THE GEOLOGICAL SURVEY OF WYOMING

S. H. KNIGHT, State Geologist

BULLETIN No. 24

THE GEOLOGY OF THE WESTERN END OF THE OWL CREEK MOUNTAINS, WYOMING

BY

DAVID LOVE

UNIVERSITY OF WYOMING
LARAMIE, WYOMING
APRIL, 1934

STATE OF WYOMING

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F O R E W O R D

This bulletin represents a definite contribution to the geology of Wyoming. No previous geological examinations of the area studied have been made. The report contains valuable additions to the Tertiary history of northwestern Wyoming.

The writer of this report was assigned the problem for his Master's thesis and it affords an excellent example of the manner in which the graduate research work of the Department of Geology of the University of Wyoming may serve the interests of the State.

S. H. Knight
State Geologist

C O N T E N T S

Geological history - continued

ILLUSTRATIONS

GEOLOGY OF THE WESTERN END OF THE OWL CREEK MOUNTAINS, WYOMING

by

David Love

INTRODUCTION

LOCATION

The region described in this report consists of an area of seventy-five square miles which is located in the northwestern corner of Fremont County, Wyoming approximately forty miles southeast of Yellowstone National Park. The area lies in T. 42 N. and T. 43 N., R. 105 W., 6th Principal Meridian and T. 7 N. and T. 8 N., R. 4 W., R. 5 W. and R. 6 W., Wind River Meridian.

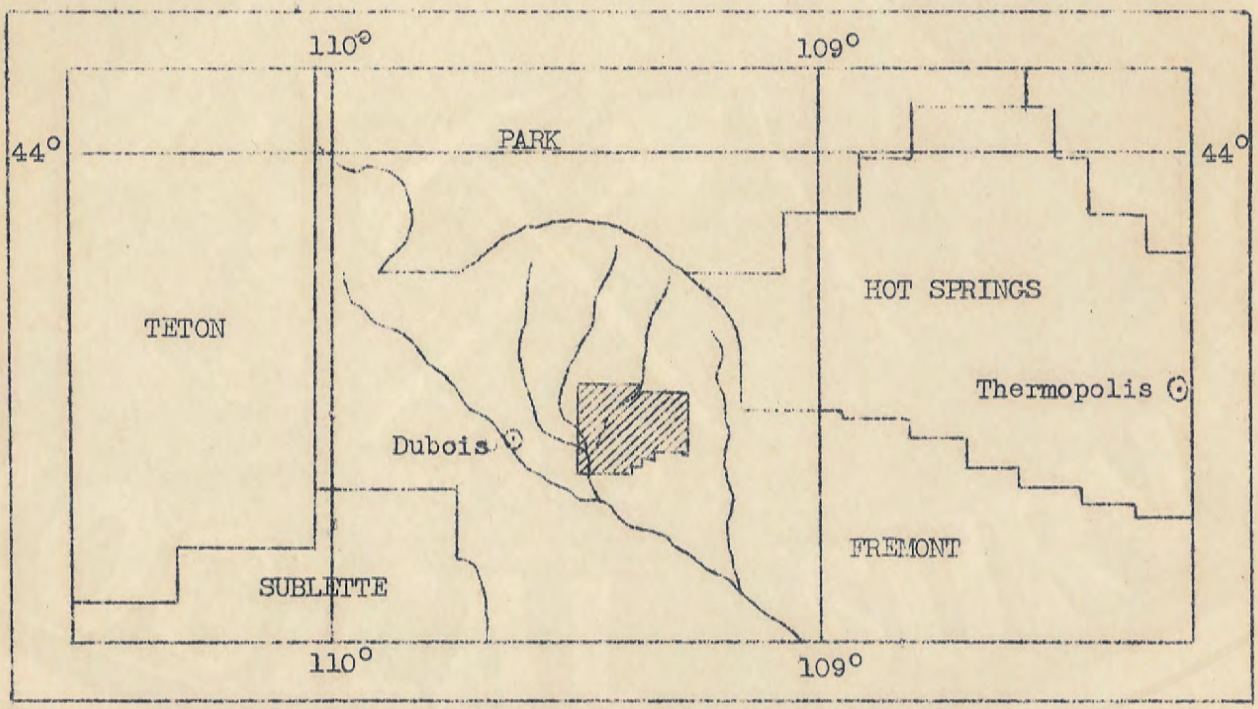


Figure 1. Index map showing the area described in this report.

The southern end of the Absaroka Range bounds the region on the east, north and northwest. In the southeast corner these mountains join and overlap the western end of the Owl Creek Range. The gently dipping eastern flank of the Wind River Mountains begins its ascent some five miles to the west of the western boundary of the area.

RELIEF

The relief of the area is extremely varied in character. The following are the most conspicuous of the land forms:

1. Mountains sculptured from volcanic rocks.
2. Bold granite ridges.
3. Basin-like depressions carved in horizontal, non-resistant Tertiary sediments.
4. Prominent ridges of steeply dipping Paleozoic sediments.
5. A broad, entranched flood plain.
6. Prominent remnants of two pediments.

In the eastern part of the area the topography is unusually rough. This is due to erosion of the peculiar type of volcanic rocks which make up the southern part of the Absaroka Range. In general, these rocks are so resistant that they form a great escarpment two thousand feet high. Steep-walled canyons flanked by pinnacles, spires and castellated remnants have been etched out of the escarpment. This is a distinctive and characteristic topographic expression of these volcanic rocks. The escarpment trends north and south in the area studied. Just beyond the northern boundary of the area it trends to the northwest.

In the southeastern part of the area the most conspicuous topographic feature is a high, but deeply eroded, granite ridge trending east-west. This forms the core of the western end of the Owl Creek anticline. To the south the ridge is flanked by Paleozoic sediments which rise higher in places than granites. The north side of the granite ridge is overlapped by the Tertiary volcanic rocks. In the north-central part of the area the granites again appear in the form of a ridge trending northwest-southeast. It rises well above the surrounding Eocene sediments and divides the area into two distinct basins. The channel of East Fork of North Fork of Wind River has cut a canyon 500 feet deep through this ridge.

The central and southern portions of the area are in the form of a major topographic basin-like depression. Erosion has etched out five smaller basins within this large one. These are established in the Eocene sediments and are surrounded by older, more resistant rocks.

In the northwestern part of the area is a jagged ridge composed of steeply dipping Paleozoic limestones which stand three hundred feet or more above the surrounding Eocene sediments. The distinctive feature of the ridge is that its long axis is parallel to the dip of the beds. Similar relationships were observed in adjacent areas and these tend to support the theory that the entire present drainage system has been superimposed.

To the east and south of the ridge the East Fork River has developed a remarkably flat flood plain which covers an area of five or six square miles. After this flood plain has been developed the river established a definite course across it and cut its channel to the present level, which is two hundred feet below that of the flood plain.

There are conspicuous remnants of two pediments in the area. One was developed on the Green River formation at an elevation of 8000 feet. The South Mesa, which is situated in the south-central part of the area, is a remnant of this pediment. The other was developed on the Wasatch formation at an elevation of 7500 feet. The North Mesa, which is located in the central part of the area, is a remnant of the second pediment. The present level of East Fork River is about 7000 feet.

PURPOSE OF THE SURVEY

The geological investigations which form the basis for this report were undertaken with the following objectives:

1. To determine the occurrence and economic significance of the mineral resources of this region.
2. To map the geological formations of this region.
3. To determine the age of the volcanic rocks of the region and to correlate them with the volcanic rocks in the northwestern part of Wyoming.
4. To describe the lithology and stratigraphy of the Paleozoic, Mesozoic and Tertiary sediments in this isolated region.

FIELD WORK

Field work was begun on September 30, 1933 and concluded on October 24, 1933, during which time a geological map was made and the stratigraphic and structural relations were worked out. The work was done solely by the writer. The topographic sheet of the Kirwin uadrangle was used as a base map. All points were checked with known locations, such as section corners and U. S. Geological Survey bench marks wherever available. Where previously established reference points were absent bench marks were established with the aid of the topographic sheet and the location of points incident to mapping were determined by means of triangulation from these bench marks. Only the larger dikes, sills and flows were mapped as the scale to which the map was drawn was not large enough to permit plotting of the numerous small exposures of volcanic rocks. Rocks of Cambrian age were mapped as Cambrian, undivided. Because of the poor exposures the entire redbed series was mapped as Chugwater.

ACKNOWLEDGMENT

The writer wishes to acknowledge his appreciation to Dr. S. H. Knight, State Geologist, who sponsored this work and made its completion possible, and to Dr. R. H. Beckwith and Mr. H. D. Thomas for their assistance in the identification of rocks and invertebrate fossils of this region. He also wishes to tender especial thanks to Mr. and Mrs. Thomas Duncan and Gavin Duncan for valuable information and assistance which greatly facilitated the successful completion of this project.

EARLIER GEOLOGICAL INVESTIGATIONS AND SURVEYS

As far as the writer has been able to determine no previous geological work has been done in this area. Eldridge (7, 32-33) included the area in a geological reconnaissance map of northwestern Wyoming which was published in 1894. At that time conditions were such that only the most generalized geological mapping could be done. Hayden (11, 97) worked farther south in the Wind River Basin proper. Darton's work (6) in the Owl Creek Mountains was terminated just beyond the eastern end of this area. E. B. Branson (3), D. D. Condit (4), and Blackwelder (2) studied the various formations along the eastern flank of the Wind River Mountains to the southwest. N. H. Brown of Lander, Wyoming, collected fossil leaves from the Green River formation four miles to the south. These leaves have been described by E. W. Berry (1) in a Professional Paper of the U. S. Geological Survey. There have been two Federal Land Surveys of the region. One used the 6th Principal Meridian as a base and the other chose an arbitrary base called the Wind River Meridian. The East Fork of North Fork of Wind River divides the two surveys. There are considerable offsets, both in township and range lines, and as the numbers are different in each survey a great deal of confusion is caused by the legal descriptions of areas along the river. The most accurate map of the region is the topographic sheet of the Kirwin quadrangle, surveyed in 1904 by the U. S. Geological Survey. The area described in this report is included in the southern part of this quadrangle. The U. S. Forest Service has made two maps of the region.

