite in the Promontory Range.

The contact between the Fish Haven dolomite and the underlying Swan Peak formation probably represents a disconformity. Evidence for this relationship is the local presence of a reworked sandstone at the base plus the relationships in nearby areas, particularly northeastern Utah, where the Fish Haven dolomite rests in places directly upon the Garden City formation. The contact with the overlying Laketown dolomite is also a disconformity as evidenced by the undulatory character of the contact plus the fact that Silurian fossils have never been found in the Fish Haven dolomite and Early Silurian forms are unknown in the Laketown dolomite of northeastern Utah. Correlation is made directly with the Fish Haven dolomite of the Logan quadrangle to the northeast. The formation has also been widely recognized to the south, southwest and west of the Promontory Range.

Stratigraphic Correlation and Terminology

Problems in correlating the Ordovician system of the Promontory Range with nearby areas are few. With the sole exception of determining whether or not the Eureka quartzite is present, correlation of the three Ordovician formations is easily made with areas to the northeast, southwest and west. The same sequence of formations completely surrounds the Promontory Range except, of course, in areas to the east, southeast and south where the Ordovician system is either totally absent or very poorly represented.
SILURIAN STRATIGRAPHY

General Statement

The Silurian system in the Promontory Range is represented by one formation, the Laketown dolomite. This formation crops out over only a small portion of the mapped area. The Silurian system is by far the least important of the geologic systems present in the Promontory Range.

Laketown Dolomite

Distribution and Thickness: The Laketown dolomite is best exposed on Mt. Baldy, north of the Old Fort Ranch on the west side of the range, where together with the Fish Haven dolomite it constitutes most of the mass of this mountainous outlier. At this locality the Laketown dolomite is 757 feet thick. As stated in the discussion of the Fish Haven dolomite there is considerable doubt concerning the placement of the Fish Haven-Laketown contact. If the contact is placed at the top of the basal dolomite unit of the Fish Haven dolomite, the Laketown dolomite is 1,618 feet thick, a composite measurement derived by combining two measured sections.

Near the head of Middle Canyon and east of the Promontory fault the Laketown dolomite is entirely present but poorly exposed. Neither contact is visible, but unlike the exposures at Whitaker Pass the dolomite has not been brecciated by the nearby Promontory fault. An estimated thickness of 530 feet has been obtained by scaling on aerial photographs and geometrical calculations. Despite this lack of an accurate stratigraphic measurement, it may be stated with certainty that the Laketown dolomite thins noticeably to the south in the Promontory Range.
Poorer exposures of the Laketown dolomite are present near the head of Owens Canyon, in the small fault block between Miller Canyon and Middle Canyon, and on Little Mountain. At the last two localities brecciation and alteration combine to render the formation almost unrecognizable. Immediately north of the dwellings at the Old Fort Ranch an outlying mass of Laketown dolomite has been downfaulted from Mt. Baldy to the northeast. This exposure was not studied in detail because of the proximity to the excellent section on Mt. Baldy.

Along the western side of the Promontory Range between Staples Flats and the Indian Caves the Laketown dolomite is not mapped separately but is grouped with other dolomite units because of the pervasive metamorphism which has destroyed paleontological proof for the presence of various individual formations in the lower plate of the Indian Caves overthrust.

Topographic Expression: On Mt. Baldy the Laketown dolomite is characteristically massive, forming sheer precipices and steep to vertical ledges. Sharp, tall, needle-like spires are common along the crests of ridges where solution has been active along fractures. At this locality the Laketown dolomite forms perhaps the most rugged topography in the Promontory Range. It stands out in sharp contrast with the underlying Fish Haven dolomite and the overlying Water Canyon dolomite which are both relatively gentle ledge-and-slope formers.

Elsewhere in the range the Laketown dolomite forms more subdued topography, much like the ledge-and-slope topography formed by the Water Canyon dolomite.
Lithology: - The lithology of the Laketown dolomite is best studied on Mt. Baldy, for this is the only locality in the Promontory Range where it is well exposed and unbrecciated. It consists of alternating light gray and dark gray dolomite units ranging from a minimum thickness of 53 feet to a maximum thickness of 429 feet, with the light gray color markedly predominant. Five lithologic units are recognized in the Laketown dolomite at this locality along the only measured complete section, but the lateral extent of these units is highly uncertain. The five units are similar lithologically and with one exception, a cherty dolomite unit, are differentiated solely on color.

No limestone has been noted in the Laketown dolomite. The texture varies somewhat (microcrystalline to finely crystalline) throughout the formation as does the color; thus the Laketown dolomite, with heterogeneous lithology, stands out prominently below the homogeneous Water Canyon dolomite. The light gray or gray dolomite units generally weather lighter, to a whitish-gray. The dark gray dolomite units also weather lighter, but most remain various shades of dark gray.

Chert is locally abundant in the Laketown dolomite with one stratigraphic interval of about 70 feet being composed mainly of black chert, probably a bedding replacement phenomenon. Some of the individual lithologic units are free of chert, but most contain black, brown, or gray chert in varying quantities present as nodules or as "stringers" filling tiny fractures. Small vugs, commonly less than ½ inch in diameter, are locally abundant and these are generally filled either by tiny, euhedral, clear quartz crystals projecting inward from the vug walls or by massive white quartz stained brown.
by limonite. The Laketown dolomite as a whole is more vuggy than the dolomite formations above and below. Much of the most coarsely crystalline dolomite weathers to surfaces with sandstone-like textures, but acid etching of hand specimens discloses no arenaceous content in the Laketown dolomite and the phenomenon is ascribed to selective etching of dolomite crystals by weathering processes or possible removal of calcite.

The heterogeneity of the formation is expressed both laterally and vertically. Many of the lithologic units which are differentiated by color are not laterally persistent and such features as chert and quartz are certainly not omnipresent throughout the extent of laterally traceable lithologic units. This heterogenous character is one of the most characteristic differences between the Laketown dolomite and the dolomite formations which underlie and overlie it.

Age and Correlation: - The Laketown dolomite has been dated throughout northern Utah and southeastern Idaho as Middle Silurian. The presence of Upper Silurian fossils in western Utah and eastern Nevada has been reported by Waite (1956), but none have been found in the Promontory Range. The following fossils collected from the Laketown dolomite have been identified by Miss Jean Berdan.

Halysites sp.

Halysites (Halysites) sp.

Halysites (Halysites ?) sp. ("probably a different species")

As with the Fish Haven dolomite, pervasive dolomitization has rendered most fossil forms indeterminate and the possibility of definitive paleontological
dating of the Laketown dolomite in the Promontory Range seems slight.

The contact with the underlying Fish Haven dolomite is one of disconformity as discussed previously. The contact with the overlying Water Canyon dolomite must also be a disconformity although, unlike the basal contact, there is no sharp break nor is the contact undulatory. Evidence from nearby areas, however, indicates that Upper Silurian strata are probably completely absent between the Laketown dolomite and the Water Canyon dolomite. Correlation is made directly with the Laketown dolomite of the Logan (Utah) quadrangle to the northeast. The formation has also been widely recognized to the south, southwest and west of the Promontory Range.
DEVONIAN STRATIGRAPHY

General Statement

The Devonian system in the Promontory Range consists of two formations, the Water Canyon dolomite and the Jefferson formation (in ascending order), and with extremely minor exceptions is entirely dolomite. The best exposures are on Mt. Baldy along the western side of the range between Owens and Broadmouth Canyons, and at the head of Middle Canyon where the system is bounded by the Promontory and Middle Canyon faults. The latter is the thickest and best exposure, although it is somewhat brecciated and concealed. The maximum thickness of the Devonian system is 1,576 feet at the head of Middle Canyon where the overlying Mississippian strata have been eroded, and the minimum thickness is 497 feet on Mt. Baldy where the Jefferson formation is absent. This thinning to the north is thought to be partially erosional, unlike the thinning to the south in the Ordovician and Silurian which is considered as stratigraphic thinning against an ancient highland. The Devonian system is generally well exposed and easily recognized; and this is fortunate, for the Devonian system has yielded far fewer fossils than any other Paleozoic system. Exposures of this system constitute a small portion of the bedrock of the Promontory Range but are very important for they record a gentle pre-Mississippian uplift (see "Middle Paleozoic Tectoniam"). The total thickness of the Devonian system prior to this pre-Mississippian uplift and erosion must have been much more than the presently exposed maximum thickness of about 1,575 feet.
Water Canyon Dolomite

**Distribution and Thickness:** The Water Canyon dolomite, referred to elsewhere in northern Utah as the Water Canyon formation, is well exposed in two areas in the Promontory Range. On Mt. Baldy it is 497 feet thick, but since the Madison limestone (Lower Mississippian) directly overlies it (see Figure 6), this is obviously an incomplete section. At the head of Middle Canyon 705 feet of the Water Canyon dolomite are present with both contacts exposed. This is a complete section, for it rests upon the Lake-town dolomite and is overlain by the Jefferson formation. Along the western side of the range between Owens and Broadmouth Canyons the Water Canyon dolomite is well exposed and locally both contacts are present. No measurement was made here but it is estimated to be intermediate in thickness between the two previously mentioned figures. The differences in thickness, a pronounced thinning to the north, is ascribed to a gentle pre-Mississippian uplift and erosion (see "Middle Paleozoic Tectonism").

**Topographic Expression:** The Water Canyon dolomite is characteristically a slope-former, but is characterized by a peculiar outcrop habit. The basal portion crops out as many blocky ledges 1'-3' thick, and a combination of planar bedding surfaces and planar vertical joint surfaces give the appearance of a flight of marble steps, such as those in front of public buildings. In the upper portion of the formation this outcrop habit persists, but the individual ledges are thicker (2'-5' thick). Thin covered intervals are common between these blocky ledges throughout the formation. Osmond (1954, pg. 1914) referred to these planar surfaces as "steps and risers", as
on a stairway.

**Lithology:** - The Water Canyon dolomite consists almost entirely of white to light gray, microcrystalline to finely crystalline dolomite, which weathers uniformly to only slightly lighter shades of white and whitish-gray. Although some of the dolomite is microcrystalline, most is very finely crystalline to finely crystalline. Locally there are some thin ledges of dark gray dolomite near the base of the formation, but these are of minor importance compared to the bulk of the lighter-colored dolomite.
The Water Canyon dolomite is very homogeneous except for the presence of quartz crystals and dolomite sand grains. A characteristic of this formation is the presence of tiny vugs which are lined with clear, euhedral quartz crystals projecting inward from the vug walls. The underlying Laketown dolomite also has this feature, but many of the vugs are filled with massive quartz, and none of the latter were found in the Water Canyon dolomite. Locally in the Water Canyon dolomite the quartz crystal-filled vugs are much more abundant than anywhere in the Laketown dolomite and they are generally much smaller (average vug diameter is ¼ inch).

Very fine-grained sandy laminae, selectively stained brown by limonite, stand out prominently on weathered surfaces. The sand grains are composed of dolomite. These sandy laminae are generally cross-bedded at very low angles to bedding and seldom does an individual lamina exceed one centimeter in thickness. As a rule these laminae are more common near the base of the formation than elsewhere. Osmond (1954) describes a widespread arenaceous (quartz sand) member near the top of the Sevy dolomite, which is a correlative of the Water Canyon dolomite, in east-central Nevada. Quartz sand grains are present in the Water Canyon dolomite of the Promontory Range, but to much lesser degree than described by Osmond. They were only observed by the writer in two thin stratigraphic intervals within the Water Canyon dolomite.

The contact between the Water Canyon dolomite and the overlying Jefferson formation is difficult to establish at the head of Middle Canyon (see Stratigraphic Sections D-2 and D-3, Appendix). The uppermost 66 feet of Stratigraphic Section D-2 are mostly concealed, but are assigned to the Water
Canyon dolomite because of the clastic character of the only exposure. Below this is a 57 foot interval of interbedded dark gray and light gray dolomite which is assigned to the Water Canyon dolomite because of a markedly similar outcrop habit. This should be considered a transitional zone between the Water Canyon dolomite and the Jefferson formation. The writer's measured thickness of 705 feet for the Water Canyon dolomite includes both of these intervals. If the Water Canyon dolomite is completely restricted to light-colored dolomite the thickness at this locality would then be 582 feet and if the interbedded interval is included the thickness would be 639 feet.

**Age and Correlation:** - No fossils were found by the writer in the Water Canyon dolomite of the Promontory Range. Fish remains have been discovered in the Water Canyon formation of the Logan quadrangle, Utah; but several diligent searches by the writer unearthed nothing similar in the Promontory Range. Dr. W. L. Stokes (personal communication) was also unsuccessful in his search for fossils in the Water Canyon dolomite outcrops on Mt. Baldy. A Lower (?) Devonian age is speculatively assigned to the Water Canyon dolomite of the Promontory Range.

Correlation is made directly with the Water Canyon formation of the Logan quadrangle, Utah. To the west and southwest a correlation with the Sevy dolomite is probably valid, but it must be remembered that the complete lack of faunal evidence makes any correlation of the Water Canyon dolomite of the Promontory Range with stratigraphic units in other areas highly uncertain.
Jefferson Formation

Distribution and Thickness: The Jefferson formation has a limited area distribution in the Promontory Range; it is not found north of North Chokecherry Canyon nor south of Middle Canyon. North of Owens Canyon on the western side of the range the Jefferson formation has not been distinguished and is mapped as part of a complex of undifferentiated dolomite of unknown age. From immediately south of Owens Canyon to Broadmouth Canyon the Jefferson formation is present as a continuous band. The basal contact with the Water Canyon formation is everywhere present along this outcrop, but because the Jefferson formation is in fault contact with the Oquirrh formation the upper contact of the Jefferson formation is not present.

The only other exposure of readily differentiated Jefferson formation is present along the crest of the range between the Middle Canyon fault and Whitaker Pass. Here on the western flank of the range is the best exposure of the Jefferson formation in the Promontory Range; 871 feet were measured before the section was abandoned on the crest of the range because of excessive concealment and possible structural complications. The writer estimates that an additional 500 feet may be represented by relatively spotty exposures on the eastern flank of the range. The upper contact, as is the case throughout the range, was nowhere observed.

No other stratigraphic sections were measured, for the other exposures are obviously thinner than the section which was measured at the head of Middle Canyon.

Along the southern wall of North Chokecherry Canyon near its mouth, a
small isolated limestone mass is questionably mapped as Madison limestone. Although no fossils were found, the lithology is so similar to typical Madison limestone that this age assignment seems plausible. Physiographic evidence strongly indicates that this bedrock mass is separated from the dolomite to the east by a minor fault, but the contact is concealed in an alluviated saddle and the relationship cannot be proven. If there is no fault, then the Jefferson formation-Madison limestone contact is present.

On Mt. Baldy the Jefferson formation is completely absent and the Madison limestone rests unconformably upon the Water Canyon formation. This is a sedimentary contact; none of the phenomena associated with low-angle overthrusting are present. The absence of the Jefferson formation in the northern portion of the Promontory Range is discussed in detail under the heading "Middle Paleozoic Tectonism".

**Topographic Expression:** - The Jefferson formation is typically a ledge-and-slope former; only at scattered localities does it form very rugged topography. On the south wall of Owens Canyon the Jefferson formation crops out as several thick, almost vertical ledges which are practically unscalable. The other extreme of topographic expression is found at the head of Middle Canyon where the Jefferson formation forms a gentle, fairly smooth slope on which thick dolomite units are expressed as well-rounded ledges.

**Lithology:** - The Jefferson formation is almost entirely dolomite. In the one section which was measured only a few very thin quartzite beds interrupted a monotonous succession of dolomite.

Most of the dolomite weathers dark gray to blackish-gray; but there are
some dolomite units which weather gray or light gray. These lighter weathering dolomites are found only at the top of the thickest stratigraphic sections; for instance, they are not present between Owens Canyon and Broadmouth Canyon. The very dark weathered color of the Jefferson formation contrasts prominently with the very light weathered color of the underlying Water Canyon formation and greatly facilitates the mapping of their common contact.

The dark-colored dolomite is silvery or spangly dark gray, very fine crystalline, and weathers dark gray to blackish-gray. The light-colored dolomite has the same very finely crystalline texture as the dark-colored dolomite, but is generally light gray on fresh surfaces and weathers gray or light gray. This lighter-colored dolomite is only locally prominent near the base of the formation, but is markedly predominant throughout the uppermost one-third of the measured portion of the Jefferson formation.

The quartzite is white to tan, very fine-grained, and weathers tan to pinkish-tan. No quartzite bed greater than one foot thick was seen and the quartzite probably represents less than one percent of the entire formation. However, the presence of the quartzite may be connected with the postulated pre-Mississippian uplift (see "Middle Paleozoic Tectonism").

North of Whitaker Pass some limestone was observed along strike from the measured section to the north, but except for this, no limestone has been noted by the writer in traverses over strata which are known to be part of the Jefferson formation.

Age and Correlation: - No identifiable fossils have been found by the writer in the Jefferson formation of the Promontory Range, and its lithologic
nature makes it highly improbable that any good fossil collections can be made. Some small cup corals have been collected but they were either poorly preserved or have been replaced and cannot be identified.

Correlation is made directly with the Jefferson formation of the Logan quadrangle, Utah to the northeast. Any correlation toward the west and south into the Great Basin would necessarily be extremely tenuous with present evidence, but it is probable that the Jefferson formation of the Promontory Range is the stratigraphic equivalent, in whole or in part, of the Simonson dolomite.

Duncan (1953, pp. 8-9) describes a basal Mississippian dolomite in the central Wasatch Mountains which was originally designated "Jefferson (?)" in U. S. Geological Survey reports but is now believed to be "a facies of the lower Madison". It is possible that the uppermost portion of what the writer considers to be the Jefferson formation may be this basal Mississippian dolomite; but more detailed work must be done to accomplish a definite correlation, for there is not sufficient paleontological evidence at the present time. A small collection of fossil corals was made in Broadmouth Canyon and Dr. Helen O. Duncan reports:

"two colonial corals -- one a Syringopora, the other a Lithostrotionella. The Syringopora ... resembles species commonly found in the Lower Mississippian; it certainly is neither of the two species that occur in the Devonian of the Great Basin. I am identifying your specimen as Syringopora cf. S. surcularia Girty --. As the lithostrotionoids, including Lithostrotionella, did not appear before Carboniferous time, you can safely rule out a Devonian age for this collection. The enclosing strata simply could not be Jefferson."

This collection was made from float, however, and although it seemed certain
in the field that the float must have come from outcrops of the Jefferson formation, there remains the remote possibility that it could have been washed in from nearby Mississippian outcrops.

The Three Forks shale, which lies between the Jefferson dolomite and the Madison limestone in areas to the east and northeast, has not been recognized in the Promontory Range. Its absence may be due either to non-deposition or to pre-Mississippian erosion similar to that of the Jefferson formation and part of the Water Canyon dolomite in the northern portion of the range. No lithologic equivalent of the Guilmette formation has been recognized in the Promontory Range.

Stratigraphic Correlation and Terminology

As is the case with the Cambrian, the Devonian system in the Promontory Range is situated between a well established Great Basin sequence to the west and south and an equally well established sequence to the east and northeast which is best represented in the Logan quadrangle, Utah. The writer chose the latter terminology mainly because of similarity of outcrop habit and general appearance.

The Water Canyon dolomite of the Promontory Range admittedly could just as well be named the Sevy dolomite, but the overlying formation resembles the Jefferson dolomite of the Logan area far more than the Simonson dolomite of the Great Basin province. Lithologic equivalents of the Three Forks shale of the Logan area and the Guilmette formation of the Great Basin province are absent, possibly due to structural omission.

The use of the Logan quadrangle terminology is largely arbitrary and may be discarded by future workers in favor of the Great Basin terminology.
UNDIFFERENTIATED MIDDLE (?) PALEOZOIC STRATIGRAPHY

Two areas of Middle (?) Paleozoic carbonates are undifferentiated on the geologic map between Staples Flat and Middle Canyon on the western side of the Promontory Range.

Undifferentiated Silurian-Devonian

Between North Chokecherry Canyon and the Chokecherry fault a thick sequence of dolomite strata is presumed to be of Silurian and Devonian age. The Fish Haven dolomite is mapped individually where recognizable. Although this sequence is predominantly dolomite, other lithologies are present. Minor amounts of limestone have been noted as well as rare, thin beds of reddish-brown quartzite and tan shale.

The widespread development of irregularly shaped chert growths, particularly along fractures, is characteristic of this dolomite sequence. Chert nodules of several colors are abundant; but white to gray chert nodules, stained dark reddish-brown by iron oxides, are the most prevalent.

Several small faults have been mapped within this sequence, but the structure may be even more complex. The lack of marker beds coupled with the tendency of the dolomite toward lateral color changes renders a complete understanding of the structural complexities practically impossible.

This sequence has not generally been subjected to pervasive alteration as has the lower plate of the Indian Caves overthrust fault. Intense brecciation has been observed only in the southernmost outcrops; this may be due to the proximity of the Chokecherry fault, rather than brecciation along the
sole of an overthrust.

Some doubtful crinoid remains have been collected from this dolomite sequence, but the dolomitization has rendered them indeterminate; none of the fossils collected from the sequence are identifiable. This dolomite sequence is mapped as "Silurian-Devonian undifferentiated".

Lower Plate of the Overthrust Fault

Between the Chokecherry fault and the Middle Canyon fault the lithologies of the lower plate of the Indian Caves overthrust fault are undifferentiated. The dolomites of the lower plate form a heterogeneous mass which is nowhere a cliff-former as is the Marjum formation of the upper plate. No recognizable fossil forms have been found in the lower plate, and the low-grade pervasive metamorphism which probably attended the period of overthrusting makes it highly unlikely that this sequence can be accurately dated by paleontological methods.

Although the major portion (estimated to exceed 95 per cent) of the lower plate is dolomite, other lithologies are present. Minor amounts of limestone, quartzite, and quartzitic sandstone have been noted. The clastic members of the sequence are commonly stained dark brown along bedding and fracture surfaces by iron oxides. One of the quartzite beds, inspected in detail, is greenish-gray on fresh surfaces and is very fine-grained. Much of the limestone observed in the lower plate is "banded" with intercalcated mudstone laminae and greatly resembles the lowermost lithologic unit of the Garden City formation; the limestone is largely confined to the Broadmouth Canyon area.
The major portion of the dolomite in the lower plate of the Indian Caves overthrust fault is light-colored, generally light gray to gray. The dolomite as a rule has been recrystallized, resulting in medium to very coarsely crystalline textures. The carbonate strata of the lower plate have locally been intensely fractured and on weathered surfaces will commonly crumble to the touch. Pervasive iron oxide staining on weathered surfaces is locally present and drab colors, such as tan, prevail on weathered surfaces.

The lower plate is on the whole a nondescript unit and cannot be reconciled in a completely satisfactory manner with any portion of the stratigraphic column of the Promontory Range. On gross composition alone it is most similar to the Upper Ordovician-Middle Devonian stratigraphic interval. It is possible that the lower plate of the Indian Caves overthrust fault is composed of the Middle Paleozoic stratigraphic sequence which is characteristic of the Great Basin to the west. Paddock (1956) has employed such terminology in the Newfoundland Mountains approximately 40 miles to the southwest.
MISSISSIPPIAN STRATIGRAPHY

General Statement

The Mississippian system in the Promontory Range consists of four formations; the Madison limestone, the Deseret limestone, the Humbug formation, and the Great Blue (?) limestone (in ascending order). The Manning Canyon shale bridges the Mississippian-Pennsylvanian systemic boundary and is discussed in a succeeding section. The system is not completely present at any one locality. The lower portion of the system is well represented on Mt. Baldy along the western side of the range and in the Bert horst northwest of the Woodward Ranch. The upper portion of the system (exclusive of the Manning Canyon shale) is present only in the upper part of Miller Canyon between the Broadmouth fault and the Middle Canyon fault.

Complete stratigraphic sections of the Madison limestone and Deseret limestone have been measured, but neither the Humbug formation nor the Great Blue (?) limestone are completely exposed anywhere in the Promontory Range. The Mississippian system is at least 3,350 feet thick; this figure includes two partial thicknesses and one which has been conservatively estimated. The Mississippian system constitutes only a relatively minor portion of the bedrock in the Promontory Range despite its considerable thickness. With the possible exception of the Pennsylvanian-Permian stratigraphic interval, the Mississippian system is the most poorly understood by the writer. Further detailed work is necessary, particularly on the Great Blue (?) limestone.
Madison Limestone

**Distribution and Thickness:** The Madison limestone is well exposed at three localities in the Promontory Range. On Mt. Baldy a thickness of 431 feet was measured and this is the only locality where both formational contacts are present and well exposed. This exposure is significant because the Madison limestone (Lower Mississippian) rests in sedimentary contact on the Water Canyon dolomite (Lower ? Devonian).

The Madison limestone forms the prominent cliffs along the eastern face of a small horst between Chokecherry Canyon and Mountain Springs on the eastern side of the range northwest of the Woodward Ranch. At least 320 feet are well exposed here and the formation may be as thick as 475 feet; but the basal contact is nowhere exposed and the lower portion of the section is obscured by sediments of Lake Bonneville, as well as being structurally complicated by its proximity to a major fault.

A small hill on the northern wall of North Chokecherry Canyon is composed of the Madison limestone, but neither upper nor lower contacts are present. Smaller outcrops to the north and south of here are questionably designated as Madison limestone; although no fossils have been discovered in them, the lithologies of both are very similar to that of known Madison limestone.

**Topographic Expression:** The Madison limestone is a consistent cliff-former throughout its known extent in the Promontory Range. It generally consists of at least four extremely thick, massive cliff-forming ledges separated by relatively thin covered intervals. The topography is thus steep and precipitous, and debris from the overlying Deseret limestone and Humbug
formation render the climbing of these slopes quite arduous. The limestone ledges crop out with uniform thickness persistently throughout the extent of the formation despite the abundant float debris furnished by the overlying formations.

**Lithology:** The Madison limestone is extremely homogeneous, consisting entirely of limestone. This limestone is distinctive from almost all of the other Paleozoic limestones in the Promontory Range; it is black, microcrystalline to very finely crystalline, and weathers either dark gray or bluish-gray. The appearance changes little throughout the extent of the formation.

The base of the Madison limestone has been detected at only one locality, i.e. the southwest slope of Mt. Baldy, where it rests unconformably upon the Water Canyon formation of Lower (?) Devonian age. There is no evident angularity, yet it is probable that at least 950 feet and possibly as much as 1,400 feet of strata are missing (see "Middle Paleozoic Tectonism"). The basal unit of the Madison limestone at this locality is a detrital limestone which ranges from six to eight feet thick. Coarse detrital calcite grains and fossil fragments, mostly crinoid columnals, are cemented by a matrix of coarsely crystalline calcite. No inclusions of the underlying white dolomite of the Water Canyon formation were observed in this unit, which is gray to light gray and weathers the same color.

Black chert nodules are present throughout the Madison limestone, but locally are particularly abundant near the top of the formation. The color and general appearance of this chert are distinctive of the Madison limestone. In the Bert horst the uppermost cliff of the Madison limestone has a large
amount of chert present as nodules and stringers up to six inches thick elongated parallel to bedding. The writer estimates that these stringers may extend laterally as much as 100 feet along outcrop; they are probably bedding replacement phenomena.

Another distinctive characteristic of the Madison limestone is the presence of thin, dark red hematite streaks which generally parallel the bedding surfaces. Much of the Madison limestone possesses a strong fetid odor when broken open. Blocky, parallel bedding is pervasive, but these beds are coalesced to form massive, almost vertical cliffs rather than expressing themselves as thin, distinct ledges. Bedding thickness ranges from two inches to two feet, but thin beds (three to six inches thick) predominate.

The Madison limestone is easily distinguished from the formations above and below by its color, massive outcrop habit, and lithologic purity. When treated with HCl acid an enamel-like surface results and unlike almost all the other limestones in the Promontory Range, exclusive of the Middle Cambrian, no clastic grains become visible on the etched surface. The Madison limestone is probably the most distinctive formation in the Promontory Range.

The basal contact of the Madison limestone reflects a low-angle unconformity (see "Middle Paleozoic Tectonism"), whereas the upper contact with the overlying Deseret-Humbug formation appears to be perfectly conformable.

**Age and Correlation:** Several fossil collections have firmly established the age of the Madison limestone of the Promontory Range as Lower Mississippian.

Mr. Walter Sadlick has identified the following from fossil collections made in the Madison limestone of the Promontory Range:
Aulopora ? sp.
Bairdia ? sp.
Brachythrys ? sp.
Chonetes loganensis
Chonetes ornatus
Composita or Athyris
Griffithides peroccidens
"Productella", small form
Reticularia ? sp.
Rhipidomella cf. thiemei
Spirifer "centronatus"
Fragment of a horn coral, Triplophyllites ?
euomphalid gastropod
Fragments of productid brachiopods
loxonemid gastropod
Orthotetid brachiopods
Ostracode poorly preserved

Mr. Sadlick states that "All of the above -- are typical Madison forms, which by themselves indicate a Kinderhook age to me --". One collection, which may be from the Madison limestone, is discussed under "Deseret limestone".

Drs. Ellis L. Yochelson and Mackenzie Gordon, Jr. have identified the following from the Madison limestone of the Promontory Range:

Loxonema sp. indet.
Punctospirifer cf. P. solidirostris (White)
Spirifer sp.
Straparollus (Euomphalus) utahensis Hall & Whitfield
Straparollus (Euomphalus) sp. indet.
Straparollus (? Straparollus) sp. indet.
Horn coral undetermined
Indeterminate gastropod

Drs. Yochelson and Gordon state "This collection is of Madison age."

Whether the Madison limestone, as herein described, represents all of Early Mississippian time is a problem which has not been solved as yet. As previously noted in the discussion of the "Jefferson formation", Duncan (1953, pp. 8-9) has described a basal Mississippian dolomite in the central Wasatch Mountains; but until the Madison limestone can be found in sedimentary contact with the underlying dolomite, the problem of its existence in the Promontory Range must remain an enigma.

There is no problem involved in the correlation of the Madison limestone in the Promontory Range. It may be correlated with well established occurrences of Madison limestone in all directions except to the northwest.

Deseret Limestone

Distribution and Thickness: - The Deseret limestone is present at the first two localities mentioned for the Madison limestone. On Mt. Baldy, with both contacts well exposed, a thickness of 316 feet is present. In the Bert horst, northwest of the Woodward Ranch, 280 feet are poorly exposed, but the lower and upper contacts are plainly visible. Like the underlying Madison limestone, the Deseret limestone is of fairly constant thickness throughout its extent in the Promontory Range.
The area covered by outcrops of the Deseret limestone is far less than that of the underlying Madison limestone, but greater than that of the overlying Humbug formation. With respect to area of exposure the combined "Deseret-Humbug formation" is easily the least important geologic formation in the Promontory Range.

Topographic Expression: - The Deseret limestone is typically a slope-former much like the overlying Humbug formation, but the Deseret limestone commonly forms a steeper slope. Both on the eastern face of the Bert horst and near the crest of Mt. Baldy the Deseret limestone maintains extremely steep slopes. There is commonly a sharp change in slope both at the contact with the overlying Humbug formation which forms gentler slopes. Exposures of the Deseret limestone are generally very poor due to masking of the bedrock lithology of the formation by abundant float from the overlying Humbug formation.

Lithology: - The Deseret limestone is predominantly limestone, with relatively minor amounts of calcareous siltstone and calcareous orthoquartzite. The limestone is gray to dull gray, silty to arenaceous (very fine-grained), and weathers dirty gray or dirty light gray. Black chert is locally abundant, particularly in the uppermost portion, as "beds" which are six inches to one foot thick. Thick stratigraphic intervals may be more than 50 per cent chert. This chert has a dull, earthy appearance and differs from the chert in the Madison limestone by its physical appearance as well as by its occurrence as "bands" of uniform thickness parallel to bedding, rather than as undulatory nodules as in the Madison limestone.
The calcareous orthoquartzite is tan to gray, very fine-grained, and weathers dull dirty brown. Fresh surfaces have abundant tiny limonite flecks and there are no visible bedding surfaces within the orthoquartzite.

The calcareous siltstone weathers light brown to dirty tan and along weathered surfaces everything except the clastics has been removed, leaving a surficial silty "rind".

The Deseret limestone differs from the overlying Humbug formation in that limestone is predominant over clastics; but it is more like the Humbug formation due to its clastic content than like the underlying Madison limestone which has no clastic content. This further strengthens the case for combining the "Deseret-Humbug" rather than using the "Madison-Deseret" terminology employed in the central Wasatch Mountains, Utah (Crittenden et. al., 1952, Plate I). The weathered appearance of the Deseret limestone is very similar to that of the Humbug formation.

The upper contact of the Deseret limestone is arbitrarily placed at the base of the lowest sandstone above the top of the Madison limestone. This requires the placement of at least one thick calcareous orthoquartzite in the Deseret limestone; but it is justifiable, for such a contact allows a natural division between cherty limestone below and sandstone above, these lithologies being characteristic of the Deseret limestone and the Humbug formation, respectively.

**Age and Correlation**: No fossils have been found in place in the Deseret limestone of the Promontory Range, but the formation is arbitrarily assigned to the Upper Mississippian.
A small fossil collection was made from float near the top of the westernmost small hill along the northern bank of North Chokecherry Canyon, supposedly from the Madison limestone; but Mr. Walter Sadlick writes the following concerning this collection:

Small fragment of a *Fenestella*
About one-half of a *Spirifer*, complete specimen would have a hingeline about 4 inches in length. Such spiriferoids are common in the type Osage group.

Mr. Sadlick states that the collection

"... is considered Osage... and could be either the upper Madison (as used by Gilluly in the Oquirrh Range) or some portion of the Deseret limestone."

The Deseret limestone of the Promontory Range is correlated directly with the Deseret limestone of the Stockton and Fairfield quadrangles, Utah, as described by Gilluly (1932). Calkins and Butler (1943) have described the Deseret limestone in the Cottonwood-American Fork area, Utah, but this description is not very similar to the Deseret limestone of the Promontory Range.

Gilluly (1932, pg. 25) noted a black shale containing phosphatic oolites at the base of the Deseret limestone which directly overlies the Madison limestone. Holland (1953, pg 35) notes that "Locally the base of the Brazer is marked by a phosphatic shale member which seems to have been deposited on the eroded upper Madison surface." Any correlation without faunal evidence over such a distance (approximately 90 miles) is exceptionally risky; but it is possible that the Deseret limestone is the stratigraphic equivalent of the base of the Brazer formation. The writer tentatively correlates the Deseret limestone of the Promontory Range with the lowermost portion of the Brazer formation of the Logan quadrangle, Utah and southeastern Idaho.
Humbug Formation

Distribution and Thickness: - The presence of the Humbug formation has been established at only two localities in the Promontory Range. On Mt. Baldy only the basal 28 feet is present and this is postulated solely on the basis of float fragments along the crest of this mountainous mass, for there are no outcrops. In the Bert horst the basal 372 feet of the Humbug formation are present, but the upper contact is nowhere seen because the Oquirrh formation is in fault contact with the Humbug formation along the western margin of the horst.\(^1\)

The Humbug formation has an extremely small outcrop area in the Promontory Range and it is generally very poorly exposed. The Deseret limestone and the Humbug formation are somewhat similar in lithology, weather in a similar way, and have almost identical topographic expressions. This marked similarity of the two formations and the lack of a marker bed near their contact has necessitated combining them into one mappable unit for cartographic purposes: the "Deseret-Humbug formation".

Topographic Expression: - The Humbug formation is typically a slope-former, much like the underlying Deseret limestone. These two formations together form the drab-colored slope situated above the prominent cliffs of

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1. In an earlier article (Olson, 1956, pg. 58) the writer gave the thickness of the Humbug formation as 1,100 feet. This has since been found to be in error, for this section was measured across a fault. Only the basal 372 feet belong to the Humbug formation (see Stratigraphic Section M-4, Appendix) and the remainder belongs to the Oquirrh formation (see Stratigraphic Section P-4, Appendix). In addition, a large portion of what was mapped as "Deseret-Humbug formation" has since been proven by faunal content to be Oquirrh formation.
Madison limestone, but the Humbug formation forms a gentler slope than the underlying Deseret limestone. There is commonly a very sharp and clear-cut change in slope at the contact between the Madison limestone and the overlying "Deseret-Humbug formation".

**Lithology:** The Humbug formation consists of interbedded calcareous sandstone and arenaceous limestone. In the incomplete section exposed in the Bert horst, the sandstone makes up 75 per cent of the exposed bedrock and the limestone constitutes the remaining 25 per cent. The sandstone is tan, light brown, and gray on fresh surfaces, consistently very fine-grained, and weathers light brown, reddish-brown, tan, and gray. The entire formation weathers to dull, drab, earthy colors and has a monotonous surficial expression. The calcareous cement has been dissolved and removed from weathered surfaces. Some of the calcareous sandstone is so well cemented as to strongly resemble calcareousorthoquartzite. Interstitial concentrations of white calcite locally may make the sandstone appear to be feldspathic, but no detrital feldspars were noted in the Humbug formation.

The limestone is various shades of gray on fresh surfaces, generally very finely crystalline, and weathers gray to tannish-gray or grayish-brown. The abundant included quartz grains are consistently very fine-grained to fine-grained and are locally so abundant that the arenaceous limestone approaches the composition of a calcareous sandstone. Some of the extremely arenaceous portions have been etched on weathered surfaces and stand out as darker beds which locally display low-angle cross-bedding.

Both Gilluly (1932) and Calkins and Butler (1943) have described the
Humbug formation as containing abundant limestone and subordinate sandstone. In the Promontory Range, calcareous sandstone is three times as abundant in the exposed portion of the Humbug formation as is arenaceous limestone. It should be noted that the true lithology of any hand sample from the Humbug formation can be satisfactorily determined only after etching with concentrated HCl acid. Along fresh fractures the calcareous cement commonly obscures the presence of clastic grains. In this respect the more clastic portions of the Humbug formation are very similar to the calcareous orthoquartzites of the Oquirrh formation.

Chert is rare in the Humbug formation compared to the underlying Deseret limestone.

The basal contact of the Humbug formation is arbitrarily placed at the base of the lowest sandstone above the top of the Madison limestone. This is compatible with Gilluly's placement of this contact, but it is far from satisfactory as a formational contact because it is not mappable. This is the main reason why the writer has chosen to map the Deseret limestone and Humbug formation as one unit and further suggests that these formations may not be locally valid and should be consolidated to form one mappable unit.

Age and Correlation: - No recognizable fossils have been found in the Humbug formation of the Promontory Range. On weathered surfaces indistinct cross sections of minute cup corals may be seen, but most remains have been obliterated; cleaning of the specimens reveals little more than is visible on the outcrop. The formation is arbitrarily assigned to the Upper Mississippian.
The Humbug formation of the Promontory Range is correlated directly with the Humbug formation of the Stockton and Fairfield quadrangles, Utah, as described by Gilluly (1932). To the northeast in the Logan quadrangle, a correlation of the "Deseret-Humbug formation" of the Promontory Range is tentatively made with the basal portion of the Brazer limestone (see "Deseret limestone"). Calkins and Butler (1943) have described the Humbug formation in the Cottonwood-American Fork area, Utah, and the lithology they describe for the basal portion is very similar to the lithology of the Humbug formation in the Promontory Range.

Great Blue (?) Limestone

**General Statement:** During the course of field work in the Promontory Range the writer believed the Great Blue limestone to be absent due to the combination of faulting and erosion. After the completion of the field work some fossils (almost entirely cup corals) were sent to Dr. William J. Sando. Although these fossils are not too well preserved, Dr. Sando believes that some of them are definitely of Upper Mississippian age. During the field work the writer was inclined to assign these outcrops tentatively to either the Madison limestone or the Oquirrh formation. The lithologic characteristics argue strongly against their assignment to the Deseret limestone, the Humbug formation, or the Manning Canyon shale; the only other formations of Upper Mississippian age in the Promontory Range. Therefore, the probable presence of the Great Blue limestone must be admitted, but because they have not been studied in detail in the field these exposures are called "Great Blue (?)" limestone.
Distribution and Thickness: - The Great Blue (?) limestone in the Promontory Range is confined to one roughly rectangular area bounded on the west by the Promontory fault, on the south by the Middle Canyon fault, on the north by the Broadmouth fault and on the east by Lake Bonneville sediments on the eastern flank of the range.

In an earlier article (Olson, 1956, pp. 59-60) the writer mapped some areas as "Great Blue limestone or Oquirrh formation" because of the almost complete lack of paleontological evidence concerning the problem at that time. Since then all of the areas thus mapped have been proven to be Oquirrh formation.

The thickness of the Great Blue (?) limestone has not been measured; indeed, any measurement would be a partial one because neither contact is believed to be exposed, although the upper contact may be locally present immediately south of the Broadmouth fault. An approximation of minimum thickness can be obtained by calculation using known elevations and geographical positions as well as bedding attitudes. By this method the calculated partial thickness of the Great Blue (?) limestone as determined along the north wall of Miller Canyon is at least 1,000 feet and may be as great as 1,500 feet. The latter figure is probably more nearly correct; however, slight changes in bedding attitude could alter these figures considerably. Gilluly (1932) reports a thickness of approximately 3,600 feet for the Great Blue limestone approximately 60 miles to the south. The absence of definite contacts plus the poorly understood structural complications in the area of outcrop of the Great Blue (?) limestone render it remotely possible that a similar thickness is present in the Promontory Range. Young (1955) has
measured 1,537 feet of Great Blue limestone in the Southern Lakeside Mountains approximately 35 miles to the southwest, but this is an incomplete section.

Clearly, the Great Blue (?) limestone of the Promontory Range requires further study. Although the only outcrops are situated in a structurally complex area, a detailed study could result in accurate stratigraphic measurement and dating.

**Topographic Expression:** - The Great Blue (?) limestone varies somewhat in its topographic expression. In the western half of its areal extent it is a cliff-former, particularly along the north wall of Miller Canyon where it has been eroded into bare, massive, vertical cliffs. Throughout the eastern half of its areal extent the Great Blue (?) limestone forms more subdued topography, but even on hill slopes covered with colluvium, bare massive limestone ledges crop out prominently, particularly on dip slopes. On the whole, however, the formation does not have a characteristic topographic expression; but compared with formations such as the Deseret limestone, the Humbug formation, and the Oquirrh formation, it is very well exposed.

**Lithology:** - Because the Great Blue (?) limestone is incompletely exposed and was believed to belong to other formations during the course of the field work, detailed attention was not paid to its lithology and no microscopic work was performed on hand specimens. It is predominantly limestone, but there are subordinate amounts of arenaceous limestone, calcareous sandstone or orthoquartzite, chert, and black shale. The limestone is blue to dark gray or dark bluish-gray, locally black, and characteristically
crops out as massive ledges 10 to 20 feet thick which are totally devoid of bedding. The arenaceous limestone and calcareous sandstone or orthoquartzite do not crop out prominently and are characteristically stained brown by iron oxides. Much of the arenaceous limestone is bioclastic. The chert is uniformly black and occurs as nodules or as bands parallel to bedding in the non-clastic limestone, probably a bedding replacement phenomenon. The boundaries between limestone and chert are sharp and distinct; this cherty portion of the Great Blue (?) limestone greatly resembles the Deseret limestone. The black shale is generally extremely fissile and weathered surfaces are characterized by a thin all-enclosing limonitic "rind". This shale strongly resembles the black shale which constitutes the major portion of the Manning Canyon shale.

