The Geology of Lost Creek Canyon with Special Reference to Igneous Activity

John Kolesar

Follow this and additional works at: http://digitalcommons.mtech.edu/bach_theses

Part of the Ceramic Materials Commons, Environmental Engineering Commons, Geology Commons, Geophysics and Seismology Commons, Metallurgy Commons, Other Engineering Commons, and the Other Materials Science and Engineering Commons

Recommended Citation
http://digitalcommons.mtech.edu/bach_theses/50

This Bachelors Thesis is brought to you for free and open access by the Student Scholarship at Digital Commons @ Montana Tech. It has been accepted for inclusion in Bachelors Theses and Reports, 1928 - 1970 by an authorized administrator of Digital Commons @ Montana Tech. For more information, please contact sjuskiewicz@mtech.edu.
THE GEOLOGY OF LOST CREEK CANYON

WITH SPECIAL REFERENCE TO IGNEOUS ACTIVITY

by

JOHN KOLESAR

A Thesis
Submitted to the Department of Geology
In Partial Fulfillment of the
Requirements for the Degree of
Bachelor of Science in Geological Engineering

MONTANA SCHOOL OF MINES
BUTTE, MONTANA

May 1935

MONTANA SCHOOL OF MINES LIBRARY.
THE GEOLOGY OF LOST CREEK CANYON
WITH SPECIAL REFERENCE TO IGNEOUS ACTIVITY

by
JOHN KOLESAR

A Thesis
Submitted to the Department of Geology in Partial Fulfillment of the Requirements for the Degree of Bachelor of Science in Geological Engineering

11288

MONTANA SCHOOL OF MINES
BUTTE, MONTANA
May 1935
MONTANA SCHOOL OF MINES LIBRARY.
<table>
<thead>
<tr>
<th>CONTENTS</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>Location and Accessibility</td>
<td>2</td>
</tr>
<tr>
<td>Climate and Vegetation</td>
<td>2</td>
</tr>
<tr>
<td>Field Work</td>
<td>3</td>
</tr>
<tr>
<td>Acknowledgements</td>
<td>4</td>
</tr>
<tr>
<td>PHYSIOGRAPHY</td>
<td>4</td>
</tr>
<tr>
<td>General Features</td>
<td>4</td>
</tr>
<tr>
<td>Relief and Drainage</td>
<td>6</td>
</tr>
<tr>
<td>Glaciation</td>
<td>6</td>
</tr>
<tr>
<td>STRATIGRAPHY</td>
<td>9</td>
</tr>
<tr>
<td>General Features</td>
<td>9</td>
</tr>
<tr>
<td>Belt Series</td>
<td>12</td>
</tr>
<tr>
<td>Newland Formation</td>
<td>12</td>
</tr>
<tr>
<td>Spokane Formation</td>
<td>14</td>
</tr>
<tr>
<td>Cambrian Series</td>
<td>14</td>
</tr>
<tr>
<td>Flathead Formation</td>
<td>14</td>
</tr>
<tr>
<td>Silver Hill Formation</td>
<td>15</td>
</tr>
<tr>
<td>Hasmark Formation</td>
<td>15</td>
</tr>
<tr>
<td>Mississippian Series</td>
<td>16</td>
</tr>
<tr>
<td>Madison Formation</td>
<td>16</td>
</tr>
<tr>
<td>Pennsylvanian Series</td>
<td>17</td>
</tr>
<tr>
<td>Quadrant Formation</td>
<td>17</td>
</tr>
<tr>
<td>Lower Cretaceous Series</td>
<td>19</td>
</tr>
<tr>
<td>Kootenai Formation</td>
<td>19</td>
</tr>
<tr>
<td>Cretaceous Undifferentiated</td>
<td>20</td>
</tr>
</tbody>
</table>
# LIST OF PLATES

<table>
<thead>
<tr>
<th>Plate</th>
<th>Description</th>
<th>Between pp.</th>
</tr>
</thead>
<tbody>
<tr>
<td>I A.</td>
<td>Lost Creek Canyon Looking Westward from the Valley</td>
<td>7-8</td>
</tr>
<tr>
<td>I B.</td>
<td>Lateral Moraine</td>
<td>7-8</td>
</tr>
<tr>
<td>I C.</td>
<td>Glacial Debris (Boulders from Newland Formation)</td>
<td>7-8</td>
</tr>
<tr>
<td>II A.</td>
<td>Madison Limestone in Contact with the Newland</td>
<td>16-17</td>
</tr>
<tr>
<td>II B.</td>
<td>Madison Limestone in the Valley Bottom</td>
<td>16-17</td>
</tr>
<tr>
<td>III A.</td>
<td>Black Cretaceous Limestone (Kootenai)</td>
<td>19-20</td>
</tr>
<tr>
<td>III B.</td>
<td>Greenish Cretaceous Shales (Kootenai)</td>
<td>19-20</td>
</tr>
<tr>
<td>IV A.</td>
<td>Outcrop of Cretaceous Shale North of Lost Creek</td>
<td>20-21</td>
</tr>
<tr>
<td>IV B.</td>
<td>Cretaceous Quartzitic Conglomerate North of Lost Creek</td>
<td>20-21</td>
</tr>
<tr>
<td>IV C.</td>
<td>Cretaceous Sandstone in Quarry near the Volcanic Ash Beds</td>
<td>20-21</td>
</tr>
<tr>
<td>V.</td>
<td>Agglomerate of Upper Cretaceous Age. (Livingston Formation?)</td>
<td>21-22</td>
</tr>
<tr>
<td>VI A.</td>
<td>Exfoliation of the Alkaline-Biotite Granite</td>
<td>29-30</td>
</tr>
<tr>
<td>VI B.</td>
<td>Granite Near Contact with Newland</td>
<td>29-30</td>
</tr>
<tr>
<td>VII A. and B.</td>
<td>Photographs Showing the Granite (light) and the diabase (black)</td>
<td>30-31</td>
</tr>
<tr>
<td>VIII A and B.</td>
<td>Photographs Showing the Granite (light) and the Diabase (black)</td>
<td>30-31</td>
</tr>
</tbody>
</table>
LIST OF PLATES

Plates

IX. Hills of Volcanic Ash and Breccia . . . . . . 34-35
1) Emmons and Calkins:

   Geology and Ore Deposits of the Philipsburg Quadrangle.
   U. S. G. S. Professional Paper No. 78, 1912.
THE GEOLOGY OF LOST CREEK CANYON
WITH SPECIAL REFERENCE TO IGNEOUS ACTIVITY

- INTRODUCTION -

This investigation was undertaken primarily as a problem in geologic mapping, coupled with a study of stratigraphy, glaciation, igneous phenomena, and structure, in order to partially satisfy the requirements for the degree of Bachelor of Science in Geological Engineering at the Montana School of Mines. The area is admirably suited to a study of geology and geologic events because it is small in extent and, therefore, was studied in some detail during the time which was devoted to field work; also, it is an area in which the record of igneous activity of past geological ages is remarkably well exposed, since Lost Creek Canyon was carved through the roof of a stock or batholith by the glaciers of the Pleistocene epoch.

The stratigraphy was studied as to the character, age, and sequence of the geologic formations that are exposed, the conclusions being based principally on the field relationships and lithology because very few fossils were found. Igneous activity, such as the intrusion of the stock, the associated dikes, sheets, sills, and lava flows, and its effect on the structure was studied. Glaciation and its effect on the topography was also studied though not in detail.