S T R A T I G R A P H Y

PRE-CAMBRIAN ROCKS

Most of the pre-Cambrian rocks are granites which are pink to buff in color. The coarse texture of the rocks indicates a deep-seated origin. The size of crystals varies in different areas but they seldom are under one-eighth of an inch in diameter. In sec. 5, T. 5 N., R. 7. W., there are a number of white and pink coarsely crystalline quartz dikes. These vary from a few inches to 6 feet in width and sometimes extend for more than a hundred yards. About two miles north of the area mapped occurs a dike of white quartz 30 feet across and a mile or more in length.

The following steps in the pre-Cambrian history of the area were recognized:

1. The formation of a basement complex consisting of black basic ferruginous schists and gneisses.
2. Intrusion of granites which digested all but a few remnants of the older rocks and gave origin to quartz veins.
3. Intrusion of many scattered dikes of diabase prophyry. These vary in width from a few inches to several hundred feet. Usually the thickest dikes dip from fifty to seventy degrees to the west. The phenocrysts are large and are lighter colored in the thickest dikes. In sec. 5, T. 7, N., R. 5 W., sec. 32, T. 8, N., R. 5, W., and sec. 7, T. 42 N., R. 104 W., there are numerous veins of amphibole asbestos which were deposited along fracture and cleavage lines in

GENERALIZED SECTION OF THE SEDIMENTARY ROCKS

SYST.	SERIES	FORMATION	SYM.	SEC.	THK.	CHARACTER
EOCENE	MIDDLE EOCENE	GREEN RIVER FORMATION	Tgr		0-2000	FINE GREEN SHALE, BUFF SANDSTONE, AND LENSES OF CONGLOMERATE
	LOWER EOCENE	WASATCH FORMATION	Tw		0-1500	FINE VARIEGATED SHALE, THIN BUFF SANDSTONES, AND ARKOSE
CRETACEOUS	UPPER	UNDIVIDED	Ku		700	VARIEGATED SHALE, GRAY SANDSTONE AND THIN LIMESTONES
	LOWER (?)	MORRISON FM.	Km		500	THIN SANDSTONES, LIMESTONES AND VARIEGATED SHALE.
JURAS.	UPPER	SUNDANCE FM.	Js		250	MASSIVE SANDSTONES, LIMESTONE AND RED SHALE
TRIASSIC (?)		CHUGWATER FM.	Ŧc		1300	RED, BUFF AND GREEN SHALES AND SANDSTONES AND SLABBY LIMESTONE
		DINWOODY FM.	Ŧd		300	BROWN SANDSTONE AND SANDY SHALE
CARBONIFEROUS	PERMIAN	PHOSPHORIA FM.	Cp		250	LIMESTONE, PHOSPHATE, CHERT AND GYPSUM BEDS
	PENN.	TENSLEEP FM.	Ct		300	CROSS-LAMINATED WHITE SANDSTONE
		AMSDEN FM.	Ca		250	SLABBY LIMESTONE, SANDSTONE AND CHERT BEDS
	MISS.	MADISON FM.	Cm		650	CHERT BEDS AND MASSIVE LIMESTONES
ORD.	UPPER	BIGHORN FM.	Ob		250	MASSIVE LIMESTONE AND DOLOMITE
CAMBRIAN	UPPER MIDDLE	CAMBRIAN UNDIVIDED	€u		1050	QUARTZITE, LIMESTONE, SHALE AND SANDSTONE
		PRE-CAMBRIAN	pre-€			GRANITE, DIABASE AND QUARTZ

a thick dike of black diabase. The fibers attain a length of three inches in some places but they are woody and brittle. Serpentine is often found between and surrounding the layers of asbestos. In this area are many veins of white calcite which were deposited along lines of weakness in the diabase. The veins attain a maximum width of six inches but are extremely irregular, and contain crystals of pyrite up to one quarter of an inch in diameter and some smaller crystals of chalcopyrite.

A deposit of hematite occurs in the granite just below the Cambrian outcrop in the SE. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 15, T. 7, N., R. 5 W. This deposit has the beneral appearance of a dike, and though partially covered by Wasatch variegated shales, it probably covers a considerable area. It has been reported to have a maximum iron content of 60%, but this report has not been confirmed. The deposit is a brilliant red and seems to have influenced the color of the overlying Cambrian quartzites and Wasatch shales.

CAMBRIAN ROCKS

In this report all the rocks of Cambrian age have been mapped as Cambrian undivided. Blackwelder (2, 417-419) has divided the Cambrian of the Wind River Mountains, into the Flathead sandstone at the base, the Gros Ventre shale in the middle, and the Gallatin limestone at the top. In the area described in this report, however, exposures were so poor and so limited in areal extent that the position of the contacts between these three members could not be definitely established. All three formations were recognized, but the lithology is somewhat different from that of the Cambrian in the Wind River Mountains to the southwest, and that of the Cambrian in the Owl Creek Mountains to the east described by Darton (6, 14-15). The total thickness is between 900 and 1000 feet.

The basal Cambrian member is separated from the pre-Cambrian granite by an erosional surface which is devoid of marked relief. The basal member consists, for the most part, of a hundred feet or more of thick bedded red to buff quartzite. In some beds the quartzite has a very distinctive red and white banded appearance, especially near the top, where it is less ferruginous than at the bottom. The basal sediments were derived from the granites, and are somewhat conglomeratic. The conglomerates grade upward into fine-grained sandstones with some shale lenses near the top.

Above the basal member is a sequence of soft buff sandstones and some shales, which is overlain by two layers of buff and gray limestone several feet thick. The upper limestone contains a few poorly preserved shell fragments. The limestone is overlain by a very friable sandstone, which is gray to brown in color, glauconitic, and contains many worm borings. Near the top of the bed is a distinctive layer of extremely ferruginous, glauconitic fissile sandstone containing well preserved specimens of Dicellomus politus. This sandstone bed is more than just a local feature, for it has been observed in several adjacent areas. Some of the green and reddish shales are remarkably fine-grained and fissile. These shales are characteristic of the middle member and are widespread, for their exact counterpart was observed 80 miles to the east on the southern flank of the Bighorn Mountains.

The upper part of the Cambrian consists of alternating layers of massive and slabby limestones, fine-grained buff sandstones and shales. Some of the more slabby limestones contain intraformational, or "edgewise" conglomerates. The limestone pebbles in the conglomerates are usually flat and somewhat worn and are pink to gray in color on freshly fractured surfaces, although the outside is usually greenish, due to a thick coating of glauconite. Many fragments of trilobites and a few worm borings constitute the only fossils and they are poorly preserved.

The lower and middle members have been referred to the Middle Cambrian and the upper member to the Upper Cambrian.

ORDOVICIAN ROCKS

Bighorn formation. - The Ordovician is represented by the Bighorn formation, which consists mainly of limestones and dolomites with a few thin beds of soft yellow sandstone and one layer of ferruginous banded quartzite near the top. The contact with the Cambrian is not exposed in the area studied. The lowest part of the Bighorn formation consists of a gray massive dolomite, containing a quantity of silica which occurs in a fine network of veins scattered irregularly through the rock. There are numerous chert lenses and nodules at various horizons.

The upper part is dark brown on weathered surfaces and a lighter buff on fresh surfaces. This member is thin and is capped by several feet of soft buff sandstones and two feet of ferruginous banded quartzite, which closely resembles the basal quartzite of the Cambrian. As no sediments corresponding to these have been found elsewhere in the Ordovician, it is possible that they may represent part of the Devonian rocks of the Wind River Mountains, although there is no direct evidence to substantiate this interpretation.

In the lower dolomite are fragmentary crinoid stems, corals and brachiopods. No fossils were found in the upper part of the formation. Miller (16, 195-213) has recently concluded that the Bighorn formation is of Richmond age.

MISSISSIPPIAN ROCKS

Madison formation. - The Mississippian is a thick succession of limestones known as the Madison formation. There is an erosional unconformity between it and the Bighorn formation representing all or part of Silurian and Devonian times. Blackwelder has described strata of Devonian age in the Wind River Mountains, but no conclusive evidence of them was found in this area, nor did Darton find them in the Owl Creek Mountains.

The Madison is the most conspicuous of the Paleozoic formations, since it is extremely resistant and forms high ridges wherever it outcrops. Its exact thickness is not known in this locality, for the contact with the Amsden is not exposed. The thickness is between 600 feet and 800 feet.

The lower part of the Madison is a pure gray limestone which contains few fossils except crinoids. Farther up in this member there are some chert lenses and nodules. The gray limestone is overlain by a massive light dove-colored, fossiliferous limestone which is easily recognizable. Most of the fossils observed were corals but there are also some crinoids and poorly preserved brachiopods. Near the top of this member is an irregular bed of chert which averages between five and ten feet in thickness. It is massive in some localities and is characterized by bedded structure in others. A fresh surface is light gray, but it weathers to a dull brownish black. This layer is prominent and forms jagged black dip slopes which are easily recognized. Some very well preserved barchiopods and corals were found in the chert, but they are extremely fragile and shatter more easily than the surrounding rock. For this reason no good specimens were obtained.

The uppermost part of the Madison is composed of cherty sandy slabby limestones, white, gray and buff in color. In some places they weather to a pale pink. Few fossils were observed in this member. The upper member is sometimes cavernous, as is the dove-colored member. A fine network of silica veins is etched out of the most cherty layers by weathering and the general appearance is similar to that of the lower Bighorn. The formation is sparsely fossiliferous in this locality. Lower Mississippian fossils have been collected from the Madison formation in adjacent localities.

PENNSYLVANIAN ROCKS

Amsden formation. - Only limited exposures of the Amsden formation were found and no complete section from base to top could be obtained. Since the Madison is strongly resistant to erosion and the Amsden is a relatively non-resistant member, the latter has been stripped from the underlying Madison limestone. The contact between the two formations is not exposed, but there is evidently no great angular discordance. A slight unconformity has been reported at the base of the Amsden in the Wind River Mountains.

The basal member consists of soft buff, gray and white sandstones of uniform texture. It is more or less massive at the bottom, markedly cross-laminated in the middle and thinly laminated near the top. There are a few lenses of massive chert in the sandstone member. These chert beds sometimes attain a thickness of four or five feet, are resistant and weather to a dark brown color.

The upper part of the Amsden formation is made up of shales, thin limestones, a few sandstones, and thin chert beds. The shales are soft gray and carbonaceous, and are thinly laminated. Only a few shale bands are more than a foot or two thick. The limestones are slabby, gray to white, relatively unfossiliferous and cherty. They vary from an inch to about ten feet in thickness. The chert beds are thin, gray or brown in color, and somewhat slabby. The sandstones are white thin-bedded fine in texture, and seldom more than two or three feet thick.