Gilluly (1932) has subdivided the Great Blue limestone of the Oquirrh Range into three units: a lower limestone unit about 500 feet thick, the intervening Long Trail shale member, and an upper limestone unit ranging from 2,400 to 3,100 feet thick. It seems likely to the writer that only the upper limestone member may be present in the Promontory Range because (1) the Long Trail shale member or its equivalent has not been recognized and (2) the lithologies described in the above paragraph are very similar to Gilluly's description of the upper limestone unit.

Age and Correlation: - Four fossil collections (cup corals) from the Great Blue (?) limestone have been identified by Dr. William J. Sando as "definitely Upper Mississippian". This is the only dating information which is available for the Great Blue (?) limestone. The dating furnished from
these collections plus the fact that their lithologies do not resemble other
Upper Mississippian formations has led the writer to employ the term "Great
Blue (?) limestone".

Tentative correlation is made directly with the Great Blue limestone of
the Stockton and Fairfield quadrangles, Utah, as described by Gilluly (1932).

Stratigraphic Correlation and Terminology

The Promontory Range lies between two well-established and well-studied
Mississippian stratigraphic sections. To the south in the Oquirrh Range,
Gilluly (1932) has described the Madison limestone, the Deseret limestone,
the Humbug formation, the Great Blue limestone, and the Manning Canyon shale
(in ascending order). To the northeast in the Logan (Utah) quadrangle,
Williams (1948) has described the Madison limestone and the overlying Brazer
formation. The Brazer formation must include the stratigraphic equivalents
of the Deseret limestone, the Humbug formation, the Great Blue limestone, and
the Manning Canyon shale. The presence of a black shale at the top of the
Brazer formation in the Logan area substantiates this correlation.

The writer has arbitrarily chosen to employ the Oquirrh Range termi-
nology for the Upper Mississippian stratigraphic sequence of the Promontory
Range, rather than to use the Logan quadrangle terminology. This has been
done primarily because the Manning Canyon shale is so well represented in
the Promontory Range.
MISSISSIPPIAN - PENNSYLVANIAN STRATIGRAPHY

General Statement

In the Stockton and Fairfield quadrangles, Utah, Gilluly (1932) has established the Mississippian - Pennsylvanian boundary as being within the Manning Canyon shale. This formation has been recognized in the Promontory Range, and due to an almost complete lack of paleontological evidence, this age designation is accepted by the writer as valid also for the Manning Canyon shale of the Promontory Range.

Manning Canyon Shale

Distribution and Thickness: - The Manning Canyon shale has been recognized in the Promontory Range only between the Coldwater fault on the south and Larsen Ridge and North Coldwater Canyon on the north. This continuous exposure is bounded on the south by the Coldwater fault, on the east by the Wildcat fault, and on the north by a sedimentary contact with the overlying Oquirrh formation. To the west this exposure is bounded by the alluvial cover of Coldwater Canyon, in which only scattered outcrops may be found.

The thickness of the Manning Canyon shale on the eastern slope of the range about two miles west of the Ray Smith Ranch is 1,088 feet, but because the base of this section is in fault contact with the Oquirrh formation the complete thickness of the Manning Canyon shale in the Promontory Range cannot be determined.

Due to the tendency of this formation to be extremely susceptible to crustal deformation, it is difficult to find localities where reliable
stratigraphic measurements may be made; and for this reason no stratigraphic sections other than the one noted above were measured.

The thickness of the Manning Canyon shale may be well in excess of 1,088 feet; but, as the basal contact is nowhere exposed in the Promontory Range, there is no way to determine its true thickness. Gilluly (1932, pg. 32) measured 1,140 feet of Manning Canyon shale in the Stockton and Fairfield quadrangles, Utah. The uppermost unit of the Brazer formation as described by Williams and Yolton (1945, pg. 1145) at Dry Lake, Utah may be stratigraphically equivalent to the Manning Canyon shale of the Promontory Range and is 950 feet thick. It seems probable that the total thickness of the Manning Canyon shale in the Promontory Range does not greatly exceed the maximum measurement of 1,088 feet.

**Topographic Expression:** - The Manning Canyon shale does not have as distinctive a topographic expression as do most of the other formations in the Promontory Range, but other features distinguish it. It forms gently rounded hills which are extensively, but randomly, dissected.

The most prominent feature of the Manning Canyon shale is the series of ridges formed by beds of red to reddish-brown weathering quartzite which stand out sharply on the drab-colored slopes of the intervening shale portions of the formation. The topographic expression of these quartzite ridges locally may resemble that of dikes which have been intruded into a relatively nonresistant country rock. Where the Manning Canyon shale has been structurally compressed, these ridges crop out conspicuously in a multitude of varying bedding attitudes and constitute the only evidence of structural complications.
Though the Manning Canyon shale has been intensely folded, none of the fold axes can be traced very far; they are extremely local features and have not been mapped by the writer.

Also striking to the eye are the many black areas or "patches" which betray the presence of black or dark gray shale underlying the surface. Oversteepening of hill faces caused by stream undercutting has locally resulted in the formation of prominent "cut banks" of black shale, which stand out in contrast with the normal vegetative cover.

The formation supports spotty growths of sagebrush and its drab-colored, rounded hills support practically no trees, in sharp contrast with adjacent formations.

**Lithology:** The Manning Canyon shale consists predominantly of shale and quartzite, but the lithology becomes more heterogeneous and complex near the top as expressed in a classically developed transitional contact with the overlying Oquirrh formation along the north wall of North Coldwater Canyon. In the only measured section of the Manning Canyon shale, shale constitutes approximately 80 per cent of the exposed bedrock and quartzite makes up the remainder. From stratigraphic reconnaissance at other localities, however, the writer is certain that shale is over-all not as abundant as stated above.

The shale is black, silty, and commonly weathers black. A peculiar weathering phenomenon is characteristic of some of the shale; a tan to light gray weathered color extends down into the fresh rock for very small distances, generally one-sixteenth inch or less, forming a lighter-colored "rind" on
shale chips which have been exposed to weathering processes. The shale generally has pronounced fissility, with laminae averaging one-fourth inch thick, but locally lacks this fissility and thus is properly considered as mudstone.

The quartzite is pale green to tan, very fine-grained, and weathers the same except where surficially stained dark brown, reddish-brown, or purplish by intense accumulations of iron oxides. Liver-brown mammary-shaped accumulations of goethite are locally abundant along fracture surfaces, a feature not associated with any of the other quartzites in the stratigraphic column of the Promontory Range. The very fine-grained texture of this quartzite also distinguishes it from all others in the range. Where the shale lacks bedding the quartzite beds resemble igneous dikes and the texture is so fine that petrographic examination is commonly required for identification. The quartzite crops out as blocky, parallel beds averaging two feet thick with rare low-angle cross-bedding faintly displayed between the well defined parallel, planar bedding surfaces.

The transitional nature of the contact with the overlying Oquirrh formation is displayed only along the north wall of Coldwater Canyon and the southern end of Larsen Ridge. At this locality the normal shales and quartzites of the Manning Canyon shale grade upward into a complex succession of interbedded siltstone, calcareous orthoquartzite, limestone, and very minor shale which in turn grades into a limestone section. The Manning Canyon shale-Oquirrh formation contact is extremely difficult to establish; the writer arbitrarily chooses it at the top of the highest clastic bed. Elsewhere, this classically developed transitional zone is concealed and the
contact is placed at the base of the lowermost exposed limestone bed of the Oquirrh formation. The basal contact is nowhere exposed within the Promontory Range, but no such transitional phase is present or indicated in the lowermost exposed portion of the formation.

The lithology of the Manning Canyon shale, i.e. predominantly shale, renders the formation extremely susceptible to deformation. It is readily apparent that in Coldwater Canyon and in that portion of the range due east of Coldwater Canyon the Manning Canyon shale has suffered the brunt of the compressive forces while the adjacent formations have been far more competent.

The Promontory Range has few springs and no perennial streams. The writer estimates that the Manning Canyon shale, despite its very small surface area, has almost as many natural springs as the entire remainder of the range. At no place does the Manning Canyon shale occur at altitudes greater than 6,500 feet, and the writer believes that the catchment area for this water must be the much higher hills of Oquirrh formation to the south. Since most of the strata of the Manning Canyon shale are impervious, the springs cannot be explained by flow in pervious strata interstratified with impervious strata; but may be caused by flow along bedding surfaces between impervious strata aided by extensive fracturing of the more competent quartzite.

**Age and Correlation:** The age of the Manning Canyon shale in the Promontory Range remains in doubt. Only two small fossil collections were made.

Mr. Walter Sadlick has inspected a small brachiopod assemblage collected approximately 500 feet below the Manning Canyon shale-Oquirrh formation contact and identified it as follows:
Spirifer leidyi? Common in Chesteran strata, but ranges into Morrowan strata.

At the type locality of the Manning Canyon shale in the Stockton and Fairfield quadrangles, Utah, Gilluly (1932, pp. 32-34) has established the Mississippian - Pennsylvanian boundary within the formation. With the meager fauna found in the Manning Canyon shale of the Promontory Range to date it seems impossible to prove or disprove such an intraformal systemic boundary.

Correlation is made directly with the Manning Canyon shale of the Stockton and Fairfield quadrangles, Utah. Correlation to the east and northeast is speculative at best, but the uppermost unit of the Brazer formation as described by Williams and Yolton (1945, pg. 1145) at Dry Lake, Utah may be stratigraphically equivalent to the Manning Canyon shale of the Promontory Range.
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PENNSYLVANIAN - PERMIAN STRATIGRAPHY

General Statement

Most of the Pennsylvanian period and the earliest portion of the Permian period are represented in the Promontory Range by one stratigraphic unit, the Oquirrh formation. Attempts to subdivide this formation into members or into several formations belonging to one group have proved fruitless from a practical viewpoint. Various portions of the formation may be recognized by clastic content or outcrop appearance and habit, but these are subtle distinctions and certainly are not mappable.

In terms of surface expression the Pennsylvanian-Permian systems combined are by far the most important in the Promontory Range. The writer estimates that the Oquirrh formation constitutes approximately 35-40 per cent of the exposed bedrock of the Promontory Range.

Oquirrh Formation

Distribution and Thickness: The Oquirrh formation constitutes more than one-half of the exposed bedrock of that portion of the Promontory Range north of the Middle Canyon fault, but does not crop out anywhere south of this major fault nor west of the Promontory fault. However, that portion of the range north of the Middle Canyon fault and east of the Promontory fault is almost entirely composed of outcrops of the Oquirrh formation.

1. On the geologic map accompanying an earlier article (Olson, 1956) the writer mistakenly mapped extensive areas of Oquirrh formation as "Deseret-Humbug formation". Subsequent paleontological research has proved this error.
The main drainage divide from the north wall of Miller Canyon to the northern end of the range is entirely in the Oquirrh formation except for a three-mile long interval west of the Ray Smith Ranch. From the northern end of Boothe Valley to the northern end of the range a view of the eastern side of the Promontory Range discloses only two relatively small outcrops of formations other than the Oquirrh formation, which constitutes easily 90 per cent of the bedrock of this side of the range.

The complete original thickness of the Oquirrh formation of the Promontory Range cannot be determined because the upper contact is nowhere present. All exposures of the Oquirrh formation in the Promontory Range have either an erosional surface at the top or are overlain by Quaternary deposits of Lake Bonneville. The basal contact of the Oquirrh formation is exposed at only two localities: along the main drainage divide west of the Ray Smith Ranch, and along the northern wall of North Coldwater Canyon and upward to the southern end of Larsen Ridge.

Indeed, even the stratigraphic thickness of that portion of the Oquirrh formation now present in the Promontory Range would be impossible, or at best extremely difficult, to obtain. The Oquirrh formation is present in huge fault blocks whose bounding faults are characterized by very large stratigraphic displacements. This fact, combined with the complete absence of "marker beds", renders attempts at stratigraphic measurement frustrating.

Four stratigraphic sections (see Stratigraphic Sections P-1 through P-4, Appendix) were measured in the Oquirrh formation. These are not believed to overlap each other stratigraphically because of differing lithologies, but the strong possibility of pronounced lateral facies changes in the Oquirrh
formation makes it possible that such vertical overlap of the sections exists. On the western side of the range southeast of Staples Flat, 1,897 feet of the Oquirrh formation were measured between the alluvial overlap at the base of the range and the erosional surface at the crest of the range. On the eastern side of the range near Mountain Springs 601 feet of the Oquirrh formation were measured between the overlap by sediments of Lake Bonneville and a fault. Along the ridge between Chokecherry Canyon and Mountain Springs on the eastern side of the range 715 feet of the Oquirrh formation were measured, bounded at the base by a fault and at the top by a complex fault zone.

The combined thickness of these three stratigraphic sections is 3,213 feet. Despite the large number of fossil collections made from the Oquirrh formation of the Promontory Range, the writer was able to procure only one collection of recognizable fusulinids. The only hope of determining the true thickness of the Oquirrh formation in the Promontory Range seems to lie in a detailed search for fusulinids and their subsequent zonation. Nevertheless the writer feels justified by extensive geological reconnaissance in stating that at least 7,500 feet of the Oquirrh formation are present in the Promontory Range. It is also possible that at least as great a thickness of the Oquirrh formation as is now present has been removed by erosion. Nygreen (1958, pg. 13) states that 18,000 feet of the Oquirrh formation are exposed in the Oquirrh Mountains and 26,000 feet have been measured in the south-central Wasatch Mountains by Baker (1947). According to Nygreen's isopachous map of the Pennsylvanian system of northern Utah (1958, pg. 20) there is a thickness of approximately 7,000 feet of Pennsylvanian strata in the Promontory Range. This agrees fairly well with the writer's prior estimates.
Low-lying hills to the northwest, north, northeast, and east of the northern end of the Promontory Range are believed to be composed largely, if not entirely, of the Oquirrh formation. This generalization includes the North Promontory Range (northwest), the low-lying outlier between the gravel road to Howell and the Bar B Ranch (northeast) and Little Mountain northwest of Corinne, Utah (east). Only brief reconnaissance was done on these outlying mountains and no fossils were collected, but the lithologies are so similar to those of well established Oquirrh formation in the Promontory Range that the writer feels justified in assuming that these outliers are composed largely, if not entirely, of Oquirrh formation.

**Topographic Expression:** - The Oquirrh formation is characterized by an almost complete lack of control upon geomorphology. This is caused by the monotonous homogeneity of the formation; differences in bedding attitude have little, if any, effect on the resulting landforms. (This is more fully discussed under the heading "Geomorphology" where the eastern geomorphic district of the northern structural block is described).

**Lithology:** - The lithology of the Oquirrh formation is described by the writer as homogeneous. This does not infer that the formation has only one lithotope, but rather that the different lithotopes are rhythmically or cyclically repeated. Furthermore, various thick stratigraphic intervals may contain only one lithotope, while other stratigraphic intervals contain distinctive patterns of repetition of two or more of the lithotopes. Thus, there are several possible combinations and these may be accentuated by
differential resistance to weathering processes. In summary, the lithology of the Oquirrh formation may be locally heterogeneous over considerable stratigraphic intervals; but as a whole the formation has homogeneous lithology and a decidedly monotonous expression.

The basal portion of the Oquirrh formation in the Promontory Range is predominantly limestone. Nygreen (1958) has studied the lower portion of the Oquirrh formation in northern Utah, divided it into two members, and has named the lower of these the "West Canyon limestone member". Sadlick (personal communication) states that the presence of a "lower limestone member" at the base of the Oquirrh formation is a characteristic of the formation in northern Utah. Southeast of Staples Flat on the western side of the range 1,897 feet of the Oquirrh formation were measured with the base not exposed (see Section P-l, Appendix) and of this thickness the basal 1,502 feet (units #1-48 of Section P-l) probably is the lithologic correlative of Nygreen's "West Canyon limestone member". Nygreen has measured thicknesses of 1,456 feet in the Oquirrh Mountains and 510 feet near Logan, Utah. The complete thickness of this lower limestone member is not exposed at any one locality in the Promontory Range and 1,502 feet must be regarded as a minimum thickness.

The limestone of this lowermost member of the Oquirrh formation is markedly bioclastic and extremely uniform in composition, appearance, and outcrop habit. The color of fresh surfaces is generally gray and the weathered

1. In an earlier article (Olson, 1956 pp. 59-60) the writer discussed this limestone unit under the heading "Great Blue limestone", although the possibility was expressed that it could also be the "basal portion of the Oquirrh formation -". Since this publication the unit has been definitely proved paleontologically to belong to the Oquirrh formation.
surfaces are a characteristic light bluish-gray. The only other limestones which even slightly resemble this are found in the Garden City formation, and these are easily distinguished by the presence of brown-stained argillaceous seams. Some of the limestone is arenaceous, either silty or very fine-grained, but this is generally not noticeable unless the limestone is etched with acid. There is some interbedded sandstone in this unit, but this is present in relatively minor amounts. The sandstone is gray, very fine-grained, generally extremely calcareous and is dull brown due to limonite on weathered surfaces where the calcareous cement has been dissolved. Oolitic beds are locally present in the limestone and dark gray chert occurs as seams and nodules parallel to bedding.

The outcrop habit of this "lower limestone member" is distinctive. The limestone ledges average 10 to 20 feet thick, stand out prominently in rib-like fashion from the enclosing slopewash, and can individually be traced laterally for miles from certain vantage points (see Figure 7). The underlying lithology of the slopewash-covered intervals between the limestone ledges is not revealed in stream cuts nor does shallow trenching reveal any clues as to its nature.

The basal contact with the Manning Canyon shale is transitional and is described under the discussion of the lithology of that formation. This contact is best displayed along the northern wall of North Coldwater Canyon. The upper contact of the "lower limestone member" is difficult to establish and is arbitrarily chosen where clastics commence to constitute approximately one-half of the bedrock lithology. It is mainly for this reason that Nygreen's "West Canyon limestone member" is not employed in the Promontory Range; the
The writer does not believe that it is a mappable lithologic unit here.

The remainder of the Oquirrh formation is more arenaceous than the "lower limestone member" and in addition its weathered surfaces generally show the arenaceous content much more clearly than the "lower limestone member" due to extensive and intense staining of the more arenaceous portions by iron oxides. Nygreen (1958, pg. 14) refers to that portion of the Oquirrh formation above his "West Canyon limestone Member" as the "Sandy Oquirrh". This twofold terminology could well be applied to the Oquirrh formation of the
Promontory Range because all of the lithologies and their mode of occurrence as described by Nygreen are also present here. The two main lithologies present in the "Sandy Oquirrh" are arenaceous limestone and calcareous orthoquartzite. The limestone is gray to dark gray (very drab colors), generally microcrystalline, arenaceous (although this feature is not noticeable on fresh surfaces until etched with acid), and weathers to lighter shades of drab, dull gray or light gray. Unlike the interbedded calcareous orthoquartzite, the limestone readily effervesces with acid on fresh surfaces and is generally free of concentrated iron oxide stain. The calcareous orthoquartzite is tan to gray on fresh surfaces, generally uniformly very fine-grained, and weathers tan to light brown. Weathered surfaces do not effervesce with acid due to leaching of calcareous cement by weathering processes and are characterized by an intense surficial iron oxide stain. A predominantly large portion of the "Sandy Oquirrh" is characterized by rhythmic or cyclic repetition of these two lithotopes, with the individual lithologic intervals generally ranging from six inches to two feet thick (see Figure 8). This rhythmic or cyclic sedimentation phenomenon is very similar to that described by Nygreen (1958, pp. 21-25) in the Oquirrh Mountains, Utah and is further accentuated in the Promontory Range by the universal tendency of the calcareous orthoquartzite to form perfectly planar joint surfaces while the interbedded arenaceous limestone forms rough, undulating, and noticeably recessed joint surfaces. Thus, the calcareous orthoquartzite intervals stand out prominently as limonite-stained "ribs" (see Figure 8).
Sandstone is also present in the Oquirrh formation, but only locally is it as abundant as the calcareous orthoquartzite and limestone. The sandstone is generally tannish-gray, very fine-grained, slightly calcareous, and weathers to a monotonous dull tan or light brownish-tan. Individual beds are commonly slabby and thin-bedded (\(\frac{1}{4}-1\)" thick), have undulatory bedding surfaces, and stand out from each other as if they were once separated by shale partings.

Figure 8. Oquirrh formation of Wolfcamp (?) age showing interbedded calcareous orthoquartzite (dark rock) and arenaceous limestone (light rock). Calcareous orthoquartzite beds stand out on weathered surfaces as "ribs".
Shale is the least abundant constituent of the Oquirrh formation. The most prominent shale exposure is at Mountain Springs, northwest of the Bert Horst. The shale is black, very fissile (readily splits into chips which seldom exceed 1/8" thick), and strongly resembles the Manning Canyon shale.

The calcareous orthoquartzite occurs only in the rhythmic or cyclic unit described above; but the limestone, almost completely devoid of interbedded calcareous orthoquartzite and sandstone, may constitute thick stratigraphic intervals, as upon the ridge between Chokecherry Canyon and Mountain Springs on the eastern side of the range (see Section P-4, Appendix). Where the limestone occurs in this manner in the "Sandy Oquirrh" it tends to be more siliceous than when interbedded with the calcareous orthoquartzite, and may locally contain sporadic black chert nodules. Chert nodules are practically totally absent in the limestones of the rhythmic or cyclic series described above. The calcareous orthoquartzite may have significant amounts of silica as a cementing agent; although no petrographic work has been done on these specimens, it is likely that the silica has replaced the original interstitial calcareous material. Quartzite beds, with no calcareous material, are extremely rare in the Oquirrh formation; long stratigraphic traverses commonly reveal no such lithology.

It should be emphasized that the true lithology of any specimen collected from the Oquirrh formation of the Promontory Range can be ascertained only after the acid-etching of a fresh surface. Clastic ratios derived in the past from hastily described stratigraphic sections of the Oquirrh formation may thus be unreliable.
Age and Correlation: Fossil collections from the Oquirrh formation of the Promontory Range have proved that its deposition was at least from Early Pennsylvanian (Morrow) to Early Permian (lower middle Wolfcamp).

Mr. Walter Sadlick has identified the following from the Oquirrh formation of the Promontory Range:

- **Antiquatonia** sp.
- **Chaetetes** ? sp.
- **Chonetes** n. sp.
- **Composita aff. magna**
- **Composita c. quadrata**
- **Composita** sp.
- **Echinoconchus** sp.
- **Fusulinella** or **Fusulina**
- **Neospirifer** aff. **cameratus**
- **Neospirifer** cf. **cameratus**
- **Neospirifer** cf. **dunbari**
- **Orthotetes** or **Derbyia** sp.
- **Spirifer** aff. **occidentalis**
- **Spirifer** cf. **occidentalis**
- **Spirifer** opimus
- **Spirifer** sp.
- Fragment of a productid, similar to "**Dictyoclostus**" americanus or "**Productus**" hermosanus
- Fragment which might be "**Productus**" arkansanus
- Very similar to **Striatifera brazerianus**

- 148 -
pectinoid pelecypod
orthotetid brachiopod

Drs. Ellis L. Yochelson and Mackenzie Gordon, Jr. have identified the following from fossil collections made in the Oquirrh formation of the Promontory Range:

Composita sp.
Crurithyris sp.
? Cypricardinia sp.
Euphemites sp.
Productid cf. Cancriella or Linoproductus
Crinoid stems
High spired gastropod indeterminate
Indeterminate bellerophontid gastropod
Indeterminate ramose bryozoan

Miss Helen O. Duncan has identified a coral specimen from the Oquirrh formation.

Syringopora cf. S. multattenuata McChesney

Mr. Grant Steele inspected the only collection of fusulinids which was made by the writer from the Oquirrh formation of the Promontory Range.

Schwagerina aff. andresensis

The Oquirrh formation of the Promontory Range is correlated directly with the type section in the Oquirrh Mountains to the south and with established sections of the Oquirrh formation in the Logan quadrangle to the northeast. It is stratigraphically equivalent in large part to the Wells formation of southeastern Idaho.
MESOZOIC AND TERTIARY STRATIGRAPHY

No Mesozoic or Tertiary sedimentary rocks have been found in the Promontory Range.

Clark and Stokes (1956, pg. 1668) describe a Triassic sequence in the Hogup Mountains, Utah on the western shore of the Great Salt Lake about 20 miles west of the Promontory Range; but no such lithologic succession is present in the Promontory Range. However, the entire Mesozoic Era is well represented in the Wasatch Mountains to the east with the Triassic extremely well developed in the vicinity of Bear Lake, Utah-Idaho.

Slentz (1955) and Slentz and Eardley (1956) describe Pliocene (?) sedimentary rocks interbedded with basalt flows at Rozel Point only ten miles west of the central part of the Promontory Range. No similar strata have been found anywhere in the Promontory Range. It is possible that Pliocene or older rocks are present along the flanks of the Promontory Range, but if so they are now concealed by the extensive Quaternary deposits of Lake Bonneville.

Larsen (1957, pp. 82-88) has recognized a thin, sporadically distributed Tertiary sequence on Antelope Island, approximately 15 miles south and east of Promontory Point. Correlatives of this sequence are absent or unexposed in the Promontory Range.
Lake Bonneville has left an extensive record of its existence around the flanks of the Promontory Range. Between the time of Lake Bonneville's maximum depth and while it was within about 250 feet below this level, the range was an island in Lake Bonneville; this has resulted in a complex development of depositional and erosional features of lacustrine origin completely circumscribing the range. The thickness of these deposits has not been measured, primarily because of the lack of stratigraphically continuous exposures, but their thickness must be at least as great as the differences in elevation between Bonneville level and the present level of the Great Salt Lake - approximately 1,000 feet.

The topographic expression of these deposits is described under "Geomorphology".

Almost all of the deposits are composed primarily of silts and very fine-grained sands, but gravel may be locally abundant. All of these deposits are unconsolidated and are best exposed in recent stream cuts. Tufa is well developed at various levels of Lake Bonneville, particularly upon outcrops of carbonate strata. On the flats north of Promontory Point, tufa deposits upon Precambrian quartzite outcrops are prevalent, but this is unusual. These tufa deposits coat the outcrops in concentric layers from three inches to one foot or more thick and commonly resemble cocoanut shells where they surround boulders (see Figure 9). Travertine is very rare in the Lake Bonneville deposits compared to tufa. "Shiprock", the name given by local residents to a natural rock formation about three miles north of
Promontory Point on the eastern side of the range, is a monolith of Lake Bonneville conglomerate cemented by travertine. Individual boulders range up to one foot in diameter, but average diameter is one to two inches and all fragments are well rounded. Concretionary origin of the travertine is obvious and is probably related to a small hot spring which is no longer active. The differential resistance of "Shiprock" as compared with the surrounding unconsolidated gravels has resulted in its expression as a monolith. Wave action by Lake Bonneville has formed extensive conglomerate or breccia

Figure 9. Tufa (Lake Bonneville origin) deposited as a concentric shell around Precambrian quartzite outliers on Lake Bonneville "flats" north of Saline, Utah.
beds, particularly along outcrops of Paleozoic carbonate strata, and many of these are cemented by either travertine or dense limestone which may owe its origin to the dissolution of Paleozoic carbonate lithologies. These lime-cemented beds resemble some intraformational conglomerates from the Paleozoic section of nearby areas, but they clearly cut across the stratification of the Paleozoic bedrock at high angles and are the products of extensive erosion and reworking along beaches of Lake Bonneville. Particularly well developed examples of this phenomenon may be seen on the eastern side of the range along the south wall of Chokecherry Canyon and along the eastern flank of the range about one mile south of the northern end of The Narrows. The tufa and the travertine are easily distinguishable on textural grounds; the tufa is lightweight, porous, and weathered surfaces are extremely rough and jagged, while the travertine is heavy, dense-textured, and weathers to a much smoother surface. No lacustrine clays, common elsewhere in Lake Bonneville deposits, have been found by the writer, but the extensive excavations being made by the Morrison-Knudsen Company in and around Little Valley may expose such sediments.

The age of Lake Bonneville deposits from nearby areas has been established as late in the Pleistocene. Dr. I. G. Sohn has identified the following forms from the unconsolidated Lake Bonneville deposits of the Promontory Range.

Candona sp.

Cytherissa cf. C. lacustris (Sarā)

Limnocythere sp.
IGNEOUS GEOLOGY

Igneous rocks are extremely rare in the Promontory Range and, with one exception, are confined to the Precambrian stratigraphic sequence. There are no stocks or other plug-like intrusive bodies and all but one of the igneous bodies are concordant with bedding. Intrusive rocks include sills and one dike; and extrusive rocks consist entirely of basic lava flows.

The only discordant igneous body observed in the Promontory Range is a dike which cuts the black phyllites of the "intermediate" Precambrian sequence a few hundred yards northeast of the CAA airport at Promontory Point. The dike is five to seven feet wide and can be traced only a few hundred feet before it is concealed by Lake Bonneville deposits. The dike has been intensely fractured and these fissures are now filled with white quartz which is enclosed by dark brown calcite. Distinct green phenocrysts have the characteristic shape of hornblende or some other amphibole mineral and have been strung out to form a very definite lineation.

Petrographic examination shows that limonite pseudomorphs after pyrite are fairly common, but scattered throughout the rock as euhedral to subhedral crystals. Large distinct phenocrysts, now completely replaced, were probably hornblende or some other amphibole mineral judging by their external shape. Calcite has completely replaced some phenocrysts, but most phenocrysts are replaced by calcite with minor amounts of quartz. Definite porphyritic texture.

Megascopically this dike rock is similar to many of the mafic lava flows in the Precambrian sequence both above and below the phyllites which the dike has intruded.

Two basic porphyry flows are present in the "oldest sequence" of the Precambrian. The older is four feet thick.
Petrographic examination shows that calcite is now by far the most abundant mineral. Large distinct hornblende phenocrysts are commonly replaced by chlorite. Biotite is present as tiny shreds around the margins of replaced phenocrysts. Chlorite and muscovite are present as shreds in the groundmass.

The younger flow is at least two feet thick and is very similar to the older flow.

Petrographic examination shows that extremely fine-grained calcite constitutes the major portion of the groundmass. Chlorite and muscovite make up a good portion of the groundmass, as does albite to a lesser degree. Large distinct pyribole phenocrysts, original composition unknown, are completely replaced by calcite and microcrystalline albite or by chlorite. Magnetite is much more abundant than hematite. Quartz is minor.

In the "intermediate sequence" of the Precambrian section there are several basic porphyry extrusives similar to those described above. It is generally necessary to examine such lithologies petrographically because of the complete alteration which they have invariably been subjected to. In most cases the sole remaining clue to their igneous origin is the porphyritic texture. A distinguishing feature of the alteration of the igneous units in the intermediate sequence is the predominance of iron oxides. The enclosing sediments, now black phyllites, were probably deposited in a euxinic environment and much of the present iron oxide content in the igneous rocks may have been derived from pyrite which developed authigenically in the sediments. Outlines of amphibole or pyroxene phenocrysts are generally visible despite their invariable replacement by calcite and/or limonite. Examination of one such typical lithology is summarized below.

Petrographic examination disclosed that the groundmass is largely calcite. Chlorite is rare in the groundmass as elongate acicular crystals. Magnetite, hematite, limonite and pyrite are also present in groundmass. Rare large hornblende
phenocrysts have been completely replaced by calcite, but generally the replaced phenocrysts appear to have the same composition as the groundmass except for having more abundant limonite. Limonite is pseudomorphous after small phenocrysts. Augite is rare. Microfractures are completely calcite-filled.

The "youngest sequence" of the Precambrian contains more igneous units than the "intermediate" or "oldest" sequences and is the only portion of the Promontory Range stratigraphic sequence in which the presence of concordant intrusive igneous units can be proven. Three sills ranging from two to eight feet thick are characterized by "baked" or "chilled" zones above and below ranging from a few inches to 1.5 feet thick. When there is a difference in the thicknesses of the upper and lower baked or chilled zones, the basal one is invariably thicker.

Petrographic examination discloses that most of the groundmass is calcite, which is by far the most abundant mineral in the slide. The mica-like mineral, locally abundant in groundmass, is probably chlorite. Large hornblende-shaped phenocrysts have been completely replaced by calcite and limonite and are characterized by very thin limonite rims along their borders. Other phenocrysts of irregularly rounded shape have been replaced either by calcite alone or by calcite and microcrystalline quartz. Quartz is also concentrated along microfractures. Limonite is present throughout the slide, but particularly abundant in the replaced Fe-Mg phenocrysts. Judging by external shape alone, probably all of the phenocrysts were originally amphibole minerals.

Some of the other igneous units in this sequence may also be intrusive, but in the absence of an upper baked or chilled zone they are considered to be extrusives. The petrography of these extrusives is similar to that of the sills, except that biotite, chlorite, and muscovite are more abundant in the groundmass. Epidote is also present, but was not noted in the sill rock.

Petrographic examination shows that calcite is very abundant as large crystals. Epidote is abundant throughout the microcrystalline groundmass. Hornblende phenocrysts are locally
preserved, but most have been replaced by epidote alone or by epidote with minor amounts of quartz.

No single petrographic description can describe all of the extrusive igneous units in the "youngest sequence" of the Precambrian, but the one given above is fairly typical.

The concordant igneous units of the Precambrian stratigraphic sequence are distinctive and conspicuous because of their dark color (caused mainly by abundant iron oxides) and their prominent outcrop habit which is due to their differential resistance. They generally effervesce readily with dilute HCl due to the extensive internal development of calcite and generally have a pronounced porphyritic texture. When this texture is not present, however, and the unit in question is microcrystalline, petrographic study is necessary in order to determine whether it is igneous or a metasediment. The metamorphism of these igneous units is discussed under "Metamorphic Geology".

The only igneous unit stratigraphically above the Precambrian is a two feet thick green sill approximately 600 feet stratigraphically above the base of the Marjum formation. This sill has been found only on the south side of Black Mountain.

Petrographic examination discloses that this is practically a monominerallic rock, composed almost entirely of very coarsely crystalline hornblende. Lamprobolite is minor as is plagioclase feldspar (composition unknown), together constituting far less than 5% of rock.

This igneous unit, unlike those of the Precambrian, has not been subjected to low-grade regional metamorphism.

Float fragments of extremely vesicular black scoria, similar to "thread-lace scoria" or reticulite, are present along the shore of the Great Salt
Lake near the Indian Caves on the western side of the Promontory Range. This material has a bulk density less than 1.0, and as there is no similar bedrock lithology within the Promontory Range it is assumed that the fragments have been floated in on the waters of the Great Salt Lake or one of its predecessors.
Regional metamorphism in the Promontory Range is almost entirely confined to the Precambrian and Lower Cambrian. The only exceptions are the metamorphism associated with the Indian Caves overthrust fault and the metamorphism of the Manning Canyon shale in Coldwater Canyon.

The regional metamorphism in the Promontory Range is definitely low-grade. There is no evidence that the regional metamorphism progressed beyond the temperatures and pressures of the "greenschist facies" of Eskola, and indeed it is probable that this state was seldom reached.

The lithologies most susceptible to metamorphism are the basic igneous extrusives and intrusives of the Precambrian stratigraphic interval. Porphyritic textures are common in these bodies, and although the phenocrysts are invariably replaced, generally completely replaced, their external crystal outline commonly gives some indication of their original composition. These pyroxene and amphibole phenocrysts have been replaced by abundant calcite, by more moderate amounts of epidote, iron oxides, and microcrystalline quartz, and by relatively minor amounts of microcrystalline albite and chlorite. The mineralogical composition of the groundmass is somewhat similar to that within the phenocryst boundaries, but is not nearly as significant because there is no evidence as to its original composition. In the groundmass calcite remains the most abundant mineral; but the micaceous minerals, particularly chlorite and muscovite, are much more abundant than within the phenocrysts. There is no doubt that the alteration of the basic minerals of the phenocrysts (amphiboles and pyroxenes) has contributed the
bulk of the minerals in the groundmass. As the phenocryst outlines are still discernible, it is obvious that the present mineral suite is largely, if not entirely, pseudomorphous. The characteristic feature of the metamorphism of these basic igneous rocks is the prolific development of calcite. This has invariably been developed to such an extreme that these rocks will effervesce when dilute HCl is applied, even though it is obvious that they originally had little or no calcite. No zeolites have been noted in the metamorphosed basic igneous rocks.

The present petrography of these igneous rocks greatly resembles the end results of propylitization as described by Williams, Turner, and Gilbert (1954, pp. 96-97). The characteristic features all obtain; i.e. the drab-green color in hand specimens, replacement of hornblende by chlorite, calcite, and iron ore, and the development of chlorite and calcite from pyroxenes. Propylitization, however, is generally regarded as a type of contact metamorphism found close to ore bodies; but there is no evidence that such alteration could not be regional. It is significant that the propylitized rocks are found within the Promontory mining district. All of this evidence strongly indicates that the basic igneous extrusives and intrusives of the Precambrian were originally andesites or had andesitic-like mineralogical compositions.

Where the pelitic strata of the Precambrian are concerned, the highest degree of metamorphism reached was the development of phyllite. Schists or higher metamorphic derivatives are absent. Where carbonate strata are in close stratigraphic proximity to the basic igneous rocks the former may be practically unmetamorphosed, indicating that the igneous rocks suffered the
brunt of the metamorphic activity.

The present mineralogical composition of the igneous rocks of the Precambrian strongly resembles that of the "greenschist facies" as described by Turner and Verhoogen (1951). However, because of the strong evidence toward propylitization it is probable that this stage was never reached. The writer believes that the extreme alteration of the basic igneous rocks of the Precambrian in the Promontory Range is anomalous and not indicative of the grade of regional metamorphism attained.

Within the Promontory mining district several carbonate beds in the Cambrian section have undergone low-grade contact metamorphism. In the Burrows limestone along the southwest face of Black Mountain the uppermost lithologic unit, a light gray, finely crystalline limestone, has been converted to white marble. This alteration is proximal to some of the major lead-zinc deposits of the Promontory mining district and is undoubtedly related to the mineralization. Irregularly shaped zones of dolomite are found near the base of the thick cliff-forming limestone at the top of the Marjum formation on the south face of Black Mountain. The contacts of these dolomite bodies do not coincide with bedding surfaces, and because the dolomite bodies are not laterally persistent, they are considered to be secondary "pods" of dolomite in a limestone. These secondary dolomite bodies also probably owe their origin to the hydrothermal mineralization in the Promontory mining district.

Carbonate strata in the lower plate of the Indian Caves overthrust fault along the western side of the Promontory Range have been extensively metamorphosed, undoubtedly as a consequence of this earliest detectable
orogeny. The metamorphism has been so intense and regionally pervasive that original textures and structures have been destroyed and it is impossible to determine which geologic formations constitute the basal plate of the overthrust. The writer's premise that these strata are Ordovician-Devonian is purely an assumption, based primarily upon knowledge of the lithology of the stratigraphic section of the Promontory Range. No identifiable fossils have been found in the lower plate of the overthrust, although several outcrops display "fossil ghosts", presumably crinoid remains which have been recrystallized. The upper plate of the overthrust has been relatively unmetamorphosed and is well dated paleontologically as Middle Cambrian through Lower Ordovician. The carbonate strata of the lower plate have generally been recrystallized resulting in coarser textures than those found in carbonate strata elsewhere in the Promontory Range. This pervasive recrystallization of carbonate lithologies is restricted to the lower plate of the Indian Caves overthrust fault and is assumed to be a consequence of an early orogeny, presumably Laramide.

In Coldwater Canyon, near the northwestern tip of the Promontory Range, portions of the Manning Canyon shale have been subjected to very low grade regional metamorphism. The approximate area covered by this metamorphism was mapped by Butler et al. (1920) as Precambrian. Although the writer has no paleontological proof that the metamorphosed strata are not Precambrian, several lines of evidence indicate that they are a portion of the Manning Canyon shale. Black shale has been converted to argillite and the superficial resemblance of this argillite to the black phyllites of the "intermediate" Precambrian stratigraphic sequence at Promontory Point may have
contributed to the aforementioned mapping error. On the floor of Coldwater Canyon the bedrock is seldom exposed outside of the main drainages. Along blocky fractures in this metamorphosed zone thicknesses of up to one foot outwardly resemble quartzite, but no quartzite was seen in place. The argil-lite resembles an exfoliated schist on weathered surfaces and wherever studied possesses a pronounced fissility. Near the mouth of Coldwater Canyon, southeast of the Keller Ranch, several outliers of dark brown-stained very fine-grained quartzite stand out, undoubtedly due to differential resistance, above the flat valley floor. Their overall appearance and definitive texture indicate that they belong to the Manning Canyon shale. Nowhere else in the stratigraphic section of the Promontory Range are similar quartzites seen except in the Manning Canyon shale. This metamorphic sequence is bounded on the south by the Coldwater fault and on the east by a somewhat doubtful northward extension of the Promontory fault. The metamorphism is believed by the writer to be associated with one of the early orogenies in the Promontory Range, probably contemporaneous with the close folding of the Oquirrh formation on Mt. Tarpey; it is highly improbable that there is any association with the Late (?) Tertiary block faulting episode to which the Coldwater and Promontory faults are assigned.
PRE-LARAMIDE TECTONICS

Evidence of Orogenies

The Laramide orogeny is clearly portrayed in the Promontory Range by overthrust faults and large isoclinal fault blocks. Evidence for several earlier orogenies, however, is found only in the stratigraphic record.

The Triassic-Pliocene gap in the stratigraphic column renders it impossible to determine with certainty the events of the Mesozoic Era; indeed, this is an interval about which little is known for almost all of northwestern Utah.

Precambrian Tectonism

The pronounced angular unconformity between the Archean (?) "Farmington Canyon complex" and the Proterozoic (?) metasediments is not exposed in the Promontory Range, but is clearly displayed approximately 20 miles to the southeast on Antelope Island (Larsen, 1957).

A lithologic correlation is postulated between the oldest Proterozoic (?) strata at Promontory Point and the oldest Proterozoic (?) strata on Antelope Island (see "Precambrian Stratigraphy"). If this correlation is valid, the angular unconformity between the Archean (?) Farmington Canyon complex and

1. Usage of the term "isoclinal" with respect to fault blocks must be here-with defined because the writer's intended meaning differs somewhat from the accepted definition. As used throughout this dissertation, "isoclinal fault blocks" means that the strata within an individual fault block are dipping uniformly - not that the strata in all fault blocks referred to are dipping uniformly with respect to each other. The writer could find no word which would express this meaning; thus the modified usage of the term "isoclinal".

- 164 -
the Proterozoic (?) sequence must lie at a shallow depth below the strata at
the end of the sheep loading pier at Promontory Point.

The Proterozoic (?) sequence and the Lower (?) Cambrian Prospect Moun-
tain quartzite in the vicinity of Promontory Point are considered to have
been deposited in a shallow sea which encroached upon the greatly deformed
Farmington Canyon complex (see "Precambrian" section of "Geologic History").

