GEOLOGY OF THE NORTHERN SNAKE RIVER RANGE, IDAHO AND WYOMING

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Thesis of

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by

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Submitted in partial fulfillment of the requirements for the degree of Master of Science in Geology in the University of Michigan, 1949.

CONTENTS

ILLUSTRATIONS

ABSTRACT

The area described in this report is in the northern Snake River Range in Teton County, Wyoming; Teton and Bonneville Counties, Idaho. Formations ranging in age from middle Cambrian to upper Cretaceous crop out in the mountains; welded tuffs overlie these formations at lower elevations on the northern slopes and in the Teton River Canyon. Rhyolite dikes occur along fault zones.

The principal structure is the Jackson thrust fault paralleled on the north by the Cache fault and on the south by the Burbank fault. A synclinal fan fold south of the Burbank fault appears to be closely related. Principal structures trend northwest-southeast. Opposing this trend are a few normal faults of small dimension.

Because of intense folding and faulting, economically valuable deposits of coal or phosphate probably do not occur. Limestone has been quarried for sugar refining, however, and welded tuffs find extensive use locally as a building stone.

INTRODUCTION

Location

The area discussed in this paper is in western Wyoming and eastern Idaho and lies almost entirely within the Targhee National Forest (see plate 1). The easternmost two and a quarter miles are in Teton County, Wyoming; the northern half of the Idaho section is in Teton County, Idaho, and the southern half in Bonneville County, Idaho. The southeastern corner of the Driggs, Idaho and Wyoming topographic sheet, covers the area on an inch to the mile scale.

The Teton Basin borders the area on the north. On the northeast the Teton River (formerly called Trail Creek) marks the boundary. On the south it is bordered by the 43°30' North parallel and on the east by the 111°00' West longitude line. The western boundary follows Murphy Creek to its headwaters; from there it extends approximately south-southeastward to the southern boundary of the area. This indefinite boundary marks the western limit reached by the field party during the four weeks spent in the field.

Accessibility

Route U. S. 20 (alternate) parallels the northeastern boundary and country roads from Victor, Idaho extend a half a mile to a mile and a half up a few of the canyons. From Irwin, on the south, the area can be reached only by trail from a dirt road in Rainy Creek Canyon. The U. S. Forest Service maintains numerous trails that cross the area.

INDEX MAP

Raisz

100 MILES

Object of Study

Field work was undertaken in order to map a section of the Driggs Quadrangle in which detailed geologic mapping had not previously been done, and, if possible, to determine the westward extent of the Jackson thrust fault. The work was also intended to provide data for master's theses by the authors.

General Statement

Between July 24th and August 18th, 1948 a party of four mapped approximately 35 square miles of rugged, heavily forested or sagebrush covered upland. The method used to accomplish this was to divide the group into two field parties. Most of the time Anne and Richard Wyman worked as one party while E. Hollis Newcomb and Dolores Marsik made up the other. Traverses were made in separate areas daily and mapping was done on separate maps. At the end of each day this work was compiled into one notebook and contacts transfered from field maps to a base map. Contacts were plotted directly on the Driggs topographic sheet.

Three different campsites were occupied during the course of the work. The first of these was located about three-fourths of a mile up Burbank Creek. The second camp was on Mike Harris Creek and the third in Pole Canyon, about four miles south of Victor, Idaho. These sites are accessible by road and have a good water supply.

Except for the section south of the divide marked by the Teton-Bonneville county line, the area was covered on foot. This southern section could not easily be reached from northern camps in one day's walk so horses were used.

R. V. Wyman wrote the sections of this report on the regional geologic setting, structural, and economic geology. Those on stratigraphy and physiography are the work of A. Wyman and the section on igneous rocks is by E. H. Newcomb. The remainder of the report is the combined work of the authors. The final preparation of maps and cross sections is the work of R. V. Wyman.

ACKNOWLEDGMENTS

Professor A. J. Eardley of the University of Michigan suggested this area for study and helped in the preparation of maps and cross sections and in the selection of campsites. The writers are indebted to Dr. Eugene H. Walker also of the University of Michigan for help given in the field and for many valuable suggestions offered during the preparation of this manuscript. Miss Dolores Marsik assisted in the field mapping; Mr. John Bayless of Michigan State College sustained the party for a period of two weeks in the field. The T. C. Sideway and Son sheep herding outfit provided transportation on their empty pack trains to the more inaccessible portions of the area and the Marshall family of Victor, Idaho, Mr. Darld Marshall, in particular, freely loaned horses and equipment for transportation to the extreme southern portions of the area. Mr. Ernst Taylor, Forest Ranger in Victor, supplied information on vegetation and trails in this section of the Targhee National Forest and Professor D. V. Baxter of the University of Michigan helped in the determination of scientific names of trees. The writers also wish to thank Drs. W. F. Hunt, E. Wm. Heinrich, and Mr. M. V. Denny for aid in the interpretation of thin sections and Dr. E. C. Stumm and Mr. Walter Wheeler for the identification of fossils. Thin sections were made by the Thin Section Laboratory in Butte, Montana; Mr. R. A. Brant aided in the preparation of photographs. The authors are also grateful to the University of Michigan for providing transportation to and from the area and for the loan of camping equipment.

PREVIOUS INVESTIGATIONS

The first work in this region was done in 1872 by Frank H. Bradley, a member of the Hayden Survey. In 1877, Orestes St. John accompanying a second Hayden party, described the main structural trends.

During the years 1910-1912 the United States Geological Survey sent reconnaissance parties into the area to investigate the coal and phosphate reserves. A. R. Schultz (1918) and E. Blackwelder (1916) studied in detail structural features and stratigraphic units. F. M. Fryxell (1941) described glacial features in the Tetons to the northeast.

In recent years work has been done in the adjoining areas by L. S. Gardner (1944), L. Horberg (1938), and J. C. Bayless (1946-1948). Gardner described the phosphate deposits and mapped the region to the south of the area described in this report. He also worked along the southern boundary of Horberg's area. Horberg worked to the north and northeast in the Teton Range and Bayless is at present working in the Big Hole Range to the west. Little work has been done in the Teton Basin.

GEOGRAPHY

Topography

The elevations in this locality range from 6250 feet at the edge of the Teton Basin to approximately 9000 feet on Oliver Peak. Almost all of the area is in steep slopes. Massive limestone beds, conglomerates, and occasionally fault breccias uphold the main ridges.

Climate

The climate is semi-arid, with rainfall averaging 14 to 16 inches; and temperatures averaging 60 to 66 degrees in July and 16 to 18 degrees in January. Summer nights are cool, and days often are very warm. Thunderheads are common and convectional showers, often bringing hail, frequently occur in the late afternoon. During late August frost often appears during the night. The remnants of snow avalanches were observed on the shady sides of the mountains during August and occasionally produced minor U-shaped valleys.

Drainage and Water Supply

The Teton River, flowing northwestward into the Teton Basin, is the largest stream in the area. Flowing into it out of the north facing canyons are several small youthful streams. Of these only Burbank Creek, West Burbank, Stateline, Mike Harris, and Pole Canyon Creeks are permanent. The other streams marked in this area on the Driggs sheet were found to be intermittent.

Many springs, both permanent and intermittent, exist in the area and are located mainly along the Burbank fault zone. They supply an adequate amount of water for both sheepherders and stock during the months of summer grazing. The water from Sherman Spring, from which Warm Creek flows, issues from a fault plane. It is the largest spring in the area and the water from it is considerably warmer than that from any of the others. Local ranchers report that Warm Creek does not freeze during the winter.

Vegetation

The following is a list of the common trees of the Targhee National Forest.

Ponderosa Pine - - - - - - -	Pinus ponderosa
Douglas Fir - - - - - - - - -	Pseudotsuga taxifolia (Poir) Britton
Lodgepole Pine - - - - - - -	Pinus contorta Dougl.
Englemann Spruce - - - - - -	Picea engelmanni (Parry) Engelm.
Alpine Fir - - - - - - - - - -	Abies lasiocarpa (Hook.) Nutt.
Limber Pine - - - - - - - -	Pinus flexilis James
Whitebark Pine - - - - - - -	Pinus albicaulis Engelm.
Mountain Mahoganies - - -	Cercocarpus ledifolius (Nutt.).
Western Red Cedar - - - -	Thuja plicata D.
(Giant Arborvitae) - - -	" " "
Rocky Mountain Juniper - -	Juniperus scopulorum Sarg.
(Common Juniper) - - - -	" " " "
Quaking Aspen - - - - - - -	Populus tremuloides Michx.
River Birch - - - - - - - -	Betula occidentalis L.

Of these only Douglas fir, lodgepole pine, Engelmann spruce, and Ponderosa pine are used commercially. Large stands of timber are located on the north and east sides of the mountains while the southern and western slopes are largely covered with sagebrush or low flowering plants. On the northern slopes in the vicinity of Burbank and Mike Harris Creeks large areas of fallen timber were observed. According to local ranchers this resulted from a severe windstorm several years before.

Very little grass was seen except on the Mike Harris Flats at the mouth of that Canyon. Here grass grew in sufficient quantity to permit the grazing of cattle.

Culture

Victor, Idaho, population 200, is the only town close to the area mapped. A few families live on the margin of the Teton Basin. Some abandoned cabins were found in the canyons on the mountain slopes.

The local population is occupied by hay and dairy farming, the manufacture of Swiss cheese, sheep herding, and lumbering. The U. S. Forest Service provides stock driveways through the Targhee National Forest to the mountain pastures. Although the number of sheep which may be grazed is regulated by the Forest Service overgrazing is prominent in some localities south of the divide.

Lumbering in the Targhee Forest is permitted on a sustained yield bases; the local ranger marks the trees that may be felled.

Certain experimental work is being carried on by the Forest Service within the area. Plantings of lodgepole pine at the northern end of Mike Harris Trail have been made in order to determine the effect of spacing on the diameter growth of the pines. The effect of grazing on the second growth of grass is also being studied by the comparison of grass of grazed land with the ungrazed grass of protected test plots. One such plot is located along the Mike Harris Creek about one-half mile south of the Teton River. Work was also carried on during the summer of 1948 to eliminate the "Mountain Pine Beetle." According to the local ranger, satisfactory results were obtained.

REGIONAL GEOLOGIC SETTING

During the Paleozoic, the Cordilleran geosynclinal seas spread over western United States with the northeastern shelf zone comprising what is now the Gros Ventre Mountains. This same situation held during the Mesozoic era when the Rocky Mountain geosynclinal basin occupied the eastern half of the Cordilleran area. In both eras the northern Snake River Range lay in the transitional zone between shelf and trough.

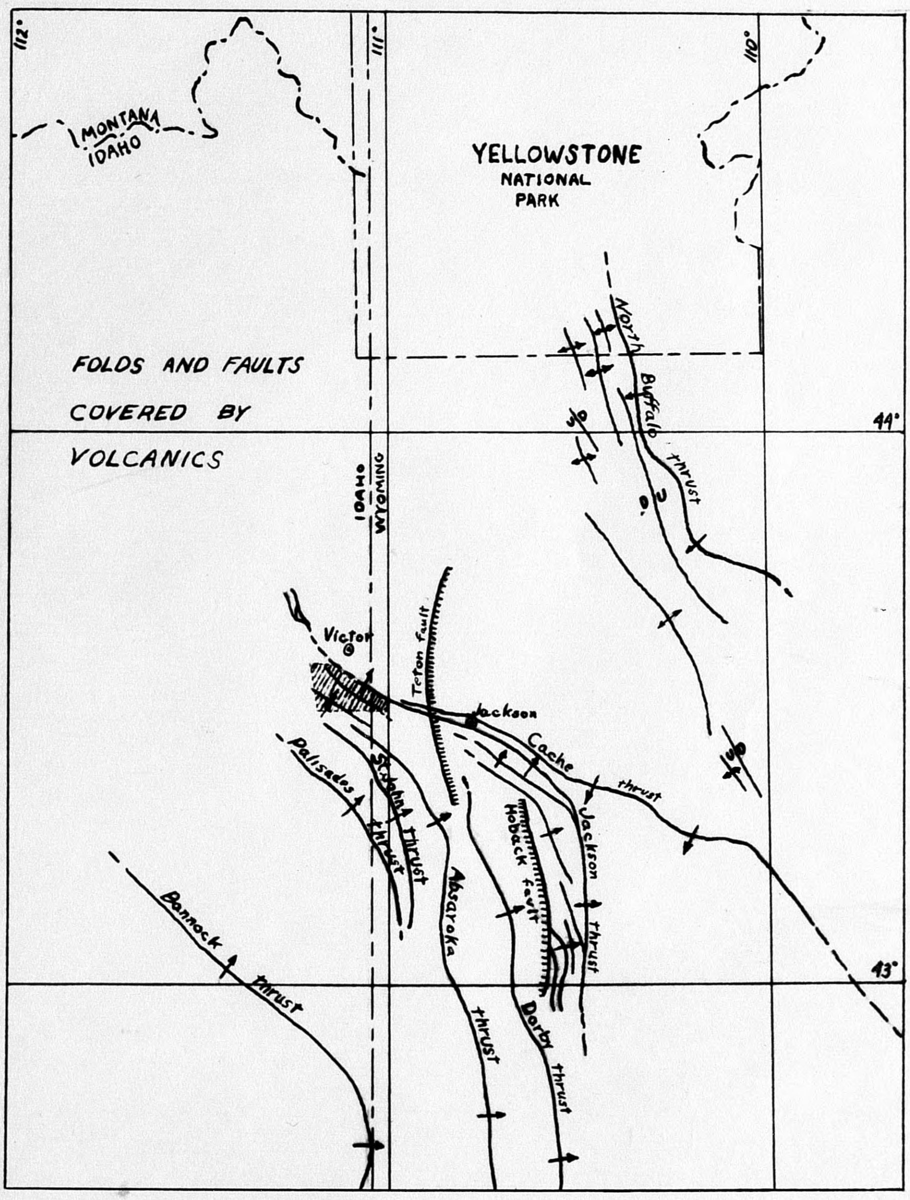
As expected, the sedimentary series is found to be of intermediate thickness in the northern Snake River Range. In the Gros Ventre Mountains, a foreland zone, the total sequence of Paleozoic and Mesozoic formations equivalent to those in the northern Snake River Range is 8760 feet (Foster, 1946); the total section for the northern Snake River Range is 14,494 feet; a generalized section for the trough zone of deposition averages 39,500 feet (Mansfield, 1927-A, pp. 48-52).

The structures of the trough zone are characterized by low angle thrust faults of great horizontal displacement such as the Bannock (Mansfield, 1927-B, p. 150), St. John's (Kirkham, 1924), Absaroka (Mansfield, 1927-B, p. 381), Darby(Horberg, 1938, p. 38) and the Jackson thrust. The relationships of these thrusts are shown on plate two. Movement on these thrusts was northeast with displacement as much as 35 miles on the largest thrust , the Bannock. Considerable folding accompanied the thrusting, locally shortening the earth's crust 48% (Mansfield, 1923, p. 283).

The structures of the foreland facies where deposition was thinner are characterized by high angle thrust faults involving the entire strati-

REGIONAL TECTONIC MAP

MODIFIED AFTER EARDLEY AND BAYLESS



graphic column from pre-Cambrian to Cretaceous. The principal movement is upward and toward the southwest with breaks probably occurring along the pre-Cambrian structures. An example of this type of structure is the Cache thrust (see plate 2) the trace of which roughly parallels the Jackson thrust, the two being only a few hundred feet apart at Teton Pass.

Another type of regional structure is the block fault. The Teton, Hoback, and Snake River faults exemplify this type of structure. Their strike is approximately due north. The origin of these faults is commonly believed to be similar to Basin and Range structure, i. e. normal faults due to tension and collapse. The Tetons themselves are a large block faulted mass, bounded on the east by the Teton fault.