The total thickness of the formation is between 200 and 250 feet. No good fossils were found in the Amsden formation and it was correlated with the Amsden farther south strictly on the basis of lithology and stratigraphic position. The age of the formation is regarded as early Pennsylvanian, although in places at or near the base, chert nodules containing Mississippian fossils have been found. They are considered as having been derived from the chert beds in the underlying Madison.

Tensleep formation. - There are only a few exposures of the Tensleep sandstone in this region and in no place is a complete section available. Both the upper and lower contacts are visible and the relationships between the underlying Amsden formation and the overlying Phosphoria formation can be plainly seen. The Tensleep rests with apparent conformity on the Amsden. The Tensleep consists entirely of buff, gray and white sandstones which often turn dark brown on weathered surfaces. In general it is massively bedded, but in places is coarsely cross-laminated. The cross-lamination is of the "festoon" type (Knight 14, 56). The troughs are from ten feet to fifteen feet in width and the individual laminae are several inches thick. The sand grains are all about the same size throughout the formation. In some places the sandstones are more ferruginous than in others and contain numerous small hematitic concretions about the size of a pea.

This sequence of rocks has been correlated with the known Tensleep in the Owl Creek and Wind River Mountains entirely on the basis of lithology and stratigraphic position. Although no fossils were found by the writer the beds are considered to be of Pennsylvanian age, on the evidence of fossils found farther south. The total thickness is between 200 and 300 feet.

PERMIAN ROCKS

Phosphoria formation. - The Phosphoria formation is exposed in only a few places, but on a cliff along East Fork River the entire section is visible. It is about 250 feet thick. The basal contact is unusually well exposed, and the Phosphoria appears to lie conformably on the Tensleep sandstone but as the contact can be seen for only a short distance the exact relationship is uncertain. The basal bed of the Phosphoria is a buff sandstone breccia resembling the underlying Tensleep sandstone and probably was derived from it.

Overlying this breccia is a sequence of slabby hard fossiliferous limestone beds, about two feet thick, interbedded with unfossiliferous arenaceous limestones of nearly equal thickness. In the fossiliferous beds of this sequence the following fossils were found: (Identified by H. D. Thomas).

Aulosteges hispidus
Meekella rotundata (?)
Composita cf. mexicana
Punctospirifer pulchra
Bryozoa

Meekella rotundata (?), Punctospirifer pulchra and many bryozoa, which have not as yet been identified, are extremely abundant while the others are comparatively scarce. On the basis of stratigraphic relationships it would seem that these beds belong to the basal Phosphoria, as it is believed that there are no underlying structural complications. Branson (3) has zoned the Phosphoria on the basis of the different types of fossils present at distinct horizons throughout the formation. The beds containing the above group of fossils have always been found near the top of the Phosphoria. This faunal zoning has become more or less standardized and is generally accepted. However, the fossils in this limestone series directly contradict the classification. Since there was no time for careful re-examination and additional collecting this question still remains an open problem to be solved only by a detailed study of the section and the compilation of a complete faunal list from the various horizons in this locality. It seems likely that in this isolated region the faunal zones may differ markedly from those at Bull Lake nearly fifty miles to the south, where the original compilation was made.

Next above the limestone beds are from fifty to one hundred feet of interbedded sandstones, thin fissile limestones, and shales. They are gray to buff in color and the limestones contain an abundance of bryozoa. Overlying this sequence are about a hundred feet of alternating chert beds, limestones and two phosphate beds. The chert beds are thickest and comprise the largest part of this succession. The chert nodules are intestine-shaped masses from one to two inches in diameter and of varying length. They are brownish to gray in color and are imbedded in a matrix of fine buff sandstone. On weathering the nodules break up and form slopes of small angular gray chert fragments. In the lower chert beds are found an abundance of _Avonia subhorrida_. These fossils are silicified and well preserved. They weather out in great numbers and combine with the chert fragments to cover the slopes at the base of the outcrop. The limestones vary from a few inches to several feet in thickness, and are cherty, argillaceous and arenaceous. They are very fossiliferous and gray to buff in color. The major part of the limestone is made up of great numbers of _Pustula nevadensis_ and specimens are abundant in the buff sandstones. There are also many crinoid fragments and specimens of _Pleurophorus_ (?), and _Composita mira_. These fossils are silicified and unusually well preserved. They often weather out perfectly.

The two phosphate beds are thin, seldom over a foot in thickness, and consist of a dark gray matrix in which are embedded small black shiny pelecypod shells. These shells are never abundant and are the only fossils present. Considerable sand is present in the light colored phosphatic beds, while the darked beds are composed almost entirely of phosphatic material.

On the top of the uppermost and thickest chert bed is a greenish shaly sandstone one foot thick. This sandstone is overlain by a bed of very impure pinkish gypsum. The gypsum is soft and poorly exposed, and because of its irregular and lenticular shape, no accurate thickness could be obtained. It probably is not more than four feet thick. The gypsum is overlain by a few feet of cherty fossiliferous limestone containing great numbers of _Productus nevadensis_ and _Hustedia phosphoriensis_.

On the basis of abundant paleontological evidence the Phosphoria has been correlated with the Word formation of Middle Permian age in Texas, (King 13,32).

TRIASSIC (?) ROCKS

Dinwoody formation. - The exact contact between the Phosphoria and Dinwoody is not visible because of the soft character of the basal Dinwoody shales and sandstones, but the formations are apparently conformable. The general lithology is essentially the same as that of the Dinwoody formation at the type section near Dinwoody Lakes. For the most part, the formation consists of extremely fissile calcareous and argillaceous brown sandstone and grayish-green shales. The sandstones are, in general, rather soft and poorly exposed. The more resistant beds weather dark brown or black, and contain great numbers of small, poorly preserved pelecypods. There are seldom larger than one quarter of an inch by one half of an inch and are so poorly preserved that identification is impossible. The top member of the formation consists of about fifty feet of hard greenish-brown sandstone which usually forms dark cliffs. No fossils were found in this member.

Gypsum was not observed although it is one of the characteristic features of the Dinwoody formation, both in the Owl Creek Mountains to the east and the Wind River Mountains to the southwest.

The age of the Dinwoody formation in this locality is uncertain due to the scarcity and poor preservation of fossils. The Dinwoody formation at its type locality has been correlated with the Woodside shale of Idaho and Utah, which is apparently Triassic in age. On the basis of this correlation the Dinwoody has been tentatively assigned to the Triassic. The total thickness of the formation is about 300 feet.

Chugwater formation. - In general the Chugwater formation is similar to the Chugwater of central and southeastern Wyoming. Locally, however, there are some very distinctive differences in its lithology. The formation is approximately 1300 feet thick in this locality. The total thickness cannot be determined owing to the fact that the base is not clearly exposed and the upper portion has been removed by erosion.

The lower part consists entirely of unfossiliferous fissile, thinly-laminated to massive red sandstone and red shales. The alternating shales and sandstones vary in thickness from a few inches to thirty feet. The shales are usually sandy but the greater part of the entire formation consists of massive to thin-bedded red sandstones in varying degress of consolidation.

There is an abrupt change in the lithology approximately 800 feet above the base of the formation. At this horizon there occurs a white to greenish ripple-marked, fine-grained sandstone about three feet thick, overlain by about thirty feet of red shales and sandstones containing a few badly macerated plant remains. Above this are more than twenty feet of variegated shales, usually red, purple or ochre in color. The red band contains gray sandstone condretions in abundance. The ochre band is ten feet thick. It is easily recognized and can be traced as far south as Dinwoody Creek. On top of the ochre shale are a few inches of brilliant green sandstone. To the south at Dinwoody Creek this member thickens to about five feet. Overlying it are about thirty feet of hard massive fine-grained red sandstone. This group of beds probably represent the Popo Agie beds of Williston (18, 688-697), for in this area N. H. Brown* found bones and teeth of a Triassic labyrinthodont. On this sequence of beds lies a conglomerate composed of light-colored, rounded limestone fragments embedded in a red limy matrix. These pebbles greatly resemble specimens of the Paleozoic limestones but their exact origin was not determined, for no fossils were found in them. This member is about fifteen feet thick. Overlying it is another limestone conglomerate of different character. It is much finer grained and the red limestone matrix is less sandy and appears to have been brecciated before the rock was completely consolidated. These conglomeratic beds are similar in lithology to the conglomerate of the Jelm formation as described by Knight (15, 68-69).

The remainder of the Chugwater formation exposed in this area consists of a hundred feet or more of alternating lavender limestones and red shales interbedded with a few thin white sandstones. The individual limestones are seldom more than two feet thick, and some are very fossiliferous. The basal limestone contain an abundance of shell fragments, but in the upper members the fossils are more numerous and better preserved. Ostrea sp. and Pteria (?) are the most common, although there are great numbers of bryozoa in some of the limestones. These fossils have not been definitely identified. The limestones are separated by red, gray, and green sandstones and red shales, the individual beds of which are seldom more than two or three feet thick. Near the top of the series is an oolitic limestone, two feet thick. Ostrea and Pteria (?) shells occur in this bed, although they are not as numerous, or as well preserved as in the underlying and overlying limestones.

The exact age of the entire Chugwater formation is not definitely known owing to the absence of distinctive fossils. In the vicinity of Lander Upper Triassic vertebrates have been found above the middle of the formation. The lower part is entirely unfossiliferous and is usually considered either Triassic (?) or Permian (?).

JURASSIC ROCKS

Sundance formation. - The Sundance formation is not exposed in this area. It is undoubtedly present in the southern part beneath the low angle fault which thrusts the Chugwater onto the Upper Cretaceous rocks. As the Sundance is exposed south of this region, a description of it is included.

In general, the Sundance formation consists of about three hundred feet of gray calcareous shale, limestones and sandstones. The basal part is represented by shales and limestones, which contain few fossils. The shales and limestones grade into fossiliferous gray shales, which become more sandy toward the top. In the middle shale member fossils are abundant and well pre-

* Personal communication.

served. Gryphaea calceola occurs in great numbers. The top member of the Sundance consists of a massive soft white sandstone. There is no evidence of a distinct stratigraphical break between the Sundance and the overlying Morrison formation. The Sundance formation is of Upper Jurassic Age.