Eardley considered a white, very fine-grained quartzite, the youngest
lithologic unit on Antelope Island, to be the Cambrian (?) Brigham quartzite
(Eardley and Hatch, 1940a, pg. 59). A cross section through Antelope Island
(Eardley and Hatch, 1940b, pg. 828) portrays a relatively thin Proterozoic
section which has two erosional breaks and is capped by the so-called Brigham
quartzite. Therefore, Eardley postulates that Antelope Island was one of the
positive areas of the Northern Utah Highland with nearly all of a thick Pro-
terozoic (?) section either eroded or never deposited prior to the deposition
of the so-called Brigham quartzite. The only way to substantiate or disprove
this theory would be the discovery of fossils in the quartzite on Antelope
Island, but as a considerable thickness of the Prospect Mountain quartzite
in the Promontory Range has yielded no fossils, this possibility seems remote.

The writer, however, regards the quartzite as early Proterozoic (?) in
age. It resembles somewhat the Prospect Mountain quartzite in hand specimen,
but the outcrop habit is similar to that of the "youngest" Precambrian se-
quence at Promontory Point. If this correlation is correct, Antelope Island
would have been the site of accumulation of Proterozoic (?) sediments as
thick as those on Fremont Island and the southern portion of the Promontory
Range. Thus, it is possible that sediments were being deposited at Antelope

165
Island during all of Proterozoic (?) time and that the almost complete absence of Proterozoic (?) strata there is due to subsequent erosion.

Eardley (1944, pg. 828) has described an unconformity in the north-central Wasatch Mountains between the Tintic quartzite (correlative of the Prospect Mountain quartzite) and the crystalline complex, with all of the Proterozoic (?) sequence absent. This relationship is not present in the Promontory Range, where the Proterozoic (?) strata may be observed at several localities in conformable sedimentary contact with the overlying Lower (?) Cambrian Prospect Mountain quartzite.

The lithologic nature and great thickness of the Cambrian section in the Promontory Range also suggests that both Antelope and Fremont Islands were buried by Cambrian sediments. After the Cambrian Period these islands were probably recurrently positive, as was the remainder of the Northern Utah Highland. Additional substantiating evidence for this theory may be found under the heading "Middle Paleozoic Tectonism".

Middle Paleozoic Tectonism

A period of tectonic unrest in the Promontory Range lasting from Middle Ordovician through Late Devonian is well indicated by field evidence. A comparison of the Middle Ordovician-Devonian stratigraphic sections on Mt. Baldy and at the head of Middle Canyon show large discrepancies in thickness as follows:
Field evidence leads the writer to conclude that the Mt. Baldy sections of the Swan Peak formation, Fish Haven dolomite, and Laketown dolomite and the Middle Canyon sections of the Water Canyon dolomite and Jefferson formation represent normal thicknesses, whereas the other measurements represent anomalous conditions.

Care must be taken in interpreting the measurements for several reasons. The basal portion of the section in Middle Canyon is close to the Promontory fault and some of its thinning may be due to brecciation. Although the quartzite of the Swan Peak formation has been intensely brecciated due to faulting, with some local structural thinning, it is not plausible to ascribe much of the thinning to Tertiary tectonism because of the relatively uniform thickness of the formation in the immediate area. The Fish Haven dolomite - Laketown dolomite contact is uncertainly established, but the combined thickness of the two formations is known at Mt. Baldy and Middle Canyon and the extent of change of the two together can therefore be told.

It is not possible to include the Garden City formation in this analysis because its base is not exposed at either locality; however, by comparing a stratigraphic section measured at The Narrows with one measured on Mt. Baldy it is evident that the Garden City formation retains a fairly constant...
thickness throughout the Promontory Range. No section of the Laketown dolomite in Middle Canyon was measured because of considerable cover; the 530 foot thickness was derived from geometrical calculations and by plotting on aerial photographs.

Two conclusions are drawn from the foregoing stratigraphic evidence concerning crustal unrest in the Middle Paleozoic:

1.) A subdued highland rose south of the Promontory Range, probably in the vicinity of Antelope Island, in the Middle Ordovician and remained high at least through Late Silurian.

2.) During Early or Middle Devonian the northern portion of the Promontory Range was subjected to a gentle epeirogenic uplift, but by the beginning of the Mississippian period any expression of it had been eliminated.

The earlier uplift in the vicinity of Antelope Island probably was never sufficiently positive to furnish clastics to any portion of the Promontory Range. This, of course, is with the exception of the Swan Peak formation, to which abundant clastics were contributed over a large part of western and northwestern Utah. No change in grain size of the quartzites was noticed between the Middle Canyon and Mt. Baldy exposures and the carbonate sequences are very similar. There is strong evidence that the area was either emergent or under very shallow water during the early stages of the Upper Ordovician (see "Fish Haven dolomite").

The writer postulates that this gentle uplift was a rejuvenation of the
Northern Utah Highland (Eardley and Hatch, 1940) of Proterozoic (?) age. Eardley has presented a strong evidence that this Proterozoic (?) highland must have remained relatively high during most, if not all, of post-Proterozoic time, and further states that it "was recurrently positive from Proterozoic (?) time onward" (Eardley and Hatch, 1940, pg. 830). The geologic record of the Promontory Range substantiates this theory with the exception of the Middle Cambrian - Lower Ordovician interval. It is difficult to visualize how such a thick sequence of carbonates with only minor clastics (8,500 feet) could be deposited near Promontory Point so close to the postulated highland (see discussion of the Charleston Thrust).

The absence of Ordovician and Silurian deposits in the north-central Wasatch Mountains (Eardley, 1944) indicates that the postulated rejuvenation of the Northern Utah Highland was connected to the craton itself. Other workers have established the edge of the craton during Middle Ordovician through Silurian time as being at the approximate western edge of the Wasatch Mountains in north-central Utah and consider that the absence of deposits to the west is due to erosion. The evidence presented here indicates that sediments may never have been deposited over the site of the Northern Utah Highland during Middle Ordovician through Silurian time. This may also be related to an east-west high described by Bissell (1955, pg. 1644) as extending from Provo, Utah to Wendover on the Utah-Nevada border, beginning as early as Ordovician and lasting until at least Early Mississippian time.

Whether this rejuvenation of the Northern Utah Highland continued into the Devonian period is unknown, due to the incomplete Devonian record on Mt. Baldy caused by the epeirogenic upwarping of the northern portion of the area.
in the Devonian. It was probably subdued during the Devonian as indicated by the presence of questionable Devonian deposits in the north-central Wasatch Mountains (Eardley, 1944, pp. 830-831.)

A complete lack of fossils in the Devonian system hinders the dating of the Devonian epeirogenic upwarping in the northern portion of the area. Between Middle Canyon and Mt. Baldy, a distance of about 11 miles, a progressive northerly omission, due to overlap truncation by the Madison limestone, of at least 950 feet and possibly as much as 1,400 feet of Devonian strata may be observed. The writer postulates that this omission of strata is due to gentle epeirogenic uplift in the general vicinity of Mt. Baldy or north of this peak. Clastic debris from this crustal uplift was nowhere noted in pre-Madison strata near Mt. Baldy, but at the Middle Canyon section several thin beds of quartzite and intraformational dolomite conglomerate were observed in the Jefferson formation (see Stratigraphic Section D-3, Appendix). It should be noted, however, that other workers (Petersen, 1956; Williams, 1948, and Young, 1955) have described clastics from the Jefferson formation and from other Middle Devonian formations in northern Utah; and the presence of the clastic beds in Middle Canyon may reflect a general sedimentary environment over a large area rather than a consequence of the gentle epeirogenic uplift in the northern portion of what is now the Promontory Range.

At several localities on Mt. Baldy the Madison limestone can be demonstrated in sedimentary contact with the Water Canyon formation and any possibility of small scale overthrusting is rendered implausible by the total absence of brecciation near the contact. There is no visible unconformity,
but this can be easily explained; for the resultant angular unconformity resulting from the removal or non-deposition of 1,400 feet of strata over an 11 mile distance would be only slightly greater than 1°.

The absence of some of the Devonian (?) strata on Mt. Baldy may be due to non-deposition rather than erosion. The uplift could have initiated as early as latest Early Devonian time and extended through to earliest Early Mississippian time. By Madison time its expression had disappeared and the Madison limestone was deposited in generally uniform thicknesses over the entire range. The Madison limestone in the Promontory Range contains no clastics, intraformation conglomerates or other evidence of nearby crustal instability.

Paddock (1956, pg. 387) has recognized similar conditions in the Newfoundland Mountains, approximately 50 miles west of Promontory Point. He states that "Tectonic uplift and probable associated epeirogenic upwarping toward the north is suggested by the removal of all Three Forks ? and Upper Devonian Guilmette beds northward in the Newfoundland Mountains. This uplift may have commenced during the Late Devonian." The uplift in the Newfoundland Mountains and the one in the vicinity of Mt. Baldy are undoubtedly related.

In a regional study of the Devonian of central Utah, Petersen (1956, Pg. 28) recognizes that orogenic movements in the Upper Devonian were more active than during the Lower and Middle Devonian. The area studied by Petersen is south of the Promontory Range and the Newfoundland Mountains, which indicates that the crustal unrest of the Late Devonian was widespread
in northwestern and central Utah.

Rigby (1959) discusses the general character of an Upper Devonian unconformity in central Utah and believes that most of the stratigraphic gap below the Upper Devonian or Lower Mississippian strata is the result of erosion and not nondeposition. The writer concedes that this may also be true in the Promontory Range but has no substantiating evidence.

The Promontory Range is characterized by many faults. Most of these faults are active, and only locally displaced. Both instances of overturned strata are minor in areal extent and in structural significance. The large overthrust fault is recognized, but with its exception, thrust faulting appears to be completely absent. Many faults of large stratigraphic displacement are present, but large synclinal or anticyclinal folds and thrusts are absent. High-angle reverse and normal faults are abundant, and there is strong evidence that many fault surfaces are vertical or nearly vertical. Large, tilted fault blocks are by far the predominant structural features of the Promontory Range.

The major faults, with but few exceptions, can be grouped into a north-south and an east-west system. The area of the faults in the northern portion of the range trend north-south.

Structural Blocks

The Promontory Range is effectively divided into two large structural blocks by the high-angle Middle Canyon Fault:

The southern structural block is 15 miles long and consists of four large fault blocks, which have been rotated with respect to each other. The fault blocks consist almost entirely of Precambrian and Cambrian strata dipping at moderate to high angles and are uncomplicated by folding, but are bounded by several vertical or near-vertical faults of large stratigraphic
STRUCTURAL GEOLOGY

General Features

The Promontory Range is characterized by many faults; but folds, including two instances of overturned strata, are only locally displayed. Both instances of overturned strata are minor in areal extent and in structural significance. One large overthrust fault is recognized, but with its exception, thrust faulting appears to be completely absent. Many faults of large stratigraphic displacement are present, but large synclinal or anticlinal folds and flexures are absent. High-angle reverse and normal faults are abundant and there is strong evidence that some fault surfaces are vertical or very nearly vertical. Large, tilted fault blocks are by far the predominant structural features of the Promontory Range.

The major faults, with but few exceptions, can be grouped into a north-south and an east-west system. The axes of the folds in the northern portion of the range trend north-south.

Structural Blocks

The Promontory Range is effectively divided into two large structural blocks by the high-angle Middle Canyon fault.

The southern structural block is 11 miles long and consists of four large fault blocks which have been rotated with respect to each other. The fault blocks consist almost entirely of Precambrian and Cambrian strata dipping at moderate to high angles and are uncomplicated by folding, but are bounded by several vertical or near-vertical faults of large stratigraphic
displacement. Thus, the predominant structural features are large isoclinal fault blocks. The major faults which separate these blocks have almost linear traces and determine the courses of valleys; all major canyons in the southern structural block are fault-line valleys which have been carved along large faults.

The northern structural block is almost completely composed of post-Cambrian strata, largely the Pennsylvanian-Permian Oquirrh formation. The faults of the northern structural block have curvilinear traces in contrast with the almost linear fault traces of the southern structural block, generally have poor topographic expression, and rarely define fault-line valleys. They are extremely difficult to trace within the Oquirrh formation. Gentle to moderate dips prevail and the fault blocks have not been rotated with respect to each other. Tight folding is locally present in the north-central portion, but there are no large anticlinal or synclinal folds.

Southern Structural Block

Complex Faulting at Promontory Point: Precambrian strata and the Prospect Mountain quartzite form most of the bedrock south and southwest of Black Mountain down to the shores of the Great Salt Lake at Promontory Point, but are extensively veneered by the Pleistocene deposits of Lake Bonneville. There are several large faults in this concealed area, but a complete comprehension of the complex faulting is rendered impossible because of the lack of an unbroken stratigraphic sequence of Precambrian strata. The presence of greatly differing Precambrian lithologies in close proximity to one another and several inliers of Middle Cambrian limestone (presumably Marjum formation)
among the Precambrian outcrops bespeaks a complex structure.

None of these northeasterly-trending faults can be traced into Black Mountain which lies only about one mile north of this faulted area. The writer postulates that these faults terminate against an older east-west fault located to the south and southwest of Black Mountain. This phenomenon of large faults terminating against earlier faults is present elsewhere in the Promontory Range and is thought to be a valid explanation of the case in point.

No accurate estimate can be made, with present knowledge, of the stratigraphic displacement of these faults; however, one of the northerly-trending faults places limestone of the Marjum formation (Middle Cambrian) against either Prospect Mountain quartzite or Precambrian quartzite indicating a stratigraphic throw of at least 2,000 feet.

**Little Valley Fault:** - The Little Valley fault is an east-west vertical fault which separates Black Mountain, composed entirely of Middle and Upper Cambrian strata, from the extensive exposures of the Prospect Mountain quartzite in Little Valley and at the head of the South Fork of Little Valley. It is rendered spectacularly visible from a distance by a sharp line of change in the pattern of vegetation. The Cambrian carbonates south of the fault support a heavy growth of juniper trees, whereas the Prospect Mountain quartzite north of the fault nourishes only sagebrush. The vertical fault plane and the associated striking vegetation pattern may be viewed from the road to Promontory Point about five miles north of the railroad camp. (see Figure 10).

The stratigraphic throw at the head of the South Fork of Little Valley
is at least 7,500 feet, with the lower portion of the Prospect Mountain quartzite opposite the upper portion of the Mounan formation. The South Fork of Little Valley and Little Valley itself are fault-line valleys, having been carved along the trace of the Little Valley fault.

Figure 10. Oblique aerial photograph taken over the western shore of Bear River Bay and looking westward along the trace of the Little Valley fault. Note vegetative difference to the north and south of the fault.

The Little Valley fault determines the southern margin of Little Valley which has been carved out of the Prospect Mountain quartzite. It is postulated that this canyon is excavated in the quartzite rather than the adjacent
Cambrian carbonates because the quartzite suffered intense brecciation. Quartzites of the Swan Peak formation have been badly shattered along faults in other areas (particularly in Middle Canyon), and this consideration lends support to the belief that the Prospect Mountain quartzite under the alluvium of Little Valley is intensely broken.

The fault trace may be easily followed from one side of the range to the other and is well displayed along the southern edge of Little Valley by the presence of small outliers of Precambrian and Lower Cambrian quartzite which are contiguous with Upper Cambrian carbonates. The trace of the fault is remarkably linear.

Black Mountain, bounded on the north by the Little Valley fault, has several small faults, but its structure is relatively simple. Cambrian strata dip gently to moderately northward with only slight variations in strike.

The northern face of Black Mountain, as defined by the Little Valley fault, is an obsequent fault-line erosion scarp with the trace of the fault crossing lateral spurs rather than terminating them in triangular facets.

Maple Canyon Fault: - The Maple Canyon fault courses somewhat east of north and separates two large fault blocks of Cambrian strata. Its trace is almost linear and the fault surface must be vertical or very nearly vertical; the latter condition is indicated by the linear trace and by the exposures of the fault in the pass between Maple Canyon and the North Fork of Little Valley.

The fault is well displayed in the North Fork of Little Valley where the Prospect Mountain quartzite to the east is opposite the carbonates of the
Middle and Upper Cambrian on the west. It is made readily visible because the Prospect Mountain quartzite forms bare slopes covered only by sagebrush whereas the Middle and Upper Cambrian carbonates are marked by a thick plant cover mostly of juniper trees. The fault is not as well exposed in Maple Canyon where Upper Cambrian carbonates are present on either side. Both Maple Canyon and the North Fork of Little Valley have been excavated along the Maple Canyon fault and are excellent examples of fault-line valleys.

The stratigraphic throw of the Maple Canyon fault as determined a short distance south of the pass between the North Fork of Little Valley and Maple Canyon is at least 4,500 feet. At this locality the Prospect Mountain quartzite-Pioche "shale" contact on the eastern side of the canyon is opposite the lower half of the Nounan formation.

The strike and dip of the strata differ in the fault blocks on either side of the Maple Canyon fault, and neither is similar to the attitude of the strata on Black Mountain. The Maple Canyon fault can be traced southward approximately six miles from where it becomes concealed west of The Narrows to the point where it meets the Little Valley fault. There is no reflection of the Maple Canyon fault on Black Mountain south of the Little Valley fault, thus the Maple Canyon fault is considered to terminate against the Little Valley fault and so postdate it. The fault block east of the Maple Canyon fault and north of the Little Valley fault has been rotated slightly, probably after the initiation of the Maple Canyon fault and certainly during the final stages of movement of both faults.

Though the Maple Canyon fault might be interpreted as a large tear fault with the eastern fault block moved northward after tilting, the writer prefers
to consider the movement as predominantly vertical during and subsequent to the tilting of the beds. The main evidence against a tear fault is the complete lack of horizontal drag and the absence of smaller sympathetic drag faults with horizontal displacement.

Long Canyon Fault: - The Long Canyon fault has very minor displacement compared to the large faults of the southern structural block, but is important because it may be traced for five miles. It is a vertical or near-vertical fault as indicated by the almost linear trace and the excellent exposures along the west wall of Maple Canyon.

Near the head of Long Canyon the stratigraphic throw of the Long Canyon fault is about 1,000 feet. This measurement is fairly accurate because the Pioche "shale" forms a good marker bed. Near the divide between Brushy Canyon and Maple Canyon the stratigraphic throw may be as much as 1,500 feet, but the formational contacts used in arriving at this figure are somewhat obscure. The maximum stratigraphic throw of the Long Canyon fault is probably not much in excess of 1,000 feet. Along the major portion of the fault, displacement is not readily visible due to the lack of marker beds. The best exposures of the fault are found near the base of the exposed Precambrian strata along the Great Salt Lake shore, about one mile downstream from the head of Long Canyon where the Pioche "shale" is displaced, and northeast of the divide between Brushy Canyon and Maple Canyon where the Marjum formation is opposite the Nounan formation. The last of these exposures is accentuated by a striking change in vegetation as well as an abrupt lateral termination of massive cliffs of the Nounan formation opposite a smooth dip slope developed
on or slightly below the uppermost beds of the Marjum formation (see Figure 11).

Much of Long Canyon and a large tributary canyon on the west wall of Maple Canyon have been eroded along the Long Canyon fault; however, over some of its extent the fault has no topographic expression. It differs from most of the

Figure 11. View of the Long Canyon fault from the mouth of Maple Canyon. Heavy growth of junipers and scrub brush covers the Nounan formation to the left of the fault. The Marjum limestone to the right of the fault supports mainly sagebrush.

other faults of the southern structural block in that it does not determine the course of a fault-line valley.

The age of the Long Canyon fault with respect to the Promontory
and Maple Canyon faults is not known because their junction is concealed.

**South Canyon Fault:** - The South Canyon fault also has little displacement compared to the large faults of the southern structural block. Its near-perfect linear trace indicates that it has vertical or very nearly vertical displacement.

Near the head of South Canyon, along its southern wall, the South Canyon fault has placed uppermost Pioche "shale" opposite the uppermost portion of the "undifferentiated Middle Cambrian" sequence, indicating a stratigraphic throw slightly in excess of 1,000 feet.

The South Canyon fault has a markedly linear trace, similar to the Little Valley and Maple Canyon faults. The presence of South Canyon owes its existence to the South Canyon fault and is thus a fault-line valley. However, because the canyon has been carved from the northern or upthrown block, the southern wall of South Canyon is interpreted as an obsequent fault-line erosion scarp. Thus, the South Canyon fault is similar to the Little Valley fault in that it defines the south side of a canyon carved from Precambrian and Cambrian quartzites. Tracing of the fault near the head of South Canyon is facilitated by the presence of outliers of Prospect Mountain quartzite contiguous with Middle Cambrian carbonate strata.

The South Canyon fault is at least five miles long, but only the north-eastermost one and a half miles can be proven by bedrock displacement. It terminates against the Promontory fault and therefore may postdate it.

**Promontory Fault:** - The Promontory fault is the major structural feature of the southern structural block. Formerly termed the "Promontory thrust"
(Olson, 1956, p. 66), the fault is now considered to be a high-angle reverse fault. Its trace in the southern structural block is less than five miles long and is poorly exposed over much of its extent. From the South Fork of Middle Canyon to its termination against the Maple Canyon fault, the Promontory fault has a very sinuous trace. This, plus the topographic expression of the fault blocks on either side — the southwest block is generally considerably higher than the northeast block — suggests a high-angle overthrust fault. From the South Fork of Middle Canyon to the Middle Canyon fault however, both the straight fault trace and more or less equal elevations of both fault blocks argue against the possibility of an overthrust fault. The Promontory fault is now considered to be a high-angle reverse fault. The dip of the fault probably changes considerably, particularly in its southernmost two and one-half miles where a pronounced decrease in dip is indicated by the sinuous fault trace and the topographic expression of the fault blocks on either side.

The stratigraphic throw of the Promontory fault on the north wall of the South Fork of Middle Canyon is at least 7,500 feet with the upper portion of the Prospect Mountain quartzite opposite lowermost Garden City formation or possibly uppermost St. Charles formation. Thus, almost the entire Middle and Upper Cambrian stratigraphic sequences are omitted. At Whitaker Pass the stratigraphic throw is probably slightly in excess of 4,500 feet with a questionable lowermost Nounan formation opposite the base of the Swan Peak formation. The first figure (7,500 feet) is undoubtedly the maximum stratigraphic throw attained by the Promontory fault.

The strata on both sides of the Promontory fault have essentially
the same strike and dip. As viewed from the main road northwest of The Narrows, Whitaker Pass would seem to be occupied merely by a less resistant member of an uninterrupted stratigraphic succession. Quartzite of the Swan Peak formation constitutes the bedrock of the pass, with the orange to brown coloration of the soil being caused by intense iron oxide accumulations on the abundant fracture surfaces of the intensely brecciated quartzite. The Promontory fault defines the southern edge of Whitaker Pass.

The Middle Canyon fault is younger than the Promontory fault which it displaces and the Maple Canyon fault must predate the Promontory fault which terminates against it. It is possible that the southeasterly-trending fault east of the divide between Maple Canyon and the North Fork of Little Valley may represent the extension of the Promontory fault, but this would be difficult to prove.

From the South Fork of Middle Canyon to the Middle Canyon fault the trace of the Promontory fault is accentuated by the lack of trees on its western side (Prospect Mountain quartzite) and the dense overgrowth of trees, mainly junipers, on its eastern side (Garden City formation and questionable St. Charles formation). Elsewhere the trace of the fault is more difficult to delineate.

Intense brecciation is commonly associated with the Promontory fault, particularly near the head of the South Fork of Middle Canyon.

**Middle Canyon Fault:** The Middle Canyon fault separates the Promontory Range into northern and southern structural blocks. This vertical or near-vertical, presumably normal fault may be traced from one side of the range to the other for a distance of about four miles. It has little topographic
expression, especially in the eastern half. The North Fork of Middle Canyon
is a poorly defined fault-line valley which has been carved out along the Middle
Canyon fault.

The stratigraphic throw of the Middle Canyon fault near the head of the
North Fork of Middle Canyon is at least 11,000 feet at one point where the
base of the Prospect Mountain quartzite is opposite the Garden City formation
but this figure includes displacements due to other faults. East of the
intersection of the Promontory fault and the Middle Canyon fault the latter
has a stratigraphic throw of at least 7,500 feet with the lower portion of
the Garden City formation opposite the Great Blue (?) limestone.

The Middle Canyon fault is younger than the Promontory fault which it
offsets. The Sandy Pass fault terminates against the Middle Canyon fault and
is therefore the younger of the two.

Going northeasterly, the trace of the Middle Canyon fault is fairly linear
until it reaches the crest of the range near the head of North Canyon where
it swings easterly in an arcuate manner. From the range divide eastward it
has a fairly linear trace. Whether this is caused by a southward flattening
of the fault surface is not known; but if this be true, the Middle Canyon
fault would be a high-angle reverse fault. From its exposures in the North
Fork of Middle Canyon, however, the writer believes it to be a normal fault.

Brecciation along the Middle Canyon fault is locally intense, particularly
along its western half. Thus, it is unlike the other faults of the southern
structural block, except for the Promontory fault which locally displays in-
tense brecciation.
Summary: - To summarize, the major features of the southern structural block are three large vertical or near-vertical normal faults and one large high-angle reverse fault. These faults separate lesser fault blocks of moderately to steeply dipping pre-Mississippian strata which have been rotated with respect to each other. Folding is practically absent and no thrust faults are recognized. Fault traces are generally remarkably linear. Two well defined fault-line erosion scarps are recognized and both are obsequent.

The chief features which distinguish the southern structural block from the northern structural block are:

1) Almost complete absence of folding.
2) Almost linear fault traces which determine large fault-line valleys.
3) Fault blocks have been rotated.
4) Generally moderate to steep dips (30°-50°).
5) Faults generally have clear topographic expression.

Northern Structural Block

Chokecherry Fault: - The Chokecherry fault is a northeast-trending vertical or near-vertical fault which can be traced for almost four miles from the eastern margin of the range to the western margin. The trace is curvilinear and does not affect the present topography except very locally. No part of Chokecherry Canyon owes its existence directly to the fault and only a small portion of Owens Canyon has been eroded along along it. This lack of topographic expression and the absence of fault-line valleys characterize most of the faults of the northern structural block and contrast strongly with the
pronounced development of both of these features in conjunction with faults of the southern structural block.

The stratigraphic throw of the Chokecherry fault is difficult to determine, for along most of its trace only the Oquirrh formation is involved and key horizons are lacking. Near the head of Owens Canyon on the western side of the range the stratigraphic throw is at least 8,000 feet because the Swan Peak formation is opposite the Oquirrh formation, but this combines displacements involving both the Promontory and Chokecherry faults. Near the mouth of Chokecherry Canyon on the eastern side of the range at least 5,500 feet of stratigraphic throw places the Madison limestone opposite the Oquirrh formation, but this also involves the displacement of the Bert horst. The maximum stratigraphic throw of the Chokecherry fault taken alone is probably much less than 5,500 feet.

Near the head of Chokecherry Canyon the fault is well displayed where massive limestone cliffs of the Oquirrh formation terminate abruptly against a slope under which the bedrock is mostly concealed. Pronounced drag on the southern side of the Chokecherry fault is well shown on the crest and high western flank of the range. Owens Spring, near the head of Owens Canyon, is located precisely upon the trace of the Chokecherry fault.

The Chokecherry fault is younger than the Promontory fault which it clearly offsets near the head of Owens Canyon. The north-south faults which define the Bert horst are younger than both the Chokecherry and Mountain Springs faults.

Mountain Springs Fault: - The Mountain Springs fault is an easterly
trending vertical or near-vertical fault which can be traced for almost five miles from one side of the range to the other. It is roughly parallel to the Chokecherry fault on the eastern side of the range, but diverges strongly from this parallelism on the western side. Except for a sharp bend near the crest of the range the trace of the Mountain Springs fault is more linear than that of the Chokecherry fault and has a much greater effect on present topography. Both the small canyon north of Chokecherry Canyon on the eastern side of the range and North Chokecherry Canyon on the western side of the range are fault-line valleys carved along the trace of the Mountain Springs fault.

The stratigraphic throw of the Mountain Springs fault is difficult to determine, for over most of its extent only the Oquirrh formation with poor faunal control and absence of marker beds is involved. East of Mountain Springs the stratigraphic throw is at least 6,000 feet where the Madison limestone is opposite the Oquirrh formation, but this also involves the displacement of the Bert horst. The displacement due solely to the Mountain Springs fault is much less than this. The stratigraphic throw in North Chokecherry Canyon cannot be determined with present knowledge.

The Mountain Springs lie on or very near the trace of the Mountain Springs fault and undoubtedly owe their existence primarily to it.

The Mountain Springs fault is younger than the Promontory fault which it is presumed to offset and is probably contemporaneous with the Chokecherry fault.

**Bert Horst:** The Bert horst is located about one mile northwest of the Woodward Ranch (formerly Bert, Utah). It consists of Madison limestone, Deseret
limestone, and Humbug formation with an aggregate exposed thickness of about 1,100 feet surrounded on four sides by fault contact with the younger Oquirrh formation (see Figure 12). This unusual structure has a surface area of less than half a square mile. The Chokecherry fault bounds it on the south and

![Figure 12. Vertical aerial photograph of the Bert horst.](image)

the Mountain Springs fault bounds it on the north. Two border faults, trending slightly west of north and each less than a mile long, define the horst on its western and eastern sides. These border faults do not extend north of the Mountain Springs fault nor south of the Chokecherry fault, but despite
their limited extent they have displacements at least as great as these large east-west faults. The stratigraphic throw of the western border fault is at least 4,000 feet and that of the eastern border fault is at least 4,500 feet.

Both border faults are well defined. The western fault crosses a prominent saddle on the ridge between Chokecherry Canyon and Mountain Springs and is made prominent by a change in vegetation; the Oquirrh formation west of the fault supports a dense growth of trees whereas the Humbug formation east of the fault is almost completely barren of vegetation. The eastern fault is concealed by hillwash, but its presence is indicated by several outcrops of the Oquirrh formation topographically below the massive cliffs of Madison limestone which constitute the easternmost outcrops of the Bert horst.

The Chokecherry fault and the Mountain Springs fault are older than both border faults. After the Bert horst was defined on the north and south by east-west faults, the two north-south border faults were formed and the small block was further uplifted (see Figure 13). Each of the periods of faulting must have contributed approximately equal amounts of uplift to the Bert horst, judging from the amounts of stratigraphic throw on the two fault systems. No appreciable rotation of the strata accompanied the building of the Bert horst, which is a unique structure in the Promontory Range. All four faults bounding the horst are considered by the writer to be either vertical or near-vertical normal faults.

Promontory Fault: - Exposures of the Promontory fault in the southern structural block have been previously discussed. The total exposed length of the fault is 17 miles, of which slightly over 12 miles are in the northern
Figure 13. Structural Elution of the Bert Horst.
structural block. The trace of the northern segment of the Promontory fault is for the most part gently curvilinear, unlike the sinuous trace of its southern counterpart. It is considered to be a high-angle reverse fault.

The stratigraphic throw of the Promontory fault on the eastern edge of Mt. Baldy is at least 4,000 feet with the Water Canyon formation opposite the Oquirrh formation. On the north wall of North Chokecherry Canyon the stratigraphic throw is at least 3,500 feet with the Madison limestone opposite the Oquirrh formation. On the north wall of Owens Canyon the stratigraphic throw is at least 5,500 feet with questionable Laketown dolomite opposite the Oquirrh formation. The stratigraphic throw at the head of Broadmouth Canyon is at least 5,000 feet with the Jefferson formation opposite the Oquirrh formation. The stratigraphic throw at the head of Broadmouth Canyon is at least 5,000 feet with the Jefferson formation opposite the Oquirrh formation. Between Broadmouth and Miller Canyons, determinations of the stratigraphic throw are complicated by the Indian Caves overthrust fault in the western block. At Sandy Pass the stratigraphic throw of the Promontory fault is at least 7,000 feet with basal Garden City formation opposite the Great Blue (?) limestone. The considerable variations in the amount of stratigraphic throw (3,500 feet to 7,500 feet) at widespread points along the Promontory fault are due primarily to its transection by several later large east-west faults; for after the establishment of this latter system, individual fault blocks could move vertically independent of each other. Slight changes of dip on either side of the Promontory fault and the absence of marker beds and faunal control in the Oquirrh formation are additional complicating factors.

The Promontory fault is younger than the Coldwater fault and the Indian
Caves overthrust fault, but is older than the Mountain Springs fault, the Chokecherry fault, the Broadmouth fault, and the Middle Canyon fault. The age relationship of the Sandy Pass fault and the Promontory fault is unknown. The offsets of the Promontory fault by the younger east-west faults are well displayed in Middle Canyon, Owens Canyon, and North Chokecherry Canyon; all on the western side of the range.

The trace of the Promontory fault is well defined throughout its northernmost ten miles because the Oquirrh formation is everywhere present along the west side of the fault throughout this distance. There is generally a slight change in the density of vegetation between the western and the eastern fault blocks and the fault trace itself is expressed topographically by saddles or notches along the east-west ridges which it transects. This feature is well shown between North Chokecherry and Broadmouth Canyons. South of its intersection with the Broadmouth fault, the Promontory fault has a more subtle or concealed trace, although the north wall of Miller Canyon shows a pronounced change in the density of vegetation at the fault trace.

The Promontory fault has a longer trace than any other fault in the Promontory Range. It must be considered, along with the Middle Canyon fault and the Indian Caves overthrust fault, as one of the three major structural features of the Promontory Range.

Sandy Pass Fault: - The Sandy Pass fault may be traced for about two miles from its termination against the Middle Canyon fault to its junction with the Promontory fault on the north wall of Miller Canyon. Its trace is poorly defined throughout its extent except between North and Middle Canyons where
extreme brecciation renders the fault zone readily visible.

The stratigraphic throw of the Sandy Pass fault is at least 2,500 feet in North Canyon where the Garden City formation lies against undifferentiated Silurian (?) and Devonian (?) dolomites.

The Sandy Pass fault is probably a branch of the Promontory fault and is younger than both the Middle Canyon fault and the Indian Caves overthrust fault. It is named after Sandy Pass, a saddle along the ridge between Miller and North Canyons which owes its existence to the erosion of a heavily brecciated zone between the Promontory and the Sandy Pass faults.

The Indian Caves overthrust fault has no surface expression east of the Sandy Pass fault, but has probably been downfaulted to a shallow depth below the ground surface (see Section C-C', Plate 1).

**Indian Caves Overthrust Fault:** The Indian Caves overthrust fault is a very low-angle overthrust fault¹ which has brought Middle and Upper (?) Cambrian carbonates upon undifferentiated Silurian (?) and Devonian (?) dolomites (see Figure 14).

The age of the upper plate has been definitely established with the identification of two trilobite collections by Dr. C. L. Balk. Of one collection Dr. Balk says:

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¹ Eardley (personal communication) believes that this is an unusual type of Laramide structure and further states that Dr. W. H. Bucher "would seize upon it as the core of the area of uplift, away from which gravity gliding has formed flow and thrust structures." Eardley further suspects that the Indian Caves overthrust fault "is a minor slide structure." The writer does not agree, but feels that it is worthwhile to mention this idea.
"...they are certainly Cambrian, and I would suspect from their appearance they come from the middle part of the Middle Cambrian, somewhere in the Bathyriscus-Elrathina zone, rather than in the Upper Cambrian."

Dr. Balk states that the other collection belongs to the Bathyriscus-Elrathina zone of middle Middle Cambrian. These two collections were made from the upper plate of the Indian Caves overthrust fault, but the basal portion of the...
over-lying Nounan formation is locally present as thin capping slivers on the ridge between North and Miller Canyons. No fossils have been found in the dolomite comprising the lower plate; but this is not surprising, for the dolomite has undergone considerable low-grade metamorphism, perhaps in part due to "dislocation metamorphism" along the sole of the overthrust fault (Williams, H. et. al., 1954, p. 164). Curiously, no portion of the upper plate has suffered such alteration. The recrystallization and subsequent obliteration of primary structures such as bedding is not intense and probably represents metamorphism only slightly more advanced than is common in sedimentary diagenesis.

The bedding attitude of the dolomite in the lower plate is in most places not discernible, but near the Indian Caves reliable bedding measurements obtained on both the dolomite and the Marjum formation are very similar - N 30°W, 25°W on Marjum formation of upper plate and N 15°W, 30°W on dolomites of lower plate. North of Miller Canyon the bedding attitudes of both plates of the Indian Caves overthrust fault are likewise very similar, where discernible. The fault contact is seldom visible because of abundant talus shed from the massive limestone cliffs of the Marjum formation which are the most prominent feature of the upper plate. South of the Indian Caves, however, the fault contact is locally well exposed and brecciation is pronounced in the lower plate. The present attitude of the thrust surface is difficult to determine, but from several local observations the writer believes it to dip approximately 5° westerly.

The possibility that this is a sedimentary contact is extremely remote. Dolomite does not underlie the Marjum formation anywhere else in the
Promontory Range and has not been recognized in a similar stratigraphic position anywhere in the Great Basin. Pervasive dolomitization of the strata below the Marjum formation leaving the latter unaffected is unlikely because of the original heterogeneity of these strata (much interbedded shale) and the present uniform composition of the dolomite of the lower plate. In summary, a sedimentary contact is ruled out because of: (1) the lack of a normal lithologic succession underlying the Marjum formation, (2) the metamorphism of the lower plate while the upper plate is relatively unaffected, and (3) brecciation along the sole of the overthrust fault.

The Indian Caves overthrust fault is considered the oldest fault in the Promontory Range and is bounded on three sides by the Middle Canyon, Sandy Pass, Promontory, and Chokecherry faults; all of which are definitely younger. The exposures of the Indian Caves overthrust fault are restricted to an area of approximately 10 square miles along the western margin of the Promontory Range. The direction of overthrusting was easterly judging from the present attitude of the strata and the fault surface.

The Indian Caves are situated on or a short distance above the trace of the Indian Caves overthrust fault and probably owe their existence to increased permeability and porosity due to brecciation along the sole of the thrust fault. No caves were observed by the writer below the uppermost level attained by Lake Bonneville.

Subsequent to the formation of the overthrust fault the area has been subjected to extensive high-angle faulting which together with erosion, has resulted in the formation of several small isolated klippen. No fensters have been recognized.
Broadmouth Fault: The Broadmouth fault extends east-west and may be traced for a distance of almost six miles from one side of the range to the other. Over much of its trace on the eastern side of the range the fault, as mapped, is somewhat speculative, but on the western side of the range the fault trace is clearly defined.

The displacement of the Broadmouth fault is minor compared with the large faults of the Promontory Range. At its westernmost exposure the Broadmouth fault has displaced the trace of the Indian Caves overthrust fault less than 1,000 feet vertically. Along its eastern portion the displacement is probably greater; a stratigraphic throw of at least 2,000 feet is indicated where the upper portion of the Great Blue (?) limestone has been placed opposite the Oquirrh formation.

The Broadmouth fault appears to offset the Promontory fault and thus is probably younger. Its extension eastward onto Little Mountain is problematical.

Maple Canyon Fault and Complex Faulting on Little Mountain: Little Mountain, an inlier on the eastern side of the range, is separated from the main mass of the Promontory Range by Boothe Valley which is about one and one-half miles wide with no bedrock outcrops. The trace of the fault which runs along Boothe Valley is completely concealed, but a hypothetical connection with the Maple Canyon fault to the south is possible. It is also possible that this fault swings easterly south of Boothe Valley and defines the truncation of the eastward-trending spurs along The Narrows. This latter possibility is strengthened by the presence of intense brecciation of the carbonate rocks which compose these spurs and the presence of several springs, generally sulphurous,
along their truncated ends.

The writer believes that the fault in Boothe Valley is a northward extension of the Maple Canyon fault. Its relationship to the Middle Canyon fault is unknown and can only be determined by geophysical methods because of the extensive cover by surficial deposits in Boothe Valley.

Little Mountain itself is complexly faulted, especially its northern half which is so intensely brecciated that geologic mapping would be almost impossible without the presence of the Swan Peak formation, an excellent marker bed. With the exception of the relatively minor exposures of the Swan Peak formation, Little Mountain is composed entirely of carbonate rocks, and these have been subjected to very low-grade metamorphism similar to that of the lower plate of the Indian Caves overthrust fault.

The intersection of the Middle Canyon fault and the Maple Canyon (?) fault may be responsible for the intense brecciation on the northern end of Little Mountain; however, the fault pattern is unlike that of the main mass of the Promontory Range and may have been formed independently of both faults.

Coldwater Fault: - The Coldwater fault is a northeast-southwest vertical or near-vertical fault which can be traced approximately four miles from the western side of the range to a point slightly east of the main drainage divide, where it appears to terminate against the Wildcat fault.

The spurs of Middle Paleozoic carbonates which form the northern flank of Mt. Baldy extend uniform distances out into the valley formed by North and South Coldwater Canyons so that their bases determine a straight line. The bases of these spurs are blunt perpendicular to their long dimension rather
than sharpening to a point, which is good evidence for their truncation by a fault line. The Coldwater fault is therefore drawn along the bases of these spurs, making South Coldwater Canyon a fairly well defined fault-line valley throughout most of its length. The northern flank of Mt. Baldy is therefore a resequent fault-line erosion scarp. East of Mud Springs the Coldwater fault is almost linear and is fairly well displayed due to contrasting lithologies; Manning Canyon formation to the north and Oquirrh formation to the south. Mud Springs is situated directly on the fault and doubtless owes its existence primarily to this major fracture.

As the trace of the Coldwater fault is almost linear, its attitude cannot depart greatly from vertical. Its offset by the Promontory fault at the northeast corner of Mt. Baldy is spectacular and excellently displayed. The Coldwater fault is older than the Promontory fault, but its relationship to the Wildcat fault is unknown. From meager field evidence the writer concludes that the Coldwater fault terminates against the Wildcat fault and thus is younger. Physiographic evidence however, does not favor this age relationship, for the upthrown block of the Wildcat fault has suffered less erosion than the upthrown block of the Coldwater fault along Mt. Baldy and has well developed triangular facets while the latter does not.

The stratigraphic throw of the Coldwater fault north of Mt. Baldy is at least 3,500 feet, with basal Laketown dolomite opposite basal Manning Canyon formation. East of the Promontory fault the stratigraphic throw of the Coldwater fault is at least 1,500 feet and probably much greater where the basal Manning Canyon formation is opposite the Oquirrh formation; how much greater cannot be determined as the base of the Oquirrh formation is
The present relative vertical displacement along the Coldwater fault is in opposite directions on either side of the Promontory fault (see Plate 1). This may have been brought about by the following sequence of structural events:

1) Establishment of the Coldwater fault along its entire present extent.

2) Establishment of the Promontory fault terminating against the Coldwater fault.

3) Uplift of Mt. Baldy.

4) Downfaulting to the north of the Coldwater fault along its full extent.

Thus, the final movement along the portion of the Coldwater fault to the west of the Promontory fault may have been opposite to the present relative vertical displacement.

**Complex Faulting on Mt. Baldy:** The bedrock of Mt. Baldy, which ranges in age from Lower Ordovician to Upper (?) Mississippian, is cut by numerous normal faults of relatively small displacement and with attitudes that are vertical or near-vertical.

The summit of Mt. Baldy is a small graben. The stratigraphic throws of the border faults probably do not exceed 500 feet.

The Mt. Baldy faults, with only one exception, conform roughly to a north-south and an east-west pattern. The normal faults and graben suggest origin within a tensional phase, possibly following the compressional phase.
which formed the chaotic folding of the "lower limestone member" of the Oquirrh formation on Mt. Tarpey.