Prior to this report no geologic map of the area has been made. The upper portion of Lost Creek was included in
the Philipsburg quadrangle by the United States Geological Survey, but the greater part of the present work was carried on east of the eastern boundary of the Philipsburg quadrangle. Some surveying has been done in connection with mining claims and the mapping of the Deer Lodge National Forest. Only two section corners were found in the entire area and these, with a few claim corners, were used as horizontal control points for the mapping.

- Location and Accessibility -

Lost Creek is approximately three miles north of Anaconda, Montana; and except for the extreme western end, the canyon is entirely in Deer Lodge County. The area included on the map lies in T5N R 11 W.

Good roads lead into Lost Creek Valley from Anaconda, Butte, and Deer Lodge. The roads are hard surfaced and, with the exception of the road into the canyon itself, remain passable during the entire year. The Butte-Anaconda paved highway is less than two miles from the lower part of the valley.

- Climate and Vegetation -

In general the climate is not very rigorous although the temperature range is from 90 degrees to minus 30 degrees Fahrenheit. However, the figures indicated are apt to give an erroneous impression, the low winter temperatures being accompanied by a dry and relatively calm atmosphere. Oppres-
sive weather is sometimes experienced in the summer, but in general chilly nights are the rule since the altitude ranges from 5,000 to 8,500 feet above sea level and radiation is rapid.

The major portion of the area lies in the Deer Lodge National Forest. Medium sized pine, fir, and spruce are abundant in the more elevated portions while poplars and willows grow on the valley slopes. Sagebrush is present everywhere from the lowest points up to timber line. Grasses grow in the valley and on some of the gentler slopes.

Farming is the major activity at present, there being several farms and dairies in the valley. Only the more hardy vegetables are grown because of the short seasons.

- Field Work -

The field work that was necessary in connection with this problem was done on Saturdays and Sundays from September 1934 to May 1935 whenever weather conditions were suitable. Due to the persistent cold weather and heavy snowfalls there were only about twenty days suitable for field work. Because of the present (April 1935) adverse conditions, field work may have to be discontinued due to lack of time for the preparation of the map and report.

Most of the area was mapped with a telescopic alidade and a plane table to a scale of one inch to 2,640 feet. The rest of the map was made with a Brunton compass and pacing traverse. The contact of the sedimentary with the igneous
rocks was obtained by sketching between points of the intersecting traverses. Most of the other contacts also were obtained in the same manner. Triangulation between various points was used whenever possible.

Other features of the field work included physiographic and geologic observations, taking of photographs, collecting samples of the sedimentary and igneous rocks, and searching for fossils.

-Acknowledgements-

The writer wishes to acknowledge the assistance of Dr. Eugene S. Perry, head of the Geology Department at the Montana School of Mines, under whose direction and supervision this study was undertaken; of Dr. Harold W. Scott who assisted in many ways especially in the stratigraphy of the area. Also, the writer wishes to thank his assistants in the field for their cooperation.

-Physiography-

-General Features-

The Flint Creek Range is a part of the Rocky Mountain physiographic province. Many of the peaks reach elevations of from 8,000 to 9,000 feet, but there is no dominant crest except that of Mount Powell (10,145 ft.) a few miles north of Lost Creek. In general, the Flint Creek Range is a mountain
system which has been dissected by stream erosion and glacia-

Level areas north and south of Lost Creek Canyon, which have an elevation of about 8,500 feet, may be remnants of an old erosion surface which probably was formed during the Tertiary and then uplifted to its present position. Deformation of this old erosion surface is strongly suggested by the fact that these plateaus are slightly tilted toward the east. During this period of extensive erosion thousands of feet of sediments were removed and the Proterozoic rocks were exposed before the Pleistocene epoch was initiated. The present topography is due to three factors: namely, (1) renewed elevation, (2) glaciation, and (3) stream erosion subsequent to glaciation. Although the first factor is undoubtedly a cause of the present physiographic and topographic features, there is no clear evidence to support it except the fact that the Rocky Mountains were involved in a folding movement late in the Tertiary period. Glaciation was, however, the dominant factor in the formation of the present surface, and there is a great amount of evidence present to show that the period of glaciation was long and intense.

All of the present valleys are relatively recent in origin. The main valley of Lost Creek is broadly U-shaped and widens out toward the eastern end. Valleys containing the tributary streams are either U-shaped or V-shaped, the last type being the most numerous. Some of the smaller valleys are steep and relatively deep and for the most part very narrow.
- Relief and Drainage -

The maximum relief within the area that is shown on the map is approximately 3000 feet, the greatest elevation being in the canyon where a height of 8500 feet above sea level is attained, while the lowest point is Deer Lodge Valley whose elevation is approximately 5200 feet above sea level. Slopes have been steepened by glaciation especially in the canyon where the walls are precipitous for several hundred feet. At the eastern end of the valley the slopes are gentle and rolling and the elevations are not great. In general, the valley walls decrease in elevation in an easterly direction.

Drainage is to the Pacific Ocean by way of the Deer Lodge, Clarks Fork, and Columbia Rivers. Lost Creek rises in the eastern slope of the Flint Creek Range. In its eastward course it receives many tributaries which, because of the semi-arid conditions, are all intermittent streams. In the canyon Lost Creek is a clear rapidly flowing stream, but in the valley the gradient is somewhat more gentle. The valley through which the creek flows is the result of the erosive action of the Pleistocene glaciers.

Several small springs rise to the surface out of the Kootenai formation. The flow is small and the water is absorbed very rapidly by the porous soil.

- Glaciation -

Glacial erosion and the deposition of the material carried by the ice were responsible for formation of the present
topographic and physiographic features that are found in the Lost Creek area. Evidence, such as hanging valleys, steep-sided valleys, U-shaped valleys, moraines, and glacial debris, supporting the existence of glaciers in past geological time is abundant in the area. The flat area in which Lost Creek heads is in all probability a glacial cirque which has been modified by subsequent weathering. The Lost Creek glacier was about 1,000 feet thick and moved in an easterly direction to about two miles west of Deer Lodge Valley. The gravels in the lower part of Lost Creek Valley probably represent the outwash plain of this glacier. Some of the characteristic features of glaciation are shown on the pictures on the next page.

The main valley of Lost Creek is a typical glaciated valley, being U-shaped and very steep-sided near the upper portion. The canyon has very precipitous slopes which in some places rise vertically for over 600 feet above the level of the creek. Both the valley and the canyon floors are covered by glacial drift. There are several well-developed lateral moraines in the valley as well as the ground moraines. In general, all of them are accumulations of boulders, some of which are by far too large to have been transported by streams. The glacial deposits are further distinguished from stream deposits by their lack of sorting, coarse and fine material being mixed indiscriminately. The boulders in the eastern portion of the valley are somewhat smaller than those farther west and were deposited not by the glacier itself but by the
A - Lost Creek Canyon looking westward from the valley.

B - Lateral moraine.

C - Glacial debris (Boulders from Newland Formation).
torrential streams that flowed from the glacier while it was melting.

At least two well-developed hanging valleys can be seen in the upper part of the main valley. Both are U-shaped and relatively short.