LOWER CRETACEOUS ROCKS

Morrison formation. - The Morrison formation is not exposed in the area studied but it is undoubtedly present. Five miles to the south the following features were observed. The Morrison rests with apparent conformity upon the Sundance. The formation consists of soft shales, sandstones and thin beds of freshwater limestone. The shales are variegated with lavender, gray, green, yellow and red colors predominating.

UPPER CRETACEOUS ROCKS

In the southwest portion of the area there is exposed a series of Upper Cretaceous formations. No attempt was made to differentiate the formations or to study them in detail. The basal beds are composed of friable sandstones and interbedded shales aggregating 100 feet or more in thickness. These beds are probably the stratigraphical equivalent of the Cloverly formation. Above the sandstone and shale beds is a thick succession of dark marine shales and gray shaly sandstones similar to the Thermopolis shale of the Bighorn Basin. In the upper portion of these beds there is a hard fissile shale, which weathers to a silver gray and which contains numerous fish scales. This shale is comparable in all respect to the Mowry shale. Overlying this succession are several thin sandstones with interbedded sandy shales and two thin coal seams. Where observed the coal seams are irregular and vary in thickness from a few inches to four feet. The coal has been crushed and is of little or no commercial value. The stratigraphical position and lithological character of the sandstones, sandy shale and coals suggests that they represent the lower portion of the Frontier formation. The younger Upper Cretaceous formations are not exposed in the area.

LOWER EOCENE ROCKS

Wasatch group. - A great unconformity separates the Wasatch sediments from all the older rocks, which were folded, faulted and so deeply eroded that all the Paleozoic and Mesozoic sediments and the pre-Cambrian crystallines were exposed. The contact between the Wasatch and older rocks shows a relief of at least 2000 feet. All the Wasatch sediments are extremely variable in color, texture and composition. These features depend, to a large extent, on the local relationships of the Wasatch sediments to the surrounding older rocks. Therefore the most satisfactory method of describing the Wasatch will be to discuss individually each locality in which it was studied. There is little similarity between the Wasatch exposures in these areas, although adjacent areas are less than a mile apart.

Section 3, T. 7 N., R. 5 W.

The Wasatch lies in a trough in the granites. The basal beds were derived largely from the granites and consist of coarse arkosic grits. The individual fragments are extremely angular, although they are seldom more than one half of an inch in diameter. The arkoses become finer-grained higher in the sequence and grade upward into fine-grained red and white shales. Interbedded with the arkosic grits is a resistant conglomerate, the individual pebbles of which are not more than in inch in diameter. This bed is four feet thick, and forms a conspicuous outcrop which is marked by a line of pine trees. The shales are red and white and very fine-grained, especially near the top where they contain a large amount of volcanic ash. In the upper part of the shales there is a lenticular bed of finely laminated brown carbonaceous shale containing quantities of macerated plant remains. They are mostly broad-bladed marsh grasses and leaves of Equisetum (?). There is some petrified and carbonized wood associated with the plant remains. A few bones and teeth of Coryphodon were found near the middle of these beds. On the basis of these fossils and similar ones found in adjacent areas this sequence of rocks has been correlated with the Wasatch of central and southern Wyoming. While the vertebrate remains are characteristic of the Wasatch time they are not sufficiently distinctive to permit a definite correlation with beds of Wind River age.

Section 16, T. 7 N., R. 5 W.

The Wasatch is composed of variegated shales interbedded with a few thin arkosic grit lenses. The color of the shales is markedly different from that in adjacent localities. Here there are few white beds and the predominating colors are red, purple, green and yellow. Much or all of the red coloring matter appears to have been derived from a ferruginous dike in the pre-Cambrian rocks exposed at the north end of the "limestone ridge" in the northeast quarter of Section 16. The yellow beds are composed of shales and soft limonitic sandstones which form buff concretions or concretionary layers several feet thick. The green shales contain a high percentage of volcanic ash which is colored green by chlorite. Two brilliant green beds, each about fifteen feet thick, form the most conspicuous lithologic units in this area. There are also several beds of a pale green color. This coloring material may have been derived, in part, from a green glauconitic bed in the Cambrian which is exposed in several places close by.

Teeth and bones of Coryphodon constitute the principle fossils but fragments of rodent incisors and some small herbivore molars were found.

Section 5, T. 7 N., R. 5 W.

Here the Wasatch formation lies in a basin partially surrounded by pre-Cambrian granites and porphyritic meta-diabases. The basin is about one half mile in diameter and from three to four hundred feet deep. The sediments are unusually corase-grained in comparison with the Wasatch in the other localities studied, and the colors are also distinctive. Pale green, pale red, pale yellow, black, gray and white are the most common. The sediments are predominately arkosic grits although there are a few shale beds both in the center of the basin and high in the succession. The black coloring material is derived from a thick pre-Cambrian dike of black porphyritic meta-diabase which is exposed all along the east side of the basin. The arkosic grits consist mainly of angular fragments of quartz and feldspar derived directly from the granites and meta-diabases. Fragments of bones and teeth of Coryphodon were found in abundance in a lower red shale member in the center of the basin. These specimens had been broken and weathered before fossilization took place.

Section 6 and 7, T. 7 N., R. 5 W.

Section 13, T. 42 N., R. 105 W.

The Wasatch sediments were deposited upon the granites in the northeast portion and across the entire Paleozoic section in the southwestern part of this locality. The extremely fine texture is a conspicuous feature of these sediments. Fine-grained variegated shales are found lying directly upon the granites and the Paleozoic sandstones and limestones. No conglomerates are present and there are only a few arkosic grit lenses and thin local sandstone beds. As in the other localities the color of the beds shows great variation. Purple is the predominating color, but red, green, white and yellow shales are also present. The white and yellow shales often contain buff sandstone concretions a foot or more in diameter. In some places these concretions are so numerous that they form lenticular beds.

Many teeth of small Eocene herbivores were found in the red shales at various horizons. A few fragments of a large incisor were collected from a dark greenish-purple bed near the base of the succession. These fragments have been tentatively identified as part of the third right lower incisor of Calamodon. The maximum thickness of this sequence is about six hundred feet.

Sections 13 and 14, T. 7 N., R. 6 W.

Here the Wasatch sediments are composed of an alternating sequence of red and white beds. The color changes between the individual beds are very sharp and they produce a most striking effect when viewed from a distance. Each red and white bed has a uniform thickness of about fifteen feet. This condition prevails throughout the entire sequence. In general, the sediments are coarse, and near the base they are entirely arkosic in character but near the top shales make their appearance. The red coloring material has been derived in part, at least, from the Chugwater formation which is extensively exposed just north of where the Wasatch was studied. The arkosic grits were derived entirely from the granites. Individual grains are seldom more than one eighth of an inch in diameter. No fossils were found in this locality and it is probable that the sediments were too coarse-grained to permit good preservation. The exact thickness of the sequence could not be determined as the basal portion is not exposed. At least 400 feet are visible.

Section 22, T. 42 N., R. 105 W.

Lying upon the upturned and eroded edges of the Chugwater formation is a consolidated layer of coarse conglomerate. The roundstones vary in size from a few inches to five feet in diameter and consist mainly of limestones, although some are composed of chert, granite and sandstone. The conglomerate lies nearly flat and appears to be more or less local in character, for it cannot be traced more than a few hundred yards in any direction. Wherever found, it forms a resistant cap on the Chugwater formation. The boulders are tightly cemented together by a fine red limy sandstone, probably derived mainly from the Chugwater. The total thickness is not more than fifty feet. The conglomerate is overlain by characteristic fine-grained variegated Wasatch shales. No fossils of Wasatch age were found in this locality but the beds contain derived fossils from the underlying Paleozoic and Mesozoic sediments.

Section 3, T. 41., R. 105 W.

In this section the Chugwater formation is capped by nearly a hundred feet of horizontal, poorly bedded conglomerates. The roundstones attain a maximum size of three or four feet at the base, and are of many sizes, but near the top of the section they are all smaller than marbles and are stratified and assorted. A fine-grained red sandstone, probably derived from the Chugwater sandstones forms the cementing matrix. On the whole, these conglomerates resemble the conglomerates overlying the Chugwater in sec. 22, T. 42 N., R. 105 W. As in that section, no fossils of Wasatch age were found but there was a bed containing numerous well preserved specimens of Gryphaea calceola and Belemnites densus derived from the Sundance, which has been entirely removed from the area. There are many specimens of brachiopods and corals from the Madison formation. Pustula nevadensis from the Phosphoria is also present.

Wasatch flows. - The volcanic extrusives which are interbedded with the sediments of known Wasatch age are termed Wasatch flows. The flows are of uniform lithological character throughout the area and with but one exception they consist of pink, green and white porphyritic rhyolites and rhyolitic agglomerates. In general, the rhyolites are coarse-textured. The quartz grains are readily seen with the unaided eye and sometimes attain a size of one-eighth of an inch and the feldspar crystals often are one-quarter inch in diameter. In many flows, the thinner ones in particular, the rhyolites contain a great deal of country rock which has been altered by contact metamorphism. This is especially true where the Paleozoic limestones have been cut by dikes. There is one flow of dark-colored fine-grained andesite in sec. 7, T. 7 N., R. 5 W.

The various flows studied exhibit individual characteristics. In order to avoid confusion each flow is discussed separately.

Section 1 and 2, T. 42 N., R. 105 W.
6, T. 42 N., R. 104 W.
5, T. 7 N., R. 5 W.

This is the thickest and most widespread Wasatch flow in the whole region. It begins on the east side of East Fork in sec. 5, T. 7 N., R. 5 W., Wind River Meridian, and extends to sec. 2, T. 42 N., R. 105 W., Sixth Principal Meridian. The thickness increases to the west, although the character of the rock remains uniform throughout the entire flow, or rather flows, for there are several, separated by thin, highly altered bands of Wasatch shale. In some cases the shale is metamorphosed to such an extent that it is hardly distinguishable from some of the softer rhyolitic agglomerates. Red and green rhyolites are the most common but there is one bluish layer just above the pre-Cambrian granites. Usually the exact relationship between the flows and the Wasatch shales is somewhat obscure, for the individual flows are separated by only a few feet of shale. The resistant character of the flows has caused them to remain in the form of a long, flat-topped ridge standing several hundred feet above the present lowland erosion surface. The ridge is capped by a layer of coarse gray rhyolite.

Section 5, T. 7 N., R. 5 W.