**Wildcat Fault:** The Wildcat fault, a north-south trending high-angle normal fault is well exposed for about seven and one-half miles within the mapped area and undoubtedly extends some distance north of the paved road which leads to the Golden Spike Monument. The fault is named after an outcrop of the Oquirrh formation, called "The Wildcat" by local residents, in the downthrown block about one mile west of the Roland Toombs Ranch.

The trace of the Wildcat fault is nearly linear in its northern half and only slightly less so in its southern half. A short distance south of "The Wildcat", the fault is displaced by a smaller east-west cross fault which can be traced for only about two miles. The amount of offset is considerable and this smaller unnamed cross fault is considered to have undergone lateral as well as vertical movement. No other fault in the Promontory Range shows such substantial evidence for the presence of both lateral and vertical movement. The Wildcat fault is clearly displayed north of this cross fault by pronounced differences in bedding attitude on either side of the fault trace and by the triangular facets west of the Larsen Ranch. South of the cross fault the Wildcat fault is clearly displayed by contrasting lithologies; the Manning Canyon formation in the upthrown western block opposite the Oquirrh formation in the downthrown eastern block.

The stratigraphic throw of the Wildcat fault west of the Larsen Ranch is at least 2,500 feet. West of the Ray Smith Ranch and south of the cross fault there is at least 3,000 feet of stratigraphic throw on the Wildcat.
fault. Several good springs on or very near the trace of the fault in the
canyon due west of the Ray Smith Ranch owe their existence to this large
fracture.

The extension of the Wildcat fault south of its intersection with the
Coldwater fault is difficult to prove as is the case with all other faults
in the Promontory Range which involve displacement within the Oquirrh
formation. Since the Coldwater fault cannot be traced to the east of the
Wildcat fault, the latter is drawn southward along the floor of a fairly
deep canyon. The cross fault which offsets the Wildcat fault is of course
younger than the Wildcat fault.

The upthrown block of the Wildcat fault north of the cross fault is a
very prominent topographic feature. The uppermost level reached by Lake
Bonneville is inscribed on the cliffs less than 100 feet above the fault
trace and these features parallel each other for the three-mile length of
the prominent cliffs west and southwest of the Larsen Ranch. The western
block has been overturned near the Wildcat fault (see Section A-A, Plate 1).

Eastward from the western side of the range toward Larsen Ridge the gentle
(30°) westward dip of the strata increases steadily until dips are steep on
the crest of the range (60° westerly) and overturned (70° to the east) on
the steep eastern flank of the range. The strata of the downthrown block
east of the Wildcat fault are nearly horizontal. A possible sequence of
events for the development of this structure is diagrammed in Figure 16.
The lack of folding in the downthrown block in close proximity to the tight
overturning in the upthrown block suggests that the folding preceded the
formation of the Wildcat fault. A period of compression is postulated, followed by the development of the Wildcat fault, which is definitely a normal fault. The offset of the Wildcat fault by the small cross fault indicates that the major movement of the cross fault was probably vertical.

The eastern face of the upthrown block of the Wildcat fault shows only negligible erosion. For this reason alone the Wildcat fault is considered to be one of the youngest of the major faults. The eastern flank of Larsen Ridge is a good example of a resequent fault-line erosion scarp.

Complex Folding on Mt. Tarpey: The Oquirrh formation in the vicinity of Mt. Tarpey has undergone locally intense deformation. Folding, commonly tight and overturned, has been observed both on the western and eastern flanks of the mountain.

The absence of reliable marker beds makes it extremely difficult, if not impossible, to map these folds for any appreciable distance. Small zigzag or chevron folds have been observed on the extreme western flank of Mt. Tarpey (see Figure 15). Traverses along the crests of the spurs on the eastern flank of Mt. Tarpey have revealed evidence of sharply divergent bedding attitudes within small areas and the pattern of the attitudes indicates the presence of large chevron folds. Although several folds have been observed, they would be very difficult to map because of the lack of associated marker beds.

The fold axes do not appear to diverge appreciably from a north-south direction. It may be stated with certainty that folds with east-west axes are not present.

- 204 -
With the exception of Larsen Ridge, the area around Mt. Tarpey represents the only portion of the Promontory Range where folding is of more than minor importance. The folding is probably the result of an east-west compressional phase which may have been contemporaneous with the folding on Larsen Ridge.

Figure 15. Small chevron fold on the western flank of Mt. Tarpey immediately east of the Promontory fault looking approximately due north.

and possibly with the Indian Caves overthrust fault, but may be due in part to gravity sliding of beds which would be expected to behave plastically at depth.

That the period of folding preceded the period of extensive high-angle...
faulting is shown by the lack of folding on Mt. Baldy directly west of the Promontory fault, while chevron folds are found in the Oquirrh formation directly east of the fault. It appears that the Oquirrh formation, particularly its "lower limestone member", bore the brunt of the folding of the early compressional phase and that subsequent faulting and erosion have removed all vestiges of the folded beds except in the vicinity of Mt. Tarpey and Larsen Ridge.

Folding West of Larsen Ridge: - The mountainous mass west of the Wildcat fault and north of North Coldwater Canyon is composed almost completely of the "lower limestone member" of the Oquirrh formation. This limestone unit is very susceptible to compressional folding, as is displayed on Mt. Tarpey. West of Larsen Ridge this structural weakness is shown by tight folding and local flowage of the beds involved in large flexures.

The folds are the result of an east-west compressional phase which predates the period of high-angle faulting and were undoubtedly contemporaneous with the formation of the overturned anticlinal fold whose eastern limb was subsequently downfaulted, resulting in the formation of Larsen Ridge.

Larsen Ridge is considered by the writer to have originally been a long north-south anticlinal fold which was overturned toward the west. The eastern limb was subsequently downfaulted, probably along the axis of the fold (see Figure 16).

Summary: - The northern structural block is distinguished from the southern structural block by these characteristics:

1) Folding (commonly tight) is locally present.
Figure 16. Structural Evolution of Larsen Ridge.
2) Faults have curvilinear traces which generally do not define fault-line valleys.

3) Fault blocks have generally not been rotated with respect to each other.

4) Strata have gentle to moderate dips (10°-30°), except in folded areas.

5) Faults generally lack topographic expression.

**Border Faults**

Mountain ranges of the Basin and Range province are generally believed to be characterized by border faults which sharply define either or both longitudinal margins. Unlike many of the other ranges in the province there is no conclusive physiographic evidence for such border faults along the Promontory Range.

A large border fault may be present along the western side of the range; evidence for this is the alignment of the ends of the bedrock spurs along this margin of the range from the Old Fort Ranch southward to the Indian Caves. These westward projecting bedrock spurs do not extend gradually down to the level of the Great Salt Lake, but generally terminate as rather steep cliffs.

Present geomorphological and outcrop evidence argues against the possibility of a large border fault along the eastern side of the range. This evidence consists of the absence of any alignment of the ends of spurs and ridges and the extreme irregularity of the range boundary. Many outliers of Oquirrh formation along the north shore of Bear River Bay and the exposure
of Precambrian tillite on Little Mountain at the southeastern corner of Bear River Bay are evidence against the possible presence of a wide north-south trending graben to the east of the Promontory Range.

However, Dr. K. L. Cook (personal communication) has conducted gravity surveys along the western and eastern sides of the range which indicate that border faults exist below the alluvium on both sides of the Promontory Range. Their topographic expression is not clear, as stated previously, but they would belong to the Basin and Range system.

Mechanisms of Faulting

With the exception of the Indian Caves overthrust fault the faults in the Promontory Range are all high-angle or vertical. Block faulting is the predominating structural feature.

A common feature is the abrupt termination of a fault against an earlier fault. This is best displayed by the termination of the Maple Canyon fault against the Little Valley fault (see Figure 17). Although the Maple Canyon fault has a stratigraphic throw of at least 4,500 feet at the head of Maple Canyon, no trace of it can be found on Black Mountain south of the Little Valley fault. Another example is the Promontory fault which appears to terminate against the Coldwater fault. Although there is at least 4,000 feet of stratigraphic throw along the Promontory fault between Mt. Baldy and Mt. Tarpey, no trace of the fault can be found north of Coldwater Canyon. The western and eastern border faults of the Bert horst are also good examples of faults terminating against earlier ones.
Figure 17. Block Faulting in Little Valley.
Most of the high-angle faults of the Promontory Range are considered to be normal, and therefore structural features of tensional origin predominate in the Promontory Range. This may be only an apparent predominance due partially to downfaulting but largely to erosion of older compressional features.

It must be remembered that movement along faults could have occurred in different directions at different times and that what is seen today is the aggregate total of these movements and not necessarily the result of the last displacement.

Possible Relation to the Charleston Thrust

An overthrust fault of large magnitude has been described southeast of Salt Lake City in the vicinity of Charleston, Utah (Baker, 1947, Baker et al. 1949, and Baker, 1959). Calkins and Butler (pg. 23, 1943) undoubtedly referred to the same overthrust fault, which is also mentioned by Crittenden et al. (pg. 24, 1952) and named the "Charleston thrust".

Baker and others have traced this main thrust fault approximately 20 miles and have found it to have an easterly trend and a southerly dip of 18°-20°. The horizontal displacement of the fault must have been great for it "resulted in the juxtaposition of facies originally deposited many miles apart" (Baker et al., pg. 1197, 1949). In the upper plate, south of the fault trace, the Paleozoic sequence above the base of the Great Blue limestone has an approximate thickness of 34,500 feet. In the lower plate, north of the fault trace, the same portion of the Paleozoic sequence is less than 3,500 feet.
That the Charleston thrust definitely preceded the block-faulting in the Wasatch Mountains is clearly shown in several places by the offset of its trace due to normal faulting. This feature, and several others noted by Baker et. al. (1949), are similar to features of the Indian Caves over-thrust fault in the Promontory Range. Baker et. al. (1949) postulate an extension of the Charleston thrust northward up the valley between the Oquirrh Range and the Wasatch Mountains and further state that "Thrust faults farther north in the Promontory Range, near Willard, and elsewhere in north-central Utah may represent a continuation of the same zone of thrust faulting -". This, of course, is highly speculative; the writer herewith offers another possibility than the correlation of the Charleston thrust with the Indian Caves overthrust fault (the only thrust fault in the Promontory Range).

The presence of a thick Paleozoic sequence (at least 27,000 feet thick) in the Promontory Range in close proximity to the "Northern Utah highland" and the north-central Wasatch Mountains with a much thinner Paleozoic sequence (less than 10,500 feet thick) suggests that the Charleston thrust may extend northward up the Salt Lake Valley, west of Antelope Island and Fremont Island, into the southern portion of Bear River Bay and possibly connect with Eardley's (1944) "thrusted area" near Willard, Utah. A further extension to the northeast may explain the great thickness of the Paleozoic sequence in the Logan quadrangle, which is in close proximity to much thinner Paleozoic sequences to the south and southeast.

The final answer to the problem, perhaps lies in regional geophysical investigations.
Structural History

Four main phases of structural activity, the first two of which may have been contemporaneous, are recognized in the Promontory Range.

1.) Overthrusting, presumably from the west.

2.) Compressional phase. East-west compression developed chevron folds and an overturned anticline.

3.) Tensional phase. Development of normal faults. Rotation of fault blocks. During this phase there was a renewal of compression resulting in the formation of the Promontory fault, the final compressional phase.

4.) Development of border fault along western margin of range. Final tensional phase.

The first two phases, overthrusting and folding, are assumed to be of Laramide age. The third phase, that of the block faulting, is also considered to be Laramide because primary scarps, a characteristic of the Basin and Range orogeny, are generally absent.

The last phase, which is poorly understood, is assumed to belong to the Basin and Range orogeny, and if so would be late Cenozoic in age.

The above age assignments are speculative due to the complete absence of Mesozoic and Tertiary deposits. Physical relationships allow relative dating of the different types of structural features; but there appears to be little hope for absolute dating, even to geologic periods, of structural events in the Promontory Range.
Beds of the Miocene-Pliocene (?) Salt Lake group at Rozel Point have been tilted, indicating that block-faulting continued well toward the end of the Tertiary. However, there is no physiographic evidence of Pleistocene faulting, nor are any of the Lake Bonneville deposits deformed.

The geomorphology of the two structural blocks of the Promontory Range is markedly different. The southern structural block, composed of steeply tilted and rotated fault blocks, has such strange topographic forms that does the northern structural block. Large, deeply eroded fault-line valleys separate the major fault blocks. Steep slopes, with many coulees and hogback ridges with well defined dip-slopes separated by contoured intervals are the typical land forms of the southern structural block.

The structure of the northern structural block does not generally affect the land forms as distinctly as does the structure of the southern structural block. The Promontory Fault, however, divides the northern block into a western and an eastern geomorphic districts. The differences between the two districts are somewhat subtle. The main distinguishing feature is that the attitude of the strata in the western district locally may determine the resultant land forms, whereas the topography of the eastern district is in no sense dependent upon the attitude of the strata.

Most impressive of all the geomorphologic features, however, are these
GEOMORPHOLOGY

General Features

The structure of the Promontory Range has directly influenced its geomorphological development. The most pronounced topographic effects are exercised by the Precambrian system and the Lower (?) Cambrian Prospect Mountain quartzite; the Middle and Upper Cambrian and the Ordovician, Silurian, and Devonian systems generally affect the topography in a more subdued manner, whereas the Mississippian and the Pennsylvanian systems have the least effect.

The geomorphology of the two structural blocks of the Promontory Range is markedly different. The southern structural block, composed of steeply tilted and rotated fault blocks, has much stronger topographic forms than does the northern structural block. Large, deeply excavated fault-line valleys separate the major fault blocks. Steep slopes, with many cuesta and hogback ridges with well defined dip slopes separated by concealed intervals are the typical land forms of the southern structural block.

The structure of the northern structural block does not generally affect its land forms as distinctly as does the structure of the southern structural block. The Promontory fault, however, divides the northern block into a western and an eastern geomorphic district. The differences between the two districts are somewhat subtle. The main distinguishing feature is that the attitude of the strata in the western district locally may determine the resultant land-forms; whereas the topography of the eastern district is in no sense dependent upon the attitude of the strata.

Most impressive of all the geomorphologic features, however, are those
imposed upon the base of the range by the Pleistocene Lake Bonneville. These features are striking because they are little eroded and in most places not concealed by hillwash. Spits, bars, hooks, cuspate forelands, former tombolos, engraved shorelines, and lake terraces are the most prominent of these shoreline features.

Southern Structural Block

The major drainages of the southern structural block are deeply incised, almost linear fault-line valleys which have been carved along faults of large stratigraphic throw.

Maple Canyon and the North Fork of Little Valley, both carved along the Maple Canyon fault, are the best examples of fault-line valleys in the Promontory Range. These narrow, almost perfectly linear valleys differ from the other major drainages of the southern structural block by having practically no valley floor except near their mouths.

The South Fork of Little Valley combined with Little Valley itself is a good example of a fault-line valley, but differs from those previously mentioned in being unusually wide. The southern edge of the valley is determined by the Little Valley fault and is almost perfectly linear (see Figure 18). It is problematical as to why Little Valley should be carved out of the Prospect Mountain quartzite rather than the adjacent Middle and Upper Cambrian carbonates and shales. The quartzites of the Swan Peak formation are normally extremely resistant, but where brecciated are very susceptible to erosion. This phenomenon may explain the anomalous behavior of the Prospect Mountain quartzite in the formation of Little Valley.
The North Fork of Middle Canyon is at best a rather poor example of a fault-line valley, despite the fact that it is carved along a major break, the Middle Canyon fault. Where quartzite is faulted against carbonates the fault-line valley is well defined, but where carbonates are present on either side it is poorly defined.

The South Canyon fault determines the course of South Canyon. Where Prospect Mountain quartzite has been faulted against Middle Cambrian carbonates, South Canyon has cut into the former. Thus, South Canyon is similar to
Little Valley, although the fault displacements involved in the formation of these valleys differ greatly.

The Long Canyon fault does not determine one continuous fault-line valley, as do the four previously mentioned faults, but has localized two fault-line valleys, one on either side of the drainage divide. The westernmost two and one-half miles of Long Canyon are a fair example, with minor local departures, of a fault-line valley. East of this to the drainage divide the Long Canyon fault has little influence on topography; but from the divide to its apparent termination against the Maple Canyon fault, the Long Canyon fault coincides perfectly with a linear fault-line valley (see Figure 11).

As large as the displacement has been on the major faults of the southern structural block, there is seldom appreciable topographic relief between the downthrown and upthrown block. Exceptions to this are found along portions of the Promontory fault and the South Canyon fault, and along the entire extent of the Little Valley fault.

At Whitaker Pass the upthrown block of the Promontory fault stands out prominently much higher than the downthrown block. This is largely due to the great susceptibility to erosion of the quartzites of the Swan Peak formation after they have been subjected to intense brecciation. The upthrown block is a resequent fault-line erosion scarp. The two faults discussed below differ from this in that their upthrown blocks are much lower topographically than the downthrown blocks.

South Canyon has a fairly wide valley floor which is locally bounded on the south side by the South Canyon fault. Thus, South Canyon is locally completely excavated from the upthrown block, which is topographically much
lower than the downthrown block. Here again the Prospect Mountain quartzite, normally a very resistant lithologic unit, has suffered extensive erosion after being subjected to intense brecciation. The trace of the South Canyon fault at one point crosses a lateral spur instead of limiting it - evidence which Blackwelder (1928, pg. 306) considers distinctive of fault-line erosion scarps. From all present evidence, the south wall of South Canyon is in part an obsequent fault-line erosion scarp.

The Little Valley fault has produced the best example of a fault-line erosion scarp in the Promontory Range. The downthrown block is much higher topographically than the upthrown block and stands out prominently above the valley floor, which is carved entirely from the upthrown block. Here again the normally resistant Prospect Mountain quartzite has been readily eroded where intensely brecciated by a major fault. Throughout the extent of the Little Valley fault, its trace on the north face of Black Mountain crosses lateral spurs rather than limiting their ends. The south wall of Little Valley is considered an excellent example of an obsequent fault-line erosion scarp.

Any pre-Pleistocene topographical features created by the extensive major faulting between the southern base of Black Mountain and Promontory Point have been completely concealed by the sediments of Lake Bonneville.

The steep dip of the strata and the characteristic bare slopes of the Precambrian and Lower (?) Cambrian clastic metasediments have aided in the local establishment of well defined systems of subsequent tributaries. The Middle and Upper Cambrian carbonates and shales form many resistant dip slopes but have not given rise to such well defined systems of subsequent tributaries
as are locally present in the Precambrian and Lower (?) Cambrian clastic metasediments. But no matter how resistant the strata may be along ridge crests, a relatively thin cover of hillwash or alluvium can nullify the possibility of the establishment of a system of subsequent tributaries.

The most prominent and abundant geomorphologic features in the southern structural block are hogbacks and steeply dipping cuestas. Dips are rarely less than 25° and they commonly range between 25° and 50°. Steep, almost planar dip slopes are present; the best of these are seen on or very near the top of the Marjum formation. Good examples of such dip slopes may be seen on the north face of Black Mountain and on the west wall of Maple Canyon immediately north of the Long Canyon fault (see Figure 11). The Precambrian and Lower (?) Cambrian metasediments in Brushy, South, and Middle Canyons are almost completely exposed and display excellent examples of hogbacks.

The southern structural block is characterized by relatively little cover. Strata are generally well exposed and excellent stratigraphic sections may be measured along ridge crests. This predominance of "bare" slopes is in sharp contrast with the northern structural block, particularly its eastern geomorphic district.

Northern Structural Block

Western District: - The western geomorphic district of the northern structural block is bounded on the north by the Coldwater fault, on the east by the Promontory fault, on the south by the Middle Canyon fault, and on the west by the Great Salt Lake and by encroaching alluvial deposits north of Owens Canyon. It is distinguished from the eastern district by the fact that
the strata, by virtue of their differential resistance, have some effect on
the geomorphology. Also, relatively "bare" slopes are abundant, unlike the
eastern district.

As in the eastern district, dips in the western district are relatively
low, rarely exceeding 30° and commonly ranging between 10° and 20°. The
strata range from Middle Cambrian to Upper (?) Mississippian with no Oquirrh
formation present. The Oquirrh formation is uniform and homogeneous over
thick stratigraphic intervals and has little, if any, effect on geomorphology.
The strata of the western district are heterogeneous and form locally well
defined cuestas and dip slopes, but no hogbacks due to the low dips. Good
examples of cuestas and dip slopes are found on the southern half of Mt.
Baldy.

Unlike the southern structural block there is no appreciable development
of major drainages along large faults. Another contrasting feature is the
absence of topographic relief along faults. The only area which does not con-
form closely to these general rules is Mt. Baldy. An excellent example of
the almost total lack of topographic relief adjacent to faults is found on the
ridge north of North Chokecherry Canyon where the Promontory fault has a
stratigraphic throw of at least 3,500 feet, yet is marked by a very minor
saddle across the ridge crest.

Eastern District: - The eastern geomorphic district of the northern
structural block is characterized by an almost complete lack of control over
its geomorphological development by the attitude of the strata. This is due
to the monotonous homogeneity of the Oquirrh formation, which makes up most
of the district, and which reacts to erosional forces as an almost homogeneous material.

The only exceptions to this lack of geomorphological control by the attitude of the strata are found where there are formations other than the Oquirrh formation; viz. Little Mountain and the Bert horst. Here cuestas are developed on strata possessing differential resistance. At the head of and west of the mouth of Coldwater Canyon limited exposures of the Manning Canyon formation with its interbedded quartzites and shales have not developed prominent cuestas because the dip of the strata is not high enough to allow the erosional stripping of the intervening shale.

Over the remainder of the eastern district the Oquirrh formation exerts very little control on geomorphic features. There is a nearly complete absence of cuestas and hogbacks. An excellent example of the weakness of the topographic control exerted by the Oquirrh formation is seen north of North Choke-cherry Canyon and south of Mt. Tarpey on the western slope of the range (see Figure 7).

As in the western geomorphic district, faults in the eastern district exert practically no control on present topography, with the notable exceptions of the Coldwater fault and the Wildcat fault. The Wildcat fault forms an abrupt and imposing front along the northernmost three miles of the eastern slope of the range (see Figure 19). Aligned triangular facets are well displayed along the base of the scarp of the upthrown block, which stands as much as 1,000 feet above the downthrown block which has been extensively concealed by Lake Bonneville deposits and alluvium derived from the upthrown block. The Wildcat fault scarp is the only one in the Promontory Range displaying well
Figure 19. Vertical aerial photograph of the Wildcat fault showing the alignment of truncated mountain spurs and associated triangular facets.

Figure 20. Vertical aerial photograph of the Coldwater fault showing the alignment of truncated spurs along the northern flank of Mt. Baldy.
developed triangular facets; however, there is no evidence that the relief of the upthrown block is due primarily to movement along the fault and it is, therefore, a resequent fault-line erosion scarp.

The portion of the Coldwater fault which lies west of the Promontory fault is similar to the Wildcat fault in that the upthrown block forms an abrupt and imposing front which extends for almost two miles along the southern edge of South Coldwater Canyon, stands as much as 1,500 feet higher than the downthrown block of Coldwater Canyon, and forms the linear northern boundary of Mt. Baldy (see Figure 20). Triangular facets in the strictest sense are absent, but a distinct alignment of the ends of the northerly extending spurs of Mt. Baldy suggest they might have shown aligned triangular facets at their ends before burial by alluvium. The relief of the upthrown block of Mt. Baldy is due to erosion, not movement along the fault; thus, the north slope of Mt. Baldy is an excellent example of a resequent fault-line erosion scarp.

In the northern structural block the Promontory fault is marked by minor saddles along ridge crests, but there is no appreciable topographic relief on either side of the fault. The eastern cliff-like face of the Bert horst is a small resequent fault-line erosion scarp developed westward from the eastern border fault of the horst. This is an excellent example of a true fault-line erosion scarp in that its present expression is some distance from the trace of the fault.

Lake Bonneville

The Promontory Range, like most other ranges in the eastern Great Basin, has been modified by Pleistocene Lake Bonneville, whose extensive deposits
and engraved shorelines completely circumscribe it. Approximately one-half of the area covered by the geologic map (Plate 1) has been modified by Lake Bonneville.

Marsall and Jones (1955, pg. 119) concluded "-that a reliable chronology is still to be achieved -" for the history of Lake Bonneville, and further state (1955, pg. 116) that the assumption "- that all of the shorelines engraved on the valley margins were formed by Lake Bonneville, the last of the Pleistocene lakes -" is probably erroneous. A detailed study of the Pleistocene deposits is beyond the scope of the present investigation. For the purposes of this report all features associated with Pleistocene lakes are ascribed to Lake Bonneville.

Five geomorphological features dominate the Pleistocene landscape. These are: (1) shorelines and associated wave-cut sea cliffs engraved in bedrock, restricted to the Bonneville level, and best exposed along the western side of the range between Little Valley and the Indian Caves; (2) lake terraces, best exposed on the northern and southern ends of the range, and locally along the eastern side; (3) bars, which are best exposed on the southeastern flank of the range and in Little Valley; (4) cuspate forelands present along the southernmost five miles of the eastern side of the range; and (5) spits and hooks, best exposed along the southeastern flank and northern end of the range.

1. Eardley (personal communication) has informed the writer that "-Jones has the idea that the lake at the Bonneville level should have one name, and at the Provo level another." The writer, in this dissertation, applies the name "Lake Bonneville" to the entire suite of Pleistocene lakes ranging from the present level of the Great Salt Lake to the Bonneville level.
Shorelines and Sea Cliffs - The most striking lake features of the Promontory Range are the highest shorelines and wave-cut sea cliffs. This is primarily due to the abrupt change from a normal erosional surface above to the depositional surfaces below; the latter are so young as to have suffered little erosion. The uppermost shoreline varies greatly in the clarity with which it has been inscribed on the flanks of the range and may be locally obscured by hillwash or alluvium from above. When Lake Bonneville was at its highest level, and while it was within about 250 feet below this level, Promontory Range was an island, completely isolated from the low-lying hills to the northeast and from the North Promontory Range to the northwest. This uppermost lake level, termed the Bonneville level, is generally an erosional feature. A notable exception to this rule is the Promontory Bar (named by the writer), a large baymouth bar which may be viewed from the main road about five miles north of Promontory Point on the eastern side of the range. It is about 5,500 feet long, 300 feet wide and stands about 30-40 feet above the base of the former lagoon behind and to the west of it. The southern half of the bar is especially well developed and almost completely undissected (see Figure 21), whereas the northern half is poorly developed with several deeply incised streams on the eastern or seaward face. Of all the depositional features developed in the range by Lake Bonneville, the Promontory Bar is undoubtedly the most perfectly preserved.

Along the western side of the range the waves at the Bonneville level must have broken against the shore with great force, for there are many wave-cut sea cliffs above the uppermost shoreline. Between Little Valley and Middle Canyon on the western side of the range several notable wave-cut sea
cliffs have been carved into the very resistant Prospect Mountain quartzite. On the eastern side of the range the Bonneville level is not generally as well shown, being represented only by a nick point on the slope. Talus slides of the Oquirrh formation may resemble the debris at the bases of sea cliffs from the distance, but there are few wave-cut sea cliffs compared to those of the western side of the range. According to the U. S. Weather
Bureau, the prevailing winds over the northwestern portion of the Great Salt Lake today are N-NE. It is quite probable that the prevailing winds during Lake Bonneville time were W-NW, thus allowing a large fetch to be active on the western side of the range while the eastern side was relatively sheltered. This would explain the more profound development of shore features on the western side.

Lake Terraces: Lake terraces are present on all sides of the Promontory Range and consist of two types: (1) wave-built, and (2) wave-cut. The former are by far more common and are best displayed on the northern end of the range where seven well developed terraces are present between the Bonneville level and a level about 300 feet below it (see Figure 22). Longshore currents undoubtedly played a large part in their formation. These terraces are unique in the range in that much material was contributed from the canyons of the range and was reworked and deposited in each terrace, whereas most of the other depositional terraces around the range merely represent reworking of minor amounts of pre-existing hillwash and alluvium. Between North Chokecherry Canyon and the Indian Caves on the western side of the range, several terraces have been cut in solid rock with only minor associated deposits. These wave-cut lake terraces have been engraved only into carbonate rocks and are not present in areas underlain by quartzite. Whether this is due to the differences in relative resistance of the two rock types or to varying intensity of wave action on the shoreline is unknown; but it is probably due to the former, for the areas of the two rock types are equally unsheltered and susceptible to wave action. These erosional terraces are seldom greater
than 100 feet wide, unlike the depositional terraces which attain much greater widths.

Along the western and southern margins of the southern structural block where Lake Bonneville inundated exposures of Precambrian and Lower (?) Cambrian clastic metasediments, the available supply of detritus and alluvium was scanty compared to all other areas. There are many inliers of basement rock which have not been concealed by lake sediments. A similar lack of

Figure 22. Vertical aerial photograph of the extreme northern tip of the Promontory Range showing depositional lake terraces in the uppermost 300 feet of the Lake Bonneville section.
detrital material must also have characterized the extensive exposures of carbonates on the western side of the range between Middle Canyon and Coldwater Canyon. Elsewhere in the range the supply of alluvium, detritus, and hill-wash was generally sufficient for the building of terraces which conceal the bedrock.

Bars: Bars built by Lake Bonneville are restricted to the southern five miles of the range. The Promontory Bar has been previously described. There are three small unnamed bars in Little Valley which have an insignificant volume compared to the Promontory Bar. The smallest of these, a bayhead bar, is near the head of the South Fork of Little Valley and the other two, which are both midbay bars, are farther downstream in Little Valley proper. All three, especially the two downstream ones, have been breached by the major drainages of Little Valley. Stream cuts indicate that gravel is a major constituent of these bars. The road up Little Valley and the South Fork of Little Valley crosses the crests of each of these bars. According to W. L. Stokes (personal communication) all three of these bars were cut into and mostly removed during the construction of the railroad fill from Saline to Lakeside, Utah.

Cuspate Forelands: Two large cuspate forelands have been constructed by Lake Bonneville along the southern five miles of the eastern side of the Promontory Range. The largest projects almost two miles from the range front eastward into Bear River Bay of the Great Salt Lake and was probably built during most of Lake Bonneville time, as its surface descends gradually from below the base of the Promontory Bar down to present lake level. Its northern
end intersects approximately the midpoint of the Promontory Bar (see Figure 21). Longshore currents must have been instrumental in its formation as well as the transportation of material from a southern source, for no material could be obtained from the mountain spurs behind the Promontory Bar which has not yet been breached by a major drainage. As previously mentioned, the Prospect Mountain quartzite is very susceptible to erosion when brecciated, as in the northern block of the Little Valley fault. This area may have been the source for much of the material in the cuspate foreland. Along the southern margin of the foreland there are several long, narrow beach ridges with accompanying wide, shallow swales.

The southernmost cuspate foreland extends eastward into Bear River Bay from a point approximately one mile south of the southeast corner of Black Mountain. It is not as large in area as the cuspate foreland which extends eastward from the Promontory Bar and has only one indistinct set of beach ridges and swales along its northern margin. Aside from this the two cuspate forelands are very similar and it is postulated that both were built during the recession of Lake Bonneville by a series of coalescing cuspate bars which were built ever farther out into the receding shallow water of the ancient lake.

**Spits and Hooks:** - Spits and hooks built into Lake Bonneville are found along the northern end of the range and along the southernmost 15 miles of the eastern side. At the extreme northern end of the range several small hooks have been constructed on the northern ends of well developed lake terraces.
The largest spit connects the range itself with the outlying Little Mountain to the east. The crest of the spit is crossed by the main access road which runs along the eastern side of the range. During the later stages of Lake Bonneville time this spit, which defines the northern end of Boothe Valley, was a large tombolo. It is approximately 7,500 feet long, but good exposures of the internal structure are present only in road cuts along the main access road.

**Lake Levels:** No detailed study of the levels of Lake Bonneville was attempted because of the complete lack of topographic control. On the southern end of the range, from the base of Black Mountain to Promontory Point, levels are well displayed which probably correlate with the Bonneville, Provo, and Stansbury levels widely described throughout the former basin of Lake Bonneville. Elsewhere in the range, localities showing all of these levels are few. One good example is the long ridge which extends eastward from the range toward the Lower Ranch midway along the eastern side of the range. On the whole the lake levels are poorly shown on the western side of the range, but south of South Canyon they are locally plainly visible. At the extreme northern end of the range a set of seven well developed terraces is present. Since the deserted town of Promontory is approximately 4900 feet above sea level, the Provo level is absent on Promontory Summit. Going eastward from the extreme northern end of the range, however, the Bonneville, Provo, and the Stansbury levels are very clearly displayed. At all good exposures showing a complete set of lake levels only three levels (Bonneville, Provo, and Stansbury) consistently predominate over all others.
ECONOMIC GEOLOGY

Lead-Zinc Deposits

The southern five miles of the Promontory Range constituted an active mining district from 1914 through at least 1924. Lead-zinc deposits, confined to Middle Cambrian strata, supported most of the activity.

Black Mountain was the site of most of the mines including all of the large ones, but minor abandoned workings are present on both canyon walls of the North Fork of Little Valley as well as in Long Canyon and its tributaries.

Siegfus (1924, pg. 1) states that "In 1915 the Promontory Point mining district was probably the most important zinc producing district in the State (sic.). It enjoyed a rather phenomenal prosperity until the year 1917 when production began to decline and in 1919, the last of the ore shipments was made."

Siegfus (1925, pg. 62) recognized two types of lead-zinc deposits, namely: "(1) completely oxidized lead-zinc replacement deposits in limestone localized near fissures and faults, (2) copper and lead sulphides in dolomite along faults and fissures", and states that only the first yielded appreciable amounts of ore. He further assumes that "The presence of igneous rocks in the district indicates that the oxidized lead-zinc deposits are probably the altered differentiates from the original magma." The writer, however, has not found the igneous rocks to which Siegfus refers, nor are they mentioned by Butler and Heikes (1916). Igneous rocks in the Promontory Range are confined to the Precambrian with the exception of a diabase sill.
in the Marjum formation. (see "Igneous Geology"). This intrusive was mentioned by Butler and Heikes (1916, pg. 6) who considered it a dike. No feeder dikes were observed from this sill and because it is 1,250 feet stratigraphically above the major deposits the writer doubts that it is directly related to the ore deposition.

Siegfus (1924, pg. 125) believes that "The igneous rocks exposed in this district are only of a limited extent but undoubtedly they represent parts of a large underlying igneous mass which furnished the primary sulphide ore." The writer maintains that any igneous rocks which may be related to ore deposition are even now at depth and nowhere exposed. It is possible, however that Siegfus is referring to some of the flows and sills in the Precambrian strata.

The principal workings on the southwest spurs of Black Mountain are within the Millard formation and all observed mine workings, except one on the west wall of the North Fork of Little Valley, are below the base of the Wheeler shale. Thus, of the 9,400 feet of strata between the Prospect Mountain quartzite and the Swan Peak formation, mineralization is almost entirely confined to the basal 1,325 feet, mostly to the basal 450 feet. The mineralization is associated with the interbedded shales and limestones which lie between the Prospect Mountain quartzite and the predominantly carbonate sequence above, and it is possible that a permeability control was exerted by this heterogeneous lithologic assemblage. Also, the fact that only one mine was located above the Wheeler shale would indicate that this dense, homogeneous, impermeable unit might have acted as a barrier to rising solutions.
The restriction of mineralization to interbedded shales and carbonates
lying above the basal Cambrian quartzite has been widely described in the
eastern Great Basin (Lindgren and Loughlin, 1919; Butler et.al., 1920; and
Gilluly, 1932). Although these other mining districts have different
mineralogy, the stratigraphic restriction of mineralization is very similar
to that observed in the Promontory Range.

The "middle limestone bed", which is cited as the principal host rock
by Butler and Heikes (1916, pg. 8) and Siegfus (1924, pg. 102), is most
likely lithologic unit #7 of the Burrows limestone in Stratigraphic Section
C-7 (see Appendix).

In the mining district the limestones in the section below the Wheeler
shale have been locally dolomitized and marbleized. As a general rule, the
marbleization has occurred close to the ore deposits, while the dolomitization
has occurred farther away at distances up to thousands of feet from the
deposits.

All observers who have inspected the mines of the Promontory District
maintain that the carbonate ores were derived from the alteration of sulphides,
even though no sulphide ore has ever been observed.

The present investigation was not primarily concerned with mine investi-
gations and none of the workings were inspected by the writer. Few workings
seem safe enough for inspection by a solitary observer. Butler and Heikes
(1916), Butler, et.al. (1920), and Siegfus (1924, 1925) should be referred
to for detailed investigations of these lead-zinc deposits.
Copper

Very minor deposits of copper have been worked in the Promontory District. The host rocks for these deposits are the Precambrian quartzites.

Butler and Heikes (1916) describe only the quartzite occurrences while Siegfus (1925) describes two types. The quartzite prospects are situated about one and one-half miles north and somewhat west from Saline station on the southwest corner of the peninsula. Butler and Heikes (1916, pg. 9) describe the ore as being "disseminated in the quartzite. The primary mineralization formed chalcopyrite and possibly bornite, but at the surface the sulphides have been altered to carbonates." Siegfus (1925, pg. 70) states that these deposits are associated with igneous rocks, but neither Butler and Heikes nor the writer observed any igneous rocks in the vicinity. Surficial staining on weathered Precambrian quartzite may be observed from the road on the western side of the range between Saline and Little Valley. This anomalous staining appears to be the result of admixture of copper and iron oxides, for its color is rarely that of the typical copper oxide suite. These deposits were negligible, with production amounting to only 14 tons (Siegfus, 1925, pg. 70).

Siegfus (1925, pp. 70-71) describes a copper property on the ridge east of Maple Canyon and the North Fork of Little Valley. There are some workings on the western slope of this ridge, but none seem to fit his description. He states that the sulphide ore (pyrite, chalcopyrite, and galena) was in the "Little Valley dolomite" (Nounan formation of the writer), but this formation has been eroded at the specified locality. The writer can add nothing, with present knowledge, regarding this occurrence.
Other Economic Commodities

With the exception of the lead-zinc and copper deposits, all known mineral products of value in the Promontory Range are non-metallic.

The Southern Pacific Railroad, which was the Central Pacific Railroad when the Lucin Cutoff was built, apparently used considerable amounts of the Precambrian phyllite and quartzite in Alum Bay as ballast for their roadbed. A close inspection of the roadbed, however, has indicated many lithologies foreign to the Promontory Range and it is possible that the aforementioned material proved unsatisfactory as ballast after a brief trial.

The Morrison-Knudsen Construction Company has recently constructed a solid fill, double-track roadbed across the Great Salt Lake from Saline to Lakeside, which replaces a wooden trestle previously used by the Southern Pacific Railroad. The ballast for this project was obtained from massive outcrops of intensely fractured Precambrian quartzite between Little Valley and Saline and from extensive alluvial and Lake Bonneville gravel deposits in Little Valley. The quartzite was mined underground by the block-caving method of extensive cross-cutting and subsequent blasting. The gravel deposits were excavated in open pits and transported to barges on the Great Salt Lake by an overland conveyor belt. The highly fortuitous occurrence of abundant gravel deposits in conjunction with extensive quartzite outcrops is found nowhere else in the Promontory Range and greatly facilitated the construction of this huge fill.
Potential Economic Commodities

The carbonate sedimentary rocks of the Promontory Range are generally impure and have much clastic and/or bdbclastic material. The purest of the carbonates are the white dolomites of the Lower (?) Devonian Water Canyon formation, but even these seem to be too impure for the most part to warrant commercial use. Exposures of this dolomite are locally very restricted in area and with one exception, at the head of Middle Canyon, are too far from the nearest railhead. Field examination of the dolomites indicates that due to the presence of clastic quartz grains they are unsuitable flux material.

Asphalt seeps at Rozel Point have been known since before the twentieth century. Boutwell (1904, pp. 470-473) and Slentz and Eardley (1956, pp. 36-40) have described their geology. No such occurrences have ever been described or were found by the writer in the Promontory Range. No oil or gas wells have been drilled within the mapped area, but the Bar B No. 1 well was drilled by Utah Southern Oil Company less than five miles northwest of the most westerly outcrop in the Promontory Range. This well was drilled to a depth of 7,922 feet and was plugged when it was considered that the Mississippian is dry (Peace, 1956, pp. 20-28). There are no visible structures favorable for the accumulation of petroleum or natural gas in the Promontory Range itself; however, it is possible that the wedging-out of formations caused by crustal unrest in the Middle Paleozoic (see "Middle Paleozoic Tectonism") could have formed stratigraphic traps favorable for such accumulation. Portions of the Laketown dolomite are vuggy enough to be a potential reservoir rock, but the Madison limestone, because of its coarse crystallinity and porosity, is
probably the best potential reservoir rock in the Promontory Range. Other formations do not seem to possess the required physical characteristics for petroleum reservoirs. Possibilities for the commercial occurrence of petroleum and natural gas in the Promontory Range seem poor.

Precambrian until the early Middle Cambrian. In this era a thickness of at least 12,000 feet of predominantly clastic sediments accumulated. The Middle Cambrian witnessed the beginning of the great PaleozoicMesozoic geosyncline in which at least 18,000 feet of dominantly carbonate sediments were deposited. From the Middle Ordovician through the Early Carboniferous, portions of the range underwent crustal disturbances, but generally during the Carboniferous the geosyncline was stable. Thrust faulting and folding occurred probably during the Late Triassic, which is so strongly evidenced in the range only 25 miles N of the town. The widespread normal faulting and relatively minor reverse faulting is thought to have occurred during the Late Cenozoic Basin and Range orogeny. Lake Bonneville completely flooded the range from all other land masses during part of the late Pleistocene.

Precambrian

The Precambrian strata in the Promontory Range were probably deposited in a shallow sea which was the predecessor of the great Cordilleran geosyncline.

Fettijohn (1949, p. 460) states that "many stratigraphic columns are slopes and cannot be called simply 'geosynclinal' or 'foreland'. Even in what was once a great geosyncline, the strata may belong to several contrasting facies. The geosyncline at times did not behave as a geosyncline.
GEOLOGIC HISTORY

General Statement

The Promontory Range was the site of a shallow sea from the Late Precambrian until the early Middle Cambrian. In this sea a thickness of at least 11,500 feet of predominantly clastic sediments accumulated. The Middle Cambrian witnessed the beginning of the great Paleozoic Cordilleran geosyncline in which at least 18,500 feet of dominantly carbonate sediments were deposited. From the Middle Ordovician through the Early Mississippian, portions of the range underwent crustal disturbances, but except for this the geosyncline was stable. Thrust faulting and folding occurred probably during the Laramide orogeny, which is so strongly evidenced in the Wasatch Range only 25 miles to the east. The widespread normal faulting and relatively minor reverse faulting is thought to have occurred during the Late Cenozoic Basin and Range orogeny. Lake Bonneville completely isolated the range from all other land masses during part of the Late Pleistocene.

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but was somewhat stabilized and sediments of the foreland type accumulated.”

He refers to such successions of strata as “mixed sections”. The Precambrian stratigraphic section of the Promontory Range is similar to his description of a "mixed section".

The Precambrian section, although incompletely exposed, indicates that a shallow sea encroached upon the greatly deformed Farmington Canyon complex. The entire Precambrian section is considered a foreland or platform facies of a shallow sea which preceded the inception of the great Paleozoic Cordilleran geosyncline. During the Late Precambrian, the Early Cambrian, and the early stages of the Middle Cambrian the foreland remained relatively stable as indicated by the uniform texture of the clastic deposits and the absence of orogenic deposits.