The material which composes the debris is derived from many sources. Granite boulders are by far the most abundant, but there are large amounts of material which were derived from the Belt series which consists chiefly of limestone and argillites from the Newland formation. Some of the material is composed of boulders of diorite, diabase, porphyry, and quartzite.

Though there is no clear-cut evidence to show that the glaciers advanced and retreated periodically, it is quite probable that such was the case, because it is a well established fact that glaciers in other areas in the neighborhood of Lost Creek underwent periodical advances and retreats before they finally melted away.

The glaciers which were present in the Lost Creek area were all of the alpine type and not a part of the great continental ice sheets, which did not extend as far south as Lost Creek. The deposits may be Wisconsin in age because, in all probability, the Lost Creek glaciers were the alpine phase of the Wisconsin ice sheet.
- STRATIGRAPHY -

- General Features -

The sedimentary series as exposed in Lost Creek Canyon and the valley furnishes a clue as to the geologic history of the area. Though sediments from the Proterozoic to the Present are exposed, many stratigraphic units are absent. There are no Ordovician, Silurian, Devonian, Permian, Triassic or known Jurassic sedimentary rocks present in the Lost Creek area. This may mean that none of them were ever deposited in this area or that deposition may have taken place but that the sediments were removed by erosion.

The base of the Belt series is not exposed in this area. Overlying the Spokane formation which is the uppermost part of the Belt in this region is the Cambrian Flathead quartzite. The Flathead is unconformable to the Belt. Above this are two other middle Cambrian formations, the Silver Hill and the Hasmak. The Madison and Quadrant formations complete the exposures of Paleozoic rocks which are found in this area.

Cretaceous rocks are the only Mesozoic sediments which are positively known to be exposed, though the Ellis may be present. No outcrops were mapped as being a part of the Ellis formation, but on the northern side of the valley included with those rocks that were mapped as Cretaceous undifferentiated, there is a basal conglomerate composed of quartzite, sandstone, and black chert pebbles which corresponds lithologically to the basal conglomerate of the Ellis as exposed on Warm Springs Creek about five miles to the southwest.
On the southern side of the valley a series of Cretaceous rocks are exposed. These rocks are sandstones, shales, and limestones of probable land and fresh water origin. On the northern side there is a great series of rocks which were mapped as Cretaceous undifferentiated. The age of this series could not be definitely ascertained because no good exposures or fossils can be found. Lithologically these rocks can belong either to the uppermost part of the Belt series or to the Cretaceous series. Near the contact with the volcanic ash on the northern side of the valley there is an exposure of conglomerate and sandstone which are undoubtedly Cretaceous in age because of the plant remains that were found in the sandstone.

The Tertiary rocks consist of intrusive and extrusive igneous rocks, terrace gravels, and arkoses. The terrace gravels and arkoses rest on the Cretaceous rocks with a marked unconformity. Extrusive rocks occur mainly at the eastern end of the valley and to the south, while the intrusives occur at the western end of the area. Among the intrusive rocks are granite, diabase, aplite, and pegmatite. The extrusives consist of andesite, volcanic ash and breccia.

Quaternary deposits are found in the main valley and in the tributary valleys and consist of glacial drift and alluvium.

The following table is a section which shows the formations and types of sedimentary rocks that are exposed in the Lost Creek area.
## General Section of Sedimentary Rocks in the Lost Creek Area

<table>
<thead>
<tr>
<th>Period</th>
<th>Epoch</th>
<th>Formation</th>
<th>Lithological Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recent</td>
<td></td>
<td>Alluvium deposited on the valley bottom.</td>
<td></td>
</tr>
<tr>
<td>Quaternary</td>
<td>Pleistocene</td>
<td>Glacial debris consisting chiefly of granite boulders.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pliocene and</td>
<td>Gravels which cap high terraces.</td>
<td></td>
</tr>
<tr>
<td>Tertiary</td>
<td>Pleistocene</td>
<td>Arkosic conglomerates, sandstones, and shales.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(unconformity)</td>
<td>Agglomerates which consist of andesitic pebbles in an andesitic matrix.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Upper Cretaceous</td>
<td>Sandstones and shales, red in color, highly metamorphosed.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Livingston(?)</td>
<td>Chiefly red and green shale, some limestone and sandstone. Also black calcareous shales and limestone.</td>
<td></td>
</tr>
<tr>
<td>Mesozoic</td>
<td>Cretaceous (?)</td>
<td>White to yellowish massive quartzite, some pink weathering magnesium limestone, brownish red shale and sandstone.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(undifferentiated)</td>
<td>Upper part: thick-bedded white and gray limestone; lower part: white marble. Some chert. Lower part is flaggy.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Upper part: white magnesium limestone. Middle part: dark calcareous shale. Lower part: Pale gray magnesium limestone</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lower Cretaceous</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kootenai</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(unconformity)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Upper Pennsylvanian Quadrant</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Quadrant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paleozoic</td>
<td>Mississippian</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Madison</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Canbrian</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hasmark</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Period</td>
<td>Epoch</td>
<td>Formation</td>
<td>Lithological Characteristics</td>
</tr>
<tr>
<td>----------</td>
<td>-----------</td>
<td>-----------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td>Paleozoic</td>
<td>Cambrian</td>
<td>Silver Hill</td>
<td>Calcareous shale with siliceous laminae in upper part. Dark green shale in lower part.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Flathead (unconformity)</td>
<td>Light colored vitreous quartzite.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Spokane</td>
<td>Mud cracked and ripple marked red sandstone and shale.</td>
</tr>
<tr>
<td>Algonkian</td>
<td>Belt</td>
<td>Newland</td>
<td>Calcareous shales and impure limestones which are colored buff on weathered surfaces.</td>
</tr>
</tbody>
</table>

-Belt Series-

Newland Formation. The Newland formation is composed of thin-bedded calcareous rocks which can be called impure siliceous limestones or calcareous argillites. In the type area the Newland contains a large amount of carbonate and is, therefore, a limestone. However, in the Lost Creek area the rocks are only about one-half carbonate, where they are unmetamorphosed, the remainder being composed of magnesia, iron, and quartz. Wherever the rocks of the formation are in contact with granite intrusives they have been changed by contact metamorphism from soft, easily decomposed rocks to tough diopsidic hornstones which are light green in color and which resemble quartzite in many ways.

The base of the formation is not exposed in the Lost
Creek region but it is known that the Newland is transitional from the Ravalli from observations made in areas adjacent to Lost Creek.

Some portions of the Newland have not been affected by contact metamorphism. These rocks are fine-grained limestones that generally break down into flags not more than a foot thick. The bedding planes are marked by bands of different colors which are usually about one-eighth of an inch thick. The unaltered rocks vary greatly in color on fresh fractures from bluish-gray and greenish-gray to cream-white. A distinguishing feature of the Newland formation is the deep grooving parallel to the bedding planes which is caused by the leaching out of the more calcareous bands that occur in certain horizons near the middle of the formation. These grooves are usually about one-half an inch wide.

Much of the Newland formation in the Lost Creek area has been highly altered by contact metamorphism. The rocks have been changed into dense, hard, green hornstones containing large amounts of diopside and amphibole accompanied by quartz and feldspars, with minor amounts of biotite and titanite. Calcite occurs in varying amounts, some of the specimens containing as much as fifteen percent of the mineral.