In the southern and eastern part of this section are a number of small thin flows which have only a short lateral extent and have been deeply eroded so that their upper and lower contacts are well exposed. In one place a sill has been intruded and the metamorphism of the underlying, overlying and adjacent sediments may be studied readily. The red shales in some places have been baked and otherwise altered to a distance of twenty feet away from the contact.

A short distance to the east of this sill, the relationship between a small flow and the overlying and underlying white shales can easily be seen. The contact between the flow and the overlying Wasatch shale can be determined exactly. The shale shows no effects of metamorphism. Instead, small fragments of the rhyolitic material from the flow are embedded in the soft white shale. The fact that the flow is also underlain by Wasatch shales is proof that there was a period of vulcanism accompanied by rhyolitic intrusions and extrusions during Lower Eocene time.

NE. $\frac{1}{4}$, NE. $\frac{1}{4}$ Section 18, T. 7 N., R. 5 W.

There are a number of small flows in this area and, as they are unusually well exposed, they furnish additional proof of a period of acid igneous activity in the Lower Eocene. Both the upper and lower contacts may be clearly seen. One flow consists of about four feet of white rhyolite lying on a white shale which has been metamorphosed for several feet beneath the contact. The contact of the flow with the overlying shale is well exposed and here the sediments have not been metamorphosed.

There are numerous other flows in the area but they are of more or less uniform character and are not as well exposed as those described.

Nearly all the Wasatch flows occur near pre-Cambrian masses or Paleozoic sediments. It seems probable that the Paleozoic sediments were partly or completely surrounded by these flows at some time. In sec. 3, T. 42 N., R. 105 W. there is a reddish band extending around the Paleozoic outcrop at about the height of the largest Wasatch flow. The same reddish band is more pronounced in the NW. $\frac{1}{4}$ sec. 16, T. 7 N., R. 5 W. Here a ridge of Paleozoic sediments is encircled by a fringe of bright-red baked shale and sandstones. As there are remnants of flows at both ends of this ridge, it is probable that they once extended completely around it. Evidently the Wasatch flows were much more extensive than at present. Most of the flow remnants are in the vicinity of older, more resistant rocks.

MIDDLE EOCENE ROCKS

Green River formation. - The Green River formation was first described by Hayden from its occurrence near Evanston in the Green River Basin. Heretofore the formation has not been described to the east or north of the Wind River Mountains, although Berry (1, 55-60) in 1930 described a Green River flora which was collected from the northern portion of the Wind River Basin. The Green River formation of this locality presents the following distinctive features:

1. It is separated from previously known Green River sediments of the formation by the Wind River Mountains.
2. There is evidence of an interval of andesitic igneous activity during Green River time.
3. The formation is separated from the underlying Wasatch by an erosional unconformity.
4. The formation in this locality is coarser than in the Green River Basin to the south.

Between the close of Wasatch time and the beginning of Green River sedimentation in this locality there was a period of profound erosion, which entirely removed the Wasatch sediments from some parts of the area. The land surface was still in a state of high relief when the basal Green River sediments were deposited. In some places there was a vertical rise of a hundred feet in a horizontal distance of three hundred feet. The basal beds consist, for the most part, of conglomerates and sandstones, although in a few places the entire basal member is made up of reworked Wasatch shales.

The conglomerates are local, probably marking stream channels, and are lenticular in shape. The pebbles are well rounded, vary in size from one quarter inch to about three inches, and are composed largely of Wasatch rhyolites. The matrix of the conglomerate is a soft sand composed usually of small fragments derived in part from the Wasatch rhyolites. Few of the individual lenses are more than three feet thick.

Wherever studied the sandstones show a striking similarity. A hand specimen from one locality cannot be distinguished from one taken several miles away. In most places the sandstones are greenish-buff in color. Some are cross-laminated, but most of them have plain stratification. The sand grains are of nearly equal size, contain many rhyolite fragments and are firmly cemented by volcanic ash. The beds are so well consolidated that they form small projecting cliffs. The thickness of the individual sandstone beds varies from a few inches to nearly seventy feet, although the average is about fifteen.

By far the greater part of the Green River formation consists of shales, which are also of very uniform character and can be easily differentiated from the underlying Wasatch. Almost all are green, varying from fine-grained bright-green hard shale to soft dull grayish-green shale. There are a few white shales and a few brown carbonaceous bands, but they are not common. Some of the gray shales near the top of the succession are so soft that on weathering, their appearance is similar to that of the gray Wasatch shales.

The green shales are usually compact, thinly laminated, pale-green, hard and brittle. Ripple marks are a common feature and there is a great abundance of plant impressions. Most of the plants are either Sparganium or Equisetum. There appear to be several species of each present, although they have not been definitely identified as yet. Most of the shales contain a quantity of volcanic ash and the leaves are well preserved in this fine matrix.

A few thin beds are made up almost entirely of a very hard brittle pink extremely fine-grained volcanic ash. No bedding is visible and the rock breaks with a conchoidal fracture. Usually there are a few poorly preserved plant fragments embedded in the ash.

In sec. 2, T. 7 N., R. 5 W. the uppermost beds of Green River age exposed in the area were studied in detail. On top of the typical hard green slabby shale is a yellow quartz grit about fifteen feet thick, which contains weathered rhyolite and andesite pebbles up to an inch in diameter. In the grit was found a partly carbonized, partly silicified black log of petrified wood, of which nearly ten feet were exposed. This member is overlain by several feet of hard pink brittle volcanic ash containing a few carbonized plant fragments. Overlying the ash are several feet of very finely laminated, fissile carbonaceous shale containing a great abundance of plant remains. Most of them have been tentatively identified as Sparganium and Equisetum. A few seeds were found. No good leaf specimens were secured, for they were macerated and imperfectly preserved. Jarosite has been deposited where the leaves were most abundant and it ruined nearly all of them near the surface. Above the carbonaceous shale several feet of loosely cemented yellow jarositic arkosic sandstone.

The next member is a second bed of brown fissile, thinly laminated carbonaceous shale about five feet thick, which contains an abundance of plant remains. Most of them are carbonized, although a few unaltered leaves were found. Most of the leaves are broad-bladed marsh grasses and palms and there are some seeds and conifer needles present. The topmost members are covered by a heavy growth of timber and could not be studied.

There is definite evidence of a period of igneous activity during Green River time. The volcanic rocks are not as thick, nor as widespread as the Wasatch flows. Many soft brown and green fine-grained andestic tuffs not more than three of four feet in thickness, are interbedded with the green shales and buff sandstones. It is difficult to differentiate the interbedded Green River flow breccias from the post-Green River dikes and sills which have been intruded into the formation, for they are both found in the same localities and many have the same general appearance. In sec. 2, T. 7 N., R. 5 W., there is an unusually good exposure of the Green River formation in which are interbedded four or more thin flow breccias of green basic andesite. The upper and lower contacts are so well exposed that there is little doubt as to the age relationship. Although the flows are only about three feet thick, they can be traced along the cliff face for several hundred feet. A number of other small exposures of igneous rock were found in the vicinity but their age relations are not clear.

It is impossible to determine the exact thickness of the Green River formation, as its lower contact is rather uneven and no younger sediments have been found on top. Between 1500 and 2000 feet of known Green River sediments are exposed in this area. It is probable that the original thickness was much greater.

The sediments described above were correlated with the Green River formation of southwestern Wyoming on the basis of plant remains found four miles south of this area by N. H. Brown. The leaves were discovered on a high mesa in two beds of brown carbonaceous volcanic ash, corresponding to the two carbonaceous beds in sec. 2, T. 7 N., R. 5 W. The leaves were identified by E. W. Berry, (1, 55-60) who states, "Of the 21 species common to the Wind River Basin and the Green River Basin, 15, or about three-fourths, are not known to occur anywhere else than in these two areas, which are not geographically remote. The conclusion seems to be reasonably well established that these deposits in the Wind River Basin are of very nearly the same age as those containing the Green River flora in the Green River Basin." The Green River formation is of Middle Eocene age.

No vertebrate remains were found but a few poorly preserved gastropods were collected.

POST-GREEN RIVER ROCKS

The Tertiary history following the close of the Green River epoch is extremely complicated. Unfortunately the lack of fossils makes it necessary to work out the stratigraphy and structure entirely on the basis of lithology and contact relations.

No evidence has been found which would definitely establish the time when Green River sedimentation ceased, or whether there were any younger sediments deposited on the top of the formation. Judging from the relationship of the oldest member of the post-Green River volcanic series to the Green River formation it seems that the region was subjected to another period of profound erosion, which removed all but the basal Green River from several places before the volcanic activity began. That considerable time must have elapsed between the deposition of the Green River sediments and

GENERALIZED SECTION OF THE TERTIARY IGNEOUS ROCKS

THE GEOLOGICAL SURVEY OF WYOMING BULLETIN NO. 24 PLATE NO. IV

SYST.	SERIES	FORMATION		SYM.	SEC.	THK.	CHARACTER
POST-MIDDLE EOCENE		RAMSHORN	ANDESITE FLOWS	Taf		0-600	COARSE PINK TO GRAY AGGLOMERATE
		RAMSHORN	WHITE TUFFS	Twt		0-700	SOFT, COARSE, BEDDED, ANDESITIC TUFF
		PINK ANDESITE AGG.		Tpab		0-600	EXTREMELY COARSE AND MASSIVE
		WHITE ANDESITE		Twa		0-650	EVEN TEXTURE AND COMPOSITION
		BROWN ANDESITE		Tbb		0-500	COARSE AND MASSIVE AGGLOMERATE
		GREEN ANDESITE		Tga		0-300	COARSE AND EVEN TEXTURED
EOCENE	MIDDLE EOCENE	GREEN RIVER FLOW BRECCIAS		Tgrf		0-20	FINE, GREEN, HARD BRECCIAS INTER-BEDDED WITH GREEN RIVER SHALE AND SANDSTONE
	LOWER EOCENE	WASATCH FLOWS		Twrf		0-50	RED AND GREEN RHYOLITE INTERBEDDED WITH WASATCH VARIEGATED SHALE AND SANDSTONE

intrusion and extrusion of the later volcanic series, is shown by the fact that nowhere along the contacts between the sediments and the dikes, has there been much distortion or metamorphism. Evidently the sediments were well consolidated before the beginning of this igneous phase.

Apparently the first of the post-Green River volcanic series intruded into and extruded on the Green River formation were green andesites. Their exact relations to the other volcanic rocks is rather obscure, for only a few small dikes and flows have been found, and most of them are entirely within the Green River. The rock is fine-grained, slabby and so resistant that the dikes stand conspicuously above the softer sediments which they cut. In general, the color is a pale green on a fresh surface and brown on a weathered surface due to oxidation of the ferromagnesian minerals.