Cambrian

Deposition of clastic sediments similar to those of the Late Precambrian continued, without a break, into the Early Cambrian. Almost 4,000 feet of quartz sand accumulated during this epoch. During Middle Cambrian time the shoreline gradually retreated eastward; this resulted in the intercalation of shale with the sandstone, followed by the intercalation of shale with calcareous siltstone and limestone. In the uppermost portion of Middle Cambrian time the shoreline was fairly distant and calcareous siltstone and limestone dominated over the shale. During the Late Cambrian the trough was sufficiently deep and distant from land so that carbonate sediments greatly predominated. Very minor intercalations of fine-grained clastics continued into medial Late Cambrian time, but after this no more clastic deposition occurred until the
Ordovician

Deposition of carbonate sediments continued without interruption across the Cambrian-Ordovician boundary, with the dolomites of the Upper Cambrian giving way to limestone deposition in the Early Ordovician. During Middle Ordovician time the deposition of the carbonate sequence was interrupted rather abruptly by the deposition of a thin shale sequence followed by a thick wedge of well-rounded sandstone. This Middle Ordovician clastic sequence is widespread over the eastern Great Basin and may have been caused by a deepening followed by a pronounced shallowing of the geosynclinal trough. A reworked zone at the top of the Middle Ordovician clastic sequence suggests emergent or extremely shallow marine conditions, probably extending well into the Late Ordovician. The geosynclinal trough deepened during the Late Ordovician and carbonate deposition resumed, but probably only after much of the epoch had elapsed.

Middle Ordovician, and possibly Upper Ordovician, sedimentary rocks thin noticeably to the south, suggesting the possibility of a highland in the vicinity of Fremont and Antelope Islands.

Silurian

It is assumed that Lower Silurian rocks are missing in the Promontory Range and that deposition of carbonate sediments did not resume until the Middle Silurian. Whether or not deposition continued into the Late Silurian
is unknown, but in view of the general absence of Upper Silurian faunas in the eastern Great Basin, particularly in northern Utah, the writer assumes that only Middle Silurian rocks are represented in the Promontory Range.

The Silurian section thins noticeably to the south, suggesting that the postulated Middle and Upper Ordovician highland in the vicinity of Antelope Island remained high through the Silurian. It is emphasized, however, that this postulated highland was probably never strongly emergent prior to the Devonian, for no clastics were furnished to the Upper Ordovician or Silurian formations.

**Devonian**

Although fossil evidence is lacking for the entire Devonian period, it is assumed that carbonate deposition resumed in the Early Devonian and probably continued into the early Late Devonian. Unlike the Middle and Upper Ordovician and Silurian strata, those of the Devonian thin northward and not southward.

Subsequent to deposition of most of the Devonian strata and prior to the deposition of the Lower Mississippian limestone, a gentle epeirogenic uplift occurred in the northern part of the area. There, Upper and Middle Devonian strata and the uppermost Lower Devonian strata are missing and Lower Mississippian limestone rests on Lower Devonian dolomite. No pre-Madison folding has been observed and orogenic deposits are not present; thus, a gentle epeirogenic upwarping to the north is postulated. This uplift ceased being a positive element prior to the deposition of the Madison limestone (Lower Mississippian).
Mississippian

By Madison time (Early Mississippian) the effects of the pre-Mississippian epeirogenic uplift had disappeared and carbonate deposition was renewed in a slowly subsiding geosynclinal trough. Carbonate deposition continued into early Late Mississippian time, followed by intercalations of carbonates and abundant clastics, and finally a return to carbonate deposition.

The deposition of a considerable amount of argillaceous sediments in latest Mississippian time may indicate a deepening of the sea and the rise of a nearby land area.

Pennsylvanian

Early Pennsylvanian seas were probably deep at first, as evidenced by a continuation of argillaceous and sandstone deposition, but soon became shallow to receive interbedded carbonate and clastic sediments. A stable environment must have lasted throughout most of the Pennsylvanian and the Early Permian.

Permian

Only the early part of the Early Permian is represented in the Promontory Range. Deposition of interbedded chemical and clastic sediments continued, without a break, from Late Pennsylvanian into Early Permian, but clastics became dominant in the Early Permian.

Mesozoic and Tertiary

The Mesozoic era and the Tertiary period have left no sedimentary record in the geologic column of the Promontory Range. Although Triassic deposits
are present in areas to the west, none have been recognized in the Promontory Range. The portion of northern Utah in the eastern Great Basin has no known deposits of the Jurassic-Early Tertiary interval.

Orogenic deposits derived from the range are probably present to the east and west, but if so have been completely buried by the deposits of Pleistocene Lake Bonneville. Thus, the diastrophism which created the Promontory Range cannot be accurately dated from evidence within the area. From what is known of nearby ranges in the eastern Great Basin, the overthrusting and folding are presumed to be Laramide and the high-angle normal and reverse faulting part of the Late Cenozoic Basin and Range orogeny.

Slentz and Eardley (1956, pp. 32-40) describe a suite of Late (?) Tertiary interbedded basalts and limestone about five miles west of the Promontory Range. These strata have been moderately deformed. A possible correlation with the Pliocene Snake River volcanic flows to the north is inferred, but there is no paleontological evidence. If this correlation is correct, normal block faulting in the area probably continued at least to the end of the Tertiary period.

Quaternary

During portions of the Late Pleistocene the Promontory Range was completely isolated from surrounding land masses by Lake Bonneville. There is no physiographic evidence to indicate that any faulting occurred during the Pleistocene.
SUMMARY AND CONCLUSIONS

The purpose of this study was to describe the stratigraphy of the area and to map the structural geology; then to correlate and integrate these findings with what is known of adjacent areas.

Strata older than Late (?) Precambrian are absent. From a time assumed to be early in the Late Precambrian until at least Early Permian time the Promontory Range was part of the great Cordilleran geosyncline. Clastic deposition prevailed until the advent of Middle Cambrian time; during this interval more than 11,500 feet of predominantly clastic strata were deposited. From Middle Cambrian time through Early Mississippian time at least 13,000 feet of carbonate strata were deposited, with only minor clastic intercalations exclusive of the Middle Ordovician. During the remainder of Paleozoic time at least 7,000 feet of interbedded chemical, clastic, and bioclastic strata were deposited.

Structural features of the Late Tertiary Basin and Range orogeny predominate in the Promontory Range, undoubtedly due to their extreme youth. Evidence of the Laramide orogeny has been largely removed by a combination of Basin and Range block-faulting and subsequent erosion, but an overthrust fault on the western side of the range and tight, locally overturned, folding in the northern portion indicate its presence in the Promontory Range. The Basin and Range faults are generally high-angle and all but a few are considered to be normal faults. These faults can be grouped roughly into north-south and east-west sets and divide the Promontory Range into several large fault blocks, generally isoclinal, which may or may not be rotated with
respect to each other. On the whole, the Laramide orogeny seems to have been a period of compression and the Basin and Range orogeny largely a period of tensional relief, although this may be a severe oversimplification.

The Upper Ordovician-Silurian stratigraphic sequence thins toward the south in the Promontory Range, while the Devonian sequence thins toward the north. The former thinning is believed to be a stratigraphic attenuation or pinch out against the Northern Utah Highland, while the latter thinning is thought to represent a gentle epeirogeny to the north or northwest and to involve significant erosion as well as stratigraphic thinning.

Igneous rocks are minor and practically all are extrusive. Regional metamorphism is sporadically present, but is a relatively minor geologic feature in the Promontory Range.

The site of the Promontory Range is considered to have been fluctuating between foreland and geosynclinal conditions during the Late Precambrian. By Early Cambrian time the great Paleozoic Cordilleran geosyncline was well established and prevailed through at least Early Permian time. During this interval the depth of the geosynclinal sea varied considerably from time to time and from place to place as evidenced by the lithologic characteristics of the strata and by pronounced variations in the thicknesses of certain formations.

Deposition probably continued into the Mesozoic Era, although no evidence of this is present. The writer concludes, however, that were Mesozoic deposits ever present in the Promontory Range they consisted of a relatively thin veneer compared to the underlying Paleozoic systems or the geosynclinal Mesozoic section in the southeastern corner of Idaho.
The early and late portions of the Tertiary Period and quite likely the close of the Mesozoic Era were times of crustal unrest. Although these orogenies cannot be dated within the Promontory Range, the Laramide orogeny is known to be of Late Cretaceous and Early Tertiary age, while the Basin and Range orogeny is known to be of Late Tertiary and possibly earliest Pleistocene age. During Late Pleistocene time the area was invaded by the pluvial Lake Bonneville.

Stratigraphic evidence indicates that there may have been a large-scale translation of the earth's crust from west to east, probably during the Laramide orogeny. Under such an interpretation the Promontory Range would be part of the upper plate of the overthrust and the central Wasatch Mountains from the vicinity of Willard southward to Provo Canyon would be part of the lower plate.
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During the course of field work 15 stratigraphic sections were measured. The method of measurement has been previously described (see "Introduction" in text).

Descriptions of the lithologies were made in the field, and in addition hand samples of characteristically different lithologies were collected for laboratory study. Approximately 100 such samples have been inspected by binocular microscopy. All igneous specimens and most of the metamorphic specimens have been thin-sectioned and studied petrographically. All carbonate specimens were etched with concentrated HCl in order to determine their true clastic content.

The Wentworth scale was used to determine grain size and the various grades of crystallinity ascribed to the carbonate lithologies correspond to the divisions of the Wentworth scale.

A standard nomenclature for the division of lithologies used is employed, giving an order: lithology, color of the fresh rock, grain size or degree of crystallinity and weathered color. The phrase "weathered color" means that there is no detectable difference between the weathered color and the color of the fresh rock. The thicknesses of the individual lithologic units have been measured to the nearest foot. Only those sections measured during the measurement of the stratigraphic sections at large scale and their direct equivalence to the sections can be fully substantiated are given.

APPENDIX
During the course of field work 46 stratigraphic sections were measured. The method of measurement has been previously described (see "Introduction" in text).

Descriptions of the lithologies were made in the field, and in addition hand samples of characteristically different lithologies were collected for laboratory study. Approximately 400 such samples have been inspected by binocular microscope. All igneous specimens and many of the metamorphic specimens have been thin-sectioned and studied petrographically. All carbonate specimens were etched with concentrated HCl in order to determine their true clastic content.

The Wentworth scale was used to determine grain size and the various grades of crystallinity ascribed to the carbonate lithologies correspond to the divisions of the Wentworth scale.

A standard nomenclature for the description of lithologic units is employed, giving in order; lithology, color of the fresh rock, grain size or degree of crystallinity, and weathered color. The phrase "weathers same" means that there is no detectable difference between the weathered color and the color of the fresh rock. The thicknesses of the individual lithologic units have been rounded off to the nearest foot. Only those fossils collected during the measurement of the stratigraphic sections or those whose stratigraphic equivalence to the sections can be firmly established are included.
PC-1. Stratigraphic Section of the "Oldest Precambrian Sequence" at Promontory Point.

This section, measured from the sheep-loading pier to the railroad cut south of the CAA airport, lies entirely below Section PC-2, whose lowermost unit is not structurally concordant with unit #11 of this section. Unit #2 of Section PC-2 has strike N 85 W and dip 25° N, while the strata of this section strike N 40 E and dip 10° NW. Thus, the relationship of these two sections is extremely uncertain. There is no repetition between this section and Section PC-2, but the amount of omission cannot be determined within the area of study, for this is the only outcrop of this "oldest" Precambrian sequence in the Promontory Range.

Thickness in Feet

11.) Limestone; dark gray, microcrystalline, weathers dirty gray. Very evenly parallel-bedded with fine laminae 1/16-1/8" thick. Upper contact is concealed.......................... 6+

10.) Interbedded shale, quartzite, and minor limestone. The shale (or argillite) is pale green, very fine-grained, quartzitic, micaceous and talcose along bedding surfaces, and weathers light green. The quartzite is light tan, fine-grained, and weathers to dark brown with abundant limonite along bedding surfaces. Petrographic analysis shows at least 10% of detrital grains are feldspars - microcline and plagioclase (probably oligoclase). At least 25% interstitial material makes this a "dirty" quartzite. The limestone is dark gray to blackish-gray, microcrystalline, and weathers dull gray............. 34

9.) Quartzite; light tan to light brown, fine-grained, weathers greenish. This unit is characterized by a green "weathering scum" on bedding surfaces and by intense hematite staining in irregular patches, imparting a mottled appearance to fresh surfaces........................................ 41

8.) Metamorphosed mafic extrusive. Low-grade metamorphism has replaced phenocrysts (can't determine whether amphiboles or pyroxenes) with albite, chlorite, and abundant calcite. Pronounced porphyritic texture, weathers light green to purplish-green. An extremely distinctive unit......................... 2

7.) Quartzite; dull green to purplish, very fine-grained, weathers dull grayish-green.......................... 3

6.) Quartzite; tan, fine-grained, weathers tan to greenish-tan, except along upper bedding surfaces where the greenish weathered color is much more pronounced.......................... 29
5.) Metamorphosed mafic extrusive. Low-grade metamorphism has replaced large hornblende phenocrysts with albite, calcite, and chlorite. Biotite, chlorite, and microcrystalline calcite present in groundmass, with calcite particularly abundant. Pronounced porphyritic texture, greenish rock on fresh surfaces, weathers a "spotty" reddish-brown (due to phenocrysts altering to limonite) or grayish-green.

4.) Quartzite; greenish-gray, fine-grained, weathers light brown to greenish-gray. Possible minor fault at base of unit.

3.) Dolomite; pink to light brown, microcrystalline, weathers a distinctive cream color with a slight pinkish tint. Parallel 1/16" thick laminae are very regularly spaced and closely spaced cross joints or microfractures are abundant. Deep etching along these features gives the dolomite a "furrowed" appearance. Hematite and recrystallized dolomite fill microfractures. Quartz is rare (less than 2%) - the rock is almost entirely carbonate. Structural relations are uncertain both at bottom and top, but minor faults are probable at both places.

2.) Quartzite; bluish-purple, coarse-grained, weathers same. Poor sorting with many very coarse and medium quartz grains present. Grains are rounded to well-rounded.

1.) Quartzite; white, medium-grained, weathers very light tan to whitish-gray. Some black obsidian (?) grains and rare detrital feldspar grains are present. Some conglomeratic horizons with pebbles of jasperoid and rose and clear quartz averaging 1" in diameter. Small cavities are partially filled with limonite, probably altered from pyrite. Base of unit is concealed by waters of the Great Salt Lake.

Total thickness of exposed "oldest" Precambrian sequence.

PC-2. Stratigraphic Section of the "Intermediate Precambrian Sequence" at Promontory Point.

This section was measured northward from the CAA airport along the "Black Cliffs" and there is a covered interval between its base and the top of Section PC-1, which was measured only a few hundred feet to the south. The strata of Section PC-1 strike northeasterly and dip 10° to the northwest, while the basal strata of this section strike approximately east-west and dip 25° to the north. The stratigraphic
relationship of the two sections is not known, but there is a structural break between the two and a large portion of the Precambrian stratigraphic sequence may be missing. The lowermost 1,500 feet of this section is fairly well exposed along an excavation made for railroad ballast. Above this, the strata are generally fairly well concealed, and the section was terminated where massive quartzites were encountered similar to those at the base of the "youngest" Precambrian sequence of Section PC-3. Units #1-17 might be considered to be one unit (1,435 feet thick), but this treatment would preclude a detailed description of the extremely heterogeneous interbedded lithologies.

**Thickness in Feet**

19.) Quartzite; olive tan, fine-grained, weathers reddish-brown. Blocky outcrop habit differs markedly from the shaly outcrop habit of unit #18 below. Outcrops are scarce due to extensive concealment by sediments of Lake Bonneville. This unit was not measured.

18.) Shale; light gray to silvery gray, predominantly silty but locally very fine-grained, weathers generally dark gray but is commonly intensely stained reddish-brown by Fe oxides, especially along fractures. Laminae ranging 1-5 mm. thick are well defined by paper-thin, olive drab, argillaceous partings which give individual hand specimens a microscopic "varved" appearance. Prominent fissility characterizes the unit and there are no visible interbedded basic extrusives or calcareous beds, as in the underlying portion of the section. Differentiated from the underlying phyllites by lack of slaty cleavage and a definite textural change...... 366

17.) Phyllite; black, only slightly silty, weathers silvery dark gray to black. Same lithology as unit #3................. 137

16.) Metamorphosed mafic extrusive. Low-grade metamorphism has replaced euhedral amphibole and pyroxene phenocrysts with calcite and microcrystalline albite. Chlorite, microcrystalline quartz (?), and abundant calcite are present in the groundmass. Pronounced porphyritic texture, light gray on fresh surfaces with pale green phenocrysts, weathers dark brown. Minor offsets of this "marker bed" may be indicative of widespread small-scale faulting......... 5

15.) Phyllite; black. Same lithology as unit #3................. 62

14.) Metamorphosed "limestone"; similar to those of unit #12 below. Light gray, aphanitic, weathers brown................. 1

13.) Phyllite; black. Same lithology as unit #3................. 53
12.) Interbedded black phyllite and metamorphosed "limestones". Calcareous beds have been subjected to low-grade metamorphism and are almost entirely composed of microcrystalline calcite with minor chlorite. Euhedral pyrite cubes are locally abundant in the fresh rock and are generally somewhat altered to Fe oxides. Fresh color is gray to light gray, but weathered color is a dirty light brown. The 3 "limestone" beds are 1' or less thick and are probably metamorphosed basic extrusives.

11.) Phyllite; black. Same lithology as unit #3. 21' above the base of the unit is a 5-7' wide dike which has undergone low-grade metamorphism. Abundant calcite and minor quartz have replaced pyroxene (?) phenocrysts and also constitute most of the groundmass.

10.) Limestone; grayish-black, slightly silty, weathers brown (probably due to local staining by Fe oxides). Probably a lens rather than a bed, for it cannot be traced laterally.

9.) Phyllite; black. Same lithology as unit #3.

8.) Metamorphosed "limestone". Low-grade metamorphism has affected this bed. Groundmass is largely microcrystalline calcite and quartz (?) with minor chlorite which has been altered to limonite. Rare detrital zircon grains. Brucite (?) or aragonite (?) present as fibrous aggregates. Euhedral pyrite cubes are locally abundant on fresh surfaces.

7.) Phyllite; black. Same lithology as unit #3.

6.) Metamorphosed mafic extrusive. Low-grade metamorphism has replaced large euhedral hornblende phenocrysts with minor albite and abundant calcite. Groundmass has rare albite and muscovite, chlorite, and abundant calcite. Garnet is present but not common as subhedral, partially developed phenocrysts. Pronounced porphyritic texture, tan rock on fresh surfaces with pale green phenocrysts, weathers bluish-black to black. Locally greatly altered and completely replaced by Fe oxides - resembles a "clinker".

5.) Phyllite; black. Same lithology as unit #3.

4.) Metamorphosed mafic extrusive. Chlorite is abundant as laths in the groundmass, but most of it has gone over to limonite. The groundmass is almost all devitrified glass, with rare scattered, small masses of calcite and muscovite. Does not effervesce on fresh surfaces with dilute HCl.
3.) Phyllite; black, slightly silty, weathers silvery dark gray to black. Very similar to unit #1 below, except that this is more platy and looks and weathers much like a "paper shale". Slaty cleavage is very prominent in intervals of 1" and less. Parting surfaces are generally less than 1/8" apart.

2.) Almost entirely concealed. Probably the same lithology as units #3 and #1, as indicated by patchy exposures and nearby road cuts which are roughly along strike. At 79' and 252' above the base of this unit there are 5' thick metamorphosed basic extrusives which have been almost completely altered to or replaced by Fe oxides. Phenocrysts, probably pyroxenes, are rare and have gone over to limonite - hematite is abundant and magnetite is present as anhedral masses.

1.) Phyllite; black, slightly silty, weathers dirty black or dark gray with local concentrations of limonite on weathered surfaces. Slaty cleavage is present throughout, but not as closely spaced as in unit #3. This lithology is closer to being argillite than is that of unit #3. Parting surfaces are ½-1" apart and are characterized, as is all the phyllite up to unit #17, by abundant muscovite and/or sericite, giving a silvery sheen when the sun's rays are reflected. Base of unit is concealed by imbricate beach gravels of Lake Bonneville in the railroad cut south of the CAA aircraft beacon.

Total thickness of exposed "intermediate" Precambrian sequence 1,801+

PC-3. Stratigraphic Section of the "Youngest Precambrian Sequence" along the south rim of Long Canyon.

The upper contact of this section is the lower contact of Section C-1. The lower contact of this section is taken where the strata become obscured by alluvium at a point approximately 10 feet above the level of the Great Salt Lake and about 50 feet east of the dirt road along the southwestern side of the Promontory Range. The strata strike consistently northward, dip 40-50° eastward, and are generally very well exposed. There are no appreciable exposures of these strata to the south, but a less complete section may be seen to the north on the north wall of Long Canyon. No unconformities were noticed within this measured section and the uppermost strata are conformable with the overlying Lower Cambrian (?) Prospect Mountain quartzite. Units #12-28 might be considered as a single unit 1,156 feet thick. Care must be exercised in the lowermost portion of the section to keep south of the Long Canyon fault.
Prospect Mountain quartzite

Quartzite; pure white, sugary, fine-grained to medium-grained, generally weathers white except where limonite concentrations color the outcrops light brown and tan. Weathers distinctly much lighter than the underlying undifferentiated Precambrian and is further distinguished by well displayed parallel bedding (average bedding thickness is 1-2') compared with the massive habit of the Precambrian quartzite. (See Section C-1).

Undifferentiated Precambrian

32.) Massive quartzite; with no other lithologies present. Fresh colors include greenish-tan, light bluish-purple, brown to light brown and light tan. Texture is predominantly fine-grained to medium-grained, but is locally coarse-grained. Weathered colors are generally dark shades of brown. Conglomeratic horizons are locally prominent, particularly in the upper half of the unit. Conglomeratic pebbles are of quartz, not quartzite, and seldom exceed \( \frac{1}{4} \)" in diameter, with most being about \( 1/8" \) in diameter. Pebbles are well-rounded and commonly occur in streaks parallel to bedding. Conglomerate becomes increasingly important up to the top of the unit, with pebbles up to 1" in diameter encased in a white, fine-grained to medium-grained quartzite matrix. Upper contact with the generally non-conglomeratic Prospect Mountain quartzite is abrupt but conformable, with no visible channeling................................. 1,410

31.) Interbedded quartzite, shale, and mafic extrusives (?). The extrusives (?) have been subjected to low-grade metamorphism which has replaced phenocrysts of unknown original composition with abundant epidote, common calcite and muscovite, and rare albite (?). Groundmass is largely quartz with some andesine, calcite, and muscovite. Limonite is commonly pseudomorphous after pyrite. Pronounced porphyritic texture, fresh rock is green to light greenish-gray, weathers dark brown to black, and is much darker than any of the other strata in this unit. The shale is light green to olive drab, only slightly silty and largely argillaceous, and weathers tan except along fractures where heavily stained reddish-brown by Fe oxides. Bedding surfaces are planar and have abundant muscovite and some quartz grains. The quartzite is generally greenish-yellow or olive-colored, fine-grained to medium-grained, and weathers reddish-brown, dark brown, and dark tan due primarily to intense surficial staining by Fe oxides. The quartzite,
in thick ledges composed of 1-2' thick beds, constitutes most of the unit. The entire unit crops out well and stands out prominently between lighter-colored units above and below.............................. 476

30.) Completely concealed. Forms topographic saddle............. 112

29.) Massive quartzite; with no other lithologies present. Basal 990' and uppermost 170' are entirely quartzite and the 264' interval between is conglomeratic quartzite. The color of the upper and lower quartzites is predominantly grayish-white, weathering same, but there are darker portions which are generally pale green to greenish-gray, weathering pale green to tan. Fusion of the quartzite grains is so complete that the individual grain boundaries (fine-grained to medium-grained texture) are rarely visible. The conglomeratic quartzite is much darker-colored than the remainder of the unit and has clear quartz pebbles, 1/8-1" in diameter, in a poorly sorted (medium-grained to very coarse-grained), greenish quartzite which weathers dark brown due primarily to intense staining by Fe oxides. Unit as a whole generally weathers brown to light gray and stands out prominently between darker units above and below.............................. 1,424

28.) Interbedded quartzite and quartzitic shale. Lithology of this unit is the same as that of unit 14. Quartzitic shale, with individual partings 1/2 cm. and less thick, occurs in thicknesses up to 6" interbedded with the more abundant, non-shaly quartzite................................. 62

27.) Quartzite; tan to light gray, fine-grained, weathers dark tan to brownish-tan............................................ 203

26.) Interbedded quartzite and quartzitic shale. This lithology persists down to the base of the measured section, with the exception of extrusives and intrusives, and is identical to unit #14 below and unit #28 above....................... 108

25.) Metamorphosed mafic extrusive (?). Low-grade metamorphism has replaced large euhedral pyroxene (?) phenocrysts with abundant calcite and minor quartz, and formed limonite "rims" around the borders of the replaced phenocrysts. Groundmass is largely microcrystalline quartz with lesser amounts of calcite and muscovite. Pronounced porphyritic texture, pale green phenocrysts impart a green color to the fresh rock, weathers dark brown to blackish-brown with a 1/16" thick "rind" of Fe oxides on weathered surfaces. Similar in composition to the sills below, but there is no baking of the adjacent rocks................................. 6

24.) Interbedded quartzite and quartzitic shales. Same lithology as unit #14 below........................................... 95
23.) Metamorphosed mafic sill. Large pyroxene phenocrysts have been replaced by abundant calcite and minor quartz, and now have limonite-rich borders. Groundmass has abundant microcrystalline quartz and calcite, with quartz locally very predominant, and minor chlorite (?). Limonite is locally pervasive. Very pronounced porphyritic texture, fresh surfaces show pale green phenocrysts which impart a green color to the rock, weathers brown. 1.5' thick baked zone at the base and a 6" thick baked zone at the top. Petrographic analysis shows the upper baked zone to be hornfels - limonite is pervasive, microcrystalline groundmass is largely calcite and quartz.

22.) Interbedded quartzite and quartzitic shale. Same lithology as unit #14 below.

21.) Metamorphosed mafic extrusive (?). Low-grade metamorphism has replaced small pyroxene (?) phenocrysts with abundant calcite and microcrystalline quartz and lesser amounts of epidote and microcrystalline albite. Microcrystalline groundmass is almost entirely calcite, with minor amounts of albite, chlorite, and quartz. Porphyritic texture is almost microscopic, fresh rock is light tan, weathers light brown.

20.) Interbedded quartzite and quartzitic shale. Same lithology as unit #14 below.

19.) Metasediment (?). No phenocrysts are present. Microcrystalline calcite constitutes most of the rock, yet fresh surfaces effervesce only slightly with dilute HCl. Albite (?), chlorite, pyrite, and quartz are minor compared with calcite. Limonite is commonly pseudomorphous after pyrite. Strongly resembles quartzite in hand specimen. Very similar to the igneous units above and below, weathers dark brown to brown.

18.) Interbedded quartzite and quartzitic shale. Same lithology as unit #14 below.

17.) Metamorphosed mafic extrusive (?) or sill (?). Low-grade metamorphism has partially destroyed euhedral amphibole phenocrysts, which are so rare that the porphyritic texture is not pronounced. The groundmass is composed almost entirely of microcrystalline calcite and quartz, with minor albite (?). Limonite is pervasive, pyrite common. Hand specimens strongly resemble quartzite. No baking is visible at either contact.
16.) Interbedded quartzite and quartzitic shale. Same lithology as unit #14 below................................. 88

15.) Metamorphosed mafic sill. Low-grade metamorphism has replaced large amphibole (?) phenocrysts with abundant calcite and minor microcrystalline quartz. Groundmass is mostly calcite with moderate amounts of chlorite (?) and microcrystalline quartz. Limonite is present throughout, but particularly abundant in the replaced phenocrysts. Pronounced porphyritic texture, pale green phenocrysts give rock a greenish color on fresh surfaces, weathers dark brown to brown primarily due to Fe oxides. Baked zones at top and bottom are 2-3" thick. Petrographic analysis shows upper baked zone to be hornfels - limonite, calcite, chlorite, and quartz are equally abundant in the microcrystalline groundmass. Like unit #13, this unit stands out prominently as a hogback.................. 2

14.) Interbedded quartzite and quartzitic shale. Quartzite is greenish-gray, very fine-grained to fine-grained, weathers brown to greenish-gray. Individual quartz grains are well fused and small concentrations of limonite characterize most fresh surfaces. Shale is light greenish-gray, silty to very fine-grained, weathers same. Parts easily along bedding surfaces which are highly micaceous and argillaceous. Shale occurs in 3-6" intervals which are interbedded with "ribs" of the quartzite up to 3" thick - these "ribs" stand out from the recessed shale due to differential resistance. Stratigraphic intervals of 1' or greater showing only one of these two lithologies are rare. Bedding is persistent laterally - the interbedding of the two lithologies is not lenticular............................. 163

13.) Metamorphosed mafic extrusive. Low-grade metamorphism has replaced abundant pyroxene (?) phenocrysts with calcite, epidote, muscovite, and microcrystalline quartz. Pronounced porphyritic texture, fresh rock is reddish-green, weathers brown to light brown with pale green phenocrysts barely visible on weathered surfaces................................. 8

12.) Interbedded quartzite and quartzitic shale. Same lithology as unit #14 above................................. 209

11.) Interbedded quartzite and quartzitic shale. Quartzite is gray, very fine-grained, weathers light greenish-gray to brownish-tan, and is very similar to the quartzite of unit #10. This unit is differentiated from unit #10 only because of the quartzitic shale which occurs in stratigraphic intervals of less than 6" sandwiched between quartzite beds 6"-2' thick.
Unit as a whole is poorly resistant and forms a topographic saddle in contrast to the more resistant units above and below.  

10.) Quartzite; tan to light gray, fine-grained, weathers consistently to dull brown and light brownish-tan. Parallel beds 1-3' thick are well displayed with cross-bedding completely absent.  

9.) Interbedded quartzite and quartzitic shale. Same lithology as unit #7 below. Upper contact is extremely sharp.  

8.) Metamorphosed mafic sill. Low-grade metamorphism has replaced large mafic phenocrysts, probably hornblende, with abundant calcite and moderate amounts of epidote and quartz. Epidote is abundant throughout the microcrystalline groundmass. Porphyritic texture, fresh rock is greenish-red, weathers orange-brown with the orange color imparted by phenocrysts which have been altered to Fe oxides. Weathering is locally very deep, with surficial portions almost friable. Baked zone at the base is 1' thick and that at the top is 6"-1' thick. Petrographic analysis shows that the basal baked zone is a carbonate-free, quartz-rich, sericite-rich hornfels.  

7.) Interbedded quartzite and shale. The quartzite is dark gray with a pale greenish tint, silty, weathers dark brown and dark reddish-brown due to Fe oxide staining. Quartzite occurs in thicker beds (1' and greater) than is usual for such interbedded units. The shale is dark gray to blackish-gray, silty, weathers gray except along blocky fractures where Fe oxides have imparted a dark reddish-brown stain. Individual laminae average 5 mm. thick. The interbedded lithologies are not lenticular but are laterally persistent. Weathers much darker than the units above and below, primarily due to intense staining by Fe oxides.  

6.) Quartzite; with minor interbedded shale and quartzitic shale. The quartzite is light gray to whitish-gray, very fine-grained, and weathers brown. Near the middle of the unit is some black, slightly micaceous, very fissile "paper shale" as very thin (less than 2" thick) partings. Gradational with unit #7 above, upper contact is arbitrarily placed.  

5.) Metamorphosed mafic extrusive (?). Calcite and epidote have replaced abundant large pyroxene (?) phenocrysts. Groundmass is largely albite and microcrystalline calcite and quartz. Biotite and chlorite are relatively rare, but magnetite or pyrite is abundant as subhedral to anhedral crystals. Fresh surfaces effervesce readily with dilute HCl. Fresh color is dull green, but weathers dark...
blackish-brown. Outcrops show a marked tendency to exfoliate and weather to rounded, knobby, or spheroidal forms. Very similar to unit #1 below.

4.) Interbedded quartzite and quartzitic shale. The quartzite is greenish-gray, fine-grained, weathers brown to dark brown due to intense staining by Fe oxides. The quartzitic shale is greenish-gray, very fine-grained, though locally silty, and weathers greenish-gray. The shale is not susceptible to intense Fe-oxide staining as is the quartzite. Quartzite occurs as beds 1"-1' thick (average 3") which are more resistant than the intervening shale and thus stand out as "ribs". The individual shale laminae are 3 mm. or less thick and bedding surfaces are fairly smooth and highly micaceous. The two interbedded lithologies are almost identical, with the major difference being in the bedding habits, and are persistent laterally, showing no evidence of lenticularity.

3.) Metamorphosed mafic extrusive (?); may be a metasediment. Rare indeterminate phenocrysts (?) have a very ragged, irregular shape. Some are completely replaced by microcrystalline calcite and others have gone over to limonite. The microcrystalline groundmass is almost entirely calcite and albite with rare muscovite. Magnetite or pyrite is abundant as small anhedral masses. Fresh surfaces effervesce readily with dilute HCl. There are a few very small, extremely angular inclusions of dull gray, fine-grained quartzite. If igneous, probably a flow - for the upper contact is well exposed and no baking is visible.

2.) Interbedded quartzite and quartzitic shale. Same lithology as unit #4, except that bedding is generally thinner.

1.) Metamorphosed mafic extrusive. Low-grade metamorphism has replaced scattered, relatively rare pyroxene (?) phenocrysts with abundant epidote and calcite, some biotite, and minor quartz. Groundmass, which constitutes most of the rock, is composed of calcite and quartz with lesser amounts of biotite. Only slightly porphyritic, greenish-gray on fresh surfaces, weathers bluish-black to purplish-black. Contains large (up to 2' in diameter) inclusions of gray, fine-grained quartzite which are well-rounded. Weathers to a rounded, knobby surface with a marked tendency to exfoliate. Base of the unit is concealed by Lake Bonneville sediments - no outcrops below this.

Total thickness of exposed "youngest" Precambrian sequence... 5,413+
C-1. Stratigraphic Section of the Prospect Mountain quartzite along the
south wall of Long Canyon.

This section is complete and is excellently exposed with good upper
and lower contacts. The strata strike consistently northward and their dip
ranges 40-50° eastward. The same section is well displayed to the north
on the north wall of Long Canyon and to the south along the north wall of
Little Valley. Although well exposed, both upper and lower formational
contacts are somewhat arbitralilly established. The upper contact is
essentially a line of color demarcation - for unit #9, with some interbedded
shale, could possibly be assigned to the overlying Pioche "shale" on the
basis of lithology alone. The basal contact is placed at the boundary
between well-bedded quartzite and massive quartzite. Section PC-3 was
measured below this and Section C-3 was measured above.

Thickness in Feet

Pioche "shale"

Interbedded quartzite and shale. (See Section C-3).

Prospect Mountain quartzite

9.) Quartzite; with some interbedded shale near the base. The
quartzite is light tan to white, generally medium-grained
although locally coarse to very coarse-grained, weathers same
as fresh surfaces except along fractures and bedding surfaces
where intense limonite coatings are locally present. Parallel
beds 1-3' thick are well displayed. Basal 20' has shale
partings up to 1' thick which form blocky ledges although the
individual laminae are 1/8" or less thick. The shale is dark tan
to olive drab, silty, markedly micaceous along bedding surfaces,
and weathers same as fresh surfaces. Upper contact with the
overlying Pioche "shale" is a knife-edge color line with no
gradation or transition whatsoever. .......................... 89

8.) Quartzite; pale greenish-tan, fine-grained, weathers
consistently to a dark tan to brown. Very homogeneous
lithologic unit with bedding uniform throughout as 1-3' thick
parallel beds. Some conglomerate present near base of unit.
A distinctive unit set off by lighter-colored units
above and below................................................. 415

7.) Quartzite; interbedded tan and white, weathering to about the
same colors except where Fe-stained. White quartzite is
very fine-grained to fine-grained and the tan quartzite is
medium-grained. Bedding is well defined with regular parallel
beds ranging 1-2' thick. Upper and lower contacts are
essentially color changes - this unit is slightly darker than
the one below and much lighter than the one above.............. 490
6.) Quartzite; white to slightly pinkish-white, coarse-grained, weathers same as fresh surface. A very uniform lithologic unit both as to composition and appearance. Portions are medium-grained, but most of the quartzite is coarse-grained. Well defined, regular, parallel beds are 1-2' thick. The units below and above are generally darker................. 384

5.) Quartzite; tan and light tan, weathers tan and light brown, the latter color due to staining by limonite. The light tan quartzite is generally somewhat coarser than usual for this formation, being coarse-grained. The tan quartzite is locally very coarse-grained. Basal 45' of unit is extremely conglomeratic, with pebbles of white quartz 2" in diameter. Parallel beds 1-2' thick are well displayed and laterally persistent. Darker than units above and below............... 547

4.) Quartzite; mostly white, locally varicolored, medium-grained to coarse-grained. Upper 310' has much varicolored quartzite, mostly bluish-purple, interbedded with thick intervals of white quartzite. The white quartzite generally weathers white except where stained brown by limonite. The varicolored quartzite commonly weathers purple and is characterized by thin, wavy, contorted purple color bands which have no relationship at all to bedding or fractures. Basal 85' is extremely conglomeratic with quartz pebbles 1" or more in diameter. This is not a very uniform unit, unlike most others in the formation. Generally weathers much lighter than the unit above and thus stands out conspicuously.............. 741

3.) Quartzite; varicolored, fine-grained to medium-grained. Unlike most other units in the formation, this interval does not have one dominant color, but is a motley assortment of pastel shades such as pink, white, and tan. Basal portion of unit shows prominent low-angle cross-bedding. Entire unit is conglomeratic and the conglomerate is commonly cross-bedded..................... 349

2.) Quartzite; greenish, fine-grained to medium-grained, generally weathers to dull brown and tan. This unit is characterized by an almost universal greenish tint on fresh surfaces and is conglomeratic throughout, with most pebbles about 1/8" in diameter. Conglomerate becomes coarser and more prominent in uppermost 50' - pebbles are of pink quartz, not "jasperoid". Unit is regularly parallel-bedded with an average bedding thickness of 1-2'............................... 631

1.) Quartzite; pure white, sugary, fine-grained to medium-grained, generally weathers white except where limonite coats outcrops with light brown and tan. Parallel bedding is well displayed
with an average bedding thickness of 1-2'. Lithologically a
very uniform unit. There is a major color change at base of
unit - this unit weathers much lighter than the one below.
This basal unit is clearly visible from great distances and
appears to be perfectly conformable on the undifferentiated
Precambrian below.

Total thickness of the Prospect Mountain quartzite. 3,884

Undifferentiated Precambrian

Quartzite; white to greenish-white, fine-grained to medium-grained,
conglomeratic, weathers greenish-gray. A massive unit which
contrasts sharply with the distinctly parallel-bedded Prospect
Mountain quartzite above. (See Section PC-3).

C-2. Stratigraphic Section of the Prospect Mountain quartzite along the
spur between the North and South Forks of Little Valley.

This section is incomplete; the basal contact of the formation is
nowhere exposed in the immediate vicinity. Small-scale faulting is
locally present near the top of the section. The strata are very well
exposed, especially along the crests of ridges. The strata strike
northwesterly and dip 20-25° toward the northeast. Section C-4 was
measured above this section.

Thickness in Feet

Pioche "shale"

Interbedded quartzite and shale. The quartzite is greenish-gray,
fine-grained, and weathers purple. The shale is dull green to olive
drab, silty, micaceous, and weathers greenish-tan. (See Section C-4).

Prospect Mountain quartzite

7.) Quartzite; probably fine-grained, although fusion of the grains
is so complete that texture is not easily discernible. Unit
definable because of light colors (light tans and browns to
white), thus stands out from darker-colored units above and
below. Bottom contact arbitrarily established. Small-scale
faulting probably present about 320' above the base and in
uppermost 40', but this measured section probably did not
cross the faults.
6.) Quartzite; tan dirty, fine-grained to medium-grained, weathers dark to light brown. Basal 150' characterized by shaly sandstone partings which are markedly micaceous, display slaty cleavage, and are generally the same color as the adjacent quartzite which has no mica minerals. Base of unit is noticeably conglomeratic with white quartz pebbles averaging 1/4" in diameter. Conglomeratic horizons are rarely present in the formation above this unit, and shaly partings were not observed below this unit. This unit stands out from those above and below due to its darker color.

5.) Quartzite; white and tan, clean, medium-grained, has a universal pink tinge both on fresh and weathered surfaces. Weathers to various shades of tan, light brown, and white. Stands out prominently between darker-colored units above and below.

4.) Quartzite; reddish-pink to tan, clean, medium-grained to coarse-grained, generally weathers an intense red-brown, due partly to scattered flecks of Fe oxides. Beds average 1-2' thick and form blocky ledges. Both contacts are very sharp lines of color demarcation, but the bottom contact is exceedingly sharp. A very prominent unit - much darker than those above and below.

3.) Quartzite; pure white, sugary, clean, medium-grained, weathers about the same as fresh surfaces, although locally stained light brown by limonite. Bedding is very uniform with average thickness approximately 6". No conglomeratic horizons or cross-bedding noted, although these features are common in units below. This unit is very prominent due to its very light color and its position between darker-colored units.

2.) Quartzite; brown to reddish-brown, dirty, fine-grained to medium-grained, generally weathers purplish-brown or dark reddish-brown. The quartzite is locally coarse-grained near the base. Conglomeratic in basal 100' and uppermost 50' with 1/4-1" pebbles, some angular. Beds average 2' thick. Low-angle cross-bedding is common, but is rare in the formation above this unit. Weathered colors are much darker than the fresh colors and this unit thus stands out prominently between lighter-colored units above and below.

1.) Quartzite; pinkish-white, tan to light tan, dirty, medium-grained. Color of fresh surfaces varies greatly, but weathered color is fairly uniform - a light red-brown to brownish-tan. Conglomeratic streaks up to 5' thick are common with pebbles of white quartz up to 1" in diameter. Indistinct
ripple marks are locally present. Parallel beds 1-3' thick show low-angle cross-bedding between the parallel bedding planes. Weathers to a lighter color than unit #2 above. Base obscured by alluvial valley deposits.............................. 543+

Total thickness of the exposed Prospect Mountain quartzite...... 2,825+

C-3. Stratigraphic Section of the Pioche "shale" on the crest of the north wall of Little Valley.

This is the best-exposed section of the Pioche "shale" in the Promontory Range. The basal contact is well exposed, but the upper contact is obscured. Vegetation offers no problem of concealment as it does with the "Undifferentiated Middle Cambrian" formations stratigraphically above. The strata strike northerly and dip 50-60° toward the east. Section C-1 was measured immediately below.

Thickness in Feet

"Undifferentiated Middle Cambrian"

Limestone float. No nearby outcrops. Not measured.