The altered rocks are also more or less distinctly banded by layers that average about one-eighth of an inch in thickness. In some specimens the texture is crystalline but generally it is so fine and dense that the constituent minerals cannot be readily distinguished megascopically.
Spokane Formation. The Spokane formation consists of sandstones and shales which have a red color where no alteration has taken place. A characteristic of the formation is the presence of ripple marks and sun cracks which indicate shallow water deposition. The red shale which overlies the Newland formation is considered to be the base of the Spokane. Some green shale similar to that in the Newland is included in the basal red shale which may indicate that there was a gradual transition between the two formations. Sandstone is the dominant rock in the upper part where it is interbedded with shale.

Metamorphism causes a gradual change in the color of the rocks. Where metamorphism has been slight the deep red has been changed to a purplish hue; where it is intense, the change has been to browns, grays, and greens. The red shales and sandstones have been altered by metamorphism into quartz-muscovite-biotite rocks and to hornstones; and the basal green shales, to green hornstones which are rich in amphibole and which closely resemble the altered rocks of the Newland formation.

- Cambrian Series -

Flathead Formation. The Flathead formation is separated from the underlying Spokane rocks by an unconformity. This relationship is best exposed on the hill just south of Lost Creek Canyon. As indicated by measurements made by Emmons and Calkins the discordance in dip is only four degrees.
A band of conglomerate marks the bottom of the formation. The pebbles in the conglomerate were derived from the Spokane formation and consist chiefly of rounded to subangular quartzite fragments which are grey in color. The main bulk of the Flathead consists of a resistant, dense, vitreous, white to pinkish quartzite. Near the top it contains some impure quartzite which is very similar to the quartzitic sandstones of the Spokane formation.

Metamorphism does not appear to have affected the Flathead rocks to any great extent although it may have changed the color, because the rocks are in general more whitish than those exposed in areas such as central Montana and the Tobacco Root Mountains.

**Silver Hill Formation.** The Silver Hill formation was first named by Emmons and Calkins from the type locality on Silver Hill, south of Silver Lake, in the Philipsburg quadrangle. It is exposed in Lost Creek Canyon about two miles west of the area included in this report. The rocks rest conformably on the Flathead and consist primarily of dark, slightly calcareous shales which are overlain by limestones with thin, brown, siliceous laminae. In the contact zone north of the canyon the upper part of the formation has been largely altered to rocks which are rich in diopside and vesuvianite with minor amounts of epidote, calcite, and quartz.

**Hasmark Formation.** The Hasmark formation is exposed near the western end of Lost Creek Canyon. It consists of a lower magnesium limestone which is usually a creamy-white in
color, an overlying shale which has brownish bands and calcareous nodules in it, and an upper pale blue-gray magnesium limestone. The brown bands in the shale are due to biotite which indicates that some metamorphism has taken place.

A thin band of calcareous shale occurs near the bottom. This shaley band may mark a transition from the underlying Silver Hill formation.

-Mississippian Series-

Madison Formation. Since neither the Jefferson limestone nor the Three Forks shale are exposed in the Lost Creek area, the relation of the Madison limestone to the underlying formations is not very clear. However, judging from the relations that are found elsewhere in Montana and particularly in areas adjacent to Lost Creek it is evident that the Madison is conformable to the underlying formations of Paleozoic age. In the Lost Creek area the Madison has been so badly faulted by the granitic intrusives that it is in contact with the Newland limestone and Cretaceous sandstones on the northern side of the valley.

The Madison formation, as exposed in the Lost Creek region, can be divided into two members: A lower member of blue-gray massive limestone which contains an abundance of chert more or less regularly distributed and an upper member of a blue-gray limestone which is very massive and which contains chert, though not as abundantly as the lower part, in irregularly distributed masses. The base of the formation
A - Madison limestone in contact with the Newland.

B - Madison limestone in the valley bottom.
is not exposed in this area.

Thin beds of white limestone, which are not found in the lower part of the formation, became more abundant in the upper half. As already mentioned, the chert in the upper half is less regular in distribution and occurs in larger masses. This is especially true near the fault contact with the Newland formation. Here much of the chert is probably secondary having been formed by the action of water which moved through the fault fissures.

The Madison limestone is much more easily recrystallized by metamorphic agencies than the Cambrian magnesium limestone. In one place on the north side of the valley the limestone has been changed into a massive, white marble. Tremolite and serpentine are the most common of the contact metamorphic minerals although a small amount of diopside is also present.

Weathering of the limestone produces prominent cliffs which are occasionally vertical. The pictures on the next page show the topography that is developed by the weathering of the Madison limestone.

- Pennsylvanian Series -

**Quadrant Formation.** The Quadrant quartzite is exposed on the southwestern side of Trask hill. It is associated with massive red sandstones and shales which are Pennsylvanian in age and also a part of the Quadrant formation. There are several smaller outcrops of the quartzite a short distance south and southeast of Trask Hill. On the hogback southeast
of Trask Hill the Quadrant quartzite is associated with thin-bedded limestones.

On Trask Hill sandstones and shales having a brownish-red color are associated with the quartzite member of the Quadrant. These sandstones and shales are characterized by greenish-white spots. Where these rocks have been affected by metamorphism the red colors have changed to a purplish hue and the spots are indistinct and frequently obliterated. Green mica is the most characteristic mineral developed in these rocks by metamorphism.

The limestones on Rocky Ridge are flaggy, have a gritty surface, and range in color from grey to brown. On weathered surfaces some bands of the limestone weather to a purplish hue. Alteration has changed much of the limestone to a greenish banded rock which contains diopside, quartz, epidote and amphibole. In general the rocks are fine-grained and resemble the hornstones of the Newland formation.

The quartzite member is a massive, thick-bedded quartzite which is stained yellow on weathered surfaces. When freshly fractured it is grayish-white in color. Metamorphism and alteration have not affected the quartzite in any way except to make the color appear to be slightly pinkish.

As exposed on Trask Hill and Rocky Ridge the section of the Quadrant which was mapped in the Lost Creek area appears to correspond lithologically with the rocks of the type section of the lower Quadrant in the Philipsburg quadrangle.
Kootenai Formation. Rocks of the Kootenai formation occupy an extensive area in Lost Creek Canyon. The rocks may be divided into several members, a lower shale and limestone, a band of "gastropod limestone," a green shale, an upper band of "gastropod limestone," a rather thick series of black limestones and calcareous shales, and a bed of massive red sandstone.

The lower shales and limestones are exposed on Rocky Ridge. In this locality the shales have a characteristic red and green color which gives them a mottled appearance. Alteration has changed some of the shale to rocks which, in general appearance, appear to be schistose. Above the shale is a fine-grained homogeneous limestone which is buff on weathered surfaces but which, on fresh fracture, is a bluish-gray in color. It contains many twig-like bodies of crystalline calcite which, being dark and hard, stand out prominently. Though they have not been positively identified as fossils they are, nevertheless, very conspicuous. This limestone is also exposed on the canyon wall directly south of Rocky Ridge.

Above the buff-weathering limestone there is a series of limestones which are very different in character than the lower limestones and which closely resemble the rocks of the Madison formation. When freshly fractured the rocks are dark gray; on weathered surfaces they are a bluish-gray. These limestones are characterized by a coarser and less compact
A - Black Cretaceous limestone (Kootenai).