The next group of rocks are brown andesitic agglomerates and breccias. It is not certain whether they are older or younger than the green andesites, for in the only place where both are found together, the contact is covered. The brown breccias must have been fairly widespread but have been almost entirely covered by younger flows. In general the breccias are pale yellowish-brown, and consist, for the most part, of angular fragments, from a fraction of an inch to several feet in size, of fine brown and green andesitic material, embedded in a hard brown ash. The agglomerates form outcrops with long steep-sided walls and pinnacles.

Cutting, and overlying the agglomerates and breccias is one of the most conspicuous of all the Tertiary igneous rocks in this region. Great dikes, sills and flows of white andesitic material were intruded and extruded onto the older rocks. Some of the dikes are from five hundred to seven hundred feet in thickness, and their extreme whitness makes them visible for miles. Another distinctive feature is the fine-grained uniform texture of this entire group of rocks. Small phenocrysts of hornblende and white feldspar are embedded in a white felsitic groundmass. These rocks are non-resistant to erosion, and the outcrops usually take the topographic expression of valleys.

The volcanic rocks overlying the white andesites comprise the most widespread and variable group of igneous rocks exposed in the region. They consist of andesites, andesitic agglomerates and breccias. The color is usually pink, but varies to gray, green, black and brown. The texture, in general, is rather coarse. However, in some instances the individual grains are hardly visible. In the agglomerates massive fragments of older igneous rocks, from ten to twenty feet in diameter, are embedded in a coarse angular breccia, tightly cemented by volcanic ash. This is the thickest group and is so resistant that it forms the crest of the extreme southern end of the Absaroka Mountains and caps all the outlying ridges. Erosion has carved these rocks into weird and fantastic shapes. On the flanks of the Absaroka range, nearly all the castellated rocks, spires and pinnacles are formed from this group of rocks. A few massive silicified tree stumps, several feet in diameter, have been found and were identified by Mr. Harry Mac Ginitie as <u>Tsuga</u> or hemlock, which suggests the possibility of a late Tertiary plant assemblage.

A great erosion interval preceded this phase of igneous activity during which time the older igneous rocks were planed off and the Green River and other formations were eroded. Due to the resistant character of the mass of dikes, sills and flows a high ridge was preserved, which stood out above the surrounding country. Next, from widely distributed fissures the andesitic breccias and agglomerates were extruded. They poured down the sides of the high ridge and in some places are still preserved in their original position, often on a slope of 30 or 40 degrees.

This group of volcanic rocks has been tentatively correlated with the "early basic breccia" of Yellowstone Park. The lack of fossil evidence and distance between the two makes exact correlation impossible but at Kirwin, 20 miles north of this region, rocks with characteristics common to both the "early basic breccia" and to the andesite breccias and agglomerates of this region have been described (Hewitt 12, 6). In the Yellowstone Park area (Hague 9, 7) there are more than 5000 feet of these rocks which form the most widespread of the volcanic groups. The texture of the "early basic breccias" is both coarse and fine, depending on the nature of the material and the distance from the source of eruption. The breccias are, in most places, dark colored due to the large amount of ferromagnesian minerals present. They consist of hornblende-pyroxene andesite, pyroxene andesite and a few thin local basalt flows. The greater part of the material is made up of coarse agglomerates held together by a cementing ash. A characteristic feature is the piling up of great masses of coarse agglomerates near the volcanic vents. Erosion has given rise to characteristic spires, turrets and pinnacles. This is best illustrated in the Hoodoo Basin of the Absaroka Range. As this description of the rocks in Yellowstone Park is the same as that of the rocks at the southern end of the Absaroka Range, it is believed that they are contemporaneous. Further correlations between the volcanic rocks of the area under discussion and those of the Yellowstone Park area are not possible in the light of present knowledge.

If the "early basic breccias" in Yellowstone Park should be of the same age as those in this region, and it is reasonable to suppose that they are, then the green andesite, the brown andesite breccia and agglomerate and the white andesite intrusives and extrusives are older than any igneous rocks exposed in the Park area, with the possible exception of the few local rhyolite flows. This could very easily by the case as there is little in common between the igneous rocks in the Park and these three lower groups in this region.

Ramshorn volcanic series. - Resting unconformably on the uneven erosional surface of the agglomerates and breccias is a thick succession of coarsely bedded light-colored soft andesite tuffs, which have been stripped far back from the resistant underlying agglomerates. In general the texture is fine, although there are some angular fragments a foot in diameter, which are usually so badly decomposed that they crumble readily. The tuffs are light colored but upon close examination numerous small crystals of pyroxene and hornblende can be seen. The bedded structure is so massive that it is not apparent unless the tuffs are viewed from a distance. The individual beds are between 20 feet and 100 feet in thickness and the succession has a maximum thickness of 600 feet in this area. To the north this succession of tuffs is much thicker.

PLATE V

A. Areal view of the central portion of the region covered in this report, taken from the eastern boundary and looking due west.

B. Pink andesite agglomerates and an inclusion of white andesite. This picture illustrates the peculiar erosional forms characteristic of the agglomerates.

C. Typical badlands formed in the Wasatch variegated shales in the central part of the area.

D. Contact between the Wasatch and Green River formations. The heavy line of trees marks the contact and shows the amount of contact relief.

E. Sandstones and conglomerates in the Green River formation. The roundstones in the conglomerate are of rhyolite and andesite.

A

B

C

D

E

Lying on the white tuffs is a series of tuffs, pink andesite flows and breccias. In places the texture of the breccias is so coarse that they resemble agglomerates, which are sufficiently resistant to form a protective capping to the soft underlying tuffs. In the northeastern corner of the area and extending for miles farther north can be seen alternating layers of white tuffs and pink andesite flows of similar character. This series of light colored andesitic tuffs and flows is here named the Ramshorn volcanic series. The name is taken from The Ramshorn, which is located twelve miles west of this area. The Ramshorn is a mountainous ridge made up of rocks of this volcanic series which also extends for miles to the north and east of the area mapped and forms many of the prominent peaks of the region.

The only fossils found in the agglomerates are a few massive tree stumps. Therefore, all that can be definitely said of the age of this series of volcanic rocks is that they are post-Green River.

QUATERNARY ALLUVIUM

As the region is still in a state of late youth, or early maturity, there is not much alluvium present. Nearly all the sediments are carried out of the area by the degrading streams, and only the coarsest material is left behind. It consists of large boulders of granite, Tertiary igneous rocks and black chert containing Mississippian brachiopods and corals. Nearly all this material turns black on weathering. In the river bottoms along East Fork is some finer alluvium but it is derived directly from the Wasatch, and is more or less limited in areal extent.

S T R U C T U R A L   G E O L O G Y

The area described in this report is bounded by portions of three great mountain ranges. To the west is a major anticline, trending about N. 45° W., which forms the Wind River Mountains. Running through the area from the southeast corner is another major anticline, that of the Owl Creek Range. These two anticlines have been developed along two major structural axes. In general, the axis of the Owl Creek anticline trends east-west. In this area, however, the axis swings sharply to the northwest and parallels the Wind River axis.

The southern extremity of the Absaroka Range lies to the east, north and northwest of the area. The mountainous character of the southern portion of the mountain range is due to the extremely resistant character of the great mass of Tertiary volcanic rocks. The general trend of the southern portion of the range is about the same as that of the Wind River Mountains. Some writers have called the southern portion of the main Absaroka Range the Shoshone Mountains. However, since the U. S. Geological Survey applied the former name to the entire range when the topographic map of the Kirwin quadrangle was made, the name Shoshone will not be used.

The only structural complications, apart from those in the Tertiary igneous rocks, are found in the Paleozoic and Mesozoic sediments on the southern flank of the Owl Creek anticline, where overturning and thrust faulting have taken place in a number of localities, which will be considered individually.

In the southeast part of the area the Paleozoic and Mesozoic sediments dip to the southwest away from the pre-Cambrian crystallines at about 30°, and they exhibit no structural complications. However, where the axial trend of the anticline swings to the northwest, the relationships are not simple. In the SW. ¼ of sec. 16, T. 7 N., R. 5 W., the direction of dip changes abruptly to the north, although the strike remains the same. Here the exposures are of resistant Cambrian limestone and they form a long ridge in which the beds stand nearly vertical. About a mile and one half to the northwest, in the center of sec. 18, these same beds outcrop again. The dip here is 24° to the northeast, toward the granites. As the intervening area is entirely covered by Wasatch shales, the explanation of the change in the dip and direction of dip is not apparent. It is probably the result of deformation by a low angle thrust fault dipping to the northeast. This interpretation is further substantiated by the relation of the sediments to the granites along East Fork in sec. 13, T. 42 N., R. 105 W. Here the outcrop of the Tensleep formation dips 10° to the southwest. The granites make their appearance 2,500 feet to the north of this outcrop. The area between is entirely covered by Wasatch shales. There would not be space enough between the granites and Tensleep for 900 feet of Cambrian, 250 feet of Bighorn, 650 feet of Madison, 250 feet of Amsden and nearly 300 feet of Tensleep, unless all these were standing vertically. As there is no indication of an abrupt steepening of the dip, it is probable that a low angle thrust fault plane passes between these two outcrops.

In the northwestern corner of the area the Paleozoic and Mesozoic sediments have been highly folded and overturned to the southwest, but there is no evidence of faulting. In the NW. ¼ of sec. 2, T. 42 N., R. 105 W., there is a deeply eroded overturned anticlinal fold. A small dome occurs in the Cambrian limestones in the northeast quarter of sec. 3. On the southwestern flank of this dome the Cambrian and Bighorn beds stand at high angles and in some places they are overturned. The lower portion of the overlying Madison limestone is also overturned in the same direction. To the southwest the dip of the Madison limestone gradually decreases to 15°. A small dome was formed in the Madison limestone in the northern part of sec. 10, T. 42 N., R. 105 W., which, coupled with the overturning, accounts for the broad outcrop of Madison in this region.