Pioche "shale"

4.) Completely concealed. There is much float from the purple-weathering quartzite unit stratigraphically below, but no limestone float was noted. Both upper and lower contacts arbitrarily established.......................... 46

3.) Quartzite; dark greenish-tan, medium-grained, weathers purple throughout its extent. Quartz grains are so completely fused that sorting and roundness cannot be determined. Fresh surfaces show abundant interstitial concentrations of orange-brown Fe oxides, locally suggestive of altered pyrite crystals. Alternating light and dark purple weathering bands, ¼"-1' thick and approximately parallel to bedding, give the unit a "banded" appearance. Thick-bedded (1-2' thick)......... 64

2.) Quartzite; green to greenish-purple, very fine-grained to fine-grained, weathers dark tan, dark brown, and only locally purplish. No interbedded shale observed. Sorting is good - larger grains are subrounded to subangular. Muscovite is common and particularly abundant along bedding surfaces. Thick-bedded (1-3') with local low-angle cross-bedding. Parallel planar bedding surfaces, common in the underlying
Prospect Mountain quartzite, are not present here. Rather, bedding surfaces are hummocky, locally ripple-marked, and have fucoidal markings.

1.) Interbedded quartzite and shale. Quartzite is green to purplish, medium-grained, weathers dark tan to dark brown. Quartz grains are so well fused that the degree of sorting and roundness cannot be determined. Low-angle cross-bedding is locally present, but on the whole, bedding is poorly displayed compared to the underlying Prospect Mountain quartzite. Large fucoidal markings are common on bedding surfaces. Shale is green to greenish-tan, locally silty, and weathers same as fresh colors. Beds are \( \frac{1}{4} \)" thick on the average and cannot be traced far laterally. Bedding surfaces are highly micaceous, predominantly biotite, and are extremely undulatory and irregular, possibly due to differential compaction. Quartzite predominates over shale - the interbedding is on a large scale, with the individual lithologies in intervals greater than 5' thick.

Total thickness of the Pioche "shale".

Prospect Mountain quartzite

Quartzite; light-colored, with no interbedded shale. Weathers much lighter than the overlying Pioche "shale". Planar, parallel bedding surfaces 1-3' apart contrast sharply with the hummocky, irregular bedding surfaces of the Pioche "shale". (See Section C-1).

C-4. Stratigraphic Section of the Pioche "shale" along the spur between the North and South Forks of Little Valley.

This section is incomplete (upper contact is concealed), and is complicated by small-scale faulting. Units #3 and #4 are probably a repetition of units #1 and #2, and it is probable that the abnormal thickness of unit #5 is due to repetition by faulting. Despite the obvious invalidity of the thicknesses of this measured section, it is presented here for the worth of its lithologic descriptions. The strata strike northwesterly and dip about 20° toward the northeast. Section C-2 was measured immediately below.

Thickness in Feet

Pioche "shale"

7.) Almost completely concealed.
6.) Interbedded shale and quartzite. Shale is dull green and olive
drab and micaceous. Quartzite is very similar to that of
unit #5 below.......................... 43

5.) Quartzite; light green to tan, fairly clean, fine-grained,
weathers dark brown to reddish-brown. Bedding thickness
averages 1'.............................. 161

4.) Quartzite; greenish-gray, very dirty, fine-grained to medium-
grained, weathers purple (along joint surfaces an intense
bluish-purple). Unit seems more dark from a distance than up
close. A very prominent marker bed - easily traced on
aerial photographs....................... 59

3.) Interbedded shale and quartzite. Dull green, silty, micaceous
shales are interbedded with quartzite similar to that of
units #2 and #4. Unit is mostly shale. Probable fault
separates this unit from unit #2 below.................. 65

2.) Quartzite; greenish-gray, very dirty, fine-grained, weathers
purple. Very similar to unit #4 above and is very likely the
same unit. Probable fault at the top of this unit.............. 54

1.) Interbedded shale and quartzite. Shale is olive drab, silty,
micaceous, and weathers greenish-tan. Thin-bedded and
laminated strata average ½-⅓" thick. Tan quartzite is
interbedded as lenses, but shale is by far predominant.
Evidence of nearby small-scale faulting is abundant......... 34

Prospect Mountain quartzite

Quartzite; light tan, brown, and white, fine-grained. No interbedded
shale. (See Section C-2).

C-5. Stratigraphic Section of the Pioche "shale" on the east wall of the
North Fork of Little Valley.

The Pioche "shale" at this locality is fairly well exposed, but neither
contact is visible. Proximity to a major fault also diminishes the accuracy
of the section and furthermore, the normal Middle Cambrian succession above
the Pioche "shale" is anomalously thin at this locality. The strata strike
northerly and dip about 35° toward the east. Section C-9 was measured
above this.
"Undifferentiated Middle Cambrian"

Limestone; gray, very finely crystalline, weathers gray to light gray. (See Section C-9).

Pioche "shale"

Quartzite; with minor interbedded shale. Quartzite is green, fine-grained, weathers dark brown and dark reddish-brown due to intense staining by Fe oxides. Beds average 1' thick and the bedding surfaces are roughly parallel with rare low-angle cross-bedding displayed between them. Intercalations of green, micaceous, silty shale, weathering green, are extremely minor in amount and generally 3" thick or less. There is much less shale at this locality than elsewhere in the Pioche "shale" within the mapped area. This formation stands out prominently by color contrast with the underlying Prospect Mountain quartzite and by its blocky ledge-forming habit from the slope above............................... 194

Total thickness of the Pioche "shale"................................. 194

Prospect Mountain quartzite

Quartzite; light tan to white, medium-grained, weathers light tan. Not measured.

C-6. Stratigraphic Section of the Busby quartzite on the west face of Lead Hill.

The Busby quartzite is well exposed here and is not structurally complicated. This formation varies greatly along strike and the shale (unit #3) is generally concealed. Only this locality, of all the exposures of the Busby quartzite which were studied, has yielded any fossils. The strata strike northwesterly and dip 15° toward the northeast.

Millard limestone

Limestone; gray, very finely crystalline, extremely silty, weathers light bluish-gray. Slightly argillaceous silty partings are spaced an average of 1" apart, are parallel to bedding, and weather orange-brown, giving outcrops a "ruled" appearance. Not measured.
3.) Shale; gray (locally stained brown and tan), silty, micaceous, weathers same. Bedding surfaces are extremely micaceous. Thin-bedded (1/8-¼" thick), slabby- and flaggy-bedded, locally resembles slate. This unit supplies much flagstone float to the slopes below. Along fractures the shale has a "blocky" appearance and bedding is not visible. Trilobite remains (mostly pygidia) are abundant on bedding surfaces. 

   Taxioura sp. ........................................... 47

2.) Limestone; pearly dark gray, medium crystalline, weathers tan to brown. No clastic particles noted. A totally massive unit with no bedding surfaces except at the top and bottom of the unit. Basal contact is planar and knife-edge sharp. Along with unit #1 and the underlying Pioche "shale", forms a precipitous cliff............................. 10

1.) Calcareous orthoquartzite; tan to brown, but predominantly brown, fine-grained to medium-grained, extremely calcareous, limonitic, weathers tan to light brown. Interstitial limonite is abundant, probably as a coating on minute calcite crystals, and gives the unit its dark color. Bedding thickness ranges 1"-1', with the thicker bedding predominant. Both contacts are planar, knife-edge sharp, and show no gradation. Forms part of an almost vertical cliff............................. 15

Total thickness of the Busby quartzite............................. 72

Pioche "shale"

Quartzite; green, very fine-grained, weathers same color as fresh surfaces. About 10' is exposed and no shale partings were noted. Base of the cliff is covered by a talus slide which extends down to the Bonneville level. Not measured.

C-7. Stratigraphic Section of the "Undifferentiated Middle Cambrian" along Lakeview Ridge at the southwest corner of Black Mountain.

This is the only measured section of the stratigraphic interval between the Pioche "shale" and the Wheeler formation which has all of the units well exposed with no structural complications. The strata are very well exposed and there is relatively little cover. The strata strike consistently northwesterly and their dip ranges 25-35° toward the northeast. Section C-12 was measured directly above this section.

- 276 -
Wheeler formation

Shale; light gray to whitish-gray, talcose, micaceous, silty, weathers light gray to tan. (See Section C-12).

Swasey limestone

13.) Limestone; gray, microcrystalline, slightly silty, weathers gray to light gray. The orange to brown argillaceous siltstone partings, common in unit #12 below, are rare. Parallel-bedded, thick-bedded. Uppermost 85' forms a steep dip slope which extends down to the sharply notched, V-shaped saddle which marks the base of the Wheeler formation.............. 100

12.) Limestone; dark gray, microcrystalline, slightly silty, weathers gray. Very thin-bedded. Parallel beds 1-3" thick are separated by orange to brown argillaceous siltstone partings. Lower contact concealed and arbitrarily placed..... 72

Thickness of the Swasey limestone exclusive of the Condor member.... 172

Condor member of the Swasey Limestone

11.) Almost completely concealed. Judging from float and few outcrops the bedrock is probably interbedded limestone and shale. Shale is pale greenish-gray, talcose, and is minor compared to limestone. Limestone is gray, weathers bluish-gray, and is thin-bedded with orange argillaceous siltstone partings...... 81

10.) Limestone; gray, weathers same or bluish-gray. Inclusions of orange-brown argillaceous siltstone give a "mottled" effect.... 18

9.) Shale; pale greenish-gray, talcose, weathers same. Paper-thin shale is characterized by closely spaced cleavages at 30° angle with bedding. Very similar to unit #7 below.............. 40

8.) Limestone; dark gray, microcrystalline, slightly silty, generally weathers dull gray to light bluish-gray. Pronounced thin-bedded habit with orange argillaceous siltstone partings along bedding surfaces. Partings are laterally discontinuous.. 59

7.) Shale; greenish-gray, talcose, weathers same. Bedding is paper-thin and cleavage at 30° angle with bedding is a prominent feature.............................. 11

- 277 -
6.) Limestone; gray to dark gray, microcrystalline, very slightly silty, weathers dull gray to dull blue-gray. Very thin-bedded (1/2-2") with orange to brown argillaceous siltstone partings along bedding surfaces............................ 21

5.) Interbedded limestone and argillaceous siltstone........................ 9

4.) Shale; silvery tan to light greenish-gray, talcose, weathers same. Extremely fissile with high-angle fracture cleavage..... 31

3.) Limestone; dark gray, very finely crystalline, weathers gray to blue-gray. Flaggy beds are 1-3" thick and orange argillaceous siltstone partings are abundant along bedding surfaces.. 20

2.) Shale; light gray to silvery gray, talcose, weathers same. Uniformly bedded paper-thin shale. Very similar to unit #4..... 5

1.) Limestone; gray, finely crystalline, weathers gray or light gray. Abundant flecks of orange-brown limonite resemble vug fillings or oxidized pyrite crystals. Thin-bedded (1-2")........... 27

Thickness of the Condor member of the Swasey limestone.................. 322

Total thickness of the Swasey limestone..................................... 494

Dome limestone

Limestone; gray, very finely crystalline, oolitic throughout, weathers blue-gray. Weathered surfaces are extremely rough. Bedding is generally indistinct and entire formation forms a single massive cliff which varies greatly in thickness.............. 39

Total thickness of the Dome limestone........................................ 39

Burnt Canyon limestone

4.) Largely concealed; but sparse outcrops indicate that bedrock lithology is interbedded limestone and shale......................... 31

3.) Limestone; dark gray, very finely crystalline, weathers gray to blue-gray. Orange argillaceous siltstone partings are prevalent along bedding surfaces..................... 24

2.) Interbedded limestone and shale. The limestone is gray and the shale is brown to olive drab. The interbedding is on a very small scale - stratigraphic intervals of more than 2" of one lithology are rare. Limestone is decidedly thin-bedded and may have a shaly habit, in which case the weathered surfaces are stained tan.............................. 21
1.) Shale; pale greenish-tan, extremely micaceous, weathers same. Very thin-bedded to laminated - average bed is \( \frac{1}{4} \)" thick. Isolated hand specimens greatly resemble portions of the Pioche "shale". An excellent trilobite fauna, consisting mostly of minute cranidia, occurs 2-4' above base of unit - remainder of unit is barren of fossils. 

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<tr>
<td>Ehmaniella cf. E. burgessensis Rasetti</td>
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<tr>
<td>Iphidella cf. I. pannula (White)</td>
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Total thickness of the Burnt Canyon limestone................................. 91

Burrows limestone

7.) Limestone; light gray to gray, finely crystalline, weathers same. Extremely uniform lithology except for uppermost 15' which has been marbleized and weathers a markedly contrasting white. Girvanella and pisolites abundant at base. Bedding surfaces are rare and unit locally forms a huge, massive cliff. Here the unit forms a prominent cuesta with the uppermost bedding surface a large "flatiron". This entire unit is extremely susceptible to severe local alteration................................. 105

6.) Shale; green, slightly micaceous, weathers same except along fracture surfaces where stained dark brown by Fe oxides. Fissility is pronounced and locally accompanied by high-angle cleavage. This unit supplies much float to underlying slopes. 

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<tr>
<td>Inglefieldia cf. I. imperfecta Lochman</td>
<td>26</td>
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<tr>
<td>Zacanthoides cf. Z. holopygus Resser</td>
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</tbody>
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5.) Limestone; with minor interbedded dolomite. Limestone is gray, microcrystalline to finely crystalline, oolitic, and weathers same. Rare 1-2' thick parallel beds of gray, very finely crystalline dolomite are interbedded with the limestone. The limestone and dolomite are massive units - ledges up to 5' thick show no bedding surfaces whatsoever................................. 47

4.) Quartzite; light greenish-gray, very fine-grained, weathers to a darker greenish-gray. Very thin-bedded (\( \frac{1}{2}-1" \)) and parallel-bedded. Extremely micaceous along flat bedding surfaces........... 4

3.) Limestone; dark gray to blackish-gray, microcrystalline, very silty, weathers dull dark gray. Irregular, undulatory bedding surfaces are characterized by light brown "splotches" of argillaceous siltstone. Basal 5' contains many broken trilobite fragments. 

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<tr>
<td>Alokistocarella sp. undet.</td>
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<tr>
<td>Glossopleura cf. G. bion or G. belesis Walcott</td>
<td>37</td>
</tr>
</tbody>
</table>

- 279 -
2.) Limestone; gray to light gray, microcrystalline, slightly silty.
Two massive limestone ledges are separated by an interval of cover. The bottom ledge is 30' thick and has been partially marbleized - its weathered color is pur white in contrast with the blue-gray weathered color of the upper ledge. The limestone is characterized by "blebs" of coarsely crystalline calcite which has been intensely stained orange to orange-brown by limonite - an extremely distinctive feature. 63

1.) Limestone; gray, finely crystalline, very silty, weathers gray to light bluish-gray. Weathered surfaces are markedly pitted with tiny "craters". Abundant silt grains are only visible when fresh surfaces are etched with HCl. Crops out as several blocky, massive ledges which average 3' thick. 19

Total thickness of the Burrows limestone 301

Millard limestone

2.) Limestone; a transitional unit between the units immediately below and above. Ledges of dark gray limestone 1-2' thick with no internal bedding surfaces are interbedded with intervals of the "flaggy" or "platy" limestone with silty partings similar to unit #1 below. The dark gray limestone is very similar to unit #1 of the Burrows limestone above. 30

1.) Limestone; dark gray, very finely crystalline, extremely silty, weathers dull dirty gray. Characterized throughout by orange to tan silty laminae rarely more than 1/8" thick and generally less than 1/16" thick. No stratigraphic interval greater than 6" is totally devoid of these partings and the limestone beds between them range ½-2" in thickness. The partings are weathered deeper than the more resistant limestone which stands out as "ribs" giving the unit a "banded" or "ruled" appearance. Generally a cliff-former. Trilobite fragments were found as float from 20' to 100' above base of unit.

Ptarmigania sp. undet. 172

Total thickness of the Millard limestone 202

Busby quartzite

3.) Completely concealed; probably shale (see unit #3 in Section C-6). Thickness of this unit varies greatly - 20' thick on the east side of this ridge to 5' thick on the west face. Upper contact of this unit placed at the base of the lowermost exposure of the Millard Limestone. 16
2.) Limestone; dark brown with tan flecks, finely crystalline, arenaceous (very fine-grained quartz particles), weathers light brown. Thin white calcite veinlets are abundant. This unit forms gently rounded ledges, unlike the blocky quartzite cliffs below, and is very susceptible to local alteration.

1.) Calcareous orthoquartzite; tan to brown (predominantly brown), very fine-grained to fine-grained, limonitic, extremely calcareous, weathers tan to light brown. Interstitial limonite is abundant. Differs from the underlying Pioche "shale" by its uniform color on weathered surfaces, calcareous content, its complete lack of shale partings and cross-bedding, and the absence of white quartz veins. Thick-bedded to massive unit - tends to form near-vertical cliffs. Basal contact with the underlying Pioche "shale" is generally extremely sharp without gradation.

Total thickness of the Busby quartzite: 45

Total thickness of the "Undifferentiated Middle Cambrian": 1,172

Pioche "shale"

Interbedded quartzite and shale. Quartzite is predominantly green with purple, brown, and tan, very fine-grained, weathers mainly dark purple to bluish-purple and green. Shale is green, silty, micaceous, and weathers same. The shale partings are minor and constitute less than 5% of the volume of this unit. Very low-angle cross-beding is prominently displayed between parallel bedding surfaces 1-2' apart. Scolithes-like vertical burrows and fucoidal markings are common. White quartz veins are locally abundant in the quartzite. No calcareous portions noted. Unit weathers conspicuously dark-colored compared to the tan or brown Busby quartzite above. Base concealed by Lake Bonneville deposits. Not measured, but at least 100' is estimated to be exposed. 100+

Total estimated thickness of the exposed Pioche "shale": 100+

C-8. Stratigraphic Section of the "Undifferentiated Middle Cambrian" south of the head of Long Canyon.

This section alone, of all those described in this Appendix, was not measured by the "Jacob staff method", but was traversed by Brunton-and-pace. Although the thicknesses may not be reliable, the section is included in order to display the lateral lithologic variations of this undifferentiated stratigraphic succession. This lithologic succession, however, resembles
the "standard" of Section C-7 more closely than any of the other measured sections, even though the Busby quartzite is missing. The strata strike northwesterly and dip approximately 45° toward the northeast. Section C-14 was measured immediately above.

Estimated Thickness in Feet

### Wheeler formation

<table>
<thead>
<tr>
<th>Shale; whitish-gray, micaceous, talcose, weathers same. Completely concealed by its own regolith. (See Section C-14).</th>
</tr>
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</table>

### Swasey limestone

2.) Limestone; dark gray, microcrystalline, slightly silty, weathers gray to light bluish-gray. Forms a prominent dip slope at the top which extends down to a V-shaped "notch" or "saddle" with its apex at the Swasey-Wheeler contact. This unit is correlated with the "Swasey limestone exclusive of the Condor member" of Section C-7.------------------ 200

1.) Completely concealed. This entire unit may represent the Condor member of the Swasey limestone.------------------ 125

Total estimated thickness of the Swasey limestone..------------------ 325

### Dome limestone

<table>
<thead>
<tr>
<th>Limestone; dark gray, microcrystalline to finely crystalline, weathers dull dark gray. Beds 1-2' thick form prominent ledges.</th>
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<tbody>
<tr>
<td>Total estimated thickness of the Dome limestone..------------------ 15</td>
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</table>

### Burnt Canyon limestone

6.) Completely concealed. May be structurally disturbed..------------------ 75

5.) Limestone; with minor interbedded shale. The limestone is similar to that of units #1 and #3. The shale is green, weathers same, and is similar to that of units #2 and #4..------------------ 100

4.) Shale; gray, extremely sericitic, weathers light greenish-gray. Extremely fissile. Bedding surfaces are highly irregular. Slickensides are extremely common, both on bedding surfaces and on planes of fissility..------------------ 5

3.) Limestone; dark gray, finely to medium crystalline, silty, weathers bluish-gray. Numerous scattered aggregations of coarse calcite crystals are selectively Fe-stained..------------------ 50
2.) Shale; greenish-gray, micaceous, weathers same. Sericitic sheen is far less pronounced than in unit #4. Platy beds average 1/16" or less thick.................................................. 5

1.) Limestone; dark gray, microcrystalline to finely crystalline, silty, weathers bluish-gray. Silt is present in scattered pockets, not disseminated uniformly throughout the rock, and is selectively orange-stained by Fe oxides. Girvanella or similar algal masses are locally abundant......................... 25

Total estimated thickness of the Burnt Canyon limestone.............. 260

Burrows limestone

3.) Dolomite; with very minor interbedded limestone and shale. The dolomite is pearly light gray, coarsely crystalline, and weathers various shades of brown. Near the base of the unit, scattered dolomite crystals are selectively stained light brown by Fe oxides, giving the fresh surfaces a "speckled" appearance. The interbedded limestone and wavy-bedded shale are very minor in volume. Hand specimens of the dolomite strongly resemble unit #1, but the outcrop habit is extremely different - this unit does not form blocky ledges............. 150

2.) Limestone; white to whitish-light gray, microcrystalline, silty, sugary, weathers whitish-gray. Orange-brown limonite has selectively stained coarse calcite crystals. Lithology is extremely homogeneous - unit has been considerably altered..... 75

1.) Dolomite; pearly light gray, very coarsely crystalline, weathers throughout its extent to a uniform tannish-brown. As with all the units of this formation, there is a complete absence of clastic material. All three units have been altered - common in the Burrows limestone. This unit has a blocky habit - bedding planes plus vertical fractures make this a "step-like" unit.................................................. 50

Total estimated thickness of the Burrows limestone.................. 275

Millard limestone

Limestone; gray, very finely crystalline, silty, weathers dull gray. Silt is more abundant here than in any of the overlying carbonate beds in this section. Thin orange siltstone laminae, average thickness less than 1/16", are roughly parallel to bedding and commonly coalesce to form thicker partings. The partings are relatively minor in volume compared to the thicknesses of the intervening limestone. The partings weather deeper than the limestone, giving the unit a pronounced "ruled" appearance. Despite
the thin bedding, this unit forms ledges which average 1' thick.......................................................... 200

Total estimated thickness of the Millard limestone......................... 200

Total estimated thickness of the "Undifferentiated Middle Cambrian" 1,075

picoche "shale"

Quartzite. Not measured.

C-9. Stratigraphic Section of the "Undifferentiated Middle Cambrian" on the
east wall of the North Fork of Little Valley.

This section was measured in a structurally complex area and the
thicknesses are probably unreliable. It is significant, however, in that
it indicates the lateral variations in the lithologic characteristics of
this undifferentiated succession. The thicknesses of units #3-6 of the
Swasey (?) limestone were derived from a questionable bedding attitude,
and a small fault may be present between units #2 and #3. The assignment
of formational names is highly speculative. The strata generally strike
northwesterly and dip 35-50° toward the northeast. The section is bounded
at the top by a major fault. Section C-5 was measured immediately below.

Thickness in Feet

Swasey (?) limestone

FAULT

6.) Limestone; dark gray, microcrystalline, very slightly silty,
weathers gray to dull or dirty light gray............................ 116+

5.) Limestone; dark gray, finely crystalline, slightly oolitic,
weathers dull gray....................................................... 39

4.) Limestone; gray to dark gray, microcrystalline, weathers
light bluish-gray. Slabby and thin-bedded, forms shaly
float. Girvanella-like masses along silty bedding surfaces
locally give a "mottled" effect........................................ 194

3.) Shale; green, very slightly micaceous, weathers greenish-tan.
Pronounced fissility. Surfaces are sericitic and strongly
resemble argillite.................................................... 43

2.) Limestone; two types of limestone are interbedded. Dark gray,
very finely crystalline, silty, limestone which weathers gray
is interbedded with gray, oolitic, silty limestone which weathers dull gray.................................................. 144

1.) Almost completely concealed. Bedrock is probably interbedded limestone and shale. Limestone is dark gray and weathers gray. Shale is light greenish-gray to tan and silty.................. 72

Total thickness of exposed Swasey (?) limestone.................. 608+

Dome (?) limestone

Limestone; dark gray to blackish-gray, microcrystalline, silty, weathers gray to dull gray. Bedding poorly defined. Very thin light brown siltstone bands are sparsely present along bedding surfaces........................................... 97

Total thickness of the Dome (?) limestone.................. 97

Burnt Canyon (?) limestone

2.) Interbedded limestone and shale. Limestone is of two types - gray oolitic and dark gray microcrystalline. Shale is light tan, extremely sericitic along bedding surfaces, weathers same, and is very minor in volume relative to the limestone.... 45

1.) Completely concealed by limestone float..................... 25

Total thickness of the Burnt Canyon (?) limestone.................. 70

Burrows (?) limestone

5.) Dolomite; pearly light gray, medium to coarsely crystalline, weathers to uniform brown. Massive habit. Exfoliates............. 62

4.) Limestone; dark gray, microcrystalline, weathers same. Parallel-bedded. Similar to unit #2 below......................... 10

3.) Dolomite; pearly light gray, medium to coarsely crystalline, weathers to uniform brown. Same lithology as unit #5 above and unit #1 below................................. 43

2.) Limestone; dark gray, microcrystalline, weathers dull gray...... 5

1.) Dolomite; pearly light gray to whitish-gray, medium to coarsely crystalline, weathers brown. Totally massive unit, which like units #3 and #5 has undergone epigenetic dolomitization........ 43

Total thickness of the Burrows (?) limestone.................. 163
Millard (?) limestone

Almost completely concealed; but limestone is probably the bedrock. Limestone is gray, very finely crystalline, weathers gray to light gray. Anomalous bedding attitudes indicate the possibility of structural complications. 

Total thickness of the Millard (?) limestone 43

Total thickness of exposed "Undifferentiated Middle Cambrian" 981+

Pioche "shale"

Quartzite; with minor interbedded shale. The quartzite is green, fine-grained, and weathers dark brown and dark reddish-brown. (See Section C-5).

C-10. Stratigraphic Section of the "Undifferentiated Middle Cambrian" on the south wall of South Canyon.

This section is close to a large fault and the thicknesses may be unreliable. The assignment of formational names is speculative. The strata are poorly exposed for the most part, strike northerly and dip 50° toward the east. Section C-18 was measured immediately above.

Marjum formation

Completely concealed over basal 151' - above this is pearly gray, coarsely crystalline dolomite weathering tan to light brownish-tan. (See Section C-18).

Swasey (?) limestone

9.) Limestone; dark gray to blackish-gray, microcrystalline, slightly silty, weathers dull gray 47

8.) Completely concealed by hillwash and abundant limestone float 116

7.) Limestone; dark gray, very finely crystalline, extremely silty, weathers dirty dark gray. Orange-brown weathering siltstone laminae 1/8-1/16" thick are parallel to bedding and almost equal to the limestone in volume. In this "banded limestone" unit the limestone peculiarly stands out in relief over the siltstone partings on weathered surfaces 11

- 286 -
6.) Limestone; dark gray, finely crystalline, silty, weathers bluish-gray. Silty "pockets" are present throughout the limestone and are selectively stained brown by limonite. 27

5.) Limestone; dark gray to black, microcrystalline, silty, weathers dirty gray. Siltstone bands up to 1/4" thick are roughly parallel to bedding and stand out sharply in relief on weathered surfaces. The entire unit is extremely susceptible to shearing. 40

4.) Limestone; gray to dark gray, microcrystalline, weathers bluish-gray. Brown to tan argillaceous siltstone partings, roughly parallel to bedding, give this unit a "banded" appearance. 55

3.) Completely concealed. 16

2.) Limestone; gray to dark gray, microcrystalline, extremely silty, weathers gray. Some limestone beds are extremely argillaceous. 69

1.) Completely concealed. Arbitrarily assigned to the Swasey (?) limestone. 36

Total thickness of the Swasey (?) limestone 417

Dome (?) limestone

Limestone; dark gray, microcrystalline and medium crystalline, weathers bluish-gray. "Splotches" of light grayish-tan argillaceous silty material are present on bedding surfaces and in fresh rock. Bedding is very poorly defined. 47

Total thickness of the Dome (?) limestone 47

Burnt Canyon (?) limestone

3.) Completely concealed. 37

2.) Limestone; gray, medium crystalline, weathers light bluish-gray. Limonite flecks are scattered throughout the fresh rock. Resembles oolitic limestone, but there are no oolites. 13

1.) Completely concealed. Arbitrarily assigned to the Burnt Canyon (?) limestone. 30

Total thickness of the Burnt Canyon (?) limestone 80
Burrows limestone

Dolomite; pearly gray, coarsely crystalline, weathers uniform light brown or tan. Light brown Fe oxide stain is scattered irregularly throughout the fresh rock. Forms 2-4' thick beds... 76+

Total thickness of the exposed Burrows limestone... 76+

Total thickness of exposed "Undifferentiated Middle Cambrian"... 620+

C-11. Stratigraphic Section of a portion of the "Undifferentiated Middle Cambrian" on the south face of Black Mountain.

This partial section was measured only to establish the stratigraphic position of two faunal collections from the Glossopleura zone. Small-scale faulting made it necessary to abandon the section long before the main objective (the Wheeler formation) could be reached. The strata strike northerly and dip 15° westerly.

Thickness in Feet

Burnt Canyon limestone

Limestone; platy, thin-bedded (1-2" thick)... 29+

Shale; green, micaceous, weathers green to greenish-gray. Bedding surfaces have pronounced sericitic sheen. No limestone was noted. Shale is finely laminated. Crops out poorly and is largely concealed. Contains an excellent trilobite fauna which is, for the most part, confined to the basal 10'.

Athabaskia cf. A. wasatchensis (Resser)
Ehmaniella cf. E. quadrans (H. & W.)
Glossopleura cf. G. bion Walcott
Glossopleura similarsis Resser
cf. Kootenia idahoensis Resser
Obolus (Westonia) ella (Hall and Whitfield)
Zacanthoides cf. Z. idahoensis Resser ........................ 51

Total thickness of measured Burnt Canyon limestone.............. 80+

Burrows limestone

Dolomite; pearly light gray, coarsely crystalline, weathers uniform dark brown. A blocky ledge-former, with bedding ranging from 3' thick to totally massive ledges. Conspicuous unit due to uniform dark weathered color. Dolomitization is probably epigenetic, because elsewhere this prominent unit is commonly limestone.............. 100
Shale; with minor interbedded limestone. The shale is green to olive drab, micaceous, and weathers same. Shale is laminated (1/16-1/8" thick) and extremely fissile. The limestone is dull gray, extremely oolitic, and weathers gray to bluish-gray. An excellent trilobite fauna is present in the shale. Trilobite fragments are locally present in the limestone, but are generally unidentifiable.

- Alokistocare cf. *A. idahoensis* (Resser)
- Athabaskia cf. *A. wasatchensis* Resser
- Ehmaniella quadrans (H. & W.)
- Glossopleura cf. *G. producta* (H. & W.)
- Zacanthoides cf. *Z. idahoensis* Resser

Total thickness of measured Burrows limestone........................ 138

C-12. Stratigraphic Section of the Wheeler formation on the southwest corner of Black Mountain.

The Wheeler formation, as at most of its other exposures, here forms a prominent V-shaped "saddle" or "notch" between the flatiron dip slope of the Swasey limestone and the overlying limestone cliffs of the Marjum limestone. At all other localities, only unit #1 is present or exposed, and it is debatable whether or not unit #2 should be assigned to the Marjum limestone. The strata are poorly exposed and have been greatly contorted. Beds strike northwesterly and dip 40° toward the northeast. Section C-16 was measured above and Section C-7 was measured directly below.

Thickness in Feet

Marjum limestone

Limestone; dark gray, microcrystalline, weathers blue-gray to gray. (See Section C-16).

Wheeler formation

2.) Shale; could be called "shaly limestone". Shale is blackish-gray to jet black, extremely silty and calcareous, and weathers peculiarly to a dirty light gray. Shaly bedding, consisting of laminae averaging 1/16" thick or less, is coalesced into beds up to 1/4" thick. Locally the strata are intensely contorted into small folds. Shearing is pervasive................................. 50

1.) "Whitewashed" unit; shale, limestone, and minor calcite "beds". Shale is tan to light gray, talcose, micaceous, silty, and weathers brown to tan. The shale is extremely fissile.
The calcite is white, very coarsely crystalline, and weathers cream-colored. Both shale and calcite stand out as thin laterally persistent "ribs" above the pervasive hillwash and regolith of this unit. The limestone is dark gray, medium crystalline, and weathers drab tan. The limestone has a pronounced shaly habit. Thoracic segments of trilobites, abundant along shale bedding surfaces, are indeterminate. Both upper and lower contacts are concealed.

Total thickness of the Wheeler formation........................................ 181

Swasey limestone

Limestone; gray, finely crystalline, weathers gray to light gray. (See Section C-7).

C-13. Stratigraphic Section of the Wheeler formation on the south face of Black Mountain.

The Wheeler formation forms a prominent V-shaped "saddle" along this ridge, which was known as "Lead Hill" by the mining men. The strata are poorly exposed and strike northwesterly with a dip of 40° toward the northeast. Section C-15 was measured directly above this section.

Thickness in Feet

Marjum limestone

Limestone; dark gray to grayish-black, microcrystalline, weathers dark bluish-gray. (See Section C-15).

Wheeler formation

"Whitewashed" unit; completely concealed by its characteristic light gray, talcose, calcareous regolith. Bedrock is probably silvery light gray, micaceous, talcose, calcareous shale which weathers silvery dark gray. The shale has paper-thin laminae and is extremely fissile................................................................. 85

Total thickness of the Wheeler formation........................................ 85

Swasey limestone

Limestone; gray, finely crystalline, weathers gray to light gray.
C-14. Stratigraphic Section of the Wheeler formation along the west ridge of the North Fork of Little Valley.

The Wheeler formation here, as everywhere else where it is present, forms a V-shaped notch or "saddle" along the ridge due to its weak resistance to erosion. The strata are poorly exposed and strike northwesterly with a dip of 55° toward the northeast. Section C-8 (with estimated thicknesses) was traversed immediately below this section.

<table>
<thead>
<tr>
<th>Thickness in Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marjum limestone</td>
</tr>
<tr>
<td>Limestone; dark gray to grayish-black, microcrystalline, weathers dark bluish-gray. Lithology not found in place, but is described from float. Not measured.</td>
</tr>
<tr>
<td>Wheeler formation</td>
</tr>
<tr>
<td>&quot;Whitewashed&quot; unit; completely concealed by its characteristic light gray, talcose, calcareous regolith. Shale is probably the bedrock lithology for all of this unit. The shale is whitish-gray, micaceous, talcose, and weathers same. Thoracic segments of trilobites are abundant along bedding surfaces, but are indeterminate.</td>
</tr>
<tr>
<td>Total thickness of the Wheeler formation</td>
</tr>
<tr>
<td>Swasey limestone</td>
</tr>
<tr>
<td>Limestone; dark gray, finely crystalline; weathers gray to light bluish-gray. (See Section C-8).</td>
</tr>
</tbody>
</table>

C-15. Stratigraphic Section of the Marjum limestone on the south face of Black Mountain.

This is the only complete section of the Marjum limestone which was measured in the Promontory Range. Both contacts are well exposed and no evidence of faulting was detected. The strata are well exposed, especially units #13-16 which form the prominent limestone cliffs at the top of the section. The strata strike northwesterly and dip 30-40° toward the northeast. Section C-13 was measured immediately below this section.
Nounan formation

Dolomite; gray to light gray, finely to medium crystalline, weathers dirty gray to light gray. Weathered surfaces have "sandy" texture, but there are no included sand grains. Crops out as blocky, thick (1-2') beds and the basal portion locally forms the crest of Black Mountain. Dolomite ledges of the Nounan formation form a succession of dip slopes on the north side of Black Mountain down into Little Valley. Not measured.

Marjum limestone

16.) Completely concealed. Most of the float is pale green to green shale similar to that of unit #15 below. The upper contact is arbitrarily placed at the base of the lowermost exposed dolomite ledge of the Nounan formation......................... 49

15.) Interbedded limestone and shale. Limestone is gray, microcrystalline, weathers gray to dark bluish-gray. Crops out as 2 or more beds 5-10' thick. Shale is green or light green, talcose, weathers same, and is finely laminated (1/16-1/8" thick) and extremely fissile......................... 38

14.) Concretionary limestone and shale. Limestone occurs as nodules and elongated stringers (parallel to bedding) encased in a shale matrix. Limestone is pale green, microcrystalline, and weathers light greenish-gray. Shale weathers brown or tan and displays pervasive high-angle fracture cleavage......................... 58

13.) Limestone; black to dark grayish-black, microcrystalline but locally very finely crystalline, locally very slightly silty, weathers dark gray. Consistently very thin-bedded, ½-2" thick beds have markedly undulatory bedding surfaces. Argillaceous siltstone partings along bedding surfaces are rarely present and are not laterally persistent. Black chert nodules are present near the middle of the unit - chert is rare in the Cambrian. Despite the almost universal very thin-beddedness, this entire unit is a prominent cliff-former and forms the most prominent cliff on the south face of Black Mountain.......................... 574

12.) Dolomite; light gray but locally whitish-gray, medium crystalline, weathers dull gray or dull browns and tans. Fresh surfaces locally show intense Fe oxide staining. Bedding is thick to massive (2' and thicker). Blocky unit, but not a cliff-former. The upper contact has about 5' of stratigraphic relief - indicating, perhaps, hydrothermal dolomitization............. 146
11.) Almost completely concealed; but there are a few outcrops of thin-bedded limestone. The limestone is dark gray, microcrystalline, and weathers gray to light gray.  

10.) Limestone; interbedded oolitic and non-oolitic limestone. The limestone is gray to light gray, generally microcrystalline, and weathers gray to dirty light gray. Unit as a whole is very thick-bedded to massive and forms rounded ledges rather than steep cliffs. Differs from unit #9 below in that there are no partings of foreign material along bedding surfaces.  

9.) Limestone; blackish-gray to black, microcrystalline, weathers dark gray. Thin beds (¼-3") are undulatory and orange argillaceous siltstone partings are abundant along bedding surfaces.  

8.) Limestone; dark gray to blackish-gray, microcrystalline to finely crystalline, weathers light bluish-gray to gray. Crops out as 2-5' thick ledges, which display no internal bedding surfaces, and differs markedly from units #9 and #7 by its much thicker bedding.  

7.) Concretionary limestone in shale; same lithology as unit #14.  

6.) "Banded limestone"; but there are no siltstone "ribs" as in unit #5 below. The limestone is dark gray to black, microcrystalline to very finely crystalline, and weathers dull gray. Occurs as thin beds which are separated by thinner laminae of extremely silty limestone. These silty limestone laminae are selectively stained intense orange-brown by Fe oxides, but this is purely a surficial phenomenon. This unit differs from unit #5 below in that the partings are not siltstone, are calcareous, and do not stand out in relief along weathered surfaces of the limestone. An augite-rich sill, 2' thick, is present about 200' above the base of the unit.  

5.) "Banded limestone". Limestone is gray, microcrystalline, and weathers dirty bluish-gray. Limestone beds ¾-⅜" thick are separated by much thinner (paper-thin to 1/16" thick) argillaceous and highly micaceous siltstone partings which stand out sharply in relief from the limestone on weathered surfaces. Selective Fe oxide staining accentuates the partings - for the limestone contains no Fe stain.  

4.) Interbedded limestone and shale. The limestone is varicolored (red, brown, and gray), microcrystalline, and weathers same. The limestone is medium-bedded (1' average thickness) and is locally oolitic. The shale is greenish-gray, slightly silty, non-calcareous, and weathers green.
3.) Dolomite; pearly gray, very coarsely crystalline, weathers dirty light brown to dirty light tan. Although the bottom contact is extremely gradational, the upper contact with the overlying limestone is sharp and well defined. .......................... 30

2.) Limestone; gray to dark gray, medium crystalline, extremely oolitic, generally weathers gray. The extremely oolitic portions display widespread and prominent low-angle cross-bedding. Differs from unit #1 below by being thick-bedded (2' and greater) to massive................................. 173

1.) Limestone; dark gray to grayish-black, microcrystalline, and weathers dark bluish-gray. Very thin-bedded (1/2-2" thick) with bedding surfaces markedly undulatory. A "platy-weathering" unit which is characterized by tan to orange argillaceous siltstone partings along bedding surfaces. These partings are generally laterally persistent................................. 163

Total thickness of the Marjum limestone.......................... 1,878

Wheeler formation

Shale; silvery light gray, weathers silvery gray. (See Section C-13).

C-16. Stratigraphic Section of the Marjum limestone at the southwest corner of Black Mountain.

This is an incomplete section of the Marjum limestone, due to a stratigraphic error by the writer. The strata are very well exposed, strike consistently northwesterly, and dip 35-45° toward the northeast. Section C-12 was measured immediately below.

Thickness in Feet

Marjum limestone

10.) Concretionary limestone in shale. Limestone nodules are encased in a shale matrix - typical of the upper portions of the Marjum limestone. Measurement of the section was stopped at the base of this unit by mistake, thinking that this was the top of the Marjum limestone. Not measured.

9.) Completely concealed................................. 57

8.) Limestone; gray, microcrystalline, very slightly silty, weathers dull gray or bluish-gray. Characterized by light brown argillaceous and silty "partings" at high angles to bedding........... 48
7.) Completely concealed; except for uppermost 2' which is an augite sill.

6.) Limestone; dark gray, microcrystalline, oolitic, weathers light gray or light bluish-gray. Totally massive. A cliff-former, as are all of the units from here down to unit #1. Fresh surfaces have scattered limonite flecks. Basal contact is extremely gradational.

5.) Limestone; dark gray to blackish-gray, very finely crystalline, weathers dull gray to dark gray. Very similar to unit #3 below, and it is probable that units #3-5 were all one unit prior to the dolomitization of unit #4 below.

4.) Dolomite; pearly gray, medium crystalline, weathers tan. Both upper and lower contacts are extremely irregular and undulatory, indicating the probability of secondary dolomitization.

3.) Limestone; dark gray to blackish-gray, microcrystalline to very finely crystalline, weathers dull gray to dark gray. Similar to unit #2 below, except that there are no brown or tan silty partings along bedding surfaces.

2.) Limestone; dark gray to blackish-gray, microcrystalline, slightly silty, weathers dirty dull gray. Thin-bedded (strata average 1" thick) with very thin (1/16" and less) argillaceous silty partings along the rough, undulatory bedding surfaces of the limestone. A steep cliff-forming unit. Trilobite remains are abundant, but are found only in the silty partings - never in the limestone.
   Bolaspidella sp.
   Glyphaspis ? sp.
   Marjumia ? sp.

1.) Limestone; dark gray, microcrystalline, weathers blue-gray to gray. Thin beds of limestone are separated by light brown argillaceous silty partings which differ from those of unit #2 above in having laterally uniform thicknesses. This unit forms inconspicuous ledges which barely crop out.

Total thickness of measured Marjum limestone.

Wheeler formation

Shale; gray to tan, calcareous, weathers generally light gray or dirty light gray. (See Section C-12).
C-17. Stratigraphic Section of the Marjum limestone along the east ridge of Maple Canyon.

This incomplete section of the Marjum limestone is atypical and is bounded at the base by a fault. Its upper contact with the Nounan formation is somewhat different than is found elsewhere in the Promontory Range in that it is more transitional. An east-west fault runs easterly from the pass between Maple Canyon and the North Fork of Little Valley and places "Undifferentiated Middle Cambrian" on the south against Marjum limestone to the north. The strata strike northwesterly and dip 30-40° toward the northeast. Section C-9 was measured south of this section and across the fault and Section C-19 was measured immediately above.