STRATIGRAPHY

General Statement

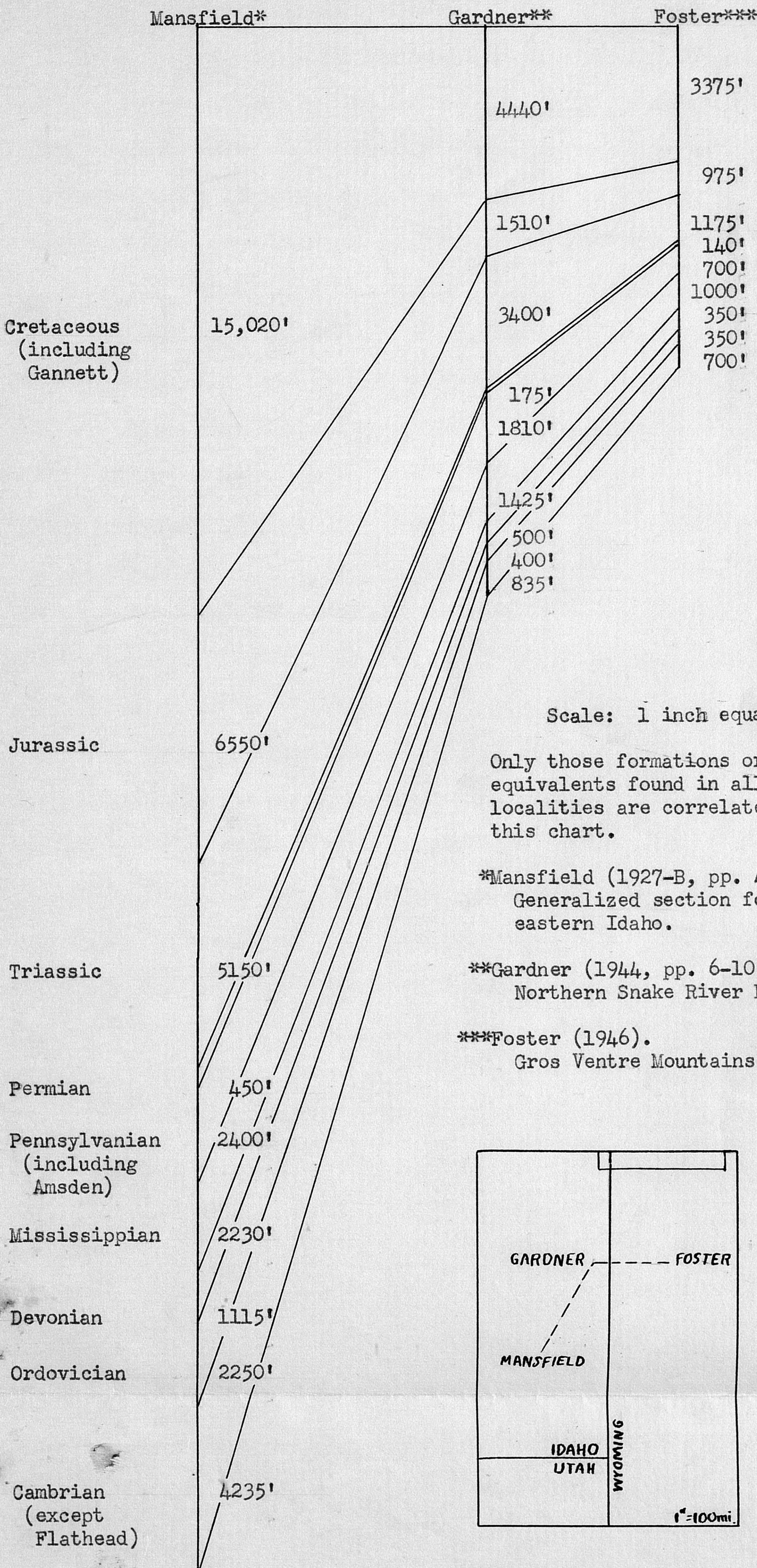
In the area covered by this report all formations from the Cambrian Gros Ventre to the Cretaceous Frontier are exposed. For the sake of presenting a complete picture, this report includes a description of the complete column of the region.

Most of the formations are so highly folded and faulted that it is difficult to measure true thicknesses, and time was too limited for the detailed studies necessary. The thicknesses given for the formations are those given by Gardner (1944, pp. 6-10), modified slightly by the present writers. The thicknesses in Gardner's report were measured in six different localities all about five miles south of the area described in this paper. In most cases the figures of Gardner have been revised downward because the formations generally thin to the north of Gardner's area as the edge of the basin of deposition is approached. (see correlation chart).

Pre-Cambrian Rocks

The peaks of the Teton Range which lie immediately to the northeast of the area described in this paper are composed of pre-Cambrian (probably Archean) gneisses, granites, and schists intruded by pegmatite and diabase dikes. This crystalline complex underlies the Paleozoic sediments on the western slope of the Teton fault block and, although no outcrops were found in the area of this report, undoubtedly a similar complex here underlies the Paleozoics.

CORRELATION CHART



Scale: 1 inch equals 3500'

Only those formations or their equivalents found in all three localities are correlated on this chart.

*Mansfield (1927-B, pp. 48-52). Generalized section for southeastern Idaho.

**Gardner (1944, pp. 6-10). Northern Snake River Range

***Foster (1946). Gros Ventre Mountains

Cambrian System

Flathead quartzite. - The Flathead quartzite (Middle Cambrian) was named by Peale (1893, p. 20) for exposures in the Flathead Pass, in the northeastern corner of the Threeforks quadrangle in Montana. It overlies the pre-Cambrian rocks almost everywhere that it is exposed in Montana, western Wyoming, and southeastern Idaho. It is a white to pink to tan quartzite containing locally a basal conglomerate and a hematitic and glauconitic transition into the overlying Gros Ventre formation. In the vicinity of Teton Pass it is approximately 250 feet thick. The Flathead quartzite is not exposed in the area studied by the authors.

Gros Ventre formation. - Blackwelder (1918, p. 417) named the Gros Ventre formation of Middle Cambrian age. The type locality is on the west slope of Doubletop Peak in the Gros Ventre Range. The Gros Ventre formation is about 800 feet thick in the Teton Pass area and in most places rests conformably on the Flathead quartzite. It is made up of three members, lower and upper shales and a persistent limestone which separates these members. The lowermost shale is known as the Wolsey shale, so named by Weed (1899) for exposures in the Fort Benton section of Montana. It is composed largely of a fine grained grey-brown shale which weathers to a rusty brown. It is poorly bedded and contains thin beds of oölitic, hematitic sandstone. Good exposures are rare because the soft shale erodes easily and the beds are generally concealed by soil and vegetation.

The Death Canyon limestone was named by Miller (1936, p. 12) from exposures in Death Canyon in the Teton Range. This member is composed of about 200 feet of fine to coarsely crystalline limestone. It is generally dark grey in color and weathers to a light cream colored grey. Red and yellow mottling and streaks of yellow were observed on this limestone. The streaks were found to be roughly parallel to bedding and it is suggested that they may represent layers of silt, included in the limestone at the time of deposition, which are weathering out leaving a pitted surface. This pitted surface is often characteristic of the Death Canyon limestone. In some places the yellow coloring was due to limonite stains on the surface. The Death Canyon limestone, especially in Mail Cabin Canyon in the extreme eastern portion of the area, contains several beds of intraformational conglomerates.

The upper member of the Gros Ventre formation, the Park shale, was named by Weed in 1899 from outcrops in Montana. It is composed of a dark grey-green micaceous shale and contains several thin beds of flat pebble conglomerate.

In this area the Gros Ventre formation is largely exposed along Burbank and West Burbank Creeks. This formation is also found in the Wind River, the Gros Ventre, and the Teton Ranges of Wyoming, in northern Utah, and as far north as the Fort Benton Quadrangle of central northern Montana.

Boysen limestone. - The upper Cambrian Boysen limestone (Gallatin) was named by Deiss (1938, p. 1104) from outcrops in the Wind River Canyon.

The Boysen is about 200 feet thick and is composed largely of massive dark bluish-grey limestone with considerable red and yellow mottling at or near the surface. It is suggested that these may be hematite and limonite stains on silt streaks which are weathering out to leave a pitted surface. The formation is cut in many places by calcite veins which are up to one-fourth inch across and in many places the crystals in these veins are interlocking or show a comb structure. Petrographic studies by Newcomb reveal that a few of the veins are composed of fine-grained limonite, and finely disseminated organic matter was found throughout the main mass of the limestone. Aside from veins, crystalline crusts and coatings of calcite were also seen in hand specimens. Locally there were hollow tubes which suggested possible stalactites and former cave fillings. The limestone is locally highly jointed and usually forms large, angular talus. Except for its position in the stratigraphic column, the Boysen limestone is almost impossible to distinguish from the Death Canyon limestone.

Thin sections of massive Boysen limestone reveal that the matrix is largely made up of granular calcite and contains concentric oölites which are not visible in hand specimens. The cores of some of these oölites are rhombs or angular fragments of calcite. Yellow veins of dolomite rhombs with limonite coatings and growth rings were also seen in this thin section. The intersticies between the rhombs are filled by limonite and massive calcite.

According to Boeckerman (1949), whose thin sections were used for this report, these dolomite rhombs may indicate dolomitization is taking place. This dolomitization is probably very irregular and local. Although there was no dolomite found in the specimens collected in the area described in this report it seems logical to assume that the same dolomitization may be taking place locally.

Two types of Boysen limestone were found - the massive specimen described in the preceeding paragraph and oölitic limestone in which the oölites were visible in a hand specimen. In this type, Boeckerman (1949) has found that the oölites are made up of radiating crystals of calcite and no concretionary structures were present, or at least not observed in thin section. In this way the oölites which are observable only in a hand specimen differ from those seen only in thin section studies. The cleavage of the calcite in these oölites creates a herring-bone type of pattern and the oölites are largely calcite coated. The intersticies between the oölites are filled by limonite, massive and crystalline calcite.

The Boysen is best exposed along the northward facing slopes between the eastern boundary of the area and Stateline Canyon. Just west of this canyon it disappears under the Tertiary volcanics. The Boysen, formerly called the Gallatin limestone, is also found in southern Montana and north-western Wyoming.

Ordovician System

Bighorn dolomite. - The Bighorn dolomite was first described by N. H. Darton in 1904 (pp. 394-401), from its type locality on the eastern side of the Bighorn Mountains in Wyoming.

The Bighorn dolomite is a massive light grey to cream colored dolomite which weathers locally light yellowish or to a darker grey. On freshly fractured surfaces it appears mottled with a dark grey cloudy pattern. There is some chert present in irregular horizontal lenses which may, on weathering out, leave a pitted surface usually found in this formation. It is suggested by Schultz (1918) that the pitting may also be due to porosity differences and to the manner in which the particles may be cemented. The Bighorn dolomite is a massive cliff former in the area and weathers to form coarse, blocky talus. Locally it contains small veins of massive and crystalline calcite.

In this area the Bighorn is best exposed parallel to the northeastern margin of the area between the eastern boundary and Stateline Canyon. Besides its location in the Bighorn mountains, the Bighorn dolomite is also found in the Bighole Mountains, the Teton, Salt River, and Gros Ventre Ranges of Wyoming and extends northward into Montana.

Silurian (?) System

Leigh formation. - The Leigh formation of possible Silurian age was named by Blackwelder in 1913. It includes the upper 30 to 40 feet of dense, thin, brittle light-grey to white limestone which was formerly considered to be the upper member of the Bighorn dolomite (Ordovician). Fossil evidence found near the base of the Leigh beds in the Glory Mountain area have been identified by Professor E. C. Case (Foster, 1946, p. 35) as upper Silurian or lower Devonian. Until more fossil evidence is found the exact age of the formation will remain in doubt.

Devonian System

Darby formation. - The Darby formation of Devonian age was named by Blackwelder in 1918 (p. 420) from outcrops along Darby Creek on the western slope of the Teton Range. In most places it rests disconformably on the Leigh formation and is about 350 feet thick. The Darby can be correlated with Peale's Threeforks shale and Jefferson limestone in Montana.

The Darby formation is composed of thin interbedded limestones, dolomites, shales and siltstones which are largely of a dark yellowish brown color. The limestones have a distinct petroliferous odor especially when freshly struck with a hammer. The Darby formation is not well exposed in the area of this report but is found to roughly parallel the Bighorn dolomite in the northeastern portion of the area.

For convenience in mapping, the Leigh and Darby formations were considered as a unit. This was done because the contact between the two formations could not be found and distinct outcrops of the formations were missing. For these reasons, and because the Leigh may be lower Devonian, the Leigh and Darby formations were mapped together as a Devonian unit.

Mississippian System

Madison limestone. - The Madison limestone was named by Peale (1893, p. 32) from an exposure in the Madison Range in the Threeforks Quadrangle in Montana. The formation is widespread in Wyoming, Montana, Idaho, and northern Utah.

The Madison is lower and middle Mississippian in age and is a prominent cliff former in the area. It is a dense blue-grey limestone which weathers light grey and sometimes shows a pitted surface. With the overlying Brazer limestone it totals about 1400 feet in thickness. For the most part it is massive, but the lower 250 feet is often thin bedded (beds up to three inches thick) and is referred to as the Lodgepole member (see figure 1). Near the base of the formation red and yellow mottling is often observed although none was seen higher up in the section. The Madison is highly faulted and the odor of hydrogen sulfide can be readily detected when a sample obtained

Figure 1. Madison limestone (Lodgepole member) in Pole Canyon.

from along a fault is struck with a hammer. Stalactites and Calcite crusts were found in several localities and probably indicate former cave fillings.

Petrographic work by Newcomb reveals that dark grey chert nodules are found in the limestone and that associated with these was some degree of dolomitization. Dolomite often occurred as rhombs in the chert. Black chert nodules found near the top of the section are probably in the Brazer limestone.

Near the lower end of Mike Harris Trail, where the Madison is in contact with Tertiary volcanics a zone of marble about three inches thick was found. This was very coarsely crystalline with crystals varying in color from light to dark grey. Because no silicate minerals were found by petrographic methods, it appears that the alteration of the limestone to marble was due to simple metamorphism.

Near the base of the Madison in Mike Harris Canyon a horizon at least ten feet thick of massive yellow tan calcareous silt was observed. Microscopic examination showed that the silt contained rounded grains of calcite and quartz. A few grains of hematite and garnet were also found and the yellow color of the silt is due to limonite. Further studies of the specimens from this locality show plagioclase feldspar of the approximate composition of oligoclase and brownish-black celestite. Abundant organic matter occurred within the crystals as inclusions.

Two types of breccia were observed in the Madison. A fault breccia was seen on the ridge west of Burbank Creek. The Madison fault breccia is dark grey, crystalline, very rough on the surface, and is limonite stained. It contains mainly angular fragments of limestone and chert and forms extremely resistant cliffs.

Within the Madison there is a breccia composed largely of light colored limestone fragments in a darker colored limestone matrix. The surface is smooth and is not limonite stained as in the fault breccia. It is suggested that this breccia may have been formed contemporaneously with the deposition of the formation. According to Lamont (1941) breccias are easily formed in partially consolidated sediments. When interbedded sediments in the process of becoming consolidated are disturbed by some shock, such as a seismic sea wave, the sediments will be disturbed and fall together into a large, heterogeneous mass. The more consolidated particles in the sediments will form the fragments within the breccia and the finer particles which were less consolidated at the time of disturbance will form the matrix. From evidence in breccias along the Irish coast, Lamont states that this appears to be a fairly common occurrence in near shore areas. Because the Madison-Brazer limestones were deposited in a near shore zone, it seems logical that the included breccias may have been formed in this way.

Fossils found in the Madison-Brazer limestones include Penniretepora sp., Productella sp., Archimedes sp., Pleurodictyum sp., and Trilophyllites sp. According to Mr. Walter Wheeler the above are new and undescribed species and Penniretepora sp. and Archimedes sp. have not previously been reported in the Madison-Brazer formations.

Brazer limestone. - The Brazer limestone of upper Mississippian age was named by Richardson (1913, p. 407). It lies conformably on the Madison limestone and in most cases the contact between the two cannot be identified. Because this contact is almost impossible to find and because the Brazer limestone is almost identical in lithology to the Madison the two formations were mapped as a unit. The Brazer contains the same two breccias whose descriptions are given in the paragraphs concerning the Madison and the fossil content, as near as could be determined, was the same. The thickness of the Brazer limestone is also included with the Madison.