In the southwestern corner of the area there is a thrust fault dipping to the northeast at a low angle. Along East Fork is a broad outcrop of Chugwater sandstone dipping eight degrees to the northeast and forming a bluff several hundred feet high. To the southwest are soft gray and black Upper Cretaceous shales dipping northeast beneath the Chugwater at approximately the same angle. Near the fault contact is an outcrop of a coal seam which is about four feet thick and brecciated because of its proximity to the fault. A tunnel driven down the dip of the coal seam for about thirty feet made it possible to determine the dip of the fault as approximately ten degrees. If this dip remained constant it would mean that there had been a movement of more than 11,500 feet along the fault plane to bring Chugwater beds on top of the Upper Cretaceous shale. The topography of this section is so rough that in several places the surface of the ground rises more steeply than the fault plane and small "Klippen" of Chugwater are found lying on the Upper Cretaceous. This fault extends several miles farther south.

The Wasatch and Green River sediments have not been folded or faulted.

GEOLOGICAL HISTORY

PRE-CAMBRIAN TIME

The history of the pre-Cambrian crystallines has been extremely complex as is shown by the various rock types present and their relations to each other. As the study of these rocks did not come within the scope of this paper, further discussion of their geological history will be omitted.

CAMBRIAN TIME

The pre-Cambrian complex had been peneplaned before the basal arkosic grits of Middle Cambrian age were deposited. The whole region must have been near base level, for there are no coarse conglomerates present. The basal arkosic grits grade upward into sandstones, shales and limestones in response to the advancing sea. Marine fossils are fairly abundant at various horizons. Next followed a time during which a few thin layers of glauconite were deposited. During the remainder of Cambrian time the sea oscillated back and forth and an alternating succession of shale and limestone were deposited. Intraformational conglomerates are characteristic of the upper part of the Cambrian of this region. The origin of these conglomerates is not definitely understood. At the close of Cambrian time the sea retreated.

ORDOVICIAN TIME

The Upper Cambrian limestones were subjected to erosion during Lower Ordovician time, and no sediments were deposited in the area. During Upper Ordovician time the sea advanced from the north and a thick sequence of limestones and dolomites was laid down on the eroded surface of Upper Cambrian limestones. Sedimentation appears to have continued without apparent interruption until the end of the Ordovician.

SILURIAN TIME

The geological history of this region during Silurian time is not known. It is doubtful whether the sea advanced over this part of Wyoming as there are no Silurian rocks present.

DEVONIAN TIME

Rocks of Devonian age were not recognized in this region, but it is possible that the thin series of quartzites, sandstones and sandy shales at the top of the Bighorn may represent the Darby formation of the Wind River Mountains. In the absence of conclusive evidence as to the age of these rocks they have been mapped as Ordovician. In the Wind River Mountains, the Devonian rocks rest unconformably on the Leigh dolomite member of the Bighorn formation. In all probability the Devonian sea advanced over this region and clastic sediments were deposited upon the eroded surface of the Bighorn formation. Following the retreat of this sea there was a prolonged erosion interval during which all of the previously deposited Devonian rocks were removed in some places.

MISSISSIPPIAN TIME

There was a widespread advance of the sea during Madison time. Thick beds of limestones were deposited, and, as they contain very little land-derived material, it is evident that there were no exposed land surfaces in this part of Wyoming at this time. Deposition continued without apparent interruption until 650 feet of more or less uniform limestones had been deposited.

PENNSYLVANIAN TIME

At the close of Madison time there was a retreat of the sea followed by an interval during which the upper portion of the formation was removed by erosion. Early in Pennsylvanian time a shallow sea covered the region. In this sea was deposited an alternating sequence of sandstones, limestones, cherts and red shales constituting the Amsden formation. The Tensleep sandstone shows a marked change in depositional conditions. This formation is similar in every respect to its occurrences throughout central and southern Wyoming. The ever-present "festoon" type of cross-lamination in the formation is one of its most conspicuous characteristics. The origin of this type of structure is not fully understood. It is believed to have been produced in relatively shallow water by strong currents.

PERMIAN TIME

The sea withdrew following the deposition of the Tensleep sandstone and did not return until Middle Permian time. The region appears to have suffered little erosion during this interval. A shallow Middle Permian sea advanced over the region and in it were deposited sandstones, limestones, shales, cherts, gypsum and phosphate beds. Such a sequence of rock types indicates varied and complex changes in the physical conditions of the region during Middle Permian time. The cherts are believed to have been the result of the chemical precipitation of colloidal silica. The abundance of invertebrate fossils is a characteristic feature not common to the underlying and overlying sediments.

TRIASSIC (?) TIME AND TRIASSIC TIME

The Dinwoody sandstones and sandy shales were deposited upon Middle Permian rocks. The physical character of these sediments and their included fossils indicate that they were deposited in a shallow sea. During Chugwater time a thick succession of bright red sandstones and sandy shales was deposited conformably upon the Dinwoody. The physical conditions under which these beds were deposited is not fully understood. However, the highly specialized amphibians in the upper portion of the redbeds indicate that shallow water conditions prevailed during this part of Chugwater time. After the deposition of the red sandstones and shales normal marine conditions prevailed. During this time a hundred feet or more of limestones, interbedded with shales and sandstones were deposited. The limestones contain an abundance of marine invertebrates. Following this period there was a return to conditions which fostered the deposition of the characteristic redbeds of early Chugwater time.

JURASSIC TIME

Early in Upper Jurassic time the Sundance sea advanced over the region and an alternating sequence of limestones, sandstones and shales, containing marine invertebrates, was deposited. The character of these sediments indicates that shallow water conditions predominated. The Sundance formation is so well known that further comment upon it is not necessary.

LOWER CRETACEOUS (?) TIME

The Morrison formation rests with apparent conformity upon the Sundance Here the Morrison is composed of a succession of variegated shales, sandstones and thin limestones. The abundance of fossil reptilian remains, for which this formation is noted, show that these sediments were deposited on a widespread, low-lying, marshy flood plain.

UPPER CRETACEOUS TIME

Conditions in this area during Upper Cretaceous time appear to have been comparable to those which prevailed over much of the Rocky Mountain region. No attempt will be made to discuss these conditions in detail, as only the basal portion of the series of Upper Cretaceous rocks is represented.

LARAMIDE REVOLUTION

There is no evidence in this area to indicate at what time the Laramide Revolution began. It is apparent, however, that all folding and faulting had ceased before the beginning of Wasatch deposition. There is evidence in other parts of Wyoming of two distinct orogenies, the first at the close of Cretaceous time and the second at the close of Basal Eocene time. Long erosion intervals separated each of these periods of folding. It was during the second or youngest of these erosion intervals that the marked relief which was buried by the Wasatch sediments in this region was produced.

LOWER EOCENE TIME

Sediments aggregating 1500 feet in thickness were deposited during Lower Eocene time upon an irregular erosion surface of bold relief which was cut from all the older rocks. The vertebrate fossils collected from these sediments indicate that they are of Wasatch age.

The vertebrate paleontologists have subdivided Lower Eocene time into a number of life zones (17, 59). The fossils found in these beds are not sufficiently diagnostic to establish to which life zone they belong. Further collecting will be necessary before the beds can be definitely correlated with the established life zones.

The river valleys which were eroded during pre-Wasatch time were filled with clastic material derived, for the most part, from the surrounding older rocks. The sediments were deposited on river flood plains and in shallow lakes. Some volcanic ash was incorporated with the finer-textured sediments, although no thick beds of volcanic tuff were deposited. The fresh and angular character of the feldspar grains in the arkosic grit beds indicates that the adjacent granitic areas were subjected to rapid disintegration. From this it would seem that the climate was relatively arid. The varying texture of the sediments suggests rapid changes in the transport power of the streams, probably due to periods of flood alternating with periods when the run-off was much diminished.

Buried stream channels are conspicuous features where there are extensive exposures. The succession of shifting stream channels produced the effect of cross-lamination on a large scale. The sediments dip at angles of three or four degrees away from the local land masses from which they were derived.

During the period of Wasatch deposition there were intermittent outpourings of rhyolite. Numerous dikes and sills were also injected into the soft variegated shales.

MIDDLE EOCENE TIME

Between the close of Wasatch time and the beginning of Green River sedimentation, there was an interval of erosion. Probably a regional uplift increased the stream gradients and caused them to cut down into the soft Wasatch sediments. Erosion must have been vigorous, for in some places nearly the entire thickness of Wasatch had been removed before the beginning of Green River deposition. The topography was extremely rough and the basal Green River conglomerates, derived from the Wasatch rhyolite flows, were deposited in the steep-walled valleys by swiftly flowing streams. The climate appears to have been more humid than it was during Wasatch time and there is no evidence of any prolonged intervals of aridity during Green River time. In general, the sediments have the aspect of lacustrine, flood plain and river channel deposits. Berry (1,4) states that there is a possibility of some of the deposits being eolian in origin. The climate must have been warm and moist, as is shown by the type of flora, and these conditions remained more or less constant throughout the whole period of sedimentation, for the rocks are all of singularly uniform character.

There were a number of extensive and intermittent ash falls which formed beds of andesitic volcanic ash. All the Green River sediments contain varying quantities of ash. Tuffs and flow breccias were also formed by explosive outpourings of andesitic material.

There is no evidence of regional deformation either during or since Green River time. All the sediments are nearly horizontal, except where they have been locally tilted by the intrusion of younger volcanic rocks.

Just how long Green River sedimentation continued and how much time elapsed before the beginning of post-Green River volcanic activity is problematical. Sufficient time elapsed in this interval for the Green River deposits to have become consolidated and for the removal of an unknown thickness of beds.

POST-GREEN RIVER TIME

Following the interval of erosion at the close of Green River time there was a prolonged period of andesitic igneous activity. Dikes and sills of andesitic material were intruded into the Green River formation and volcanic agglomerates were explosively extruded onto the surface. Following the extrusion of the agglomerates there was an interval of erosion which removed an unknown thickness of these volcanic rocks and more of the Green River formation. The resistant character of the volcanics caused the eastern part of the area to remain as a mountainous upland. Several hundred feet of coarse andesitic agglomerates were heaped up on the surface cut during this erosion interval. The character of these agglomerates indicates that they were violently extruded from widely distributed vents. The agglomerates poured down the sides of the mountainous upland and are so resistant that they have preserved its original form. During the periods of quiescence vegetation flourished. The climate was still warm and moist.

Several thousand feet of white tuffs and pink andesite breccias referred to in this paper as the Ramshorn volcanic series, were deposited on the uneven surface of agglomerates. Some of the tuffs show evidence of having been deposited by water.