B - Greenish Cretaceous shales (Kootenai).
texture than the lower limestones and by the remains of fresh-water gastropods which are very abundant and conspicuous on weathered surfaces. Another band of the same general type of limestone separated by about ten feet of green calcareous shale lies above the "gastropod limestone." The fossils in the upper band are of a different species and not as abundant except in a zone near the top.

The calcareous shales which are interbedded with the "gastropod limestones" and overlying them are olive-green in color. Above these shales there occurs a series of black calcareous shales and limestones. The black shales and limestone are massive and generally resistant to the action of weathering and metamorphism. The uppermost beds mapped as Kootenai consist of a little red shale and sandstone.

- Cretaceous Undifferentiated -

On the northern side of the valley there is a great series of conglomerates, sandstones, and shales extending from the fault contact with the Madison limestone on the west to the volcanic ash and rhyolite deposits on the east. As already mentioned on page ten, there is some doubt as to their exact age. A part of these deposits are Cretaceous in age and probably belong to the Kootenai formation.

The series of sandstones, conglomerates, and shales are prevalingly red in color and highly metamorphosed. Some of them are very soft, especially those in the quarry slightly west of the ash beds, others are hard and massive. To the
A - Outcrop of Cretaceous shale north of Lost Creek.

B - Cretaceous quartzitic conglomerate north of Lost Creek.

C - Cretaceous sandstone in quarry near the volcanic ash beds.
east of the aplite dike, which is east of the limestone, there is a great series of red and brown sandstones and red and black shales which are highly metamorphosed.

The conglomerates and sandstones in the quarry are light brown to nearly white in color. The conglomerate is arkosic and contains pebbles of chert and quartzite, the quartzite being predominant. Most of the sandstone is massively bedded and very pure consisting of fine grains of quartz. Some plant remains were found in the sandstone which is probably Kootenai in age.

The same general series continues westward for about a quarter of a mile where a change in lithology becomes apparent. Here the rocks are chiefly shales of a deep brown color which are highly metamorphosed. About a mile west there is a quartzitic conglomerate which contains black chert pebbles exposed in the arkosic shales found in that region. This conglomerate may mark the base of the highly metamorphosed shales which have just been described.

- Upper Cretaceous Series -

Livingston Formation? The Livingston formation in the Lost Creek area is composed of agglomerates which are associated with volcanic ash, volcanic breccia, and rhyolite. None of the outcrops are large enough to map though there are many of them. All of the outcrops occur on the southern side of the valley about one mile west of the Deer Lodge highway.
Agglomerate of Upper Cretaceous Age

(Livingston Formation?)
The formation is composed of pebbles of andesite which are imbedded in a matrix of andesitic material. All of the pebbles are rounded, showing the action of water, red or green in color and about two inches in diameter. The matrix is composed of a green, fine-grained andesitic material which was laid down under water. Although the agglomerates are igneous in origin they were undoubtedly laid down under water. The material which comprises the formation was blown out of a volcanic vent and fell into a body of water probably a large lake where the material was reworked and cemented in such a manner that the formation appears to be sedimentary rather than igneous.

- Tertiary Series -

Arkoses. Arkosic conglomerates, sandstones, and shales occupy a fairly large area on the northern side of the valley. Several outcrops on the southern side of the valley are too small to be mapped. The arkosic formations are, in general, very soft and composed of fine-grained sandy material. The conglomerates are brownish-gray in color, the sandstones are nearly white, and the shales are greenish-gray. All of the rocks weather easily though the sandstones and conglomerates are more resistant to the action of weathering than are the shales. The arkoses are composed of feldspars, quartz and minor amounts of mica. The particles are angular and the feldspars in the shaley zones have been largely altered to kaolin. Since the particles were not transported for any
great distance and were derived from granitic rocks, the arkoses are Tertiary in age because the nearest granitic rocks are only a short distance west and are Late Cretaceous or early Tertiary in age. Another factor that indicates the Tertiary age of these deposits is the fact that fossils, which were identified as plant remains, were found in some of the shaley zones of these arkoses.

Terrace Gravels. Terraces, the highest parts of which rise about 300 feet above the valley are conspicuous near the eastern end of Lost Creek Valley, although most of them have been dissected by erosion. The terraces slope gently toward the valley their grade increasing gradually toward the hill-sides so that their upper limit is indistinct. A capping of gravel, which is known to overlie rhyolite and beds of volcanic ash, covers the terraces. Some of the gravel is clearly stream gravel, and some is material which has been washed from adjacent slopes. The gravels are of two types; those composed of sandstone and quartzite pebbles derived from the Spokane formation and those composed of fragments of andesite.

The gravels are probably of two different ages because the sandstone and quartzite pebbles are, in some places, covered with the capping of andesitic gravels. However, since both gravels overlie rhyolite and volcanic ash beds and are frequently partly covered with glacial material, they were probably deposited during the Miocene and Pliocene epochs.
- Quaternary Series -

Glacial Drift and Alluvium. All of the main valley floor and the floors of all the subsidiary valleys and gullies are covered with glacial drift and alluvium which are not differentiated on the map. In general, wherever the deposits are shown in the minor valleys and gullies they consist of alluvial material. Near the eastern end of the main valley there are several small alluvial fans at the mouths of some of the steeper gullies. Except for two small areas of alluvial material, one around Trask Hill and Rocky Ridge and the other near the eastern end of the valley, Lost Creek Valley is covered with glacial debris in the form of ground and lateral moraines. The material composing the glacial deposits has already been described in detail on pages seven and eight under glaciation.

The alluvium is composed of material which has been washed from the hillsides since the period of the last glaciation. At the eastern end of the valley it is composed of fine-grained particles of volcanic ash and rhyolite.

- INTRUSIVE IGNEOUS ROCKS -

- General Features -

Intrusive rocks consisting of granite, diabase, aplite, and pegmatite occur over an extensive area near the western boundary of the Lost Creek area. The granite is an alkaline-
biotite rock which contains some fluorite. The dikes of aplite and pegmatite are probably the last products of differentiation in the alkaline granite. A small amount of pink granite, which is slightly more acidic than the alkaline-biotite granite but the same in mineral composition, is in contact with the fluorite-bearing granite in the upper portions of the canyon walls.

Along the contact with the limestone there is a gneissic granite which was evidently derived by the assimilation of the limestone along the walls of the chamber which contains the intrusion. The gneissic granite contains orthoclase and an abundance of biotite together with some quartz. This is the only evidence of assimilation that can be seen.

The method by which the magma was intruded is not clear though from the fault pattern of the area, which was evidently caused by the intrusion, it seems quite probable that the magma forced its way into the strata by lifting the overlying sedimentary rocks by the force of the immense hydrostatic pressures which were developed in the molten magma. Magmatic stoping and assimilation probably played an important though minor role in the intrusion. The possibility of any great amount of assimilation is eliminated in this area by the slight contact effects upon the sedimentary rocks: Limestones have been recrystallized, especially the magnesium limestones which were altered to marbles with the development of diopside; shales have been altered into diopsidic hornstones; and sandstones, into quartzites. Contact meta-
morphism rarely extends more than 1,000 feet from the contact and more commonly much less than that. The clean-cut truncation of the strata as seen in the walls of the canyon indicates that magmatic stoping may be very important.