Pennsylvanian system

Amsden formation. - The Amsden formation was named by Darton (1904, p. 394-401) for its type locality on the Amsden Branch of the Tongue River, west of Dayton. Horberg (1938, p. 17) considers the Amsden to be the lower part of the Wells formation, so named by Richards and Mansfield in 1912 (p. 689) for exposures in Wells Canyon, Bannock County, Idaho. The Wells formation of Idaho includes the Amsden and overlying Tensleep (Pennsylvanian) formations of Wyoming and corresponds to the Quadrant formation of Montana. The Amsden has generally been regarded as Pennsylvanian but fossil evidence found recently indicates that the lower part of the formation may be upper Mississippian.

The Amsden formation is approximately 710 feet thick and consists largely of interbedded dark grey limestone, red to brown shales, and the Darwin sandstone, a prominent series of sandstones named by Blackwelder (1918, p. 422) for an exposure on Darwin Peak in the Gros Ventre Range. Three sands are recognizable in the Darwin series. The lower sand is dark red, sandy and friable and contains rounded grains of quartz. The middle member is composed of pink to light tan quartzitic sand and the uppermost member is white quartzitic sand. These beds are persistent and form good marker beds in the area. A fault breccia is also recognizable in the Wells formation and fragments of Darwin sandstone were found in the breccia. The Amsden and Tensleep fault breccia was formed by the Burbank fault and is well exposed at the top of the ridge southeast of Burbank Creek. The Amsden and Tensleep fragments are cemented together with a white quartzitic sandstone and form large resistant monoliths.

Dark red chert is characteristic of the Amsden formation and red and grey agate and small geodes are also common throughout the formation. On the ridge just east of Mikesell Canyon, where the Amsden is exposed along the Burbank fault hematite and limonite stains are common.

Petrographic studies show that the hematite stains found in the Amsden formation occur as growth rings on the surface of secondary quartz. This quartz is euhedral and in some of the cavities is large enough to be seen with a hand lens. Yellow stains found in the Amsden formation are limonite coloring on secondary quartz.

Fossils found in this formation include Caninia sp., and Syringopora surcularia. The latter is especially abundant in the red chert zones.

Tensleep formation. - The Tensleep was named by Darton in 1904 (pp. 394-401) from an exposure in the walls of the lower canyon of Tensleep Creek. The Tensleep overlies the Amsden and is considered by Horberg to be the upper member of the Wells formation.

The Tensleep consists of light tan to pink quartzite and sandstone and weathers to a darker pink or tan. It is fine-grained and shows violet to dark purple laminations locally. The Tensleep weathers to form large, blocky talus. As in the Amsden, the fault breccias in this formation also remain as prominent monoliths.

Locally the Tensleep contains numerous small garnets. Optical properties show that most of these have been almost completely altered to hematite and quartz, but the crystal outline remains very indicative of garnet.

Permian system

Phosphoria formation. - The Permian Phosphoria formation was named by Richards and Mansfield (1912, p. 683-689) from its type locality in Phosphoria Gulch, which joins Georgetown Canyon northwest of Meade Park, southeastern Idaho. The formation extends into eastern Idaho, central and southern Montana, western Wyoming, and northeastern Utah where it is called the Park City formation.

The Phosphoria is approximately 170 feet thick and consists of two members. The lower member consists largely of phosphatic shales and the upper member is the Rex Chert. The lower phosphatic shale member is composed of non-resistant black to grey shales and brown to grey limestones and siltstones. The main zone of economically important phosphate rock occurs near the base of this member.

The Rex chert member is present in the area described in this report and is best exposed along the divide at the head of Mikesell Canyon. Here it consists mainly of cherty dolomite and limestone and contains some layers of sandstone and shale near the top. No layers of chert were found. This is largely a transition zone between the chert beds found in the Rex chert in Wyoming and the coarse grained sandstones found to compose this member in the Bighole Range.

A petrographic study of specimens of the sandstones from the Rex chert revealed that a small amount of brown chert and a minor amount of volcanic glass are present. The main body of the material is made up of very small rounded to very angular particles of quartz and contains much carbonaceous material. Iron stained quartz grains and a moderate amount of alkali feldspar are present. Abundant chloritic material, probably due to the weathering of biotite, was found as well as zircon, which is present as a heavy detrital.

Triassic system

Dinwoody formation. - This formation was named by Blackwelder (1918, p. 425) from an exposure at Dinwoody Creek on the northern slope of the Wind River Range.

The Dinwoody consists of 750 feet of buff to light tan siltstones and shales and brown limestones. It usually weathers to a dark brown but locally may weather light grey. A few zones of dendrite were observed on unweathered surfaces.

Microscopic examination of this formation showed that it is largely made up of quartz fragments with chert varying from colorless to black present in small amounts. Minor quantities of alkali feldspar, hematite, limonite, and chlorite were also observed.

No fossils were found in the Dinwoody in this area, but usually present is an upper Lingula zone and a lower Claria zone.

The Dinwoody is best exposed in this area along the divide at the head of Stateline Canyon and is also well defined in Western Wyoming.

Woodside formation. - The Woodside formation of Triassic age was named by Boutwell (1907, p. 439-458) from exposures at Woodside Gulch, Park City District, Utah.

Figure 2. Jurassic section west of Pole Canyon. Jg, Gannett; Js, Stump; Jt, Twin Creek; Jn, Nugget; Ra, Ankareh; Rth, Thaynes.

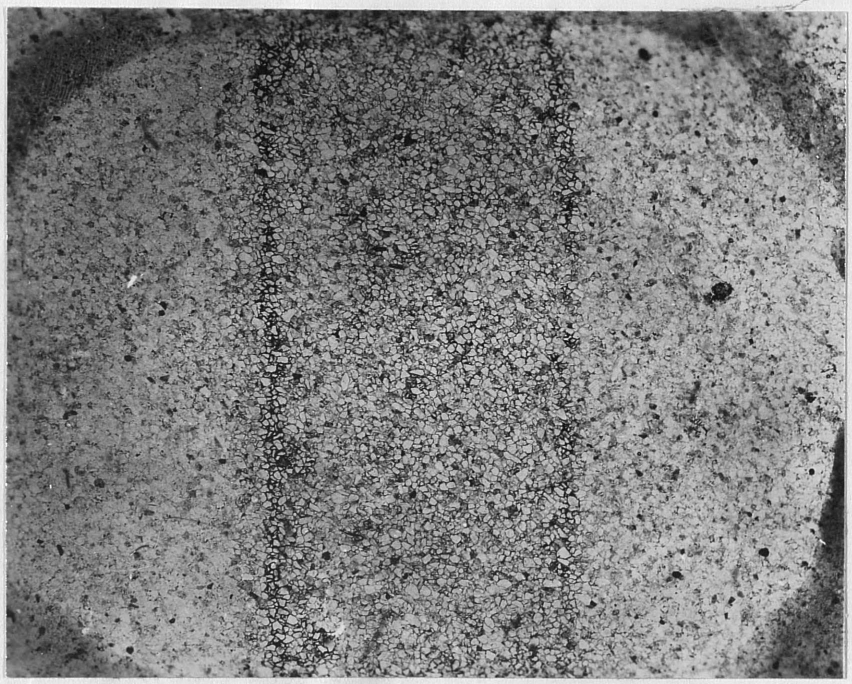


Figure 3. Band of hematite in Nugget sandstone from ridge south of Burbank Creek. (9.5 diam.)

This formation consists of about 1100 feet of fine-grained thinly bedded dark red shales and reddish-orange siltstones. Upon weathering a darker red color appears. Locally calcite coatings and small calcite veins were observed.

In this area the Woodside is well exposed on the southern slope of Oliver Peak. Regionally it is also found in northeastern Utah, and southwestern Wyoming.

Thaynes formation. - The Thaynes formation (see figure 2) was named in 1907 by Boutwell (pp. 439-458) from outcrops in Thaynes Canyon in the Park City District of Utah. It is also exposed in southwestern Wyoming and southeastern Idaho.

This formation consists largely of thin bedded grey to light tan or buff colored siltstones and limestones. In the adjoining area to the south Gardner (1944, p. 8) measured 1000 feet of the Thaynes formation. In this area, in many places, the Thaynes is generally much thinner due to faulting. It is readily observed north of the divide at the head of Burbank Creek where it lies between the red shales of the Woodside formation and the maroon siltstones of the overlying Ankareh formation.

Thin section studies of the Thaynes show that the main constituent is quartz, about one percent being chert grains. Also present in small and about equal quantities are calcic plagioclase, microcline, and orthoclase. Minor amounts of sericite, chlorite, sphene (with leucoxene as an alteration product), zircon, tourmaline (showing green and blue zoning), apatite, and small garnets were also observed. The cementing material is limonite. Sorting is excellent with grains being about

.04 millimeters in diameter. Fragments are, for the most part, angular and very slightly interlocking. Both the quartz and garnet grains show a slight degree of rounding.

Ankareh formation. - The Ankareh formation (see figure 2) was also named by Boutwell, (1907, pp. 438-458) from exposures along Ankareh Ridge in the Park City District, Utah. The Ankareh is also well exposed in areas of southwestern Wyoming. In 1907 Veatch used the name Nugget sandstone (see below) for these beds plus those now assigned to the Nugget. The term Ankareh was redefined by Gale and Richards (1910, p. 479-480) to include only the dark red and maroon siltstones and shales which lie between the sandstones of the Nugget formation and the buff colored limestones of the Thaynes. The term Ankareh is used on this basis in this report.

The Ankareh is distinguished from the Woodside largely on the basis of a darker red color and its stratigraphic position. As measured by Gardner (1944, p. 8) it is approximately 550 feet thick. In this area it appears much thicker due to crumpling and shearing.

Jurassic system

Nugget sandstone. - The Nugget sandstone (see figure 2) was named by Veatch (1907, p. 56) from its type locality at Nugget Station on the Oregon Short Line in southwestern Wyoming.

The Nugget consists of about 325 feet of buff to pink and red fine-grained massive sandstones. These sandstones are usually quartzitic in areas where orogenic movements have occurred. Locally red and white quartzitic sands are mixed in hand specimens. The exposure on the ridge south of Burbank Creek contains rings, streaks, and bands of specular hematite which contrast sharply with the adjacent rock. (see figure 3). The hematite appears to be more concentrated along the edges of these bands which vary in thickness from one-eighth to two inches. The origin of these markings has not been determined.

The Nugget forms coarse, angular talus which weathers black.

Thin section studies of the Nugget sandstone show that the main body of the rock is composed almost entirely of quartz with other constituents making up about two percent of the rock. The minerals included in this two percent and their approximate percentages are listed as follows:

chert	44%
magnetite	15
orthoclase . . .	12
plagioclase . . .	10
microcline . . .	9
tourmaline . . .	6
zircon	1
sphene	1

The tourmaline found in the Nugget shows the same green and blue markings and zoning that was present in the Thaynes tourmaline. The pink color often characteristic of the Nugget is caused by finely disseminated red hematite.

The sorting in the Nugget is good with fragments varying from sub-angular to sub-rounded, the feldspars being more angular than the quartz grains. The grains are approximately .08 millimeters in diameter.

In this area the Nugget sandstone is well exposed at the top of the ridge east of Pole Canyon (Station 39 of the Hayden Survey) and along the divide at the head of Burbank Creek.

Twin Creek limestone. - The Twin Creek limestone (see figure 2) was named by Veatch (1907, p. 56) for exposures on Twin Creek between Sage and Fossil, southwestern Wyoming. As used in this report the name Twin Creek includes the grey and red limestones and shales which were considered by Gray (1946) to be a separate formation (the Gypsum Springs) underlying the Twin Creek.

The Twin Creek consists of about 950 feet of interbedded dark to medium grey limestones and shales which weather to a light grey or cream color. Resistant calcite veins are abundant and the limestones are locally stained with limonite.

Local zones of Gryphea calceola nebraskensis, Pentacrinus columnals, Aucella sp., and Astarte cf. meeki have been identified. According to Gray (1946, p. 47) Astarte is probably in the Gypsum Springs formation.

Petrographic work shows that the dark grey color often observed in the Twin Creek limestones appears to be caused by an abundance of organic material.

In this area good exposures of the Twin Creek can be found immediately south of the divide below the aforementioned Nugget exposure.

Preuss sandstone. - The Preuss sandstone (see figure 2) of Jurassic age was named by Mansfield and Roundy (1916, p. 76-81) for exposures on Preuss Creek in the northeastern part of the Montpelier quadrangle about 12 miles northeast of Montpelier. The formation is best exposed in areas of southeastern Idaho, but also appears in western Wyoming.

The Preuss consists of about 50 feet of red and maroon interbedded sandstones, siltstones, and shales. Good exposures were entirely lacking in this area, but traces of it could be seen occasionally in float. For these reasons and because both the Preuss and overlying Stump formation are upper Jurassic in age, these formations were mapped together for this report.

Stump sandstone. - This sandstone was named by Mansfield and Roundy (1916, p. 76, 81) for Stump Peak at the head of Stump Creek, near the center of T. 6 S., R. 45 E., Boise Meridian.

The Stump is composed largely of greenish grey fine-grained calcareous sandstones which weather to a brownish grey. Near the top of the formation a bluish-grey limestone can be seen in some localities. It is estimated by the writer that about 125 feet of Stump are present in this area. A good exposure can be seen along the trail in Pole Canyon just north of the divide.

Cretaceous system

Gannett group. - The Gannett group of Cretaceous (?) age was named by Mansfield and Roundy (1916, p. 76, 82-83) for the Gannett Hills in Bannock County, Idaho and Lincoln County, Wyoming. They are located in the eastern portion of the Wayan quadrangle. At its type locality at the above location it is composed of five distinct members which are, from bottom to top, the Ephriam conglomerate, the Peterson limestone, the Belcher conglomerate, the Draney limestone, and the Tygee sandstone. Because these members were, for the most part, not distinct in the area mapped for this report the Gannett group was mapped as a unit. The Gannett formation correlates with the Cloverly formation of central and eastern Wyoming and the Morrison formation of Colorado and Wyoming.

The Gannett is about 900 feet thick and on Fogg Hill near the southern boundary of the area the Ephriam (?) conglomerate stands up in 100 foot cliffs resembling battlements on a medieval castle (see figure 4). Here the conglomerate contains coarse to very fine pebbles of red to purple and maroon limestones (see figure 5). The pebbles vary in size from one-tenth to two to three inches in diameter. Dark colored chert nodules are common throughout the conglomerate and are usually dark purple, dark blue or black, but some nodules are light grey, and orange colors were often observed. The conglomerate weathers to a reddish-brown color and is locally stained with limonite. The matrix of the conglomerate is quartzitic and varies from light grey to cream colored and is limonite stained. Although the pebbles vary in thickness and size there are usually horizons in the conglomerate of approximately the same size pebbles (see figure 5). Slickensides (see figure 6) are common throughout the conglomerate and apparently faulting has taken place within this member. Cross bedding is apparent in the quartzite near the lower part of the conglomerate.

On the eastern side of Fogg Hill good exposures of light grey limestone and maroon to red shales of the Gannett group can be seen. Along the divide at the head of Pole Canyon beds of lithographic limestone of approximately 100 feet in thickness stand out as resistant beds (see figure 7). Gastropods contained in these limestones indicate that this may be the Peterson limestone member of the Gannett group.

Figure 4. Cliffs of Gannett conglomerate on Fogg Hill. (Note person near center of photo for scale).

Figure 5. Pebble horizons in Gannet conglomerate on Fogg Hill. (Lighter part of outcrop consists of fine pebbles; darker part consists of coarser pebbles).

Figure 6. Slickensides in Gannett conglomerate on Fogg Hill.

Figure 7. Lithographic limestone of the Gannett group along the divide at the head of Pole Canyon.

Thin sections of the Gannett conglomerate show that the material is about one-half quartz and one-half chert. The quartz grains are about one-third of a millimeter in diameter and the chert forms the larger particles. The chert ranges from very fine-grained chert containing angular sand particles (see figure 8) and sericite to coarse grained chert mixed with chalcedony.

In thin sections one or more large size pebbles of quartzite, devitrified volcanic glass, oölitic material replaced by silica, and chalcedony (see figure 8) were found. Pebbles of these are common throughout the main mass of the conglomerate.