Thickness in Feet

Nounan formation

Dolomite; pure white, medium crystalline, weathers white to grayish-white. (See Section C-19).

Marjum limestone

12.) Limestone; very dark gray to black, microcrystalline, weathers various shades of gray. Basal portion has abundant hematite streaks. Forms a dip slope.................. 118

11.) Interbedded limestone, mudstone, and shale. Limestone is dark gray to black, microcrystalline, slightly silty, and weathers same. Shale or mudstone is greenish-gray, silty and slightly micaceous, and weathers light green. Basal 15' has a small amount of the "concretionary limestone in shale" lithology described in units #6 and #9 below...................... 117

10.) Limestone; with light brown siltstone seams.................. 47

9.) Concretionary limestone in shale................................. 10

8,) Limestone; gray to dark gray, microcrystalline to very finely crystalline, slightly silty, weathers blue-gray to gray. Light brown to tan siltstone laminae (1/16" thick) are abundant along the limestone bedding surfaces, and are selectively stained brick-red or light reddish-brown by Fe oxides......... 101

7.) Interbedded limestone and argillaceous siltstone. Siltstone forms distinct beds rather than undulatory partings.............. 9

6.) Concretionary limestone in shale. Greenish-gray, microcrystalline (locally almost lithographic) limestone is present as nodules 3"-2' long parallel to bedding in a shale matrix. Shale is
greenish-gray, silty, weathers tan, and is slightly calcareous on fresh surfaces. Fracture cleavage at high angles to bedding is present throughout the shale.

5.) "Banded" limestone; interbedded limestone and argillaceous siltstone. The limestone is generally blue-gray, microcrystalline, slightly silty, and weathers same. The siltstone is light gray to light tan, but is selectively stained dark brown by Fe oxides along joint surfaces. Outcrops have a distinctive "ruled" appearance.

4.) Limestone; gray microcrystalline to very finely crystalline, oolitic, weathers to light bluish-gray.

3.) Dolomite; silvery gray to pearly gray, medium to coarsely crystalline, generally weathers light gray.

2.) Limestone; silvery light gray, microcrystalline to very finely crystalline, slightly oolitic, weathers dull bluish-gray. Despite the unit's thin-beddedness, there are many thick ledges which form sheer vertical cliffs. Differentiated from unit #1 below because of cliff-forming tendency and the absence of siltstone partings. This unit forms the highest knob on the ridge north of "Promontory" triangulation station.

1.) Limestone; dark gray to black, microcrystalline, weathers dark gray. Tan siltstone laminae are present along most bedding planes. Thin-bedded, parallel-bedded habit.

Total thickness of exposed Marjum limestone:

FAULT

"Undifferentiated Middle Cambrian"

Limestone; dark gray, microcrystalline, very slightly silty, weathers gray to dull or dirty light gray. (See Section C-9).

C-18. Stratigraphic Section of the Marjum limestone on the south wall of South Canyon.

This partial section of the Marjum limestone is very close to a major fault. The Wheeler formation may be represented by units #1 and #2, but because the clayey regolith so characteristic of the Wheeler formation is absent, the entire measured section is considered to be Marjum limestone. The strata strike northerly and dip 50° toward the east. Section C-10 was measured immediately below.
11.) Limestone; tannish-gray, microcrystalline, very slightly silty, weathers gray. Brown to orange-brown argillaceous siltstone bands, 1/8" thick, are roughly parallel to bedding. Section was terminated here, due to excessive concealment above. 13+

10.) Limestone; dark gray, medium crystalline, weathers dull light gray. Massive unit - there is no visible bedding. 12

9.) Dolomite; gray to light gray, medium crystalline, weathers dull light gray to a light tannish-gray. Bedding is generally absent, but where present is generally thicker than 1". 153

8.) Limestone; dark gray, finely crystalline, weathers dark bluish-gray. Bedding is generally absent, but thin parallel beds are locally well displayed. 43

7.) Interbedded limestone and dolomite. The dolomite is similar to that of unit #6 below and the limestone is similar to that of unit #8 above. This unit probably represents a transition between units #6 and #8. 40

6.) Dolomite; silvery light gray, very finely crystalline, weathers dirty light gray to tannish-gray. Weathered surfaces have a "sandy" texture, but there are no included clastic grains. 53

5.) Dolomite; silvery dark gray, finely crystalline, weathers very dark tan to dark brown. Differentiated from dolomite units above and below by well displayed medium-bedding (6"-1'). 50

4.) Dolomite; silvery gray, medium crystalline, generally weathers gray to dull gray, but some intervals weather darker to light brown or brownish-tan. Upper contact is gradational. 193

3.) Dolomite; pearly gray, coarsely crystalline, weathers tan to light brownish-tan. Forms one massive ledge. 8

2.) Completely concealed by talus. 111

1.) Completely concealed by hillwash. This unit and unit #2 above may represent the Wheeler formation, which is not exposed along this ridge. 40

Total thickness of measured Marjum limestone. 716+
Swasey (?) limestone

Limestone; dark gray to blackish-gray, microcrystalline, slightly silty, weathers dull gray. (See Section C-10).

C-19. Stratigraphic Section of the Nounan formation along the east ridge of Maple Canyon.

This is the only known complete exposure of the Nounan formation in the Promontory Range. There are many other better exposures uncomplicated by complex structure, e.g. along the west wall of Maple Canyon, but none of these have an upper contact. The only known exposure in the Promontory Range of the Worm Creek member of the St. Charles dolomite is present at the top of this section. The strata strike northwesterly and dip 35-70° to the northeast, but structurally disturbed areas indicate the probable presence of complicating faults. Of all the Cambrian stratigraphic sections, this is by far the least reliable as to true stratigraphic thicknesses. The basal contact of the Nounan formation is generally well exposed and easily established elsewhere in the range, but here the contact was more arbitrarily chosen. Section C-20 was measured immediately above the top of this section and Section C-17 was measured immediately below.

Thickness in Feet

St. Charles dolomite

Worm Creek quartzite member

Interbedded quartzite, quartzitic sandstone, and shale. (See Section C-20).

Nounan formation

28.) Interbedded dolomite and limestone. Dolomite predominates and is gray, very finely crystalline to finely crystalline, and weathers dirty light gray. Limestone is bluish-gray, microcrystalline, and weathers same as the dolomite.................. 31

27.) Limestone; dark gray, microcrystalline to very finely crystalline, weathers gray. Abundant argillaceous siltstone laminae are selectively stained brown or tan by Fe oxides and are parallel to bedding. Thin-bedded (2-4"), parallel-bedded unit............ 81
26.) Interbedded limestone and dolomite. Limestone is whitish-gray to white, microcrystalline, and weathers same. Dolomite is tan to gray, microcrystalline to very finely crystalline, and weathers uniformly to light tan "sandy" or "silty" surfaces. This texture is due to the solution of a crystalline texture, for there are no included clastic grains. 16

25.) Dolomite; white to pinkish-white, very coarsely crystalline, weathers tannish-gray to whitish-gray. Bedding indiscernible. 29

24.) Dolomite; silvery gray, finely crystalline, weathers to very uniform light gray to gray. Massive unit. Crops out well. 69

23.) Completely concealed. Bedrock lithology is probably light tan- to light brown-weathering dolomite. 39

22.) Limestone; white, generally microcrystalline, weathers light gray to whitish-gray. Texture is locally coarsely crystalline. Resembles unit #17 below. A massive ledge-former. 37

21.) Limestone; dark gray, very finely crystalline, weathers gray to dark bluish-gray. Characterized by irregularly shaped concentrations of Fe oxides which have no relation to either bedding or fractures. 53

20.) Dolomite; silvery gray, finely crystalline, weathers to uniform light gray, locally whitish-gray. An extremely uniform and homogeneous unit which is extremely well exposed and forms massive ledges despite its well defined parallel bedding surfaces. Upper and lower contacts are sharp. 118

19.) Dolomite; gray, medium crystalline, oolitic, weathers gray to dark gray. No siltstone or mudstone partings. A massive ledge-former. 47

18.) Limestone; gray, very finely to finely crystalline, silty, weathers gray or light gray. Unit is banded with micaceous siltstone laminae which are parallel to bedding and stand out in sharp relief on weathered surfaces as "ribs". All partings are selectively stained brown to orange-brown by Fe oxides. Limestone beds between the partings are 1™ thick. 147

17.) Limestone; light tan to light gray, microcrystalline, weathers whitish-gray. Stands out prominently from units above and below. Extremely difficult to fracture with the pick. 37

16.) Dolomite; dark gray, very finely to finely crystalline, weathers dark gray. Crops out as massive ledges in which bedding is completely indiscernible. Stands out prominently between lighter units above and below. 57
15.) Dolomite; silvery gray to gray, finely to medium crystalline, weathers dirty light gray, light bluish-gray, or tannish-gray. Massive ledges up to 10' thick contrast with unit #14 below. These blocky ledges can not be traced far laterally. 417

14.) Interbedded limestone and dolomite. Limestone is generally dark gray and weathers dark blue-gray. Dolomite is generally gray and weathers gray to dull light gray. Parallel-bedded, thin-bedded (generally less than 6" thick). 56

13.) Dolomite; same lithology as unit #11 below, except that there is more dolomite and fewer silty, argillaceous "bands". 40

12.) Limestone; gray, microcrystalline, weathers blue-gray. Parallel-bedded, thin-bedded (2-6"). Characterized by abundant silty and argillaceous partings which parallel bedding, are rarely greater than 1' long, and are selectively stained light orange-brown by Fe oxides. 16

11.) Dolomite; gray, very finely crystalline, slightly silty and arenaceous (very fine-grained), and weathers grayish-tan. "Banded" by silty argillaceous laminae ½-1" apart and almost perfectly parallel to bedding. These laminae are selectively stained light brown by Fe oxides and are more resistant than the dolomite - therefore, they stand out as "ribs". 50

10.) Dolomite; pinkish-white to white, medium crystalline, weathers dull light tan or light grayish-tan. Thick-bedded to massive unit which stands out sharply in color contrast with the units above and below. 45

9.) Dolomite; dark blue-gray, finely crystalline, weathers gray to slightly bluish-gray. Bedding is absent and the entire unit crops out poorly. 175

8.) Completely concealed. Probably tan silty mudstone or argillaceous siltstone, judging from the abundant float. 226

7.) Limestone; dark gray to blackish-gray, ranges from very finely to coarsely crystalline, generally weathers gray to dark gray. Locally oolitic. Unit is poorly exposed. 54

FAULT?? Probably very small in magnitude.

6.) Dolomite; similar to unit #5 below, except that all trace of bedding is gone and forms massive ledges. 41

5.) Dolomite; dark gray, finely crystalline, weathers dirty tan. Well bedded in 2-4" thick parallel beds. 73
4.) Almost completely concealed. Float is similar to unit #5 above.

3.) Limestone; gray to dark gray, very finely crystalline, weathers dull light bluish-gray or dirty tan. Thick-bedded, forms discontinuous blocky ledges and steep dip slopes.

FAULT - Fault zone between strata with regional bedding attitude is about 100' wide along line of section. Measured section below this fault zone is questionable, but the 2,039' interval measured above is valid. There is no repetition of strata; if anything, portions of the Nounan formation are omitted.

2.) Interbedded limestone and dolomite. Limestone is gray, finely crystalline, and weathers dull light gray. Dolomite is dark gray, finely crystalline, and also weathers dull light gray.

1.) Dolomite. Uppermost 47' is gray to light gray, finely to medium crystalline dolomite, weathering dull light gray. Basal 22' is pure white, medium crystalline dolomite, weathering white to grayish-white, an extremely distinctive unit on this drab hillside. Bedding generally absent.

Total thickness of the Nounan formation

Marjum limestone

Limestone; dark gray to black. (See Section C-17).

C-20. Stratigraphic Section of the St. Charles dolomite along the east ridge of Maple Canyon.

This is the only known locality in the Promontory Range where both the upper and lower contacts of the St. Charles dolomite are present. The section is well exposed as numerous ledges on the crest of the ridge, but unfortunately the ridge crest is aligned much more closely with the strike rather than with the dip of the strata. The beds strike northwesterly and dip about 40° to the northeast. Section 0-2 was measured immediately above this section and Section C-19 was measured immediately below.
Thickness in Feet

Garden City formation

Limestone; gray, microcrystalline, weathers characteristically to bluish-gray. Extremely thin (less than 1/16" thick), pale orange to light brown argillaceous and silty seams are generally parallel to bedding and stand out in relief on weathered surfaces from the limestone mass. (See Section O-2).

St. Charles dolomite

15.) Dolomite; gray or silvery gray, finely to medium crystalline, weathers light gray to grayish-tan. Differential etching of calcareous crystalline texture imparts a "sandy" appearance to weathered surfaces. Thick-bedded, yet not a ledge-former. Gray chert is present, but rare, in basal 20'. Uppermost ledge forms dip slope down to alluvial saddle at base of the Garden City formation. .................................................. 75

14.) Completely concealed.................................................. 27

13.) Mostly concealed; but several thin beds of gray dolomite crop out. Dolomite is similar to that of unit #15 above, but generally much lighter in color................................. 37

12.) Dolomite; gray, very finely to finely crystalline, weathers dull gray or slightly more drab than the fresh rock. Contains no clastics, but commonly weathers to "sandy" surfaces due to differential solution of a calcareous crystalline texture. Massive unit, bedding is generally absent. Ledges up to 5' thick are discontinuous laterally and not prominent, except for uppermost 50' which forms a prominent cuesta. Gray chert nodules are sparsely present in basal 70' or so of the unit................................................................. 447

11.) Almost completely concealed. Bedrock lithology is probably interbedded, thin-bedded, light and dark gray dolomite - judging from float and sparse outcrops.............................. 39

10.) Dolomite; silvery light gray to pearly gray, finely crystalline, weathers light gray. Extremely light-weathering unit stands out prominently between two darker-colored units. Generally massive, the unit consists of several ledges up to 20' thick separated by concealed intervals of similar thickness. Weathers to a "sandy" surface, yet contains no clastics..... 149

9.) Dolomite; silvery dark gray, finely crystalline, weathers dirty gray to dark gray. Locally thick-bedded (up to 3' thick), but generally massive. Weathered surfaces appear "sandy".... 58
8.) Completely concealed......................................................... 72

7.) Dolomite; silvery gray, very finely crystalline, weathers gray to dirty light gray. Weathered surfaces have "sandy" texture although there are no included clastic grains. Either massive or thick-bedded habit. A cuesta-former........ 57

6.) Completely concealed......................................................... 44

5.) Limestone; gray to dark gray, microcrystalline, locally slightly silty, weathers gray to bluish-gray. Parallel-bedded, thin-bedded unit which forms prominent but small cuestas......................................................... 26

4.) Limestone; light gray, coarsely crystalline, weathers either pinkish-gray or light bluish-gray. Forms thick ledges which are extremely well defined and laterally continuous.............. 49

Total thickness of the St. Charles dolomite exclusive of the Worm Creek quartzite member............................. 1,080

Worm Creek quartzite member of the St. Charles dolomite

3.) Shale; dark tan, extremely argillaceous, slightly silty but not micaceous, weathers same. Extremely fissile. Unit is all shale except for 6" quartzite bed near base.............. 20

2.) Quartzite. Basal 18' is white, very fine-grained calcareous orthoquartzite, which weathers tan to light brown. This grades into alternating quartzitic sandstone and quartzite. The upper portion is fine-grained and extremely limonitic, unlike the basal calcareous orthoquartzite which is devoid of Fe oxides. Parallel-bedded, no cross-bedding noted....... 49

1.) Interbedded quartzite and quartzitic sandstone. Quartzite is white, very fine-grained, and weathers white. Its quartz grains are almost completely fused together. Quartzitic sandstone is white to whitish-gray, very fine-grained, largely cemented by calcareous material, and weathers tan to light brown......................................................... 11

Total thickness of the Worm Creek quartzite member............. 80

Total thickness of the St. Charles dolomite.......................... 1,160

Nounan formation

Interbedded limestone and dolomite. (See Section C-19).
The Garden City formation is not present in its entirety at any one locality within the mapped area. This section is the best one known in the Promontory Range. The upper contact is present, but generally concealed, and the lower contact is completely concealed by alluvium and Lake Bonneville deposits. Most of the formation is below the Bonneville level. This section was measured north of the spur along which Section 0-4 was measured. The strata have a northerly strike and dip 15-30° toward the east.

<table>
<thead>
<tr>
<th>Thickness in Feet</th>
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<tbody>
<tr>
<td><strong>Swan Peak formation</strong></td>
</tr>
<tr>
<td>2.) &quot;Shale&quot; unit, commonly present a short distance above the base of the Swan Peak formation, is here extremely poorly exposed and forms a regolith with few outcrops. Upper contact obscured by huge float boulders from massive quartzite unit above. Not measured.</td>
</tr>
<tr>
<td>1.) Calcareous orthoquartzite; gray, very fine-grained, weathers uniformly brick-red or dark brown. Only slightly calcareous on fresh surfaces. Color change on weathered surface is peculiar and probably represents a concentration of the scattered Fe oxide flecks which are present throughout the fresh rock. A blocky cliff-former, this ledge crops out almost throughout the entire length of exposure of the formation.... 16</td>
</tr>
<tr>
<td><strong>Garden City formation</strong></td>
</tr>
<tr>
<td>6.) Completely concealed. Abundant quartzite float from above masks the slope.............................. 39</td>
</tr>
<tr>
<td>5.) Dolomite; dark gray, microcrystalline to very finely crystalline, weathers gray or light gray. Weathered surfaces have very fine-grained texture, but there are no included sand grains. Abundant closely spaced fractures are filled with light gray chert which is stained light brown by limonite. Distinct 6&quot;-2' thick parallel beds give this unit a blocky appearance. Differentiated from unit #4 below by distinct bedding and a lighter weather color......................... 16</td>
</tr>
<tr>
<td>4.) Dolomite; dark gray, finely crystalline, weathers tan or grayish-tan. Massive unit. Abundant hematite present on fresh surfaces. Weathered surfaces have silty to &quot;very fine-grained&quot; texture, but there is no included silt or sand in the dolomite. No chert noted. Together with unit #5 above, this unit stands out prominently between covered slopes above and below.................................................................................... 132</td>
</tr>
</tbody>
</table>
3.) Limestone; dark gray, medium crystalline, weathers dark gray to bluish-gray. Weathered surfaces commonly have fine-grained to medium-grained "sandy" texture which is probably caused by solution, for there are no included clastic grains. Crops out as a massive cliff. Bedding generally indistinct. Large black chert nodules, up to 1' long parallel to bedding, are abundant. In the upper portion of the unit chert layers up to 3" thick and 5' long parallel to bedding are present. This limestone unit differs from all other limestone below by having black chert rather than brown, by weathering blue-gray rather than gray, and by being massive to thick-bedded rather than thin-bedded to laminated. There is also a complete lack of the siliceous and argillaceous partings, or "brown bands", so characteristic of unit #1 below. 230

2.) Completely concealed. Uppermost Lake Bonneville terrace hides all bedrock. The greater portion of this concealed interval probably belongs to unit #1 below. 115

1.) Limestone; light gray to gray, very finely to finely crystalline, weathers light bluish-gray to light gray. The limestone is locally arenaceous (very fine-grained), but is generally free from clastics. About one-half of this unit is characterized by argillaceous, siliceous partings which average ¼" thick and are parallel to bedding. They have been selectively stained brown by Fe oxides and stand out in "bas-relief" on weathered surfaces from the less resistant limestone. On magnification, these "brown bands" seem to be the surficial weathered expression of paper-thin clay partings. Much of the unit has gray chert nodules, stained light brown by limonite, elongate with bedding and commonly clustered along bedding surfaces much like fucoidal markings. Hintze (1951, pp. 94-96) found all of his listed Garden City fauna in this unit. 637+

Total thickness of exposed Garden City formation. 1,169+
Lake Bonneville sediments plus alluvium conceal all bedrock down to the shore of the Great Salt Lake.

0-2. Stratigraphic Section of the Garden City formation at The Narrows.

This is the only known locality in the Promontory Range where the base of the Garden City formation is definitely exposed. Unfortunately the upper contact is not present here, although it may be observed at almost all other localities where the formation is exposed. Here the basal portion of the formation is well exposed in a topographic saddle on the ridge between
The Narrows and Maple Canyon. The section is terminated by a fault not far south of the point where the ridge becomes covered by sediments of the Great Salt Lake. There are no outcrops immediately north of the main road to Promontory Point. Units #1-11 could be coalesced into one large unit to represent the "lowermost lithologic member" of the Garden City formation. The strata strike northwesterly and dip 40° to the northeast. Section C-20 was measured directly below this section.

Garden City formation

Dolomite; gray to dark gray, very finely crystalline, weathers light gray. Separated from unit #21 below by a vertical fault breccia 1' wide.

FAULT

21.) Limestone; gray, microcrystalline, silty, with some minor interbedded dolomite. Weathers dirty bluish-gray and crops out as a ledge-former. Forms prominent dip slopes. The dolomite is gray, very finely crystalline, silty, and weathers light gray to whitish-gray. The two carbonate lithologies grade into each other. This unit could be transitional between the two uppermost "lithologic members" of the Garden City formation

20.) Mostly concealed; but a few limestone ledges crop out. Limestone is gray to dark bluish-gray, microcrystalline to coarsely crystalline, weathers dirty light brown

19.) Limestone; dark gray, medium to coarsely crystalline, slightly silty, weathers gray to a dirty bluish-gray. Weathers to "sandy" surfaces. Characterized almost throughout by irregularly shaped masses of gray chert which have been selectively stained dark brown by limonite. Abundant "stringers" of silt less than ½" thick are generally parallel to bedding and selectively stained red and pink by hematite. This unit differs from the 4 more or less massive limestone units by being less resistant and not a thick ledge-former

18.) Completely concealed

17.) Limestone; dark gray, microcrystalline to medium crystalline, slightly silty, weathers bluish-gray. Characterized by local hematite "splotches" along bedding surfaces and by abundant black chert nodules. This is the lowermost observed occurrence of black chert in the formation. Commonly massive, but locally thick-bedded. Forms prominent cuestas

Thickness in Feet

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<thead>
<tr>
<th>Garden City formation</th>
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<tbody>
<tr>
<td>Dolomite; gray to dark gray, very finely crystalline, weathers light gray. Separated from unit #21 below by a vertical fault breccia 1' wide.</td>
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<tr>
<td>17.) Limestone; dark gray, microcrystalline to medium crystalline, slightly silty, weathers bluish-gray. Characterized by local hematite &quot;splotches&quot; along bedding surfaces and by abundant black chert nodules. This is the lowermost observed occurrence of black chert in the formation. Commonly massive, but locally thick-bedded. Forms prominent cuestas</td>
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<th>Thickness</th>
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<tr>
<td>31</td>
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</table>
16.) Completely concealed.......................................................... 9

15.) Limestone; gray microcrystalline, slightly silty, weathers dirty light gray. Weathered surfaces are gritty, due to both included silt and the differential solution of carbonate texture. Generally massive and forms prominent cliffs........................... 34

14.) Completely concealed.......................................................... 27

13.) Limestone; tannish-gray, microcrystalline to finely crystalline, slightly arenaceous (very fine-grained), weathers dirty gray. Forms massive ledge much like unit #12 below, but is nowhere as coarse-textured and lacks intense Fe oxide staining...... 18

12.) Limestone; dark gray, coarsely crystalline to very coarsely crystalline, weathers bluish-gray to dirty gray. Parallel bedding locally present. Characterized by intense concentrations of hematite and limonite throughout the fresh rock. Extremely prominent topographic unit which forms a massive cliff. Differs from all other limestone units in this section because of its very coarse texture.............. 29

11.) Completely concealed.......................................................... 14

10.) Limestone; tannish-gray, very finely crystalline, argillaceous and slightly silty, weathers dirty gray to light bluish-gray. Weathered surfaces are "gritty" or "sandy". The light tan, silty, argillaceous partings noted in the units below are relatively minor and do not stand out on weathered surfaces as "ribs"................................................................. 164

9.) Mostly concealed; probably bluish-gray-weathering limestone... 54

8.) Limestone; light gray, microcrystalline, argillaceous, weathers light bluish-gray. Tan, slightly silty, argillaceous stand out prominently in relief on weathered surfaces and are intensely limonite-stained.................................................... 36

7.) Completely concealed.......................................................... 19

6.) Limestone; tan to gray, microcrystalline, argillaceous, weathers very light bluish-gray. The argillaceous partings are minor in amount, are not intensely Fe-stained, and do not stand out in relief along weathered surfaces.................... 38

5.) Completely concealed.......................................................... 41

4.) Limestone; light gray, finely crystalline, argillaceous, weathers light blue to light bluish-gray. Similar to unit #2 except that the tan, silty, argillaceous partings are rarer.. 54

- 308 -
3.) Completely concealed

2.) Limestone; gray to light gray, microcrystalline to finely crystalline, extremely argillaceous, weathers light blue to light bluish-gray. Characterized by light brown to tan, silty, argillaceous partings (less than \( \frac{1}{16} \)" thick) which stand out in sharp relief from the limestone along weathered surfaces. The partings occur in 6"-2' thick intervals which are separated by similar intervals of limestone without partings. Weathered surfaces of the partings are dark reddish-brown due to intense Fe oxide staining. Prominent ledge-former.

1.) Almost completely concealed

Total thickness of the exposed Garden City formation.

St. Charles dolomite

Dolomite; gray to silvery gray, finely to medium crystalline, weathers light gray to grayish-tan. (See Section C-20).

O-3. Stratigraphic Section of the Garden City formation near the head of Middle Canyon.

This partial section of the Garden City formation is close to the Promontory fault, which at this locality has a stratigraphic throw of at least 7,500 feet. The section probably crosses some small faults, but it is believed that these do not greatly diminish the accuracy of the stratigraphic measurements. The thick dolomite unit at the base of the section probably represents uppermost St. Charles dolomite. Both the top and the bottom of this section are determined by faults. Section O-5 was measured above this section and north of a small fault.

Thickness in Feet

Swan Peak formation

Concealed. (See Section O-5).

FAULT

Garden City formation

4.) Limestone; dark gray to black, microcrystalline, locally very slightly silty, weathers to uniform dark bluish-gray. Fe oxides are present throughout the fresh rock. Bedding is well displayed by 2-5' thick ledges. Uppermost 100' is estimated.
3.) Limestone; gray, finely crystalline, argillaceous, weathers dirty gray. Argillaceous partings are indistinct and do not contrast greatly with the limestone as in unit #2 below. Acid-etched surfaces display abundant disseminated argillaceous material in the limestone between the partings. 156

2.) Limestone; gray to greenish-gray, microcrystalline, silty and argillaceous, weathers light bluish-gray to light gray. Characterized by abundant thin argillaceous partings, parallel to bedding, which have been selectively stained light brown and tan by Fe oxides. Uppermost 5' has sparse gray chert. Possible small fault may be present between this unit and unit #1 below. 275

1.) Limestone; gray, microcrystalline, very slightly silty, weathers gray with light bluish tint. Argillaceous partings are absent, but except for this the unit strongly resembles basal Garden City formation. Parallel beds are well defined and stand out as "slabby" masses. 356

Total thickness of the exposed Garden City formation......... 1,027 ±

St. Charles dolomite ?

Dolomite; gray to silvery gray, very finely crystalline, slightly calcareous, generally weathers dark gray. Weathered surfaces have a "sandy" texture, but there are no included clastic grains. A massive, ledge-forming unit. 359

FAULT

0-4. Stratigraphic Section of the Swan Peak formation on the west flank of Mt. Baldy northeast of the Old Fort Ranch.

This section is well displayed on a westward-trending spur. The strata have a consistent northerly strike and dip 20-25° to the ast. The upper contact is concealed, but it is possible that it is a fault contact with the overlying Fish Haven dolomite. If so, it is estimated that as much as 50 feet of the Swan Peak formation could be missing. The reasons for this postulated fault are the absence of the reworked zone at the base of the Fish Haven dolomite, the brecciated character of the uppermost quartzites of the Swan Peak formation, and the presence of a well displayed fault across the canyon to the north. Section 0-9 was measured directly above this measured section.
Fish Haven dolomite

Dolomite; dark gray, finely crystalline, weathers blue-black. Reworked sandstone, commonly present at the base, is absent here. (See Section 0-9).

Swan Peak formation

5.) Quartzite; white, very fine-grained to fine-grained, weathers white with sparse limonite stains. Quartz grains are generally fused together so that the original grain boundaries are indiscernible. Differentiated from unit #4 below by its massiveness, much lighter weathered color, and by its persistent white color on fresh surfaces. Uppermost 10' is probably a fault breccia. Cross-bedding not noted. 220

4.) Quartzite; varicolored, very fine-grained to fine-grained, generally weathers reddish-brown to orange. Basal half of unit is light tan to white and upper half of the unit is varicolored. Limonite is particularly abundant. Parallel bedding is distinct and well displayed. Some of the quartzite beds in the basal portion of the unit are separated by thin partings of less resistant quartzite and quartz sandstone... 289

3.) Completely concealed by huge quartzite talus blocks up to 6' long on a side. Most of this interval probably belongs to the shale unit below. 202

2.) "Shaly" unit; in which there is little true argillaceous shale except near the top. Most of the unit consists of platy, impure limestone beds about %" thick. Limestone is finely to medium crystalline and commonly has a "sandy" texture on weathered surfaces. Black shale float is abundant near top of unit and may represent the bedrock lithology of unit #3 above. 78

   Anomalorthis utahensis
   Orthambonites sp.
   O. michaelis
   Orthidiella ? sp.
   Receptaculites sp.

1.) Calcareous orthoquartzite; dark gray to gray, very fine-grained, weathers dark brown or reddish-brown. Weathered surfaces are intensely stained with Fe oxides which form a 1/16" thick "rind" around weathered exposures. Parallel-bedded in indistinct beds ranging 2"-2' thick. A blocky-weathering, prominent unit which stands out distinctly between slopes above and below. Base of unit is concealed. 15+

Total thickness of the Swan Peak formation. 804+
Garden City formation

Uppermost portion concealed at this locality. Youngest exposed bedrock of the formation is dolomite; dark gray, microcrystalline, weathers gray or light gray.

O-5. Stratigraphic Section of the Swan Peak formation near the head of Middle Canyon.

The Swan Peak formation at this locality has a well exposed upper contact, but the lower contact is a concealed fault. The formation is well exposed above unit #1. In this structurally deformed area the quartzites of the Swan Peak formation have suffered almost all of the brecciation at the expense of adjacent formations; so the thicknesses may be unreliable. The strata strike northwesterly and dip 45° northeasterly. Section O-7 was measured immediately above this section and Section O-3 was measured below and slightly south.

<table>
<thead>
<tr>
<th>Thickness in Feet</th>
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<tbody>
<tr>
<td>Fish Haven dolomite</td>
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<tr>
<td>Dolomite; silvery dark gray to blackish-gray. (See Section O-7).</td>
</tr>
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</table>

Swan Peak formation

<table>
<thead>
<tr>
<th>Layer</th>
<th>Description</th>
<th>Thickness in Feet</th>
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<tbody>
<tr>
<td>5.)</td>
<td>Quartzite; white (locally varicolored), fine-grained, weathers dirty white to grayish-white. Small flecks of limonite are scattered throughout the fresh rock.</td>
<td>152</td>
</tr>
<tr>
<td>4.)</td>
<td>FAULT BRECCIA. White, very fine-grained quartzite fragments are in a brecciated Fe-stained quartzite matrix. Unit crops out prominently as a hogback ledge - much higher in relief than the remainder of the formation.</td>
<td>15</td>
</tr>
<tr>
<td>3.)</td>
<td>Quartzite; white, very fine-grained, weathers light grayish-white. Limonite specks are scattered throughout the fresh rock. Brecciation is locally present.</td>
<td>89</td>
</tr>
<tr>
<td>2.)</td>
<td>Quartzite; reddish-brown, very fine-grained, weathers reddish-brown. Rare outcrops show thin-bedded character.</td>
<td>19</td>
</tr>
<tr>
<td>1.)</td>
<td>Completely concealed. Measured by Brunton and pace.</td>
<td>60+</td>
</tr>
</tbody>
</table>

Total thickness of exposed Swan Peak formation. | 335+ |
Garden City formation

Limestone; dark gray to black, microcrystalline, locally slightly silty, weathers to uniform dark bluish-gray. (See Section 0-3).

0-6. Stratigraphic Section of the Swan Peak formation—Fish Haven dolomite contact on the west slope of Mt. Baldy north of the Old Fort Ranch.

The "contact ledge" described below is not generally exposed along ridges which afford good exposures of the Swan Peak formation and the overlying Fish Haven dolomite, commonly being mantled by rock debris. As far as the writer knows, this ledge is only exposed where streams flow down a dip slope and clear away the covering debris derived from the overlying formations. The ledge itself is arbitrarily assigned to the Fish Haven dolomite. No visible angularity can be observed at this contact.

Thickness in Feet

Fish Haven dolomite

2.) Dolomite; dark gray to black, finely crystalline, weathers gray or dull gray. Thick-bedded, with distinct 2-3' beds forming ledges. Basal portion of dolomite has no included sand grains and is remarkably clean. Not measured.

-------- Disconformity --------

1.) Sandstone; dull gray, fine-grained, calcareous, weathers dirty light gray to tan. Quartz grains are rounded to well rounded and the sorting is good or better. Effervesces with dilute HCl on fresh surfaces but not on weathered surfaces. Very difficult to fracture with the pick. Generally weathers to "knobby" or spheroidal forms and is recessed as a "notch" between the ledges of dolomite above and quartzite below.... 3

-------- Disconformity --------

Swan Peak formation

Quartzite, white, fine-grained, generally weathers dull white except where stained light brown by limonite. Massive unit. Not measured.
0-7. Stratigraphic Section of the Fish Haven dolomite near the head of Middle Canyon.

The Fish Haven dolomite is believed to be completely exposed here, but in this faulted and brecciated area it is possible that the measured thickness is not reliable. The reworked sandstone zone, generally present at the base of the Fish Haven dolomite, was not observed. The strata strike northwesterly and dip 60° northeasterly. Section 0-5 was measured immediately below.

 Thickness in Feet

Laketown dolomite

Dolomite; banded light gray and dark gray dolomite. Cherty, unlike the underlying Fish Haven dolomite. Not measured.

Fish Haven dolomite

Dolomite; silvery dark gray to blackish-gray, very finely crystalline, weathers to an extremely uniform dark gray with a slight blackish tint. Rare outcrops have either very thin bedding (1-2") or are totally massive. Poorly exposed, except for uppermost 30'........ 168

Total thickness of the Fish Haven dolomite....................... 168

Swan Peak formation

Quartzite, white, fine-grained, weathers dirty white to grayish-white. (See Section 0-5).

0-8. Stratigraphic Section of the basal portion of the Fish Haven dolomite near the southeast corner of Mt. Baldy.

This section is included because, along with Section 0-9, it furnishes a true picture of the lithology and thickness of the Fish Haven dolomite. Units #2 and #3 of this section are probably the stratigraphic equivalents of units #1 and #2, respectively, of Section 0-9. The strata strike northerly and dip approximately 35° easterly. Streams flowing intermittently along a dip slope have stripped away the rock debris and completely exposed the measured section.
Fish Haven dolomite

3.) Dolomite; interbedded dark gray, gray, and light gray dolomite in 6"-5' thicknesses. The dark gray dolomite beds are characterized by chert nodules and large irregularly shaped chert masses up to 1' maximum dimension. All chert noted is black. Vugs in the dolomite about 20' above the basal contact are lined with clear quartz crystals. Not measured.

2.) Dolomite; spangly dark gray to blackish-gray, very finely crystalline, weathers to an extremely uniform dark gray - generally darker than the fresh surface. An extremely uniform and homogeneous lithologic unit. Forms vertical cliffs 10' or more thick and has a massive, blocky habit. Chert is rare. Convoluted coralline masses compose whole beds up to 1' thick and resemble sponges or brains.......................... 151

1.) Sandstone; greenish-gray, very fine-grained, fairly well sorted, weathers only a slightly lighter greenish-gray than fresh surfaces. Larger quartz grains are extremely well rounded, some spherical, but the majority of the grains are sub-rounded. Partings of argillaceous material are locally admixed with the sandstone parallel to bedding. The partings impart a variegated appearance to the entire unit wherever they are abundant. Extremely well cemented by calcareous material. This unit is recessed between the dip slope of the Swan Peak formation below and the overhanging cliff of Fish Haven dolomite above. Upper contact is extremely sharp and shows some gentle undulatory features resembling ripple marks. Basal contact is concealed at this locality............................. 7

Total thickness of measured Fish Haven dolomite....................... 158

Swan Peak formation

Quartzite; white, very fine-grained, well sorted, weathers white, light brown, or locally pinkish-white. Well defined parallel beds are 1-2' thick. The resistant beds form prominent, flat dip slopes from which streams have washed away the debris. Not measured.
0-9. Stratigraphic Section of the Fish Haven dolomite on the west flank of Mt. Baldy northeast of the Old Fort Ranch.

The Fish Haven dolomite is well exposed on this bare hillside with clearly exposed lower and upper contacts, but minor faulting may complicate the extreme basal portion of the measured section. The presence of this small-scale faulting is indicated by the brecciation at the top of Section 0-4 and the absence of the "reworked zone" at the base of the Fish Haven dolomite which is so well displayed a few hundred yards south in Section 0-6. The strata strike northwesterly and dip 30-35° easterly. Section 0-4 was measured immediately below. The Laketown dolomite forms flatiron dip slopes on the eastern flank of the mountain and was not measured at this locality.

Thickness in Feet

Laketown dolomite

Dolomite; light gray to gray, very finely crystalline, weathers light gray to whitish-gray. Weathered surfaces are "sandy", but acid-etched spots on fresh surfaces disclose no arenaceous content. Extremely vuggy and coarse-textured to the uppermost unit of the underlying Fish Haven dolomite. Euhedral quartz crystals commonly line the vug walls. More massive than unit #8 of the Fish Haven dolomite and weathers distinctly lighter. The basal contact is sharp, but is essentially a color change. Stratigraphic relief of the formational contact is 6" or less. Not measured.

Fish Haven dolomite

8.) Dolomite; gray to blackish-gray, very finely crystalline, weathers dull gray to dull dark gray. Acid-etched spots show definite euhedral dolomite rhombs. This dense rock is not vuggy. Basal 1/3 of unit has some indeterminate Streptelasma-like forms. Most of this unit has a massive habit............. 438

7.) Dolomite; gray, very finely crystalline, weathers light gray, locally almost whitish-gray. A massive unit which forms ledges or small cliffs. Prominent unit because of its homogeneity, lack of "banding", and light color - which contrasts markedly with unit #8 above......................... 46

6.) Dolomite; gray, very finely crystalline, weathers dull gray to dull light gray. Shaly or platy thin-bedded habit distinguishes this unit from the massive or blocky, very thick-bedded habit of most of the Fish Haven dolomite. Some shaly limestone partings. Generally crops out very poorly.................. 31

5.) Dolomite; gray to dark gray, microcrystalline to very finely crystalline, weathers dull gray to dark gray. Uniform
lithologic unit - there is no "banding" or interbedding of different colored dolomites. Weathers lighter than unit #4 below, but darker than unit #6 above.

4.) Dolomite; interbedded light gray and dark gray. The light gray dolomite is microcrystalline to very finely crystalline and weathers light gray. The dark gray dolomite is very finely crystalline and weathers blackish-gray to black.

3.) Dolomite; blackish-gray to black, very finely to finely crystalline, weathers gray to black. Generally very thick-bedded (3-5' thick), this unit is a prominent ledge-former. Abundant black and brown chert nodules and stringers in basal portion of unit. Characteristically "mottled" with light gray "splotches" on weathered surfaces.

2.) Dolomite; interbedded light gray, gray, and dark gray (weathered colors). Weathered colors are no indication whatsoever of what the fresh colors are. This "banded" unit has remarkably parallel bedding surfaces limiting the individual bands of different-colored dolomite which have very uniform thicknesses for great distances along strike. The thicknesses of the "bands" ranges 6"-10', but averages 2-3'.

1.) Dolomite; dark gray, very finely crystalline, weathers to a darker gray than fresh surfaces. The mass color effect of the weathered surfaces is black or blue-black (about the color of gun steel). An extremely uniform lithologic unit. Streptelasma cross sections and sponge-like masses of Halysites are locally common. Chert is present and abundant near the top. The basal half of the unit has euhedral brown-stained quartz crystals lining vug walls. Probable fault at base.

Total thickness of the Fish Haven dolomite.

Swan Peak formation

Quartzite; white, very fine-grained to fine-grained, weathers white with rare limonite stains. Uppermost 10' is probable fault breccia. (See Section 0-4).

S-1. Stratigraphic Section of the Laketown dolomite north of the Old Fort Ranch.

The Laketown dolomite is displayed in its entirety on the north wall of the northernmost canyon on the west flank of Mt. Baldy. This isolated mountain mass has the best exposures of the Laketown dolomite in the entire range, but it is difficult to find a complete section at one locality.
because of the abundant faulting. This section is believed to be the only one which shows the entire formation. The upper contact is well established, but the lower contact is highly conjectural and subject to controversy as to its placement. Rugged topography and steep cliffs (characteristic of the Laketown dolomite), accompanied by the lack of good bedding attitudes, combine to diminish the accuracy of the measured section. The formation is well exposed along the line of section. The strata strike northeasterly and dip approximately 25° northwesterly.

Thickness in Feet

Water Canyon dolomite

Dolomite; light gray, microcrystalline to finely crystalline, weathers to a characteristic light gray or whitish-gray. Weathered surfaces have a very fine-grained "sandpaper" surface, but acid-etching discloses no arenaceous content. Low-angle cross-bedding is present. Crops out as blocky, stair-like ledges 2-4' thick which are separated from each other by hillwash. Not measured.

Laketown dolomite

5.) Dolomite; light gray to silvery gray, very finely to medium crystalline, weathers dirty light gray. Small clear quartz crystals fill vugs. Acid-etched surfaces disclose no arenaceous content. Massive habit. Good ledge-former...... 53

4.) Dolomite; gray to dark gray, microcrystalline to very finely crystalline, weathers gray to dull gray - much darker than unit #5 above. Commonly weathers to "sandy" surfaces, but acid-etched specimens show no arenaceous content. Generally massive. Large vugs are filled with massive white quartz which is commonly limonite-stained. Smaller vugs are filled with tiny clear quartz crystals. A gentle slope-former, in sharp contrast with the massive unit #3 below................ 71

3.) Dolomite; light gray to silvery gray, very finely to medium crystalline, generally weathers light gray to dirty light gray. Weathered surfaces are "sandy", but there are no included clastic grains. Tiny clear quartz crystals and massive white quartz commonly fill vugs throughout the unit. A 3-5' thick chert bed is present 175' above base of unit - a prominent zone in this massive dolomite unit. Several lenticular masses of darker colored dolomite are present in the light colored dolomite and the contacts are extremely gradational. The entire unit is massive. Weathers along numerous joint surfaces to form tall "rock spires". Crinoid "ghosts" are locally abundant......................... 429
2.) Dolomite; cherty. Dark gray to black chert, stained intense brown by limonite, is in 3'-1' thick "bands" which follow bedding, but are discontinuous laterally. They are likely selective bedding replacement phenomena, being enclosed in light gray dolomite similar to that of units #3 and #1. Much of the dolomite has strata of very fine sand grains which are stained brown by limonite along etched, weathered surfaces. Basal contact is extremely abrupt. Upper contact is gradational. Chert constitutes an estimated 50-75% of the unit. Generally a cliff-former between steep slopes above and below. Good marker bed.......................... 71

1.) Dolomite; gray to light gray, microcrystalline to very finely crystalline, weathers light gray in sharp contrast with dark gray dolomite below. Weathered surfaces are "sandy", but acid-etching discloses no arenaceous content. Basal portion is mottled dark gray. Tiny euhedral quartz crystals and massive white quartz fill vugs. Upper contact is sharp and planar. Basal contact is only slightly disconformable, displaying local relief of from 6" to 1'...................... 133

Total thickness of the Laketown dolomite................................. 757

Fish Haven dolomite

Dolomite; dark gray to blackish-gray, very finely crystalline, weathers same. Vugs are commonly filled with tiny clear euhedral quartz crystals. Bedding is generally indiscernible. Lithology is extremely homogeneous and uniform. Unit is bounded at the base by a fault. Not measured.