Magmatic stoping is a process by which blocks of sedimentary rocks are broken off from the roof and walls of the containing chamber by a molten magma. The method by which blocks are broken off is generally conceded to be the loosening from the walls and roof of blocks by the magma which is intruded into cracks or along the bedding planes in sedimentary rocks. Once loosened the blocks were either pushed aside by further intrusions or sank through the viscous magma to great depths where they were assimilated by the molten magma. In the first case inclusions would be formed upon the solidification of the granitic mass. If inclusions are a proof of magmatic stoping then it is quite possible that stoping was important in the Lost Creek area because there are some included blocks visible in the granite on the canyon walls as well as along the contact with the limestone. These inclusions were impregnated by the magma so that there is no resemblance between these blocks and the country rock, though it is relatively easy to distinguish the fact that they are not a part of the original magma. Inclusions are rarely found at any great distance from the contacts.

Since there is no evidence of extensive assimilation or magmatic stoping, it seems probable that most of the intrusion made a way for itself by lifting large blocks of the already folded sedimentary rocks. There is no evidence that
the magma domed the overlying rocks. Large-scale faulting on both borders of the granite, as well as minor faulting in the Newland and Spokane rocks and in the valley, indicates that large blocks of strata were lifted by the intruded magma. It may be quite possible that the thrust faulting which placed the Madison and Newland formations in contact with each other may have occurred before the intrusion. The relationship of faulting and intrusion are discussed on page under Structure.

Age of the Intrusions

There is no direct evidence of the age of the intrusive rocks in the Lost Creek area. The granite and diabase have invaded Algonkian and possibly early Cretaceous strata. There is, however, a relationship between the granite exposed in Lost Creek Canyon and that exposed in the Philipsburg quadrangle. In discussing the age of the granitic intrusives in the Philipsburg quadrangle Emmons and Calkins said that "the irregular or batholithic masses are probably all of Tertiary or, at the earliest, of very late Cretaceous age." Igneous intrusions are, in general, accompanied by deformation of the overlying strata. No distinct angular unconformities were recognized in the stratigraphic series from the Cambrian to the Cretaceous in the Lost Creek or adjacent areas. This fact may be taken as evidence that there were no great intrusions during that period. Faulting which has broken the Cretaceous strata has not affected the granite.
Since the beds of volcanic ash and breccia which are of probable Miocene age have not been disturbed, it is quite evident that the granite is older than Miocene. Since the granites of Lost Creek and the Philipsburg area probably represent different stages of differentiation of a larger mass, it is quite probable that they are offshoots of the Boulder batholith which is conceded to be late Cretaceous or very early Tertiary in age.

The age of the diabase sheets, which are intruded into the Spokane and Newland formations of Lost Creek, cannot be definitely determined. These sheets were intruded into horizontal strata which was later involved in intense folding. They are also cut by the dikes that are associated with the granite. It therefore seems probable that these sheets are certainly pre-Tertiary in age.

-Alkaline-Biotite Granite-

Granitic rocks occupy an area of several square miles near the western boundary of the area and on the slope north of Warm Springs Creek. The best exposures of this granite occur on the steeply glaciated walls of the canyon north and south of Lost Creek. It is whitish in those places where it is least weathered; however, nearly all of it is stained by iron oxide in tints of yellow and orange. The surface of the glaciated canyon walls reveals few joints except in the more weathered portions above the granite where it is cut by
many irregular joints. All of the joints in both portions of the canyon are curved and nearly parallel to the surface and appear to be due to weathering.

The walls of the canyon show the relation of the intruded granite to the Algonkian Newland formation. The surface of the main mass of granite cuts across the bedding of the Newland formation at a low angle and dips gently to the west. Dikes of granite, pegmatite, and aplite penetrate both the rocks of the Newland and the diabase by which it is intruded. Numerous dikes of tourmaline-bearing aplite and pegmatite cut the rocks of the Newland formation south of Lost Creek on the canyon wall. The distribution and relationship of these dikes makes it very probable that they belong to the granite.

The granite is an alkaline-biotite rock containing fluorite which cannot be distinguished megascopically. Upon megascopic examination the granite appears to consist chiefly of feldspar, quartz, and biotite. A smoky tinted quartz is a characteristic of the granite. A pink granite which is exposed on the upper portion of the canyon walls is similar in composition and appearance to the alkaline-biotite granite except that the rock is more acidic and the feldspar is pink in color.

Several specimens of the granite were examined microscopically. In thin section the alkaline granite was found to consist of microcline, albite, quartz, biotite, and fluorite. The quartz and microcline are about equal in amount and the biotite and fluorite are subordinate. Magnetite, apatite, and some minerals which were not identified are
A - Exfoliation of the alkaline-biotite granite.

B - Granite near contact with Newland.
accessory minerals and are scarce. The biotite is greenish and no alteration to chlorite was recognized. The pink granite is similar in mineral composition except that quartz is slightly more abundant than microcline.

- Diabase -

The upper part of the Spokane formation contains several sheets of diabase which have taken part in all of the intense folding and faulting of the Algonkian rocks. Near the western boundary of the area there are many irregular diabase dikes which have been intruded into the sedimentary rocks of the Newland formation. The best exposures of the sheets occur on the north wall of the canyon where they have been intruded into the flaggy sandstone beds of the Spokane formation. This sheet was not mapped, but its relations are the same as that of the basic sill which is shown cutting the Spokane formation.

The diabase is evidently older than the granite and the aplite and pegmatite dikes, because in several exposures on the canyon walls the granite and its associated dikes can be seen cutting through the diabase.

Megascopically the diabase is a rock composed chiefly of plagioclase and augite with an ophitic texture. It is heavy, compact, nearly black except on weathered surfaces where the rock tends to become rusty, and has a fine texture. On the weathered surfaces the feldspars can readily be distinguished from the black minerals which form the ground mass.
A and B - Photographs showing the granite (light) and the diabase (black).
A and B - Photographs showing the granite (light) and the diabase (black).
of the rock.

When examined microscopically the diabase is found to contain plagioclase, augite which is mostly altered to green hornblende, biotite, quartz, apatite, and several minerals which were not identified. The biotite is greenish brown in color. Specimens of the diabase that were strongly affected by contact metamorphism were found to be essentially the same mineralogically as the relatively fresh diabase except that the growths of quartz are slightly larger.

-Aplite and Pegmatite-

Dikes of aplite and pegmatite are exposed on the steep canyon walls north and south of Lost Creek and about one mile northwest of Trask Hill. There the aplite is associated with a dike of quartz porphyry which parallels the aplite dike. The pegmatite taken from the rocks of the Algonkian series is composed primarily of quartz, white feldspar, muscovite, and small black prisms of tourmaline which are conspicuous in the white background of the matrix. The aplite facies is represented by rocks having a sugary texture. They are white and composed of microcline, quartz, muscovite and short black prisms of tourmaline. These rocks grade into others composed of quartz and tourmaline which contain only small amounts of feldspar.

The quartz porphyry dike northwest of Trask Hill consists of a massive white quartz, which on weathered surfaces is stained brown and red, a little muscovite and biotite, and a large amount of pyrite.
EXTRUSIVE IGNEOUS ROCKS

General Features

Extrusive rocks occupy relatively large areas south of Lost Creek Valley and at the eastern end of the valley. The rocks are chiefly rhyolite, andesite, volcanic ash, and breccia. There are some andesitic rocks interbedded with Cretaceous rocks which evidently were extruded on the surface and then covered with sediments. This is true because none of the rocks above the andesite are affected by metamorphism. Andesitic rocks are the most abundant, while rhyolite, volcanic ash, and breccia are next in importance.