Bear River formation. - The Bear River formation was named by Hayden in 1869 (p. 91, 92) for coal bearing strata near Bear River City, Wyoming. It was first believed to be of Tertiary age, but later Hayden placed it in the Cretaceous.

The Bear River is about 875 feet thick in this area and consists of interbedded black shales, ferruginous sandstones, grey shales, and impure coal beds. Fossils are abundant in the shales and were identified as Pergolifera sp., Campoloma sp., and Ostrea sp.

The Bear River formation is best exposed on the divide southwest of Pole Canyon.

Aspen formation. - The Aspen formation was named by Veatch (1907, p. 64) for exposures near Aspen Station on the old Union Pacific Railroad line in southwestern Wyoming. Along the north fork of Palisades Creek the best exposures of Aspen were seen.

The lower part of the Aspen consists largely of interbedded black shales and arkosic "salt and pepper" sandstones. In the upper Aspen

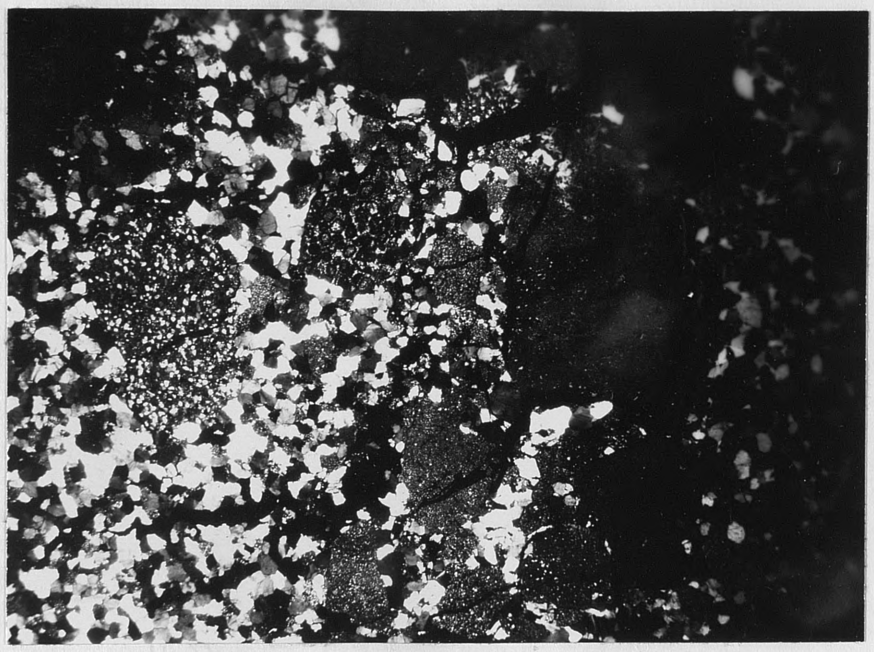


Figure 8. Chert pebbles and oölitic material in the Gannett conglomerate on Fogg Hill. (11 diam.)

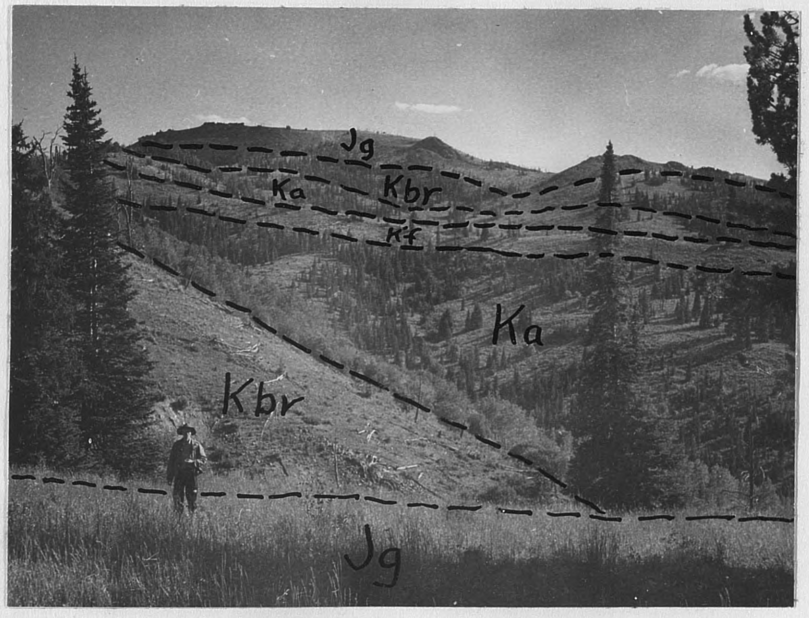


Figure 9. Cretaceous section exposed in fan fold north of Fogg Hill. Jg, Gannett; Kbr, Bear River; Ka, Aspen; Kf, Frontier.

beds shales and siltstones are interbedded with vitrified tuff (Bastanchury, 1947, p. 21) called porcellainite by early workers. These beds occur in a variety of colors, namely red, green, grey, and black and sometimes appear oölitic although thin sections show the glass to be homogeneous. The porcellainite beds are often grey and green spotted.

Frontier formation. - The Frontier formation was named by Knight (1902, p. 721) for exposures near Frontier, in southwestern Wyoming. Veatch (1907, p. 69) places the formation in the upper Cretaceous.

The Frontier formation is approximately 600 feet thick and consists of interbedded greenish grey to buff and brown colored sandstones and shales. It is conglomeratic near the base and contains several thin impure coal beds near the top of the formation. The conglomerate is made up of rounded pebbles not over one inch in diameter in a matrix of brown-speckled white arkosic sand. The pebbles consist largely of purple, pink and black chert and weather out of the less resistant matrix leaving an irregular surface pettern. There is abundant pink feldspar in the matrix of the conglomerate.

A thin section of the Frontier shows that the rock is made up of about equal parts of chert, quartz, and feldspar. The chert varies from fine to coarse-grained and some is limonite stained. The feldspar is about half calcic plagioclase and half orthoclase and is highly altered to kaolinite. Limonite is present as an alteration product. Chlorite altered from biotite and leucoxene altered from sphene also appear in the thin section. Heavy minerals including biotite, sphene, hornblende, zircon, and apatite total about 2 percent of the rock. Of these biotite and apatite are the most abundant; hornblende is the most scarce. The cement in the Frontier is largely chloritic material and chert.

In general, the sorting is average to poor and grains vary in size from one-fourth to one millimeter in diameter. Fragments are, for the most part, sub-angular.

The Frontier is best exposed on the hill halfway between Fogg Hill and the divide at the head of Pole Canyon (see figure 9).

Eocene series

Hoback formation. - The Hoback formation is not exposed in the northern Snake River Range, but is well exposed at its type locality in the Hoback Basin about 35 miles southeast of the area described in this report. The formation was named by Eardley (1944) and is estimated by him to be about 15,000 feet thick. The formation consists of dark grey shales and interbedded arkosic "salt and pepper" sandstones and a few impure fresh water limestones. A few conglomeratic lenses are present. The formation has been placed in the lower Eocene on the basis of invertebrates identified by Kellum (Eardley and Kellum, 1944) and in the Paleocene by John A. Dorr (personal communication, 1949) on the basis of vertebrate remains.

Pass Peak formation. - The Pass Peak formation is not exposed in the area described in this report, but is found in the Hoback Basin. Here it comprises about 2000 feet of coarse red and grey conglomerates which grade toward the top of the formation into sandstones and shales. It has been dated middle Eocene in age by Eardley (1944) and is of importance in dating the Laramide orogenies.

Miocene series

__Camp Davis formation__. - The Camp Davis formation was named by Eardley (1942, p. 1800) for exposures near Camp Davis, Wyoming. Here it is composed of a lower grey conglomerate and an upper red and tan conglomerate which are separated by a fresh water limestone. A horse's tooth dates the formation as upper Miocene or lower Pliocene. This formation does not appear in the area described in this report, but appears in the Calamity Point area about 12 miles to the south.

IGNEOUS ROCKS

Intrusives

__Rhyolite dikes.__ - Dikes of this type occur in the southeastern and central portions of the area along the trace of the Burbank fault. They have been injected into Carboniferous, Permian and Triassic sediments. Rhyolite fragments similar to the dike rocks occur within the pyroclastics near the trace of the Jackson fault. The fragments are angular and vary in size from splinters a half an inch long to pieces an inch and a half in diameter. It is quite probable, therefore, that similar dikes were associated with the Jackson fault but are now covered by alluvium and volcanics.

The dikes are all composed of white porphyritic rhyolite with a felsitic groundmass and glassy phenocrysts (see figure 10). Weathered surfaces may be grey to brown depending on the intensity of chemical alteration. The more weathered portions are brown due to the formation of limonite by the decomposition of biotite.

Microscopic examination shows that the phenocrysts make up about 20% of the rock. These phenocrysts are made up of groups of diversely oriented subhedral to euhedral crystals of quartz, calcic-albite, sanidine, and biotite (see figure 11). Some of the phenocrysts are monomineralic but in general the texture may be called glomeroporphyritic, with a felted micro-crystalline groundmass (see figure 12). The maximum size of the glomerophenocrysts is 6 millimeters. The phenocrysts are roughly 60% quartz, 25% albite, 10% sanidine, and 5% biotite. Much of the quartz is embayed and many of these embayments are partially filled with plumose sericite and chalcedony (see figure 13).

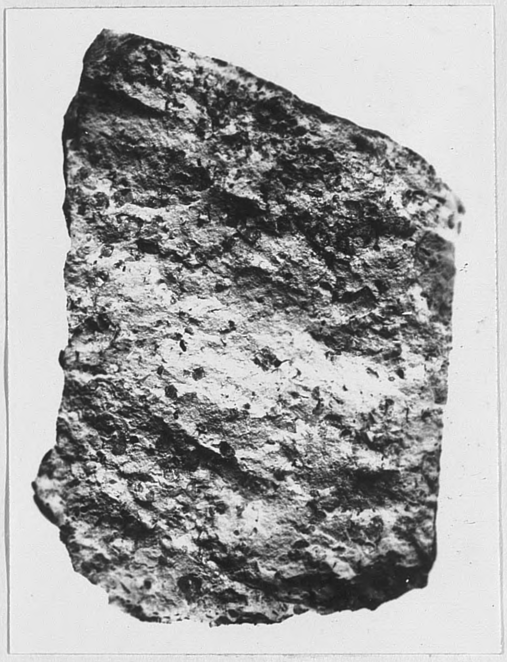


Figure 10. Hand specimen (natural size). The dark spots are the phenocrysts.

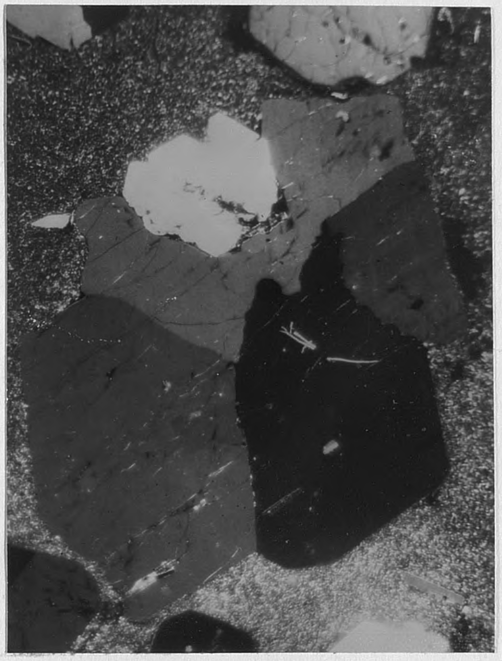


Figure 11. A glomerophenocryst made up of quartz and sanidine. (13 diam.)

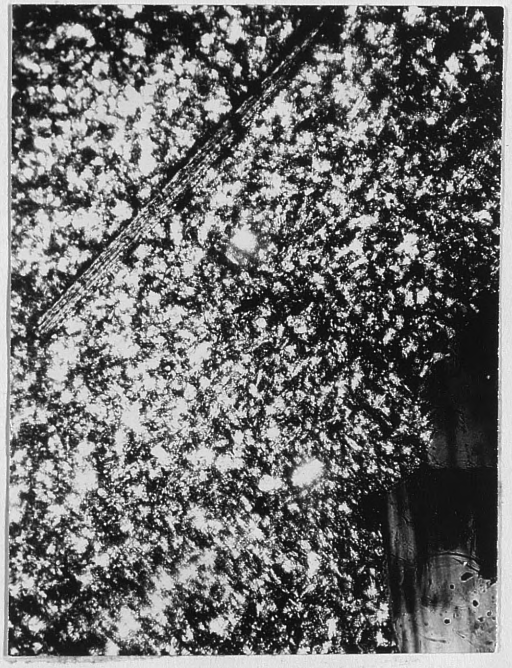


Figure 12. Texture of the groundmass and including plagioclase and biotite crystals. (88 diam.)

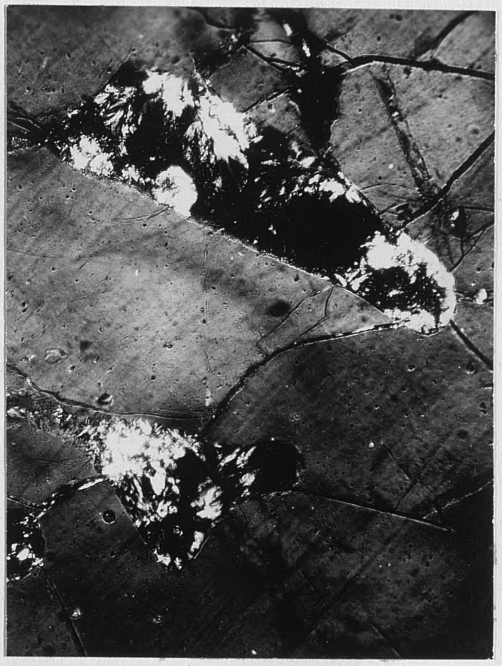


Figure 13. Portion of a quartz phenocryst showing embayments containing sericite and chalcedony. (82 diam.)

The groundmass is composed of about equal parts of quartz and potash feldspar. The feldspar occurs as laths and the quartz is interstitial and anhedral. Sericite and biotite are also found in the groundmass in subordinate amounts.

Pyroclastics

General statement. - The pryoclastic rocks are located in the north and northeastern portions of the area where they unconformably overlie sedimentary rocks and cover the trace of the Jackson fault. They occur between the Paleozoic and Mesozoic rocks of the mountains and the Quaternary alluvium of the Teton Basin.

The material is, in general, rhyolitic in composition and may be divided into two categories: pumaceous tuffs and welded tuffs. Rhyolite rocks containing a similar mineral assemblage occur in surrounding areas. Mansfield (1921) described rhyolitic cone flows, dikes and ash from Bingham and Bannock counties; and Kirkham (1927) described a series of Tertiary late lavas which contained rhyolite flows which are also similar. Rhyolitic rocks are also found in great abundance in Yellowstone Park (Iddings, 1899).

Mansfield and Ross (1935, p. 311) states that

> " . . . the rhyolitic rocks of the mountain ranges in southeastern Idaho tend to thicken and become more conspicuous northeastward toward the Yellowstone area."

This would indicate either, that Yellowstone was the source area for these rhyolites, or, that volcanic activity was more vigorous in regions near to the Park.

Mansfield, also, mentions the rhyolitic cones of the Henry and Cranes Flat Quadrangles and the volcanic buttes of east-central Idaho as possible but probably less adequate sources.

In a personal communication to Mansfield (op. cit. p. 311)

> "Stearns calls attention to the possibility that some of the vents may now be buried beneath the basalt flows of the Snake River Plain. He presents the hypothesis that one of the major sources of silicic flows was a chain of volcanoes extending from Yellowstone National Park towards Boise along the axis of the Snake River."

Similar volcanic activity may have existed within the Teton Basin either as a chain of vents or as erupting fissures.

<u>Pumaceous tuff</u>. - These tuffs occur north of the Teton River, just west of the Idaho-Wyoming state line. They appear to lie unconformably upon Jurassic sediments.

The rock is pink to cream colored, contains glassy phenocrysts and possesses a fragmental texture (see figure 14). The specific gravity is very low and the rock is only slightly resistant to abrasion. Unaltered rounded pebbles of sandstone up to 3/4 of an inch in diameter and altered limestone pellets up to 1/4 of an inch in diameter occur within this material.