FAULT

D-l. Stratigraphic Section of the Water Canyon dolomite on the southwest flank of Mt. Baldy about 2 miles north of the Old Fort Ranch.

As far as the writer knows, this is the only locality in the immediate vicinity where the upper contact of the Water Canyon dolomite is present. Both upper and lower contacts are well exposed, with the upper contact being much sharper and more certainly established. The strata strike northwesterly and dip 10-20° to the northeast. The upper contact, with the Madison limestone, is unconformable with Lower Mississippian strata lying upon Lower (?) Devonian strata. There is no visible angularity between the uppermost beds of the Water Canyon dolomite and the lowermost beds of the Madison limestone. Section M-1 was measured above this section after making a slight offset to the northwest.

- 319 -
Madison limestone

2.) Limestone; black to dark gray, microcrystalline, weathers generally dirty gray. Forms massive, vertical cliff about 50' high. Acid-etching discloses no clastic grains. Not measured.

1.) Limestone; light gray, coarse-grained to very coarse-grained, weathers same. Many of the grains are well rounded, probably detrital, and are cemented together by calcite. Limonite is extremely rare. Crops out distinctly, easily traceable... 6+

--- Disconformity ---

Water Canyon dolomite

6.) Dolomite; gray microcrystalline, weathers to an extremely uniform light gray. Weathered surfaces have "silty" texture, but there is no included clastic material. This is purer, cleaner dolomite than that of unit #5 below... 82

5.) Dolomite; gray, sandy, weathers light brown. Quartz sand grains scattered rather uniformly throughout the rock locally constitute about 25% of its volume. Weathered surfaces show the carbonate cement etched from between the sand grains, which stand out in sharp relief. The sand grains are selectively limonite-stained on weathered surfaces while the dolomite is not, giving the sandy ledges a prominent light brown color. Quartz grains are rounded and medium-grained. Basal half of this unit is much sandier than upper half. Planar vertical joint surfaces and parallel bedding combine to give blocky, "stair-like" ledges......................... 152

4.) Dolomite; light gray, microcrystalline, weathers lighter to whitish-gray. Weathered surfaces have pronounced "silty" texture, although fresh surfaces show no arenaceous content. Midway in the unit, tiny vugs are filled with euhedral quartz crystals. These vugs are also present, but not so abundant in the units below this one. Crops out as massive, laterally persistent ledges.................... 65

3.) Dolomite; light gray, finely crystalline, weathers tan to light gray. "Boxworks" of light gray to white chert, stained brown by limonite, are abundant only for brief stratigraphic intervals. Rare sandy strata are composed of fine-grained quartz sand which has been selectively stained light brown by limonite. Forms the blocky, "stair-like" ledges (here 1-2' thick) so characteristic of the Water Canyon dolomite...... 81
2.) Dolomite; gray to light gray, very finely crystalline, weathers dirty light gray. Weathered surfaces are "silty" or "sandy", but there are no included clastic grains. Massive ledges 5-10' thick are extremely well defined and laterally persistent, unlike the Laketown dolomite below. Completely lacks the thin-bedded character of unit #1 below...................... 60

1.) Dolomite; gray, finely crystalline, weathers to dirty light gray. Weathered surfaces show marked "silty" and "sandy" textures, but there are no included clastic grains. Thin beds (2-4") are coalesced into 1-3' thick ledges and the dolomite is commonly thinly laminated (1/16" thick and less) within the thin beds. The laminae display prominent low-angle cross-bedding........................................ 57

Total thickness of the Water Canyon dolomite......................... 497

Laketown dolomite

Dolomite; silvery gray, medium crystalline, weathers dull dirty gray.

D-2. Stratigraphic Section of the Water Canyon dolomite near the head of Middle Canyon.

The Water Canyon dolomite is well exposed at this locality, and despite its proximity to two large faults, the strata have not been greatly disturbed. This is the only measured section of the Water Canyon dolomite which has both upper and lower contacts conformable. The strata strike northwesterly and dip 45-55° northeasterly. A deeply incised stream cut nearby affords inspection of some of the units which are concealed on the hillslope along the line of section. Unit #8 is the base of a transitional zone between the Water Canyon dolomite and the overlying Jefferson formation, and although lithologically unlike the Water Canyon dolomite, is assigned to it because of a pronounced similarity in outcrop habit. Section D-3 was measured immediately above.

Thickness in Feet

Jefferson formation

Dolomite. A "banded" unit with dark gray-weathering dolomite predominant over gray- and light gray-weathering dolomite. (See Section D-3).

Water Canyon dolomite

11.) Completely concealed. (See remarks under unit #9 below)........ 39
10.) Calcarenous sandstone; light tan to light gray, fine-grained, weathers dirty brown to tan........................................2

9.) Completely concealed. Nearby slopes indicate that much of the interval of units #9-11 masks dark-colored dolomite similar to that of the overlying Jefferson formation. This 66' interval is arbitrarily placed in the Water Canyon dolomite because of the clastic nature of its only exposure................25

8.) Interbedded dark gray and light gray dolomite. This is a transitional unit between the light-colored dolomite below and the predominantly dark-colored dolomite above, and is assigned to the Water Canyon dolomite because of the marked similarity of outcrop habit........................................57

7.) Dolomite; light gray, microcrystalline to very finely crystalline, weathers characteristically whitish-gray or white. Rare, well rounded quartz grains are locally present, but they are scattered and do not form strata. Blocky, "stair-like" ledges crop out prominently from the hillwash and may be traced laterally for great distances. This is a very uniform and homogeneous lithologic unit.........................................391

6.) Completely concealed..................................................49

5.) Dolomite; gray to dark gray, very finely crystalline, weathers dull gray to tannish-gray. A much darker unit than the remainder of the Water Canyon dolomite. Blocky beds form "stair-like" ledges 1-2' thick........................................13

4.) Completely concealed..................................................18

3.) Dolomite; light gray, very finely crystalline, stained uniform light tan along weathered surfaces. Shaly beds similar to those of unit #1 below make up most of this unit............................50

2.) Completely concealed..................................................44

1.) Dolomite; light gray, microcrystalline to very finely crystalline, weathers reddish-brown due to Fe oxide staining. Silt grains are locally present. Occurs as shaly beds 1-3" thick..............17

Total thickness of the Water Canyon dolomite..........................705

Laketown dolomite

Dolomite; gray to silvery gray, finely to medium crystalline, weathers dull gray. Crops out as massive ledges up to 20' thick, with bedding indiscernible. Not measured - but estimated to be 500' thick.
D-3. Stratigraphic Section of the Jefferson formation at the head of Middle Canyon.

This is the only measured section of the Jefferson formation. All other exposures of this formation are far less complete. The base is well exposed but the upper contact has been eroded. The section was terminated at the crest of the range. It is estimated that at least an additional 500 feet of the Jefferson formation may be present above the top of unit #16, but the measured section was not extended to these hogback ledges on the eastern flank of the range because of excessive concealment. It appears, however, that all outcrops above the Bonneville level on the eastern flank of the range along the extended line of this section belong to the Jefferson formation, but whether or not this interval is complicated by faulting is unknown. The stratigraphic units of this section are well exposed, despite a thick overgrowth of junipers. The strata strike northwesterly and dip 45-50° toward the northeast. Section D-2 was measured immediately below this section.

<table>
<thead>
<tr>
<th>Thickness in Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jefferson formation</td>
</tr>
<tr>
<td>16.) Interbedded gray and dark gray dolomite, very finely crystalline. Differentiated from unit #15 below by lacking &quot;platy&quot; or &quot;flaggy&quot; bedding.</td>
</tr>
<tr>
<td>15.) Interbedded light gray- and gray-weathering dolomite. Differs from unit #16 above by having much &quot;shaly&quot; or platy-bedded dolomite interbedded with thin-bedded dolomite.</td>
</tr>
<tr>
<td>14.) Interbedded dolomite and quartzite. Dolomite consists of interbedded light gray- and gray-weathering dolomite similar to the units above and below. White to tan, very fine-grained quartzite, weathering same, is present as beds up to 1' thick interbedded with the dolomite.</td>
</tr>
<tr>
<td>13.) Interbedded light gray- and gray-weathering dolomite. Dolomite is thin-bedded (6&quot;-1'). This unit and those above it differ from most of the remainder of the formation by having no massive ledges cropping out.</td>
</tr>
<tr>
<td>12.) Completely concealed. Probably same lithology as unit #13.</td>
</tr>
<tr>
<td>11.) Dolomite; dark gray, very finely crystalline, weathers dark gray. Basal 20' has some light gray dolomite.</td>
</tr>
<tr>
<td>10.) Quartzite and intraformational conglomerate. Quartzite is tan and very fine-grained. Intraformational conglomerate consists of fragments of dark gray and light gray dolomite in a light gray dolomitic matrix. Fragments have marked angularity.</td>
</tr>
</tbody>
</table>
9.) Dolomite; silvery dark gray, very finely crystalline, weathers dark gray. Similar to unit #7 below.................. 52

8.) Quartzite; white to grayish-white, very fine-grained, weathers pinkish-tau. Very slightly calcareous, but is not calcareous orthoquartzite.......................................................... 1

7.) Dolomite; silvery dark gray, very finely crystalline, weathers dark gray. Sparse gray chert present as "stringers" less than 6" long and parallel to bedding. Separated as a lithologic unit from unit #9 above only by the quartzite of unit #8..... 23

6.) Dolomite; silvery dark gray, very finely crystalline, mottled, weathers dark gray. Similar to the dolomite of unit #4 below, except there is much less mottling in this unit........ 102

5.) Dolomite; gray to dark gray, very finely crystalline, generally weathers gray. Weathers to "sandy" surfaces, but there are no included clastics. Forms massive ledges 3-6' thick. Distinguished from units #4 and #6 by absence of mottling.... 27

4.) Dolomite; silvery dark gray, very finely crystalline, mottled, weathers dark gray. Characterized throughout by 1-2" long oval concentrations of white, very coarse dolomite crystals with the long dimension parallel to bedding. These spotty concentrations give the entire unit a "mottled" appearance... 54

3.) Dolomite; silvery dark gray, microcrystalline to very finely crystalline, weathers same or gray. Extremely homogeneous lithologic unit. Thick-bedded to massive, locally a ledge-former................................. 59

2.) "Banded" dolomite; the color contacts between the alternating light and dark dolomite beds are extremely sharp - nowhere gradational. The dark gray dolomite is predominant over the light gray dolomite. Bedding is either thick or totally absent. Much of the unit has white "mottling"........... 122

1.) Dolomite; dark gray to black, weathers same. A sharp contrast with the lighter colored dolomites of the underlying Water Canyon dolomite........................................................ 50

Total thickness of the exposed Jefferson formation............ 871+

Water Canyon dolomite

Dolomite; light gray, microcrystalline, weathers whitish-gray or white. Crops out boldly as "stair-like", blocky ledges. (See Section D-2).
M-1. Stratigraphic Section of the Madison limestone north of the Old Fort Ranch.

This section was measured immediately below Section M-3 and a few hundred feet northwest of Section D-1 due to the greater amount of Mississippian strata exposed in this small graben. The formation is well exposed as four massive limestone cliffs which crop out very prominently, but are separated by concealed intervals. The strata strike northwesterly and dip 10-15° to the northeast. Except for unit #1, all the outcrops are extremely similar.

<table>
<thead>
<tr>
<th>Thickness in Feet</th>
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<tbody>
<tr>
<td>Deseret limestone</td>
</tr>
<tr>
<td>(See Section M-3).</td>
</tr>
<tr>
<td>Madison limestone</td>
</tr>
<tr>
<td>9.) Completely concealed. This unit and unit #1 of Section M-3 combine to form a single unit.</td>
</tr>
<tr>
<td>8.) Limestone; black, very finely to finely crystalline, weathers dark gray. Rare black chert nodules toward the top. Poorly exposed, does not crop out as well as the three massive limestone units below. Forms isolated small outcrops.</td>
</tr>
<tr>
<td>7.) Completely concealed.</td>
</tr>
<tr>
<td>6.) Limestone; black, microcrystalline, weathers dark gray and is commonly coated with mud from above. No chert was noted. Forms more or less massive cliffs.</td>
</tr>
<tr>
<td>5.) Mostly concealed.</td>
</tr>
<tr>
<td>4.) Limestone; black, microcrystalline, weathers dark gray. Similar to unit #6 above. Dark red hematite present as streaks along otherwise indiscernible bedding planes. Although the limestone forms sheer cliffs, it is generally parallel-beded in 3-6&quot; thick beds. Indeterminate crinoid fragments and small brachiopod fragments along bedding planes. No chert noted.</td>
</tr>
<tr>
<td>3.) Mostly concealed. Fossils listed below probably came from unit #4 above as float. Bairdia ? sp. orthotetid brachiopod Spirifer &quot;centronatus&quot;</td>
</tr>
</tbody>
</table>
2.) Limestone; black, very finely crystalline, weathers dark gray. Massive unit and an excellent cliff-former which forms by far the most prominent cliffs in the Madison limestone. Abundant dark black chert nodules 2" thick and 3"-1' long are parallel to bedding. Hematite is present, but relatively rare. 

1.) Limestone; gray to light gray, coarse-grained, detrital, weathers same. Detrital calcite grains and fossil fragments are cemented by a coarsely crystalline calcite matrix. Most hand specimens show abundant crinoid columnals commonly oriented flat along bedding surfaces. Basal contact arbitrarily chosen midway in a concealed interval.

spiriferoid brachiopod ........................................8

Total thickness of the Madison limestone.........................431

Water Canyon dolomite

Dolomite; light gray, microcrystalline, weathers same.

M-2. Stratigraphic Section of the Madison limestone northwest of the Woodward Ranch.

The Madison limestone is exposed at this locality as a series of massive limestone cliffs forming the eastern face of the Bert horst. The base of the formation is concealed by alluvial and Lake Bonneville deposits and the upper contact was placed a short distance above the top of the uppermost limestone cliff. The overlying Deseret limestone and Humbug formation shed float down onto the upper contact and the actual lithologic break between the Madison limestone and the Deseret limestone is thus concealed. Section M-4 was measured immediately above. It is difficult to determine how much of the basal 155 feet of the measured section, if any, belongs to the Madison limestone. The strata strike westerly and dip about 10° toward the south.

Thickness in Feet

Deseret limestone

(See Section M-4).

Madison limestone

5.) Limestone; dark gray to black, microcrystalline, slightly silty, weathers gray. Black chert is abundant throughout this unit as nodules and stringers which are generally elongate parallel
to bedding. Some of these black chert stringers extend laterally as much as 100' parallel to bedding planes and are probably bedding replacements phenomena. Thin; dark red hematite streaks, generally parallel to bedding, characterize the upper half of the unit. Forms one massive, laterally persistent, vertical cliff.........................

4.) Completely concealed........................................ 46

3.) Limestone; locally dark gray but predominantly black, microcrystalline to very finely crystalline, weathers blue-gray. Brown-stained black chert is present as irregularly shaped masses. Limestone has a fetid odor when broken open. Abundant cross sections of brachiopod pedicle valves are completely replaced by white calcite. Generally crops out prominently as a massive ledge............................ 46

2.) Mostly concealed.................................................. 80

1.) Limestone; dark gray to black, microcrystalline to very finely crystalline, weathers bluish-gray. Blocky parallel beds are 2"-2' thick. Most of the limestone has a fetid odor when broken open. Forms a precipitous cliff, but is not as persistent laterally as the ledges of units #3 and #5. Black chert is present, but not as abundant as in the remainder of the formation. Base of this unit is concealed.

- Aulopora ? sp.
- Chonetes loganensis
- C. ornatus
- Composita or Athyris
- Griffithides peroccidens
- "Productella"
- Reticulariia ? sp.
- Rhipidomella cf. thiemei
- Spirifer "centronatus" ................. 57

Total thickness of the Madison limestone definitely in place...... 320

Mostly concealed by Lake Bonneville terraces and shorelines. There are few outcrops and even these are questionably in place. "Outcrops" are dark gray, microcrystalline limestone which weathers dirty gray. Abundant thin white calcite veinlets are probably due to the proximity to a major fault. Thus, the Madison limestone could be as thick as 475' if all of this measured interval is in place......................... 155

FAULT

Possible thickness of the Madison limestone...................... 475
M-3. Stratigraphic Section of the Deseret limestone and Humbug formation north of the Old Fort Ranch.

These strata are exposed on the same slope as are those of Section M-1, but were measured to the northwest of Section D-1 because a small graben at this locality displays the maximum thickness of Mississippian strata. The exposures are poor at best due to the widespread concealment by Deseret-Humbug float which masks the bedrock lithology as far downslope as the Laketown dolomite. All formational contacts are hidden and arbitrarily chosen halfway between outcrops which are characteristic of the various formations. The Deseret limestone is present in its entirety, but the presence of the Humbug formation is postulated solely on float at the top of Mt. Baldy which strongly resembles the lithology of the basal portions of the Humbug formation at other localities. The strata strike northwesterly and dip 15° to the northeast. Section M-1 was measured immediately below.

### Humbug formation

<table>
<thead>
<tr>
<th>Thickness in Feet</th>
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<tr>
<td>Humbug formation</td>
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</tbody>
</table>

| Sandstone; grayish-tan, very fine-grained, silty, weathers tan or light brown. No outcrops, only float. Weathers as "slabs" averaging 1" thick which are absolutely non-calcareous on both fresh and weathered surfaces. | 28+ |

### Deseret limestone

<table>
<thead>
<tr>
<th>Thickness in Feet</th>
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<tr>
<td>Deseret limestone</td>
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| 5.) Limestone; gray, silty to very fine-grained arenaceous, weathers dirty light gray. Basal 10' has prominent outcrop of gray, fine-grained arenaceous limestone with black chert in 6" thick bands parallel to bedding constituting about ½ the rock. Black chert is prominent throughout the unit. | 93 |
| 4.) Almost completely concealed. Bedrock is probably light brown to dirty tan calcareous siltstone. | 73 |
| 3.) Calcareous orthoquartzite; tan to gray, very fine-grained, weathers to a dull dirty brown. Fresh surfaces have abundant tiny limonite flecks. Massive unit. | 11 |
| 2.) Interbedded calcareous siltstone and very fine-grained to fine-grained arenaceous limestone, weathering uniformly light brown. Bedding is platy and float fragments are "slabs" resembling flagstones. This unit furnishes much float to the slopes below. Extremely poorly exposed. | 111 |
| 1.) Completely concealed. Steep slope is masked by brown and slightly reddish-brown shingle-like float from unit #2 above. Probably has the same bedrock lithology as unit #2. Basal | 328 |
contact is concealed and is arbitrarily established........ 28

Total thickness of the Deseret limestone............................. 316

Madison limestone

(See Section M-1).

M-4. Stratigraphic Section of the Deseret limestone and Humbug formation northwest of the Woodward Ranch.

This section is exposed along the east-west crest of the Bert horst. The base of the Deseret limestone is present, but not exposed, and the upper limit of this measured section is determined by a major fault. The strata are poorly exposed due to the abundant float which they shed to the slopes below. The Madison limestone-Deseret limestone contact is a sharp topographic break; the uppermost Madison limestone forms a vertical cliff and the Deseret limestone forms a steep, smooth slope. The strata strike northwesterly and dip about 15° to the southwest. Section M-4 was measured immediately below this section and Section P-4 was measured immediately above.

Thickness in Feet

Oquirrh formation

Limestone; gray, medium crystalline, weathers gray to dirty light gray. (See Section P-4).

FAULT

Humbug formation

11.) Completely concealed. Forms prominent topographic "saddle", undoubtedly caused by the major fault above.................. 51+

10.) Limestone; gray, medium crystalline, arenaceous (very fine-grained), weathers dull gray to tannish-gray on sandy surfaces. Black chert is present as nodules up to 6" long - the only chert noted in the Humbug formation................................. 28

9.) Limestone; gray to brownish-gray, microcrystalline to very finely crystalline, arenaceous (very fine-grained), generally weathers light gray, but locally weathers light brown to tan on sandy surfaces. Similar to unit #10 above.......................... 11

8.) Completely concealed. Float consists of sandstone and light gray limestone............................................... 22
7.) Sandstone; tan to grayish-tan, very fine-grained, calcareous, weathers same. Weathered surfaces have had the calcareous cement removed. Furnishes much float to slopes below. 41

6.) Completely concealed. 13

5.) Limestone; gray to light gray, finely crystalline, arenaceous (fine-grained), weathers same. Hematite is present along joint surfaces and interstitially as a coating on calcite crystals. Massive unit shows no bedding whatsoever. 2

4.) Completely concealed by sandstone float. 18

3.) Limestone; dark gray to gray, arenaceous (fine-grained), weathers dirty gray to grayish-brown. Locally is extremely arenaceous. Low-angle cross-bedding is locally displayed. Unit forms a prominent ledge above a slope. 27

2.) Sandstone; light brown to tan, very fine-grained, silty, calcareous, weathers same color as the fresh surfaces. Not a prominent topographic unit. 120

1.) Sandstone; gray, very fine-grained to fine-grained, calcareous, weathers light brown to reddish-brown. Weathered surfaces have had calcareous cement removed. Parallel beds 6"-4' thick are well displayed and intense Fe oxide staining is present as seams along bedding surfaces. Unit forms two prominent ledges with a covered interval between them. These are the first prominent outcrops above the top of the Madison limestone. 39

Total thickness of exposed Humbug formation: 372+

Deseret limestone

2.) Limestone; dull gray, silty and arenaceous (very fine-grained), commonly weathers dirty gray. Bedding thickness ranges 6"-1'. Entire unit crops out very poorly. 43

1.) Completely concealed. This slope forms a sharp contrast with the vertical cliffs of the underlyng Madison limestone. Reddish-brown-weathering, very fine-grained calcareous sandstone float is abundant. Minor gray limestone float. 237

Total thickness of the Deseret limestone: 280

Madison limestone

(See Section M-2).
MP-1. Stratigraphic Section of the Manning Canyon shale west of the Ray Smith Ranch.

Only one section of the Manning Canyon shale was measured in the Promontory Range because of the structural complexity of most of the exposures. More detailed lithology can be observed to the west along the western slope of the range at the head of Coldwater Canyon, but the strata are so contorted that accurate measurement is extremely difficult. It is possible that compressive forces, which have so greatly deformed nearby strata, have affected the shale units of this section more than the other lithologies. Bedding attitudes are commonly anomalous in these shale units. The strata strike northwesterly and dip 15-35° toward the southwest. The base of the Manning Canyon shale is nowhere exposed in the Promontory Range. At this locality the base of the section terminates against a downfaulted block of the Ouirrh formation. Section P-2 was measured immediately above.

Thickness in Feet

Ouirrh formation

Concealed. Arenaceous limestone and calcareous orthoquartzite float are abundant and limestone ledges are present elsewhere along strike. (See Section P-2).

Manning Canyon shale

11.) Quartzite; very pale green to light tan, very fine-grained, weathers same. Crops out as 3 or 4 generally massive ledges. Blocky parallel beds are 3' and thicker with low-angle cross-bedding locally present between the planar bedding surfaces. 25

10.) Completely concealed. Basal 170' has abundant shale float and uppermost 76' has abundant quartzite float. 246

9.) Shale. Basal 315' has dark gray to black, silty shale which weathers same color as fresh surfaces. Uppermost 119' is light tan shale which is siltier than the basal shale. Planar fracture surfaces are stained dark brown by Fe oxides. Fissility is pronounced. 434

8.) Mudstone; black, silty, weathers tan to light gray, and is extremely well indurated. Lacks fissility completely. 23

7.) Completely concealed. Probably the same lithology as unit #8 above. 56

6.) Interbedded quartzite and shale. Quartzite is varicolored, very fine-grained, and generally weathers purple to blackish-brown. Fe oxides are abundant throughout the quartzite, with goethite predominant. Shale is dark gray or blackish-gray,
silty, and weathers dark gray. Uppermost 8' of this unit forms a vertical ledge, but remainder forms an even slope........... 30

5.) Quartzite; pale green to tan, fine-grained, weathers dark brown to reddish-brown. Abundant Fe oxide stain and liver-brown mammary-shaped goethite accumulations are present along fractures. Bedding almost completely indiscernible. Forms a prominent ledge cropping out on an otherwise smooth slope.. 26

4.) Almost completely concealed. Shale float is abundant, with quartzite float minor........................................ 169

3.) Shale; black, slightly silty, weathers black. Same lithology as unit #1 below.............................................. 25

2.) Completely concealed. Abundant black shale float indicates that bedrock lithology is the same as that of units #3 and #1..... 39

1.) Shale; black, slightly silty, generally weathers black except along the feather edges of laminae where the shale is leached to dull tan. Characteristically fissile....................... 15+

Total thickness of the exposed Manning Canyon shale............. 1,088+

**FAULT**

Major north-south fault places Oquirrh formation on the east against the Manning Canyon shale to the west. There are probably at least 100' of concealed Manning Canyon shale between the base of unit #1 and the fault.

**MP-2. Stratigraphic Section of the Manning Canyon shale-Oquirrh formation contact on the north wall of Coldwater Canyon.**

This measured section includes the uppermost portion of the Manning Canyon shale and the lowermost portion of the Oquirrh formation. The transitional nature of this formational contact is well displayed by the intricate intercalation of greatly differing lithologies. The contact is arbitrarily chosen at the top of unit #11 of the Manning Canyon shale where limestone becomes predominant over shale and other non-carbonate clastics. Although the contact itself is classically transitional, the individual units have sharp contacts with each other, showing little, if any, gradation. This is one of only three localities in the Promontory Range where this contact is present, and is the only place where it is well exposed. Elsewhere, there is a covered interval between the uppermost quartzite of the Manning Canyon shale and the lowermost exposed limestone
of the Oquirrh formation; a stratigraphic interval roughly equivalent to that of this section. Several small faults complicate the lower portion of the section, but no repetition was encountered below the top of unit #4 of the Oquirrh formation, where the section was abandoned. The strata strike east-west and dip 20-25° to the north.

Thickness in Feet

Oquirrh formation

4.) Limestone; brown, coarsely crystalline, slightly arenaceous, weathers tan. Similar to the limestone of unit #8 of the underlying Manning Canyon shale. The characteristic ledges of the "lower limestone member" of the Oquirrh formation crop out boldly a short distance above................. 6

3.) Limestone; dark gray to black, very finely crystalline, silty, weathers dull gray. Fe oxide staining is abundant. Generally a thin-bedded unit. Extremely similar to unit #1 below...... 58

2.) Completely concealed.................................................. 101

1.) Limestone; dark gray to blackish-gray, very finely crystalline, silty, weathers dull gray. Parallel-bedded, thin-bedded. This unit furnishes much "slabby" float to slopes below....... 50

Total thickness of measured Oquirrh formation..................... 215

Manning Canyon shale

11.) Sandstone; varicolored (green, red, and gray), very fine-grained, argillaceous, calcareous, weathers greenish-tan. Locally grades into calcareous orthoquartzite. Could be combined with units #9 and #10 below to form one large "shaly" unit....... 40

10.) Calcareous orthoquartzite; with minor interbedded shale..... 56

9.) Shale; black, silty, weathers silvery light gray. Extremely micaceous along bedding, imparting a silvery sheen to bedding surfaces. Fissile. Individual laminae only 2 mm. thick..... 42

8.) Limestone; orange-brown, coarsely crystalline, slightly arenaceous, weathers tan to light brownish-tan. Massive unit. Crops out as a ledge or cliff with knife-edge contacts........... 7

7.) Calcareous orthoquartzite; varicolored, very fine-grained, weathers brown due to intense concentrations of Fe oxides on weathered surfaces. Paper-thin argillaceous partings along bedding surfaces are intensely limonite-stained. Parallel beds are laterally persistent. Unit has a "shaly" habit..... 23

- 333 -
6.) Limestone; dark gray, microcrystalline, slightly silty, weathers dirty gray. Paper-thin silty, argillaceous partings parallel to bedding surfaces are intensely stained reddish-brown by Fe oxides. Weathered surfaces have abundant hematite stain... 5

5.) Calcareous orthoquartzite; varicolored, very fine-grained, weathers reddish-brown to purplish-black due to intense Fe oxide stain on weathered surfaces. Parallel bedding is laterally persistent. Entire unit has "shaly" habit............ 10

4.) Siltstone; gray, quartzitic, calcareous, weathers dirty tan. Entire unit displays faint fissility and has a pronounced "shaly" habit. Laminae average less than ½" thick............ 16

3.) Limestone; dark gray, microcrystalline to medium crystalline, slightly silty, weathers dirty gray. Bedding indiscernible... 5

2.) Completely concealed.................................................. 102

1.) Quartzite; tan to light brownish-tan, very fine-grained, weathers same except along fracture surfaces where limonite imparts a dark brown color. Interstitial limonite is abundant. Parallel-bedded. Base of unit concealed by valley fill....... 38

Total thickness of the exposed Manning Canyon shale.............. 344

P-1. Stratigraphic Section of the Oquirrh formation west of Staples Flat on the west side of the Promontory Range.

This section is well exposed with no vegetative cover, but neither the top nor the base of the formation are exposed nearby. The section was measured near the head of the unnamed canyon immediately north of North Chokecherry Canyon. The rocks strike northerly and dip uniformly eastward 10-20°. There is a complete absence of detectable faulting and individual beds may be traced laterally for miles by the naked eye.

Thickness in Feet

Oquirrh formation

59.) Sandstone; gray to dark gray, very fine-grained, calcareous, weathers gray or dull gray. Bounded at top by range crest... 11+

58.) Completely concealed.................................................. 35

57.) Sandstone; gray, very fine-grained, calcareous, commonly stained brown by limonite. Similar to unit #59............... 11
56.) Completely concealed................................................. 13

55.) Limestone; dark gray, very finely crystalline, slightly arenaceous, weathers gray or dull gray. Interbedded, calcareous, very fine-grained sandstone is intensely limonite-stained.... 15

54.) Completely concealed.................................................. 32

53.) Interbedded arenaceous limestone and calcareous sandstone. Bulk of unit is dark gray, finely to medium crystalline limestone weathering blue-gray to light bluish-gray........... 71

52.) Limestone; dark gray, microcrystalline, slightly arenaceous, weathers dirty gray to dull gray. Much cert as nodules...... 78

51.) Completely concealed.................................................. 53

50.) Calcareous orthoquartzite; tan to gray, very fine-grained, weathers light tan to brown except where intensely limonite-stained. Good marker bed........................................ 50

49.) Completely concealed. Probably should belong to unit #50..... 26

48.) Limestone; gray to light gray, medium to coarsely crystalline, generally weathers gray. Gray chert is abundant as nodules and "stringers" elongated parallel to bedding.................. 8

47.) Completely concealed.................................................. 28

46.) Limestone; gray to light gray, very finely to medium crystalline, weathers light bluish-gray. Good marker bed...................... 13

45.) Limestone; dark gray, very finely crystalline, weathers gray.. 36

44.) Completely concealed.................................................. 100

43.) Interbedded limestone and calcareous sandstone. Bulk of unit is dark gray, very finely to medium crystalline limestone which weathers gray to light blue-gray. Sandstone occurs as ½-1" thick "ribs", parallel to bedding, giving "ruled" appearance. 28

42.) Mostly concealed. Probably interbedded sandstone and limestone, judging from sporadic outcrops. Limestone has black chert.. 195

41.) Limestone; dark gray, microcrystalline, weathers gray. Black chert is abundant as nodules up to 3" in diameter.................. 22

40.) Limestone; dark gray, medium crystalline, weathers gray to bluish-gray. Forms a single massive, vertical cliff............. 5
39.) Sandstone; light gray to very light tan, very fine-grained, calcareous, limonite-stained................................. 22
38.) Completely concealed.................................................. 13
37.) Interbedded arenaceous limestone and calcareous sandstone.... 40
36.) Completely concealed.................................................. 41
35.) Interbedded arenaceous limestone and calcareous sandstone. Similar to unit #37 above, but lacks black chert............. 35
34.) Limestone; gray to light gray, medium crystalline, weathers light bluish-gray. Rare chert. Forms a vertical cliff........ 9
33.) Completely concealed.................................................. 25
32.) Limestone. Gray, arenaceous (very fine-grained) limestone is interbedded with dark gray, microcrystalline to medium crystalline limestone as beds at least 1' thick.................. 7
31.) Completely concealed.................................................. 17
30.) Limestone; dark gray, microcrystalline to finely crystalline, weathers gray to blue-gray. Gray chert is locally present... 57
29.) Completely concealed.................................................. 13
28.) Limestone; dark gray, medium crystalline, arenaceous, weathers gray. Gray chert nodules are locally abundant.............. 20
27.) Limestone; dark gray, microcrystalline, slightly silty, weathers gray to light bluish-gray................................. 59
26.) Completely concealed.................................................. 9
25.) Limestone; gray to dark gray, microcrystalline to medium crystalline, oolitic, slightly arenaceous, weathers same...... 26
24.) Completely concealed.................................................. 14
23.) Limestone; gray, microcrystalline, slightly arenaceous, weathers to darker gray than fresh surfaces. Black chert is locally abundant as nodules and stringers along bedding...... 47
22.) Limestone; gray, microcrystalline to very finely crystalline, slightly arenaceous, generally weathers light bluish-gray to blue-gray. Gray chert is present as 3-6" thick bands parallel to bedding and up to 50' long. Good marker bed..... 15
21.) Limestone; light gray, microcrystalline, weathers gray........ 35

20.) Sandstone; white, very fine-grained, calcareous, weathers white or light tan where faintly Fe-stained......................... 9

19.) Completely concealed.................................................... 23

18.) Sandstone; tan to gray, very fine-grained, extremely calcareous, oolitic, weathers to dirty tan. Black oolites (coarse-grained) are present as 1/8" thick bands parallel to bedding................. 4

17.) Limestone; gray, microcrystalline, very slightly arenaceous, weathers light gray to light bluish-gray. Rare chert........ 138

16.) Limestone; gray, arenaceous (very fine-grained), weathers lighter shades of gray. Gray chert nodules up to 12" long are elongate parallel to bedding.............................. 28

15.) Limestone; gray, microcrystalline, slightly arenaceous (very fine-grained), weathers same. Tan chert locally present..... 30

14.) Completely concealed.................................................... 33

13.) Limestone; light gray to light tan, microcrystalline, slightly arenaceous, oolitic, weathers uniform light gray to light bluish-gray.................................................. 55

12.) Completely concealed.................................................... 32

11.) Limestone; gray, finely crystalline, slightly arenaceous, weathers gray. Black chert nodules are locally present..... 18

10.) Completely concealed.................................................... 29

9.) Limestone; dark gray, microcrystalline, very slightly arenaceous, weathers bluish-gray. Black chert is present as nodules and tabular bedding replacement masses.......................... 9

8.) Completely concealed.................................................... 12

7.) Limestone; gray to light gray, extremely arenaceous (very fine-grained), weathers tan to light gray. Gray to tan chert is present as nodules up to 6" thick and 2' long parallel to bedding. Arenaceous strata stand out in relief............. 17

6.) Completely concealed.................................................... 32

5.) Interbedded limestone and sandstone. Parallel-bededded...... 21

4.) Limestone; similar to unit #1 below................................. 16

- 337 -
3.) Limestone; dark gray to black, slightly arenaceous (very fine-grained), weathers dull gray. Black chert nodules abundant... 7

2.) Mostly concealed. Probably gray, finely to medium crystalline, slightly arenaceous limestone which weathers light gray... 38

1.) Limestone; dark gray, microcrystalline to medium crystalline, weathers dull gray. Dark gray chert occurs as \( \frac{1}{2}-1^\circ \text{ thick} \) seams parallel to bedding.................................................. 12+

Total thickness of the exposed Oquirrh formation.................. 1,897+

P-2. Stratigraphic Section of the Oquirrh formation west of the Ray Smith Ranch.

The basal contact of the Oquirrh formation is present here, but is not too well exposed. The section, however, is interesting because this is one of only three localities in the Promontory Range where an appreciable portion of the Manning Canyon shale (see Section MP-1) is present in sedimentary contact with the overlying Oquirrh formation. The strata strike northerly and dip about 15° toward the west. The Oquirrh formation is present here as relatively small outliers on a large mass of the Manning Canyon shale. Section MP-1 was measured immediately below.

<table>
<thead>
<tr>
<th>Thickness in Feet</th>
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<tbody>
<tr>
<td>Oquirrh formation</td>
</tr>
<tr>
<td>9.) Mostly concealed. Probably limestone similar to that below. Upper limit of this unit is the range crest. Not measured - an estimated thickness............................... 125‡</td>
</tr>
<tr>
<td>8.) Limestone; dark gray, microcrystalline to very finely crystalline, arenaceous, weathers uniform light bluish-gray. Massive ledges are characterized by light tan chert nodules 6&quot;-1' long and commonly 2-3&quot; thick................................. 96</td>
</tr>
<tr>
<td>7.) Completely concealed......................................................... 66</td>
</tr>
<tr>
<td>6.) Interbedded arenaceous limestone and calcareous orthoquartzite. Similar to unit #4 below except that limestone by far predominates.......................................................... 41</td>
</tr>
<tr>
<td>5.) Completely concealed.......................................................... 48</td>
</tr>
<tr>
<td>4.) Interbedded arenaceous limestone and calcareous orthoquartzite. Parallel beds are 6&quot;-2' thick. Limestone slightly predominant. Similar to unit #6 above......................... 24</td>
</tr>
</tbody>
</table>
3.) Completely concealed................................................. 9

2.) Limestone; dark gray to blackish-gray, very finely crystalline, arenaceous, weathers light bluish-gray. Weathered surfaces are sandy due to differential etching of silt-sized quartz grains. Dull gray chert is locally present...................... 12

1.) Completely concealed. Much limestone and calcareous orthoquartzite float. Bedrock lithology is probably the same as that of unit #2 above.................................................. 200

Total thickness of the exposed Oquirrh formation.................... 621

Manning Canyon shale

Quartzite; light tan, very fine-grained, weathers pale green to light tan. (See Section MP-1).

P-3. Stratigraphic Section of the Oquirrh formation north of the Mountain Springs Road and east of Wm. L. Flint’s wheat field.

An extremely dissected hill lying east of the main mountain crest between Mountain Springs and the Promontory Schoolhouse is composed entirely of the Oquirrh formation. Neither the bottom nor the upper contact of the formation is exposed nearby. The area is structurally complex and no single measured section within the immediate area would be able to embrace much of the Oquirrh formation. This section is stratigraphically above the “lower limestone member” of the Oquirrh formation. The strata strike northwesterly and dip 20-30° toward the northeast.

Thickness in Feet

Oquirrh formation

FAULT

4.) Sandstone; tannish-gray, very fine-grained, calcareous, with minor interbedded gray, arenaceous (very fine-grained) limestone. Both lithologies rarely occur in one outcrop.... 162

3.) Completely concealed................................................. 65

2.) Interbedded calcareous sandstone and arenaceous limestone. Extremely similar to the lithologies of units #1 and #4. Sandstone is tannish-gray, very fine-grained, and weathers tan. Limestone is gray to dark gray, weathers tan or light brown, and has included very fine quartz grains......................... 86
1.) Interbedded calcareous orthoquartzite and arenaceous limestone. Similar to the lithologies of units #2 and #4. The calcareous orthoquartzite is uniformly very fine-grained, tan to gray on fresh surfaces, and generally weathers tan to light brown. The limestone is gray on fresh surfaces, is characterized by silt-sized to very fine quartz grains, and generally weathers dirty gray tinged with tan. Both lithologies occur in 6"-1' thick beds and the calcareous orthoquartzite stands out as "ribs", being more resistant than the limestone. Base of unit concealed by its own talus and by alluvium and Lake Bonneville sediments................................................. 288+

Total thickness of the exposed Oquirrh formation................. 601+

P-4. Stratigraphic Section of the Oquirrh formation northwest of the Woodward Ranch.

This section is exposed along the ridge crest between Chokecherry Canyon and Mountain Springs. The base of this section is in fault contact with the Humbug formation and the section was terminated at the top when a complex fault zone was encountered. The stratigraphic position of this section is unknown, for neither the top nor the bottom of the Oquirrh formation are present nearby. Although there is a dense growth of junipers, the section is fairly well exposed. The strata strike northerly and dip about 10° toward the west. Section M-4 was measured immediately below this section.

Thickness in Feet

Oquirrh formation

EDGE of FAULT ZONE

12.) Completely concealed. Abundant gray limestone float fragments probably represent the bedrock lithology......................... 35+

11.) Limestone; gray, microcrystalline, slightly silty, weathers to a lighter gray than fresh surfaces. Bedding ranges from "shaly" to thin-bedded. Abundant hematite staining locally colors the limestone pink to red............................... 32

10.) Mostly concealed. Abundant quartzite float is greenish-tan, very fine-grained, and weathers light brown to dark tan...... 15

9.) Limestone; dark gray to black, microcrystalline, weathers very light gray to whitish-gray............................... 17
8.) Limestone; dark gray, microcrystalline, slightly silty, weathers gray to light gray. ........................................ 76

7.) Completely concealed. ........................................... 11

6.) Limestone; gray to dark gray, medium crystalline, slightly silty, weathers gray to light gray. Basal portion has hematite "blotches" along bedding surfaces. ....................... 61

5.) Mostly concealed. No certain outcrops. Gray limestone float, weathering light gray, is abundant. .......................... 34

4.) Limestone; dark gray to black, microcrystalline, weathers light gray. Red hematite "blotches" are along bedding surfaces. .. 51

3.) Completely concealed. ........................................... 29

2.) Limestone; dark gray, microcrystalline, weathers uniformly to drab, dull gray. Indeterminate cup corals are locally present in basal portion. Black chert rarely seen on outcrop, but is abundant in float which is obviously derived from this unit. Beds average 1' thick, but the ledges are seldom greater than 3' thick. Approximately half concealed. .... 331

1.) Limestone; gray medium crystalline, weathers gray to dirty light gray. Crops out as 1-2' thick beds. Intensely veined with white calcite. Base of unit determined by a major fault......................................................... 23+

Total thickness of the exposed Oquirrh formation. ......... 715+

FAULT

Humbug formation

(See Section M-4).

- 341 -