These rocks are strongly unconformable on the older sedimentaries and have not been metamorphosed by the intrusions. They have been somewhat deformed by folding and faulting though much less so than the Cretaceous and older rocks.

Age of the Extrusive Rocks

In general, it may be said that the extrusive rocks of the area are contemporaneous with the intrusions. Their age is probably Miocene or older, more probably late Eocene. They are overlain in one place by Miocene volcanic ash and breccia and in other places by Pliocene gravels. There is only slight evidence of pre-batholithic andesites. In one place south of Lost Creek andesitic rocks are found between beds of Cretaceous sandstones. On the northern side of Lost
Creek Valley the same type of andesite occurs between the beds of an early Cretaceous shale. Though there is some doubt as to the age of the shales north of Lost Creek, those on the southern side are Cretaceous and the andesitic rock is therefore Cretaceous in age.

- Andesitic Rocks -

A large area in the Lost Creek region is overlain by andesitic rocks that consist of flows and tuffs. At the eastern end of the area there are extensive deposits of rhyolite on both sides of the valley. A small area about one mile east of Trask Hill is overlain by rhyolite. Andesitic rocks also cover large areas south and southwest of Lost Creek Valley and north of Anaconda. In general, the rocks were classified as rhyolite and andesite.

The rhyolite is an aphanitic rock containing quartz, feldspar, biotite, and a little hornblende. Phenocrysts are not abundant with the result that the rock has a felsitic texture. The color does not vary a great deal; in general, most of the rocks are brown or black on weathered surfaces and white or light gray on fresh fracture. The andesites are commonly darker in color and grade into rhyolite. About one mile northwest of Anaconda the andesitic rocks grade into rocks which have the appearance of basalt. Mineralogically, the andesites are composed of striated feldspars, hornblende, pyroxene, and biotite. As in the case of the rhyolite, phenocrysts are not abundant and the rock is felsitic in
texture. On weathered surfaces the andesites are red, while on fresh fractures they are dark gray.

In the area north of Warm Springs Creek, where the rocks were mapped as andesitic, there are several small deposits of terrace gravel and tuff.

- Volcanic Ash and Breccia -

An extensive deposit of volcanic ash and breccia occurs near the eastern end of Lost Creek Valley associated with and overlying the rhyolites and andesites. Since the ash and breccia are not resistant to weathering, water and erosion have carved out many deep gullies in the deposits. The hills are all low, gently sloped, and rounded. In some of the gullies erosion has exposed the ash and breccia deposits, which were evidently ejected from a volcanic vent, and having fallen into a lake, were rudely stratified and loosely cemented.

The prevailing rocks of these formations are composed of white, fine-grained, homogeneous materials which crumple very readily. Obscure traces of bedding planes are seen in the outcrops, but none can be observed in hand specimens. Upon breaking a specimen from the volcanic ash deposits it was found to consist principally of minute angular fragments of volcanic glass. The breccia is similar to the ash except that it contains angular fragments of lava which are visible to the eye, and that it is more indurated and somewhat harder.

-34-
- STRUCTURE -

The unconformity at the base of the Flathead shows that the region suffered uplift and folding before the deposition of the Cambrian rocks. This uplift affected the Algonkian strata to some extent. The overlying rocks from the Cambrian to the Cretaceous are conformable to each other because there is no evidence of an angular unconformity. Deformation of this great series of rocks evidently took place in late Cretaceous or early Tertiary times because the Tertiary sediments are not greatly disturbed. It is quite probable that this great movement, which was part of the Laramide Revolution, took place at the same time as the intrusion.

Folding can be noticed in many places in Lost Creek Canyon, especially on the walls north and south of the canyon. Folds can also be seen in the Cretaceous rocks on the southern side of the canyon. Faulting is also developed on a large scale. Many faults can be seen in the canyon walls as well as in the valley. Only the larger faults were mapped.

- Folding -

The character of the intense and complex folding in Lost Creek is best seen in the exposures on the walls of the canyon north and south of Lost Creek. In general, "the boundary between the Newland and Spokane formations here appears in profile as a sigmoid curve, but the Algonkian beds have been thrown into extremely intricate small folds recumbent mostly toward the west, but partly toward the east." On the south
Hills of Volcanic Ash and Breccia

(Near the Entrance to the Valley)
side of Lost Creek Canyon the Cambrian limestones which rest on the overturned Flathead quartzite have been closely folded. These folds are also recumbent toward the west.

South of Trask Hill the Cretaceous rocks show folds which, though not as complex as those in the canyon, are rather close and have their steepest limbs toward the west. In the quarry near the volcanic ash beds folding is also prominent. The folds are flat and poorly developed. Intense folding of the marble of the Madison formation is exposed north of the road. The folds have their steeper limbs toward the west.

There are several small anticlines in the area the most prominent of which has been developed in the Cretaceous rocks south of Trask Hill. The limbs are not steep and dip east and west, the western limb being the steepest. This anticline has been cut by a fault. Other anticlines have been developed in the Madison limestone south of Lost Creek.

-Faulting-

There are three major faults in the area two of which were mapped. The largest of these brings the Spokane and Cambrian rocks in contact. This fault is clearly exposed on the northern wall of Lost Creek Canyon about one mile west of the western boundary of the area. It is nearly vertical and resulted from the force exerted by the igneous intrusions which lifted a large block of Proterozoic rocks above the Cambrian. The contact of the alkaline-biotite granite with
the Madison limestone north and south of the Canyon is clearly a fault. Intense brecciation is noticeable in the limestone. The contact dips gently eastward. North of Lost Creek Canyon the relations are very clear. Here the fault dips steeply toward the east and has caused intense brecciation of the limestone. A gulch has been eroded along this fault.

The third major fault brings the Madison limestone and Cretaceous rocks into contact north of Trask Hill. Brecciation of the limestone is very intense. The fault dips steeply toward the east.

The faults at the contact of the granite and limestone and at the contact of the limestone with the Cretaceous sandstones and shales probably represent a series of step faults which caused the Newland to be raised above the limestone and represents a down dropped block between the Newland and Cretaceous rocks.

A large fault may have been a primary cause in the formation of the canyon and valley. The relationships are not clear, but the Cretaceous rocks on the northern side of the valley have been raised relative to those on the southern side.

Along the lower parts of Lost Creek the ash has been folded and cut by faults. The dip is to the east. At the place where Lost Creek enters Deer Lodge Valley it is about 80°.

The Cretaceous rocks north and south of Lost Creek as well as the Madison limestone are cut by numerous faults of
small magnitude. Many of these faults are noticeable only through slight changes in dip and strike within the formations. Gullies have been developed along many of these faults.

The intricate fault pattern in the Lost Creek area was probably caused by the intrusion of the granite which slightly domed the strata while it was being emplaced. When this magma forced its way into the strata it lifted large blocks. This was especially true of the Proterozoic rocks in the canyon. Upon cooling and shrinkage of the magma the blocks settled somewhat and numerous faults were developed.