The groundmass of the rock is composed of glass shards among which are many unbroken gas bubbles. It may, therefore, be classified as a vitric tuff. These glass fragments show the beginnings of devitrification along the edges of the shards. Microscopic, vesicular structure is present and the shards are slightly distorted by compaction (see figure 15).

The phenocrysts make up about 10% of the rock volume. About 80% of them are orthoclase. The remainder is about half andesine and half quartz with minor amounts of augite and biotite. These phenocrysts

Figure 14. Hand specimen showing the porous fragmental texture. (natural size).

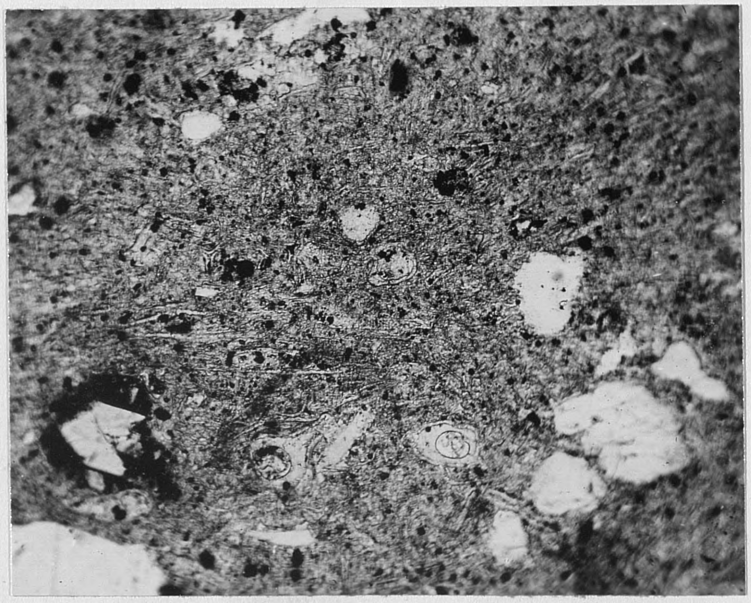


Figure 15. Texture of the groundmass and including phenocrysts of orthoclase and quartz. (48 diam.)

have been somewhat broken and possess corroded, irregular outlines. Sphene and magnetite are present as accessary minerals and are almost invariably found grouped together.

Fragmants of other volcanic glasses, quartzite and granite are found within the tuff.

This rock is cemented by the partial fusion of the particles.

<u>Welded tuffs</u>. - The volcanics which may be described by this term occur in the northern Snake River Range at the edge of the mountain front where they rest upon sedimentary rocks varying in age from Cambrian to Cretaceous. They cap the hill which lies between the trace of the Jackson fault and the Teton River and form a gently sloping terrace at the foot of the mountains.

Mansfield and Ross (1935, p. 310) noted that rocks, appearing similar to the welded tuffs that he described, occur in the area of this report and extend northward towards Yellowstone Park along the west slope of the Teton Range.

The term "welded" was first used in a petrological sense by Iddings (1899) in his description of some of the rhyolites of the Yellowstone area. Welded tuffs also occur in the Katmai region, Alaska (Fenner, 1920, 1923, 1937), southern Peru (Fenner, 1948), eastern California (Gilbert, 1938), New Zealand (Marshall, 1932, 1935), Martinique and St. Vincent (Lacroix, 1904, 1908) and southeastern Idaho (Mansfield, and Ross, 1935).

In New Zealand the term "ignimbrite" is used to define these rocks. It is probably a better term as it does not imply that the fragments which constitute the rock traveled through the atmosphere. The term welded tuff is used in this report solely on the basis of its use in nearby localities.

The formation of this type of pyroclastic was first observed in Martinique. Hot, gaseous, moving and spreading bodies called nuées ardente have issued from Mt. Pelée and associated fissures and solidified into ignimbrite or welded tuff. Anderson and Flett (1902, p. 444) described one of these nuées in the following manner.

> "It is a lava blown to pieces by the expansion of the gases and it contains . . . (and) the mixture of dust and gas behaves in many ways like a fluid."

The recently formed Katmai welded tuffs were deposited by a volcanic sand flow that took ten years to cool. This sand flow appears to be similar in most respects with nuees ardentes.

Mansfield (ibid.) found that the welded tuffs were deposited upon surfaces of greatly varying elevation and that the sorting of the fragments was excellent. He therefore concluded that the fragments were transported for miles through the air without loosing their heat.

In the area covered by this paper the field relations do not necessitate such an explanation and the author feels that the tuffs were probably emplaced by a nuée ardente.

Fenner (1948, p. 8883) defines two types of welded tuff by the character of the induration.

> "Induration may be brought about in two ways. At one extreme the heat of the accumulated mass is so high after emplacement that pumice inclusions collapse and the small fragments or shards of glass of the matrix become softened and are pressed down and aligned by the weight of the material above them. To the naked eye the result in extreme cases, may appear altogether like a felsitic rhyolite or even a structurless glass, but thin sections reveal the forms of original fragments. At the same time a minute recrystallization

> of shards takes place in a texture that Iddings (1899) has termed axiolitic and Marshal (1935) pectinate . . ."
>
> ". . . In a second form of induration, softening is absent of minor, but recrystallization by pneumatolytic exhalations is important."

The material found in the area covered in this report is of the first type. There are no cementing secondary minerals present and all of the material shows some degree of distortion, compaction and flowage. This is the type of material described by Gilbert (1938) as occurring in the Bishop tuff. Gilbert states that this tuff is soft and porous at the top and grades downward into more consolidated material. Although no field evidence was noted in the northern Snake River Range, it is possible that the material described as pumaceous tuff is, in a similar manner, related to the welded tuffs.

Due to soil cover and limitations in time, it was impossible for the field party to establish the relationships between the many types of welded tuff. They vary greatly within short distances as to texture, color and degree of weathering. On a fresh surface the major portion of the material shows glassy phenocrysts and the groundmass color may be purplish brown, pale lavender, or olive green. The color of the weathered surfaces appears to have no relation to the true color of the rock and may vary through brown, drab lavender, brownish green and reddish brown. Inclusions of rounded sandstone and limestone pebbles up to two inches in diameter are not uncommon (see figure 16). These inclusions are surrounded, respectively, by reaction rims of chalcedony or calcite. Angular fragments of felsitic rhyolite were also present as is described on page 41. Examination of thin sections revealed the presence of altered particles of chert, granite and diorite. The fracture is irregular to conchoidal. Some of the rock is slightly vesicular and possesses flow structure and some is completely aphanitic in hand specimen (see figure 17).

Studies of thin sections showed that all the welded tuffs were composed of glass shards, fibers and bubbles outlined in a brown dust which may be limonite, hematite, or magnetite. In general, the distortion of these structures increases in the material found in the northeast. (see figure 18). Iddings (1899, p. 406) found similar textures in the rhyolites of Yellowstone Park and described them in the following manner.

> "In some cases their (glass fibers and films) shape closely resembles that of fragments of pumice pressed together and welded . . . In others it appears as though such fragments had been drawn out and twisted by the movement of the mass."

The pyroclastic nature of these rocks was not observable in the field but the glass shards and bubbles are incontrovertible evidence of their fragmental origin. They were hot at the time of emplacement as is shown by the unfractured distortion and collapse of bubbles and bubble fragments. Furthermore, the underlying rocks, such as the Madison limestone on Mike Harris Trail and the Dinwoody formation one half mile east of Smith Canyon, were altered by the heat of the mass at the base of these volcanics. Faint, spherulitic crystallization is observable in much of the welded tuff. This structure has almost no relation to the shard boundaries or the flowage. It is extremely difficult to photograph these spherulites as the alignment of the crystals is observable only when the stage of the microscope is rotated. Similar features

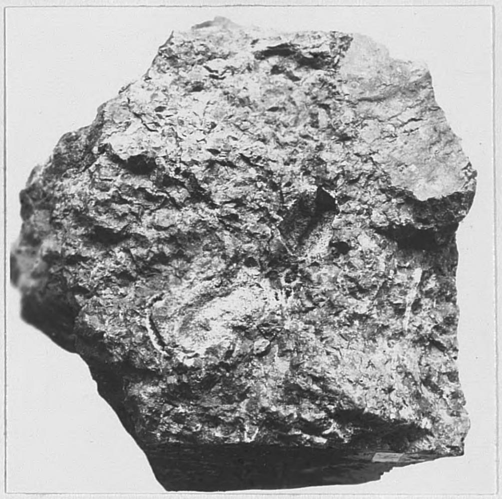


Figure 16. Hand specimen showing a sandstone pebble and a pebble cavity. (5/7 diam.)

Figure 17. Hand specimen showing slight flow structure. (natural size).

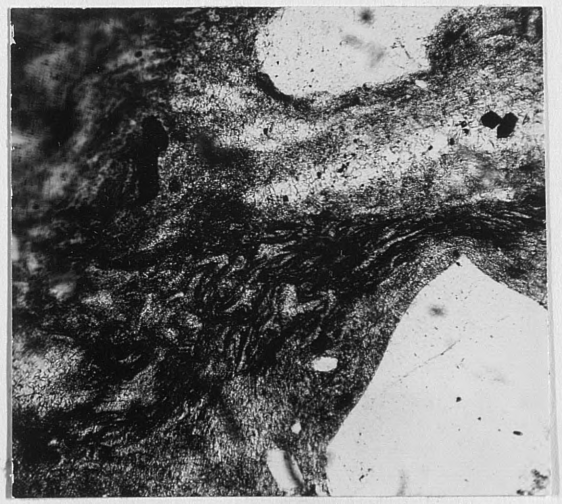


Figure 18. Thin section showing a high degree of distortion. (55 diam.)

appear in the welded tuffs of Yellowstone Park.

> "In some forms of rhyolite the appearance of welded glass fragments or veil structure is retained, although the mass is faintly doubly refracting and may be spherulitic in part, incipient spherulite needles traversing the rock in various direction without regard to the former lines of flow, which are marked by opaque dust-like particles. In these cases it is evident that the spherulitic crystallization took place after the molten mass had come to rest." (Iddings, 1899, p. 418).

The material which is non-spherulitic appears to have undergone stress resulting in flowage since the beginnings of crystallization and solidification (see figures 19 and 20). The glass threads are highly distorted and the birefringent material is parallel to the flow lines.

The coloration of these tuffs is highly uneven in thin section. This apparently is due to different states of oxidation of the iron. Some areas are light grey and others dark brown. The boundaries between the different shards is usually poorly defined. Figure 21, however, shows that when the color change has definite boundaries it is due to inclusions of tuff that became partially solid before the groundmass did. The glass fibers of the inclusions are completely welded and pressed together. Usually they are somewhat parallel to the flow lines of the ground mass but this is not always the case. The solidification of these areas was not complete until the groundmass cooled. This is shown by the fact that the birefringence has little relation to the inclusion boundaries. Spherulite needles which traverse this area in all directions were observable beneath the microscope (see figure 22).

The phenocrysts constitute approximately 8% of the volume of the

Figure 19. Groundmass showing flowage since the beginning of solidification. (51 diam.)

Figure 20. Same as Figure 19. The birefringence follows the flow lines. (crossed nicols, 51 diam.)

Figure 21. Inclusion of welded tuff within welded tuff. (43 diam.)

Figure 22. Same as Figure 21. The birefringence is unrelated to shard or inclusion boundaries. This material is spherulitic but only th center of one spherulite shows in the top photograph. This center is at top of central edge of the inclusion. (crossed nicols, 43 diam

rock. They are composed of basic oligoclase, sanidine, augite and quartz. The augite posses reaction rims of limonite and is a minor constituent that occurs as large phenocrysts only east of Nordell Canyon. Quartz, sanidine and oligoclase occur in equal amounts in the material which forms the hill. Quartz and oligoclase become less prominent to the west and south. The phenocrysts are fragments of euhedral crystals which have been broken in the formation of the tuffs.

Magnetite is the major accessory mineral and occurs throughout the glass as both crystals and dust. Finely disseminated augite is frequently found. Sphene, zircon and tourmaline are present in small amounts.

Two types of tuff quite different from the above described material were found.

The first of these occurs just west of the mouth of Pole Canyon. In hand specimen it appears to be an amygdaloidal porphyry (see figure 23). Approximately half the volume of the rock is made up of pellets of white pumice which contain cresent shaped gas cavities. These pellets resemble amygdules and are set in a brown aphanitic matrix. Glassy phenocrysts occur in both the groundmass and the pellets. The resemblence to an amydaloidal rock is heighted by the fact that the pellets are soft and weather out rapidly. They are very irregular in size and range in diameter from 1/8 to 4 inches.

Microscopic examination of this rock revealed that the matrix was composed of the same type of fragments as were found in the other tuffs. The color is due to a fairly high percentage of dusty brown limonite (?).

The pellets are composed of tuffaceous material that differs only in color and induration from the groundmass. Shards and distorted bubbles found on the boundary continue from matrix to pellet with no change in form (see figures 24 and 25). This rock shows slightly less distortion than is found in the other tuffs.

The centers of the pellets contain stream worn fragments of magnetite, biotite, green hornblende, microcline, acid andesine and quartz in varying amounts (see figure 26). It is suggested that this type of rock may indicate an edge phase of a nuée ardente. Sedimentary material picked up by the moving fluid would cool the surrounding tuff to a point of solidification. These pellets of sediment and tuff would become mingled with the surrounding mass by the movement of a nuée. Gases evolving from the pellet would be unable to escape and would collect within in cresent shaped pockets on the upper side.

Phenocrysts comprise only 4% of this rock. Sanidine is slightly more abundant than quartz and there is no plagioclase present. Sphene, augite, and magnetite are the accessary minerals. The augite shows alteration to basaltic hornblende, chlorite, or limonite.

The second aberrant type is found near the mouth of Murphy Creek. This rock is bluish-black in hand specimen (see figures 27 and 28) and contains glassy phenocrysts of sanidine, quartz and plagioclase. The sanidine is by far the most abundant of these. The rock is slightly vesicular and is composed of glass shards with a higher limonite (?) content than any of the other tuffs. Flow structures are not as confused as in the other rocks and compaction is more prominent. The bubbles occurring in this tuff are completely flattened and the shards

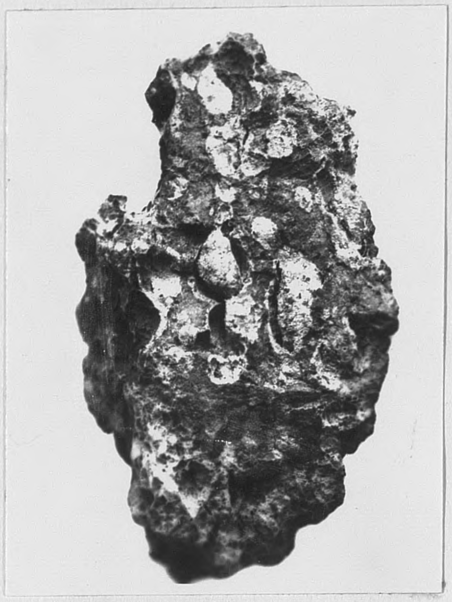


Figure 23. Hand specimen showing the white pellets and the dark groundmass. (natural size).

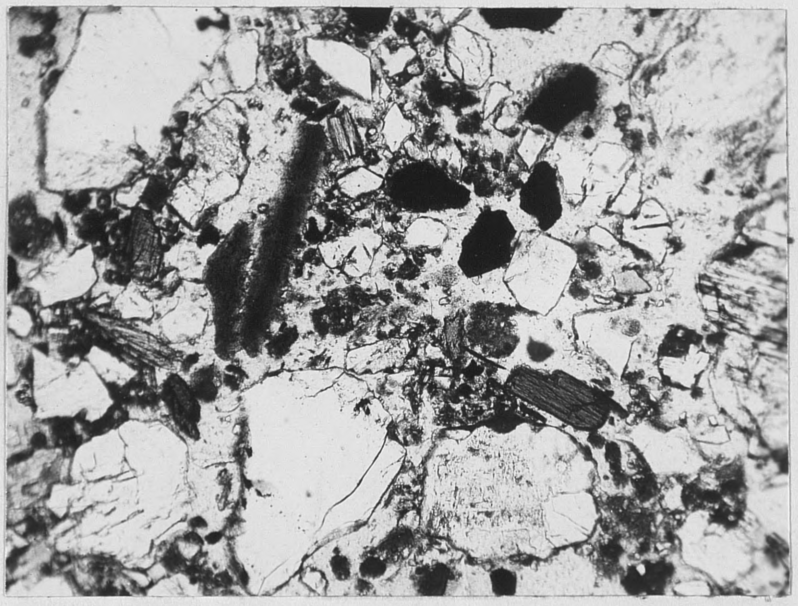


Figure 24. This section shows the relation of groundmass to pellets and included sedimentary pebbles. (4 diam.)

Figure 25. Boundary between pellet and groundmass. The lower, lighter portion of the photograph is the material of the pellet. (45 diam.)

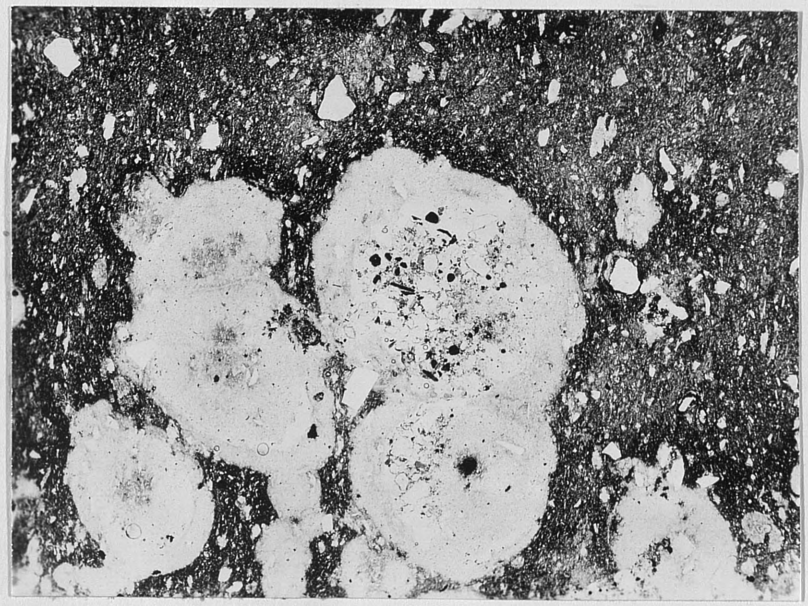
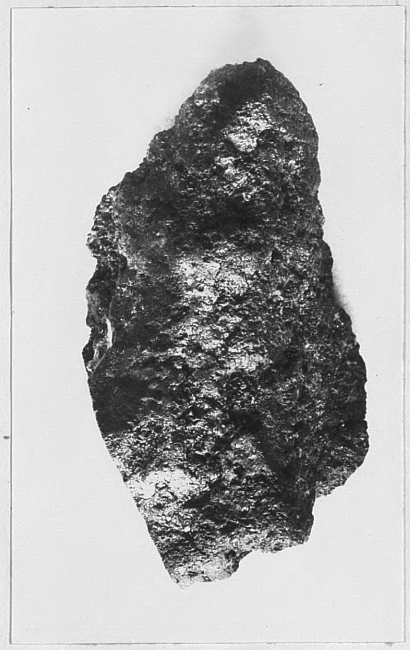


Figure 26. Rounded sedimentary material found in the center of a pellet. (45 diam.)



Figures 27 and 28. Hand specimens showing dense vesicular texture (natural size).

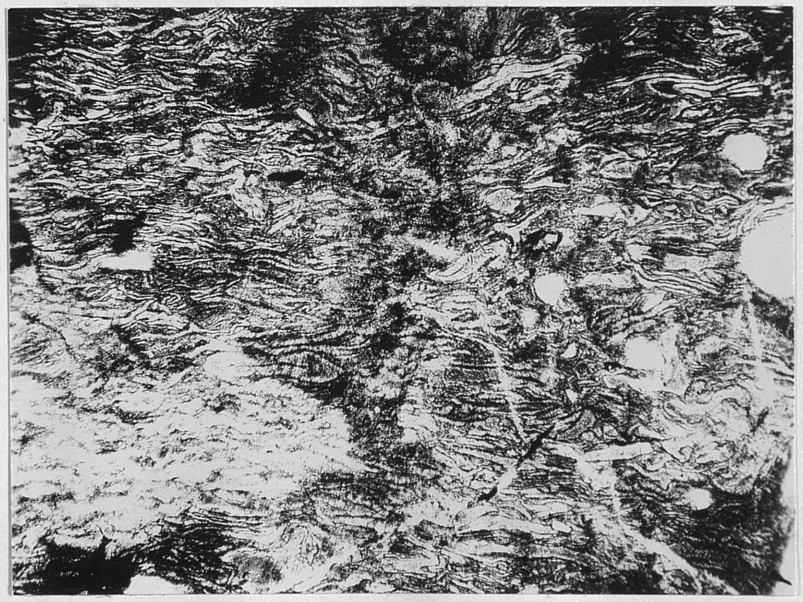


Figure 29. Groundmass in thin section showing flattened bubbles and shards. (50 diam.)

more perfectly aligned (see figure 29). Spherulitic structure is more prominent here than elsewhere although it is still un-photographable. Magnetite is the only accessory mineral.

This may be a bottom phase of a nuée ardente and has been flattened and aligned by the overlying weight after the escape of the gases.

<u>Conclusion</u>. - With the scanty evidence available it would be presumptuous to indicate any more definite origin for these tuffs than what has already been presented. A more thorough search for outcrops, trenching in the covered zones and detailed petrographic study would probably reveal the lacking details.

STRUCTURAL GEOLOGY

General Statement

The structural geology of the northern Snake River Range presents a complex picture of Laramide thrust faulting, and associated folding, normal faulting and crumpling of beds. This complexity of structure was alluded to first by Orestes St. John (Hayden Survey Report, 1877) who noticed a sharp reversal of beds to an overturned position southeast of Station 39, "showing what appears to be the result of great disturbance." Station 39 of the Hayden Survey was at the top of the hill capped by Nugget sandstone east of Pole Canyon. The sharp reversal of dip is the north limb of the fan fold (see page 63).

Schultz (1918) did reconnaissance work in the area in search of phosphate and coal and says "the structure of this part of the range may be more complex than it appears from a distance." (Schultz, 1918, p. 53).

Jackson Thrust Fault

The Jackson thrust is the easternmost of the low angle Laramide thrust complex. It has been traced continuously from the Hoback Basin in Wyoming to the Big Hole Mountains in Idaho where it disappears under the Snake River Lava flows. The stratigraphic throw is 11,850 feet in the northern Snake River Range, and the horizontal displacement is unknown.

The Jackson thrust was named by Horberg (1938). Its age, according to Eardley (personal communication) is lower to middle Eocene, dated by its relationship to the Hoback and Pass Peak formations (see strati-

Figure 30. Faulting in the Madison limestone along the west side of Mikesell Canyon.

graphy).

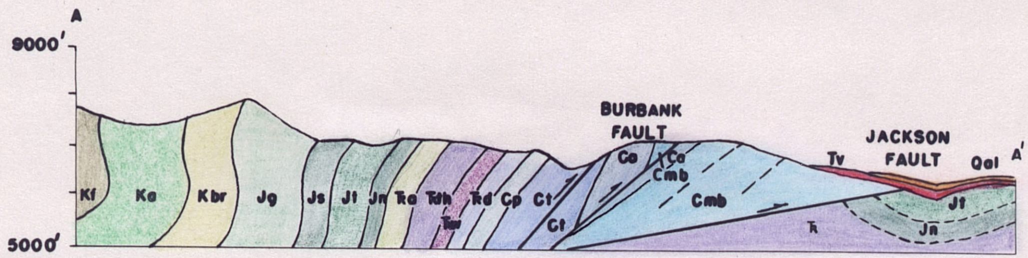
Evidence of the low angle of the thrust plane can be found at the mouth of Mail Cabin Canyon, just west of Teton Pass, where an outcrop of Aspen sandstone is found in the floor of the canyon in the "V" formed by the eroded trace of the fault. Lubrication of the thrust was on shales of the Gros Ventre formation, which can be found along the fault plane on Burbank Creek.

In the development of the Jackson thrust, compressional forces formed an asymmetrical anticlinal front which broke under continued pressure into a low angle fault. A remnant of the Cambrian core of this anticline forms part of the northern edge of the Snake River Mountains.

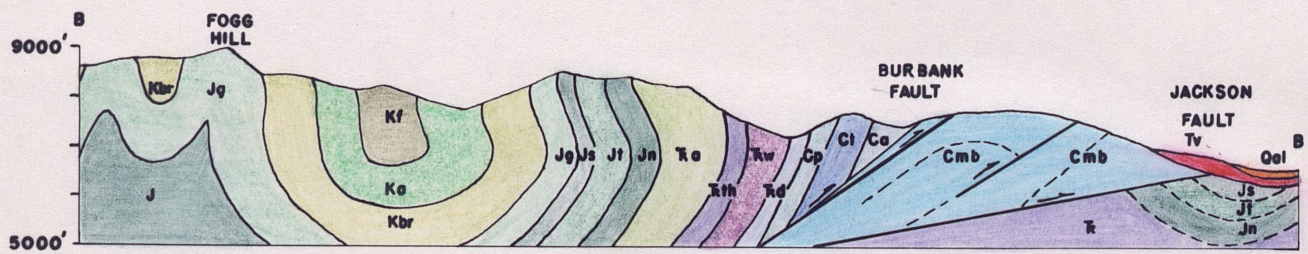
During the thrusting the competent beds of Madison limestone were horizons in which imbrications of the movement took place (see plate 3). In each instance the folds show drag and brecciation along the fault. Behind the major fault, these imbrications become increasingly steeper. (see figure 30).

Originating in the Amsden formation another type of structure appears which cannot be described as a simple imbrication of the Jackson thrust, although it occurred due to release of the same compressional forces. The change in structural type would be expected in the Amsden, if at all, because this is the lowest incompetent formation with the exception of the Gros Ventre formation.

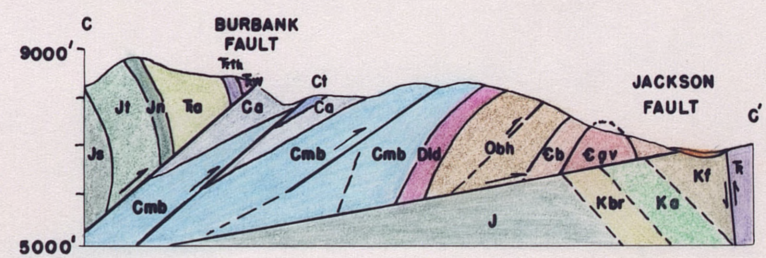
STRUCTURAL CROSS SECTIONS



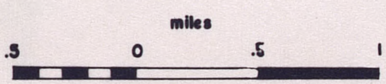
From Divide to Teton Basin



From Fogg Hill to Teton Basin



From Divide to Teton River



EXPLANATION

Qal	Alluvium
Tv	Volcanics
Kf	Frontier fm.
Ka	Aspen fm.
Kbr	Bear River fm.
Jg	Gannett gp.
Js	Stump & Preuss fms.
Jt	Twin Creek fm.
Jn	Nugget ss.
TRa	Ankareh fm.
TRth	Thaynes fm.
TRw	Woodside fm.
TRd	Dinwoody fm.
Cp	Phosphoria fm.
Ct	Tensleep ss.
Ca	Amsden fm.
Cmb	Madison & Brazer ls.
Dld	Leigh & Darby fms.
Obh	Big Horn Dolomite
€b	Boysen ls.
€gv	Gros Ventre fm.

Burbank Fault

The continuous high angle fault occurring mainly within the Amsden formation has been designated the Burbank fault by the writers, from the locality of its discovery on the ridge southeast of Burbank Creek (see geologic map). The fault is unusual in that its upper block is a synclinal fan fold. Kirkham (1928) reports a similar fault in the Lemhi Range north of Bernice, Idaho.

At many places along the fault there is no stratigraphic displacement to betray its location, but the fault can be traced by other means. Some of the criteria used in the field to trace this fault were 1) a breccia zone which makes resistant cliffs and monoliths in many cases, 2) an abrupt change of dip from south to north coincident with this zone, 3) repetition of formations of same dip, 4) a zone of mineralization, metamorphism, and igneous activity along this zone, and 5) a line of springs coincident with the fault.

The amount of vertical movement could not be computed. The dip of the fault plane is greater than 60°; the stratigraphic throw at the most is 700 feet.

The faulting occurred during or after folding which involves upper Cretaceous beds, and before volcanic activity which covers its trace in the west. Its age is therefore post-Cretaceous and pre-volcanics. No closer determination seems possible. It is believed by the writer that the fault is closely enough tied structurally to the Jackson fault to consider it as the same age.

Mansfield (1923, p. 277) says that the folding in southeastern Idaho preceeded overthrust faulting, and possibly the Burbank fault was formed as a continuation of the forces that developed the fan fold, which would date the Burbank fault as pre-Jackson fault.

Cache Fault

The Cache fault was named by Horberg (1938) and is a high angle thrust fault roughly paralleling the Jackson thrust (see plate 2). Movement has been in the direction opposite to that of the other regional thrusts, being from northeast to southwest. An exact age has not been assigned to the Cache fault, but it cuts the mid-Eocene Pass Peak formation in the Hoback Basin and so may be regarded as part of a later phase of Laramide activity.

The Cache fault is vertical at Teton Pass and is reported by Horberg to die out shortly west of the pass where the forces were spent forming the Taylor Mountain anticline.

On the basis of recent evidence, this fault may continue for several miles west of the Taylor Mountain anticline. Gardner mapped a high angle fault in the Teton River Canyon with a stratigraphic throw of 8400 feet on the east and 4500 feet on the west where the trace disappears (see geologic map). The authors found an outcrop of Aspen sandstone at the mouth of Mail Cabin Canyon in Wyoming only 1200 feet south of the Dinwoody formation. The intervening space was covered with river alluvium, but represented a stratigraphic interval of 7000 to 8000 feet.

Thus, on the basis of mapping done by the authors, and by Gardner (1944) the writer believes this fault can be extended west to Stateline Canyon, where the trace disappears under the alluvium of the Teton River.

Folds

Fan fold. - Between the Burbank fault and Fogg Hill a synclinal fan fold is well developed. As exposed, its width is one and a half to two miles, but reverse dips of as much as 50° show it must be much wider below the surface. Slickensides caused by bedding plane movement were found on the formations throughout this syncline.

In the formation of the fold, much of the pressure was released through the Ankareh formation, it being mostly incompetent shales. As a consequence the Ankareh was tremendously thickened by the folding (see plate 3 and geologic map).

Kirkham (1924, p. 31; 1925-A, p. 71-74; 1927) describes several fan folds of both anticlinal and synclinal type occurring in the mountains to the south, especially in the Caribou Range. Their occurrence is similar, being in thrust sheets and sometimes related to high angle faulting.

Anticlines on Fogg Hill. - Fogg Hill, just south of the fan fold, is an anticline with a small syncline in its crest. The dips taken were steep at all places, and it appears that much shearing accompanied the folding as seen by the prevalence of slickensides in all horizons. (see figure 6).

Normal Faults

A few normal faults were found in the area mapped. All of these strike approximately perpendicular to the strike of the beds and the major structure.

Between Pole Canyon and Mike Harris Creek a small graben was formed in the Madison and Amsden formations. The block was tilted slightly during faulting, giving the beds in the graben less dip than the surrounding beds. This faulting occurred after the folding and after the Burbank fault. The time relationship to the Jackson thrust is uncertain.

Another normal fault is farther upstream on Mike Harris Creek, where the fault expresses an abrupt change in dip of the formations involved. Here the upthrown side exposes overturned beds of the fan fold, while the downthrown side retains the formations with their normal dip. The vertical movement cannot be computed, but probably represents many hundreds of feet.

Two other normal faults occur along in Cretaceous beds of the fan fold along the southern margin of the area.

These faults are all perpendicular to the regional structures as would be expected in tensional breaks closely following the compressional thrusts and reverse faults.