- Other Features -

Glaciation was responsible for a peculiar structure in the valley. It is entirely possible that Trask Hill and Rocky Ridge came to their present position through the agency of the glaciers which either scooped these small hills into the valley from the slope on the southern side or so undermined the underlying rocks that these hills slid into the valley after the glaciers retreated.

Jointing in the granite is confined to the granite in the upper parts of the canyon walls. These joints are curved and nearly parallel to the surface and appear to be due to weathering.
The first record of geological activity in the Lost Creek area was the deposition of the calcareous rocks of the Newland formation. These rocks were probably deposited in a large, shallow basin which was at no time deeply submerged; intermittently it was exposed to the atmosphere. The rivers that carried the sediment probably drained an old land surface and flowed slowly. The absence of gypsum indicates that the basin of deposition probably had an outlet.

The character of sediments at the base of the Spokane formation shows that deposition was continuous from the Newland to the Spokane. A subsiding delta plain received the sediments which were carried by a large muddy river. This basin was probably dotted with many shallow lagoons and areas which were almost wholly dry. The intermittent submergence and emergence of the sediments from the water caused them to be dried by the sun and later cracked and broken up. The ripple-marked character of the upper sandstones seems to indicate deposition in flowing water or in a very large lagoon rather than in stagnant water. The increasing coarseness of the sandstones indicates a slow uplift which rejuvenated the streams flowing into the large delta plain. This gradual uplift kept ahead of erosion. The angular unconformity between the Flathead and Spokane formations indicates the termination of Belt sedimentation by an extensive uplift which was followed by a very long period of erosion before the Flathead quartzite was deposited.
in middle Cambrian times. Due to the subsidence of the land the area was invaded by an arm of the sea in which the sands of the Flathead quartzite were deposited. The pebbles in the conglomerate at the base of this formation were derived from the Algonkian rocks either through the erosive action of swiftly moving streams which emptied into the seas or through the erosive action of the waves on the Algonkian formations which formed the coastline.

As the sea became deeper the sands and limey oozes of the Silver Hill formation were deposited to be followed by the deposition of the calcareous muds of the Hasmark formation, which were probably deposited in fairly deep water at some distance from the coast. Conditions of deposition varied throughout this period. The bands of shale which are interbedded with the limestone seem to indicate periods during which the streams were rejuvenated by slight uplifts.

Sediments, representing the geological history from the time of the deposition of the Hasmark in the middle part of the Cambrian to the deposition of the Madison limestone in Mississippian times, are not present in the Lost Creek area. On upper Lost Creek, a few miles west of the area included in this report, the Madison limestone rests conformably upon the Devonian Jefferson limestone. This may indicate that the Devonian rocks were deposited in the lower part of the Lost Creek region and were either removed by erosion or are not exposed.

The sea in which the sediments comprising the Madison
limestones were deposited was probably the last in which all of the conditions required for the deposition of very pure limestone were present. Approximately 1000 feet of limestones were deposited in this sea during Mississippian times. The sea was probably relatively deep and the calcareous ooze comprising the Madison formation were evidently deposited in deep water at some distance from the shore.

The abrupt lithological change from the Madison limestone to the quartzite and sandstone of the Quadrant formation indicates a marked change in the conditions of sedimentation. The varying thickness of the Madison in the Philipsburg quadrangle\(^1\) probably indicates a period of erosion before the Quadrant was deposited. The red sandstones and impure limestones of the Quadrant were deposited in an inland sea\(^1\) which retreated and advanced before the deposition of the quartzite member. The period between the retreat and advance of the sea was in all probability a period of erosion.

At the close of the Paleozoic era the sea bottom was elevated and exposed to erosion. The absence of the Triassic is due to one of two conditions, either the sediments were not deposited or else they were removed by erosion. No rocks of known Jurassic age are exposed though further work in this area may show their existence. The Jurassic period in adjacent areas\(^1\) was a time of marine deposition. The seas were all shallow and the sediments comprising the Ellis were deposited near the shoreline.

By the beginning of the Cretaceous period the Jurassic sea bottom had been elevated and exposed to erosion. This
surface became the site of fresh water deposition very early in the Cretaceous because the material comprising the Kootenai formation was in all probability deposited in a large fresh water lake. This conclusion is supported by the great number of fresh water gastropods that are found in the limestones of the Kootenai. The sandstones of the Kootenai were deposited on a large river flood plain.

Following the deposition of the Kootenai there was a period of uplift and erosion followed by a gradual subsidence beneath sea level. Following this came the deposition of the black muds of the Colorado formation, which is marine, and a shallow water deposit. The coarseness of the succeeding sandstones indicates a rejuvenation of the streams by a slight uplift.

The period from the late Cretaceous to the early Tertiary was one of great crustal disturbance. All of the sedimentary rocks from the Proterozoic to the late Cretaceous were folded and faulted in a very complex manner. Associated with the disturbance was large-scale igneous activity in the form of granitic intrusions. During the period from the Eocene to the close of the Miocene volcanoes were very active. Most of the products were andesite and ash. The ash probably fell into a large lake where it was reworked and rudely stratified.

The entire Tertiary period was one of erosional activity. The high mountains developed by the Laramide disturbance were dissected by erosion and brought to a common level after which erosion was invigorated by a slight upheaval of the land.
This happened several times during the Tertiary. The last general uplift occurred at the close of the Pliocene.

Glaciation greatly modified the land surface during the Pleistocene. Large glaciers, which had their origin in the higher mountains to the west, moved down the present Lost Creek Valley to a place about two miles east of Trask Hill. There may have been several periods of glaciation, but the record is very obscure. Evidence of two glacial advances can be found.

The period following glaciation has been one in which streams have cut their valleys down to the main valley of Lost Creek. Some alluvial material has also been deposited.

ECONOMIC GEOLOGY

There are no deposits of great economic importance in the area. Mining has been engaged in since about 1870, but it has always been intermittent. Gold was mined in several localities: Namely, along the granite-limestone contacts, in the metamorphosed and faulted Cretaceous sandstones and shales, and along the fault contacts of the Madison limestone and Cretaceous sandstone. None of the deposits were extensive or of high grade. The largest mine in the area was along the granite-limestone contact north of Lost Creek near the entrance to the canyon. At the present time the Ironhill mine, which is in the fault contact between the Madison and Cretaceous, is the only deposit that is being worked. The ore
is an oxidized gold ore containing pyrite, limonite, and quartz.

The Madison limestone and Cretaceous sandstone north of Lost Creek have been quarried intermittently since about 1880. At one time the limestone was burned to CaO and shipped to Anaconda. The sandstone is very pure and is used for making a highly refractory silica brick.

There is also a small deposit of fire clay in the Cretaceous rocks north of Lost Creek which is not being utilized at the present time.
GEOLGIC
OF
LOST CREE
SCALE:

IGNEOUS ROCKS

Intrusive
Granite
Diabase
Aplite

Extrusive
Rhyolite
Andesite Rocks
Ash & Breccia
GEOLLOGICAL MAP
OF
EAST CREEK CANYON
SCALE: 1" = 2640'

LEGEND

Quaternary
Alluvium & Drift

Tertiary
Terrace gravel
Arkoses
Cret. Undit.

Mesozoic
Koolenit

Paleozoic
Quadrant
Madison

Algonkian
Flathead
Spokane
Newland

Streams
Faults