Teton Basin

The origin of the Teton Basin (see topographic map) from a structural standpoint, represents an interesting problem. According to Schultz (1918, p. 69) the basin is a syncline comprising Cretaceous and older sediments overlain by lava which is overlain by alluvium. The west side is bordered by the Jackson thrust, and on the east the sediments of the back slope of the Teton block dip under the lavas.

This idea would explain the situation if the Jackson thrust paralleled the Big Hole Mountains on the west; but its trace crosses the basin, and the formations in the area mapped strike towards the basin where they have been eroded away forming a straight front which marks the south end of the basin.

Two explanations appear possible to account for this feature. First, a line of faults across the foothills on the south may indicate a fault which would make the southern Teton Basin a graben (Schultz, 1918, p. 53). No other evidence of faulting was found. A second possibility is that Pine Creek excavated this southwestern corner of the basin to great depth during Tertiary time before the volcanics filled the basin.

PHYSIOGRAPHY

Physiographic Province

According to Fenneman's classification of physiographic provinces the Snake River Range is in the Middle Rocky Mountain Province. This province is characterized by linear uplifts with a single range corresponding usually to a single anticlinal uplift or fault block. The Snake River Range is one of a chain of small ranges found along the Idaho-Wyoming border.

Physiographic History

The physiographic history of the region is almost impossible to work out due to the lack of distinguishable peneplains or erosion surfaces. It is probable that the general elevation of 8500 feet which represents most of the peaks in the area may have been an ancient surface. A later erosion surface may be indicated by the level of 8000 feet which represents many of the divides. It is also suggested that the higher peaks may have been monadnocks on the 8000 foot level and do not indicate a separate surface. No definite evidence of either level could be found.

The topography of the region is mostly mature and the streams are largely in the youthful stage. The streams are entrenched approximately 1500 feet below the divides between the canyons. The two streams which are not youthful are Mike Harris Creek and the Teton River. Mike Harris Creek in its lower portions is mature and has cut a valley flat. The Teton River is also in the mature stage having developed small flood plains in several places along its course.

Special Features

Volcanics in front of the Jackson thrust form a decided bench across the front of the north facing spurs. Several stream terraces, containing rounded cobbles of varying composition, were seen along the Teton River.

The mouth and bottom of Mikesell Canyon are composed largely of an alluvial fan. No stream was found in the canyon although one was marked on the Driggs sheet. The entrenching of alluvial fans at the mouths of Pole Canyon and the Teton River Canyon indicates a climatic change toward increased rainfall.

The area between Smith Canyon and Murphy Creek consists of landslide topography developed on the Jurassic Gannett, Stump, Preuss, and Twin Creek formations.

Glacial Features

No evidence of glaciation could be found within the area. To the north in the Teton Range there was considerable glacial activity during the Pleistocene, but the northern section of the Snake River Range appears to have escaped glaciation because of lower elevation.

ECONOMIC GEOLOGY

Metals

No metalliferous deposits were found in the northern Snake River Range. However, a mineralized zone was found which is coincident with the Burbank fault. The possibility exists that ore minerals may be found along this zone. Mineralization consisted of quartz and calcite veins in Carboniferous (Madison and Amsden) and Jurassic (Twin Creek) limestones and showed two stages of mineralization. Some of the mineralization took place as open fillings in brecciated zones. Euhedral crystals of quartz containing hematite appear as deep red crusts on breccia fragments in the Amsden formation. On fresh fracture, these breccias give off a strong sulfurous odor.

Non-metals

Petroleum. - Several of the formations outcropping in the Snake River Range are oil producers in nearby states, and others correlate directly with other producing formations. Production has come from the Tensleep formation in Wyoming, and from the Amsden in Montana. Of the producing formations of Montana and Wyoming, the Embar formation correlates with the Phosphoria formation of Idaho, the Chugwater formation correlates with the Woodside and Thaynes formations, and the Sundance formation is similar in age to the Nugget, Twin Creek, Preuss and Stump formations. The Morrison formation, an oil producer of Colorado and Wyoming, correlates with the Gannett group.

Due to a lack of suitable structural conditions, the northern Snake River Range appears to have few possibilities for commercial production of petroleum. One formation, the Phosphoria, is known to produce some oil on distillation.

The Fogg Hill anticline has been tightly squeezed and the frequency of slickensides suggests that any oil originally present probably has escaped.

The only possible oil producing structures would be those under the thrust plane of the Jackson thrust fault where the structure is unknown and unexposed. At places it can be inferred to be monoclinal or synclinal and as such could create a suitable trap beneath the gouge of the Jackson thrust.

Coal. - Coal has been mined in adjacent areas in two formations, the Bear River and Frontier, both of Cretaceous age. A surface prospect pit in black carbonaceous shales of the Bear River formation was visited. This prospect is near the junction of Murphy Creek and Pine Creek, and had been opened by the Pine Creek Coal Company, reportedly on a four foot bed of coal. (Schultz, 1918, p. 74). No coal was found by the writers. Possibly a small amount of coal was there when the prospect was opened, but was since mined out. Bear River coals are characteristically discontinuous and lenticular (Schultz, 1918, p. 64).

On the North Fork of Rainy Creek, Slaveljub Pintar of Driggs, Idaho, owns a coal claim which includes two sections in the area mapped. This claim embraces the Frontier formation in the center of a synclinal fan fold (see structure). Coal beds within the Frontier formation are mined in the Big Hole Mountains, and are frequently reported elsewhere. However, the formation at this point is highly folded, with slickensides present throughout evidencing much bedding plane movement. Under these conditions the coal may not prove as continuous as it would in less contorted sediments.

Phosphate rock. - The Phosphoria formation, (see stratigraphy) the nation's largest phosphate reserve, crops out in the Snake River Range in the area mapped. Much of the rich Phosphatic shale has been ruined by smearing along fault surfaces associated with the Burbank fault (Gardner, 1944, p. 1).

Phosphate of this formation is mined at Conda and Montpelier in Bear Lake County, Idaho by the Anaconda Copper Company. The phosphate rock contains from 68% to 76% tricalcium phosphate and is further concentrated into a superphosphate for use as fertilizers by reaction with sulfuric acid.

No phosphate has been mined in the northern Snake River Range. However, the writers visited a prospect in Coal Canyon, north of the area in western Wyoming, where John Cluff of Victor, Idaho explored the formation for coal in 1911, apparently abandoning the venture without realizing the nature of the deposit. (Schultz, 1918, p. 57).

Limestone. - Madison limestone has been quarried on a small scale in Pole Canyon where a kiln was operated for roasting the stone (see figure 31) to produce quicklime for shipment to sugar refineries. According to local residents this operation was abandoned in 1940 and has not been worked since.

Building stones. - Two types of building stones are found near the Teton Basin. A pink variety of welded tuff (see igneous rocks) is quarried just north of alternate U. S. 20 near the Teton Basin. This stone finds a ready market locally where it is used for construction of public and private buildings. It is strong, durable, light weight, and easily quarried and dressed.

Figure 31. Abandoned lime kiln in
Pole Canyon.

Nugget sandstone where occurring in beds 3 to 6 inches thick is termed "flagstone" and is used locally for chimney construction. Clarence Brown of Alpine, Wyoming has quarried this stone in adjacent areas. It is a strong, siliceous sandstone, easy to dress because of its bedding, but finds limited use because it is generally inaccessible in this part of the Snake River Range.

Ground Water

The water supply furnished by the northern Snake River Range is the principal resource valued by the local residents. The northward flowing streams are fed by springs occurring along the Burbank fault zone, along the foothills south of the Basin, and along the divide south of Pole Canyon. These springs on the divide appear to have no watershed above them of sufficient size to account for their volume of flow during dry seasons. These springs occur in the Gannett group and the author believes them to be the result of an artesian flow across the fan fold, with their catchment area in the region of Fogg Hill. This would give them a hydrostatic head of 800 feet and a larger catchment area.

SUMMARY OF GEOLOGIC HISTORY

With the exception of the Silurian Period, sedimentation was continuous in the Cordilleran geosyncline throughout Paleozoic time. During Permian time vulcanism to the west of the geosyncline (Eardley, 1947) contributed volcanic material to the Phosphoria formation (see page 25).

In Mesozoic time the Rocky Mountain geosyncline was formed, embracing the eastern half of the Cordilleran geosyncline. Deposition in this trough continued to the end of the Cretaceous when the compression and general uplift of the Laramide revolution set in.

During the first phase of the Laramide revolution compression from the southwest produced the Absaroka, St. John, and Darby faults. Rapid denudation of the newborn highlands resulted in the deposition of the lower Eocene or Paleocene Hoback formation in the lowlands.

Renewed movement from the southwest forced the Jackson thrust sheet over the Hoback formation and continued erosion spread the sands and conglomerates of the Pass Peak formation of middle Eocene age over intermontane basins. The Burbank fault (see page 61) and northwest-southeast trending folds are believed to belong to this phase.

During a third phase of compression from the northeast high angle thrusts developed and the Pass Peak formation was overridden. Of these thrusts, the Cache (see page 62) directly affected the northern Snake River Range.

As compression relaxed, north-south trending block faults formed, affecting all earlier structures. The Teton fault is of this type, and in the area mapped there were several others of small throw. Rapid erosion of the upthrown block formed the Camp Davis formation of upper Miocene or lower Pliocene age. Faulting occurred in several episodes deforming the Camp Davis formation itself. Regional truncation and basin filling followed the faulting.

Along fault zones, rhyolite dikes were intruded, followed by several cycles of erosion which excavated basins below their present depth. Into the excavated Teton Basin, welded tuffs (see page 46) were deposited, covering the floor of the basin and tributary canyons.

Renewed basin filling began, covering the tuffs with coalescing alluvial fans. In recent years a more humid climate has reversed the cycle and the alluvial fans are again being eroded by the streams that formed them.

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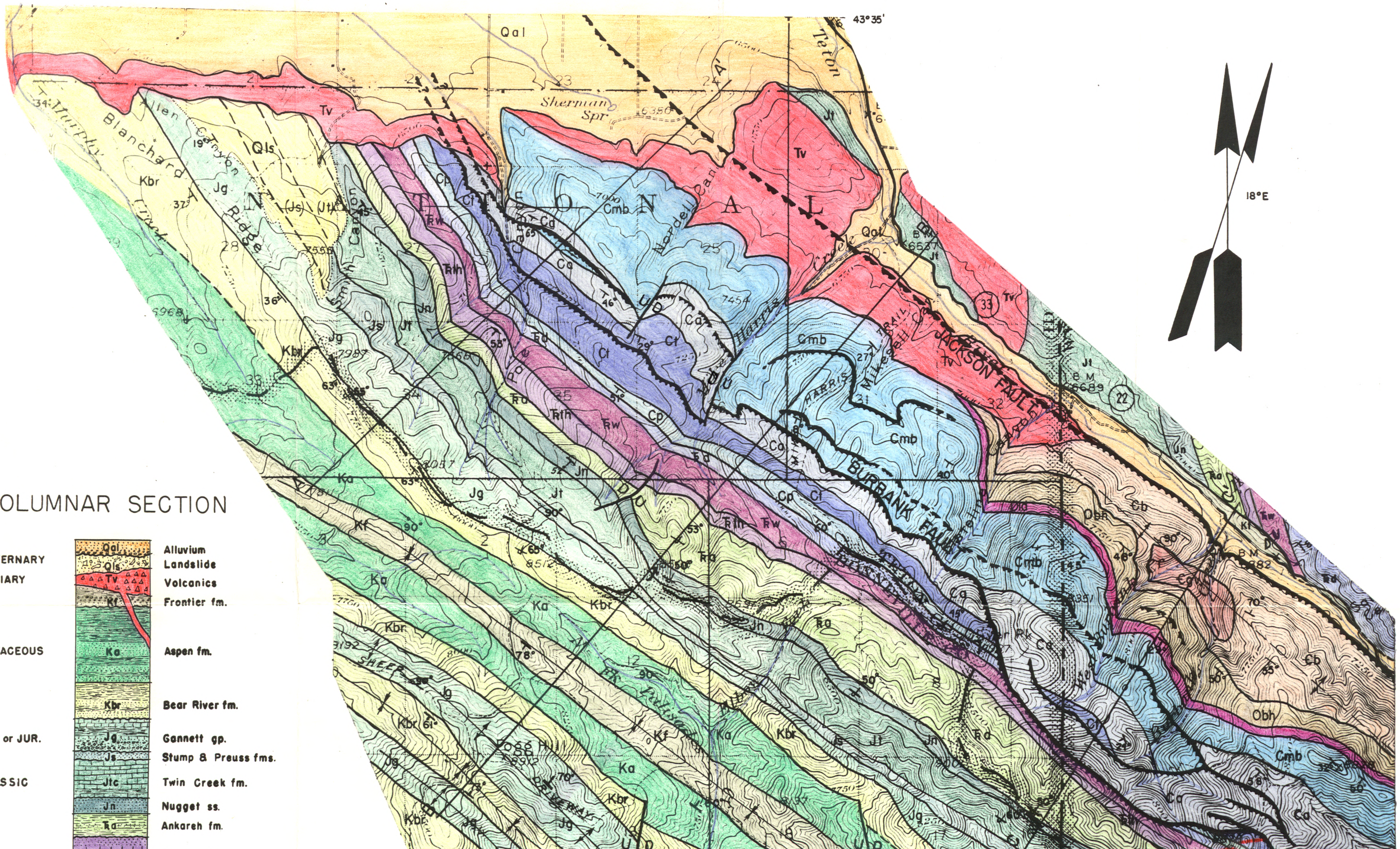
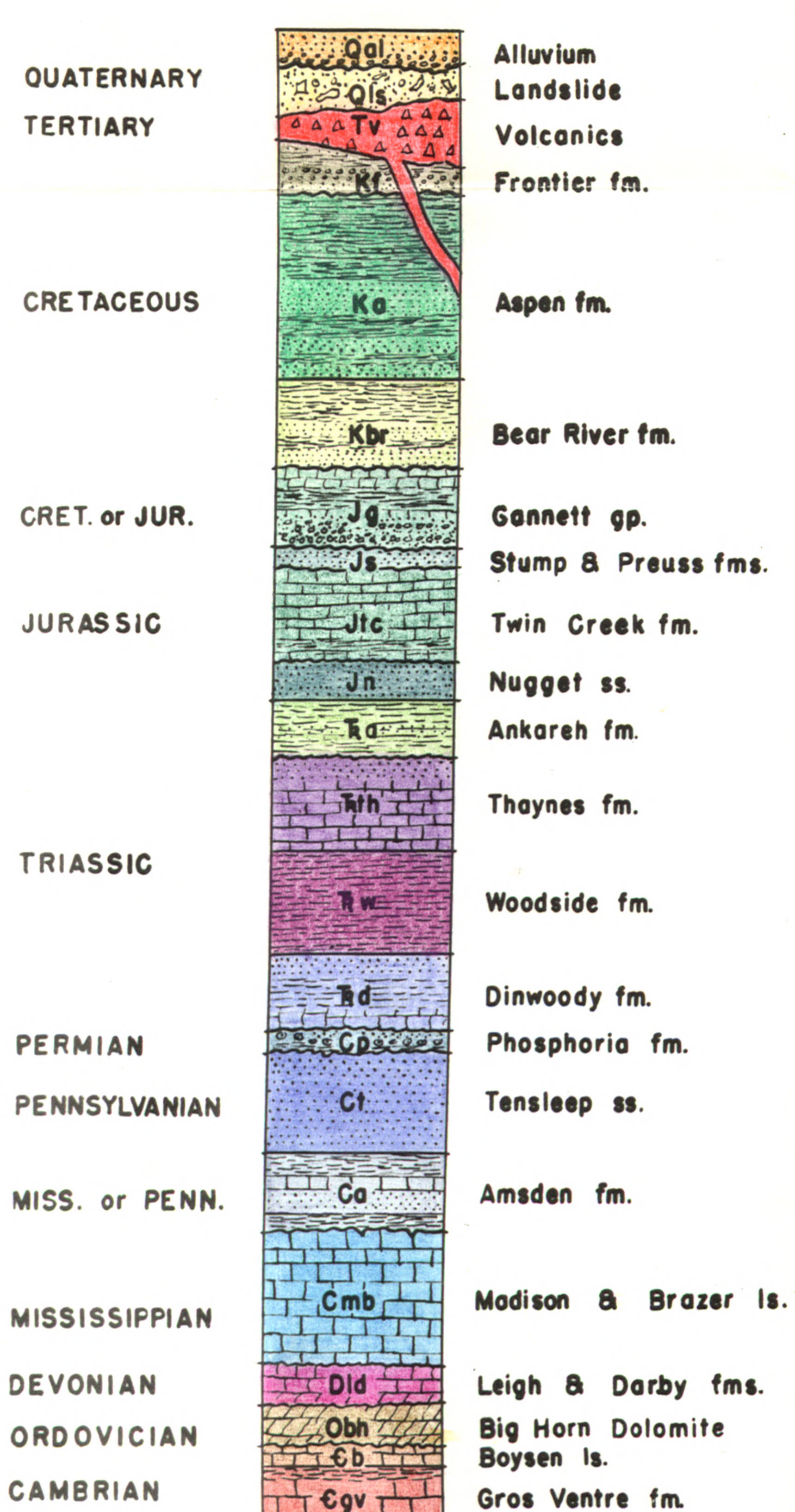


Base – Driggs, Ida.-Wyo. quadrangle U.S.G.S.

COLUMNAR SECTION

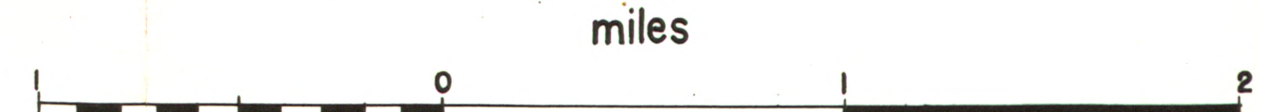


one inch = two thousand feet

GEOLOGY OF THE NORTHERN SNAKE RIVER RANGE

Mapped by R.V.Wyman, A.F. Wyman, E.H.Newcomb, and D.D.Marsik, July-Aug. 1948

miles



Thrust and Reverse Faults

Normal faults

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

IDAHO - WYOMING
DRIGGS QUADRANGLE
15-MINUTE SERIES

Mapped by the Geological Survey
1943

APPROXIMATE MEAN DECLINATION 1943

Scale 1/62500

Contour interval 50 feet
Datum is mean sea level

Polyconic projection. 1927 North American datum
5000 yard grid based on U.S. zone system, F
10000 foot grids based on Idaho (East) and Wyoming (West) rectangular coordinate systems

ROAD CLASSIFICATION 1946

Dependable hard-surface heavy-duty road		Dry weather roads	
Secondary hard-surface all weather road		Loose-surface, graded	
		Unsurfaced, graded	
		Dirt road	
U. S. Route		State Route	

More than two lanes indicated along road with tick at point of change 3 LANE 4 LANE

DRIGGS, IDAHO-WYO.
Edition of 1946

N4330-W11100/15

THE TOPOGRAPHIC MAPS OF THE UNITED STATES

The United States Geological Survey is making a series of standard topographic maps to cover the United States. This work has been in progress since 1882, and the published maps cover more than 47 percent of the country, exclusive of outlying possessions.

The maps are published on sheets that measure about 16½ by 20 inches. Under the general plan adopted the country is divided into quadrangles bounded by parallels of latitude and meridians of longitude. These quadrangles are mapped on different scales, the scale selected for each map being that which is best adapted to general use in the development of the country, and consequently, though the standard maps are of nearly uniform size, the areas that they represent are of different sizes. On the lower margin of each map are printed graphic scales showing distances in feet, meters, miles, and kilometers. In addition, the scale of the map is shown by a fraction expressing a fixed ratio between linear measurements on the map and corresponding distances on the ground. For example, the scale $\frac{1}{62,500}$ means that 1 unit on the map (such as 1 inch, 1 foot, or 1 meter) represents 62,500 of the same units on the earth's surface.

Although some areas are surveyed and some maps are compiled and published on special scales for special purposes, the standard topographic surveys and the resulting maps have for many years been of three types, differentiated as follows:

1. Surveys of areas in which there are problems of great public importance—relating, for example, to mineral development, irrigation, or reclamation of swamp areas—are made with sufficient detail to be used in the publication of maps on a scale of $\frac{1}{31,680}$ (1 inch = one-half mile) or $\frac{1}{24,000}$ (1 inch = 2,000 feet), with a contour interval of 1 to 100 feet, according to the relief of the particular area mapped.

2. Surveys of areas in which there are problems of average public importance, such as most of the basin of the Mississippi and its tributaries, are made with sufficient detail to be used in the publication of maps on a scale of $\frac{1}{62,500}$ (1 inch = nearly 1 mile), with a contour interval of 10 to 100 feet.

3. Surveys of areas in which the problems are of minor public importance, such as much of the mountain or desert region of Arizona or New Mexico, and the high mountain area of the northwest, are made with sufficient detail to be used in the publication of maps on a scale of $\frac{1}{125,000}$ (1 inch = nearly 2 miles) or $\frac{1}{250,000}$ (1 inch = nearly 4 miles), with a contour interval of 20 to 250 feet.

The aerial camera is now being used in mapping. From the information recorded on the photographs, planimetric maps, which show only drainage and culture, have been made for some areas in the United States. By the use of stereoscopic plotting apparatus, aerial photographs are utilized also in the making of the regular topographic maps, which show relief as well as drainage and culture.

A topographic survey of Alaska has been in progress since 1898, and nearly 44 percent of its area has now been mapped. About 15 percent of the Territory has been covered by maps on a scale of $\frac{1}{500,000}$ (1 inch = nearly 8 miles). For most of the remainder of the area surveyed the maps published are on a scale of $\frac{1}{250,000}$ (1 inch = nearly 4 miles). For some areas of particular economic importance, covering about 4,300 square miles, the maps published are on a scale of $\frac{1}{62,500}$ (1 inch = nearly 1 mile) or larger. In addition to the area covered by topographic maps, about 11,300 square miles of southeastern Alaska has been covered by planimetric maps on scales of $\frac{1}{125,000}$ and $\frac{1}{250,000}$.

The Hawaiian Islands have been surveyed, and the resulting maps are published on a scale of $\frac{1}{62,500}$.

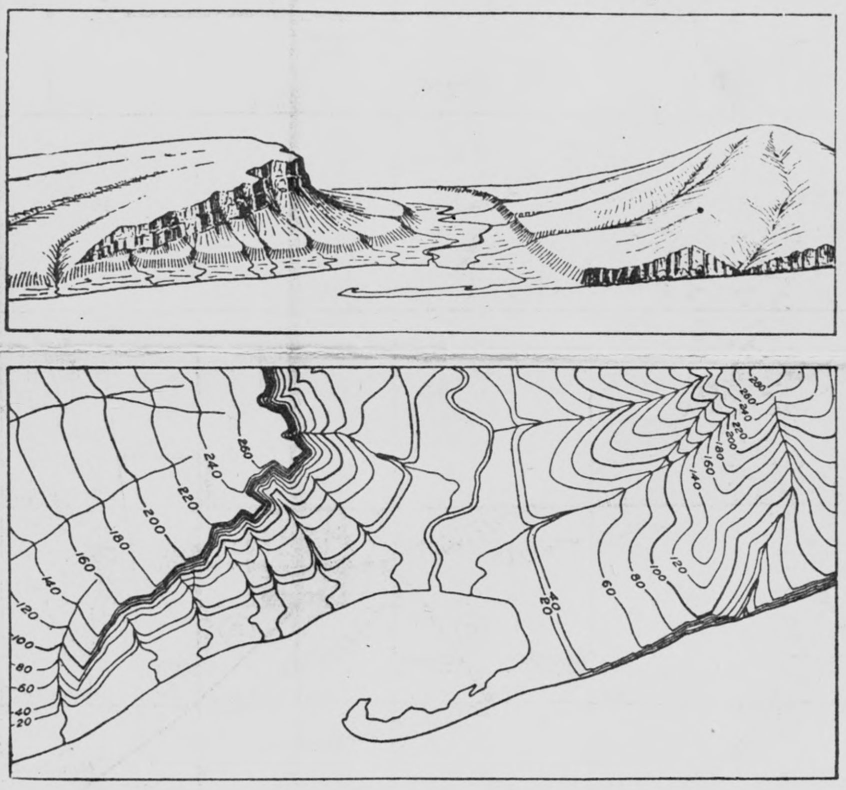
A survey of Puerto Rico is now in progress. The scale of the published maps is $\frac{1}{30,000}$.

The features shown on topographic maps may be arranged in three groups—(1) water, including seas, lakes, rivers, canals, swamps, and other bodies of water; (2) relief, including mountains, hills, valleys, and other features of the land surface; (3) culture (works of man), such as towns, cities, roads, railroads, and boundaries. The symbols used to represent these features are shown and explained below. Variations appear on some earlier maps, and additional features are represented on some special maps.

All the water features are represented in blue, the smaller streams and canals by single blue lines and the larger streams by double lines. The larger streams, lakes, and the sea are accentuated by blue water lining or blue tint. Intermittent streams—those whose beds are dry for a large part of the year—are shown by lines of blue dots and dashes.

Relief is shown by contour lines in brown, which on a few maps are supplemented by shading showing the effect of light thrown from the northwest across the area represented, for the purpose of giving the appearance of relief and thus aiding in the interpretation of the contour lines. A contour line represents an imaginary line on the ground (a contour) every part of which is at the same altitude above sea level. Such a line could be drawn at any altitude, but in practice only the contours at certain regular intervals of altitude are shown. The datum or zero of altitude of the Geological Survey maps is mean sea level. The 20-foot contour would be the shore line if the sea should rise 20 feet above mean sea level. Contour lines show the shape of the hills, mountains, and valleys, as well as their altitude. Successive contour lines that are far apart on the map indicate a gentle slope, lines that are close together indicate a steep slope, and lines that run together indicate a cliff.

The manner in which contour lines express altitude, form, and grade is shown in the figure below.



The sketch represents a river valley that lies between two hills. In the foreground is the sea, with a bay that is partly enclosed by a hooked sand bar. On each side of the valley is a terrace into which small streams have cut narrow gullies. The hill on the right has a rounded summit and gently sloping spurs separated by ravines. The spurs are truncated at their lower ends by a sea cliff. The hill at the left terminates abruptly at the valley in a steep scarp, from which it slopes gradually away and forms an inclined tableland that is traversed by a few shallow gullies. On the map each of these features is represented, directly beneath its position in the sketch, by contour lines.

The contour interval, or the vertical distance in feet between one contour and the next, is stated at the bottom of each map. This interval differs according to the topography of the area mapped: in a flat country it may be as small as 1 foot; in a mountainous region it may be as great as 250 feet. In order that the contours may be read more easily certain contour lines, every fourth or fifth, are made heavier than the others and are accompanied by figures showing altitude. The heights of many points—such as road intersections, summits, surfaces of lakes, and benchmarks—are also given on the map in figures, which show altitudes to the nearest foot only. More precise figures for the altitudes of benchmarks are given in the Geological Survey's bulletins on spirit leveling. The geodetic coordinates of triangulation and transit-traverse stations are also published in bulletins.

Lettering and the works of man are shown in black. Boundaries, such as those of a State, county, city, land grant, township, or reservation, are shown by continuous or broken lines of different kinds and weights. Public roads suitable for motor travel the greater part of the year are shown by solid double lines; poor public roads and private roads by dashed double lines; trails by dashed single lines. Additional public road classification if available is shown by red overprint.

Each quadrangle is designated by the name of a city, town, or prominent natural feature within it, and on the margins of the map are printed the names of adjoining quadrangles of which maps have been published. More than 4,100 quadrangles in the United States have been surveyed, and maps of them similar to the one on the other side of this sheet have been published.

Geologic maps of some of the areas shown on the topographic maps have been published in the form of folios. Each folio includes maps showing the topography, geology, underground structure, and mineral deposits of the area mapped, and several pages of descriptive text. The text explains the maps and describes the topographic and geologic features of the country and its mineral products. Two hundred twenty-five folios have been published.

Index maps of each State and of Alaska and Hawaii showing the areas covered by topographic maps and geologic folios published by the United States Geological Survey may be obtained free. Copies of the standard topographic maps may be obtained for 10 cents each; some special maps are sold at different prices. A discount of 40 percent is allowed on an order amounting to $5 or more at the retail price. The discount is allowed on an order for maps alone, either of one kind or in any assortment, or for maps together with geologic folios. The geologic folios are sold for 25 cents or more each, the price depending on the size of the folio. A circular describing the folios will be sent on request.

Applications for maps or folios should be accompanied by cash, draft, or money order (not postage stamps) and should be addressed to

THE DIRECTOR,
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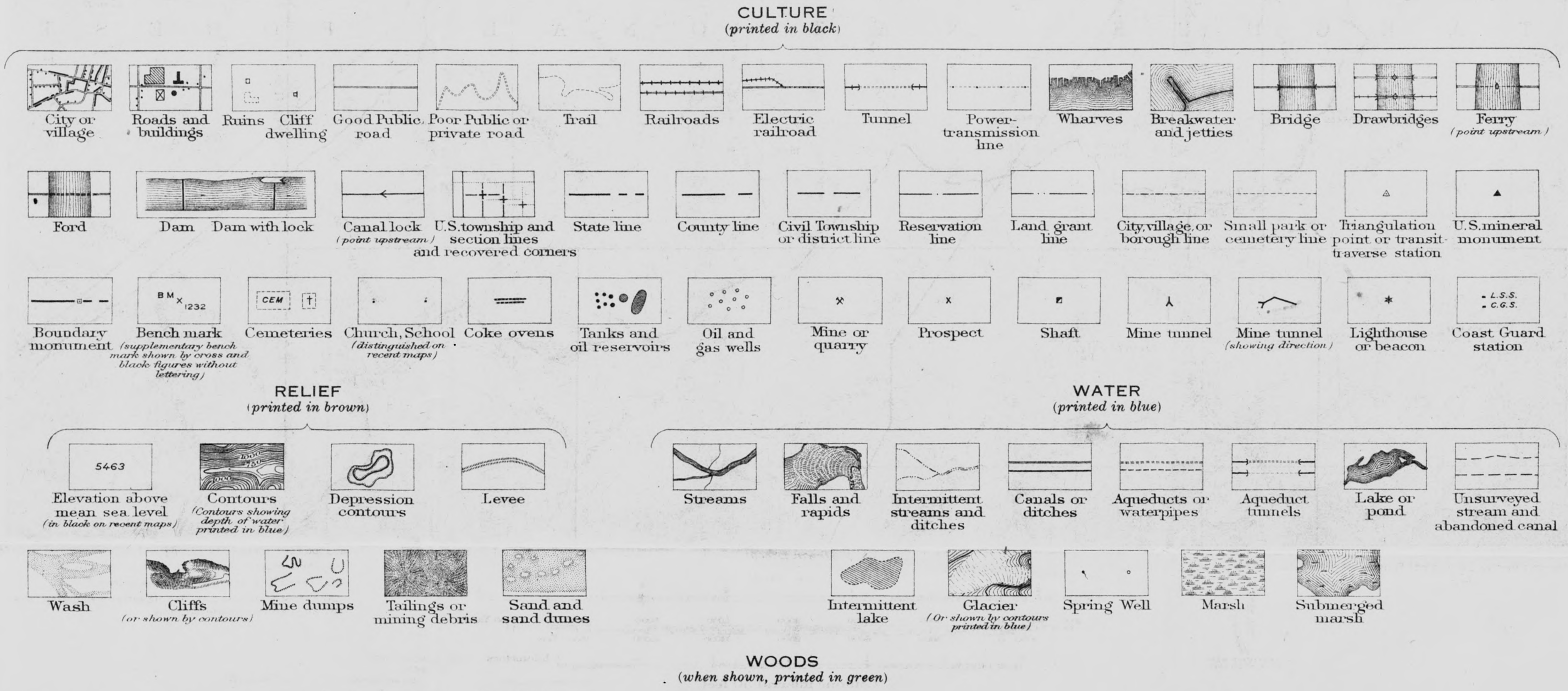

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Master's thesis

Wyman, Richard V., Anne F., and Newcomb, Esther H.
Geology of the northern Snake River Range, Idaho and Wyo-