At present there is no definite knowledge as to how long this period of igneous activity lasted. It may represent Upper Eocene as well as Oligocene Miocene and Pliocene time. In other parts of Wyoming where there are no dikes and sills in the Tertiary sediments of these ages contain a great deal of andesitic volcanic ash and pebbles of andesite. It is probable that some of this material came from northwestern Wyoming.

In Pleistocene time the region was extensively eroded and the present land surface and drainage patterns were established. The dying effects of vulcanism continued into Pleistocene time, for a few miles southwest of this region there are extinct geyser vents surrounded by thick deposits of geyserite of comparatively recent origin. Imbedded in the geyserite are a large number of leaves. The geyser vents are known locally as "The Blue Holes".

PETROGRAPHY

Thin sections of thirteen representative rock specimens collected in the area were prepared in order to classify accurately the various Tertiary igneous rocks and determine the type of material from which the Green River sediments were derived.

WASATCH RHYOLITES

Specimen No. 8. - Amygdaloidal rhyolite flow breccia from a flow interbedded with red and white Wasatch shales in sec. 7, T. 7 N., R. 5 W., Wind River Meridian.

Megascopic description: The specimen is a vesicular pinkish-gray porphyry with small angular phenocrysts of quartz and larger phenocrysts of feldspar embedded in a felsitic groundmass.

Microscopic description: The rock consists of angular broken fragments of microcline, orthoclase and quartz embedded in an aphanitic groundmass. Rock fragments cannot be distinguished, and it is therefore probable that the brecciation was caused by flow of a very viscous, partially consolidated magma, rather than by explosive volcanic activity. The rock contains large, rounded quartz aggregates showing a mosaic pattern between crossed niccols. With ordinary light the fragments show a colloform banding around the edges. The quartz aggregates are probably amygdules.

Specimen No. 11. - Porphyritic rhyolite flow breccia from the top of the largest flow interbedded with the Wasatch variegated shales in sec. 1, T. 42 N., R. 105 W., 6th Principal Meridian.

Megascopic description: The specimen is a reddish-gray porphyry consisting of small quartz phenocrysts and feldspar phenocrysts up to one-quarter of an inch in diameter embedded in a felsitic groundmass, which is speckled with orange limonite spots.

Microscopic description: The rock is principally a fine, aphanitic groundmass. In addition there are a few large grains of quartz, microcline and biotite. Many of the large grains have a jagged outline indicating fragmentation, probably as the result of flow of the magma.

Specimen No. 12.. - Porphyritic rhyolite flow breccia from the top of the largest flow in the Wasatch in sec. 1, T. 42 N., R. 105 W., 6th Principal Meridian.

Megascopic description: The rock is a very hard red rhyolite. It has a felsitic texture and prophyritic structure, the phenocrysts are of quartz and acid feldspars and attain a maximum size of one-quarter of an inch. These are embedded in a fine hard red matrix.

PLATE VI

A. Green River sediments. Wind-sorted or water-sorted andesite tuff. Taken with ordinary light, x 40. The two large dark masses near the center of the field are clay galls. The lath-shaped white fragments are crystals of andesine.

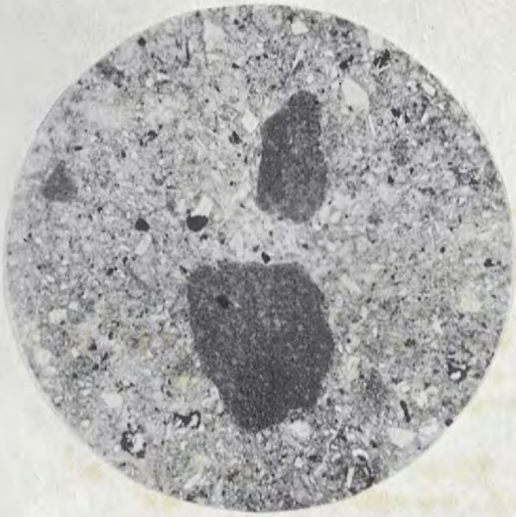
B. Green River andesite. Taken with ordinary light, x 30. Most of the field is occupied by a fragment of andesite consisting of lath-shaped phenocrysts of clear white andesine embedded in a finer matrix containing abundant iron oxide (black). The lighter portion around the edge of the field is the matrix in which the rock fragment is embedded.

C. Post-Wasatch basalt. Taken with ordinary light, x 40. The mineral of high relief forming the phenocrysts is augite, the lath-shaped crystals in the groundmass are labradorite and the black grains are magnetite.

D. Post-Wasatch basalt. Same view as C but between crossed niccols, x 40.

E. Green River sediment. Wind-deposited or water-deposited andesite tuff. Taken with ordinary light, x 35. The white grains are andesine. One-half of an inch above and to the right of the center of the field is a fragment of felsitic andesite containing a crystal of andesine.

F. Post-Green River andesite. Taken between crossed niccols, x 40. The largest grain is zonary banded andesine. Crystals of hornblende are located to the right of the large andesine grain and near the left side of the field.



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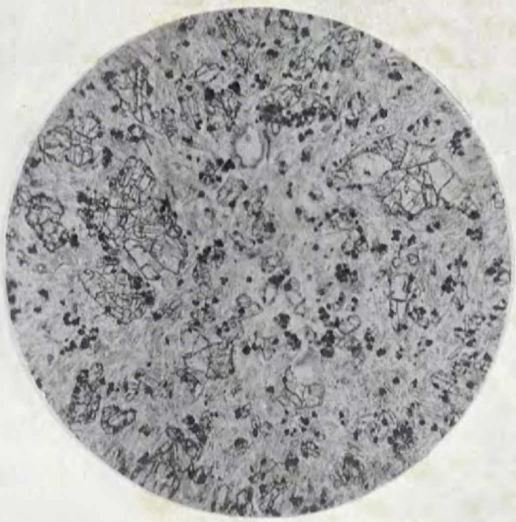

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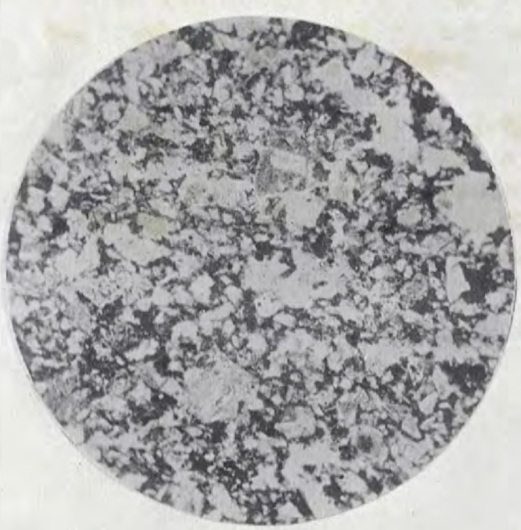

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Microscopic description: The rock consists of abundant large phenocrysts of quartz, microcline and orthoclase, and a few of biotite, embedded in a groundmass consisting of glassy material and small angular fragments of quartz and microcline. Some of the phenocrysts have also been broken.

Photomicrographs: (Pl. VII A, ordinary light, X 30; Pl. VII B, crossed niccols, x 30.) The large grain below and to the right of the center of the field is microcline. The large grain at the top of the field and the two large ones at the lower right edge are quartz. The small white angular grains embedded in the glassy groundmass (black under crossed niccols) are both quartz and microcline.

POST-WASATCH BASALT

Specimen No. 9. - Basalt from a dike approximately eight feet thick and one mile long which cuts the Wasatch in sec. 26, T. 7 N., R. 6 W., Wind River Meridian.

Megasopic description: The rock is predominately green in color, but contains some soft yellow material which has been removed from the harder matrix on the weathered surfaces, leaving them pitted. A columnar structure has been developed parallel to the shortest axis of the dike.

Microscopic description: The rock is composed of light yellow augite phenocrysts embedded in a groundmass of labradorite laths and rounded augite grains. Approximately thirty per cent of the rock is pyroxene. Magnetite is present as an accessory mineral. Small amounts of serpentine or chlorite and carbonate material have been formed by hydrothermal processes or weathering.

Photomicrographs: (Pl. VI C, ordinary light, x 40; VI D, crossed niccols, x 40.) The mineral of high relief forming the phenocrysts is augite, the lath-shaped crystals in the groundmass are labradorite and the black grains are magnetite.

GREEN RIVER SEDIMENTS

Specimen No. 1. - A wind-sorted or water-sorted andesite tuff from a green shale band in the middle portion of the Green River formation in sec. 18, T. 7 N., R. 4 W., Wind River Meridian.

Megascopic description: The rock is a hard, brittle green shale with a rather coarse texture. It contains a number of angular fragments of finer-grained material, which vary in size up to one-eighth of an inch. These are so numerous in some places that the rock has the appearance of a fine breccia. The fragments are thinly laminated, but the matrix in which they are embedded shows no distinct planes of stratification. Scattered through the green shale are small irregular masses of fine brown shale which are so much softer than the green shale that they weather out first and leave the rock with a characteristic pitted surface.

Microscopic description: The rock consists of abundant angular fragments of andesine and a few angular fragments of brown hornblende embedded in a fine-grained isotropic matrix. The fragments of feldspar and hornblende are fairly uniform in size, indicating a process of sorting by running water, or wind, during deposition. There are also larger subangular bodies of darker fine-grained material, which are clay galls. Most of the rock shows little alteration, but there are a few spots of secondary carbonate material.

Photomicrograph: (Pl. VI A, ordinary light, x 40.) The two large dark masses near the center of the field are clay galls. The lath-shaped white fragments are crystals of andesine.

Specimen No. 6. - Wind-deposited or water-deposited andesite tuff from a shaly bed in the upper part of the Green River formation in sec. 2, T. 7 N., R. 5 W., Wind River Meridian.

Megascopic description: The rock is a hard, compact bedded sediment. It is gray in color but contains a quantity of macerated black plant remains which lie parallel to the bedding planes. The texture is uniform and fine.

Microscopic description: The rock consists of angular fragments of andesine and porphyritic andesite embedded in a fine sericitic matrix. The fragments are uniform in size, indicating sorting by the transporting agent. The matrix is nearly opaque. This may be the result of the presence of finely divided iron oxide, since the thin section appears pink by reflected light. Some of the opaque material may be carbonaceous. The hand specimen contains carbonized plant remains, which are not present in the thin section, probably because they were lost during the preparation of the section.

GREEN RIVER ANDESITES

Specimen No. 3. - Andesite flow breccia or tuff from one of the four larger flows in the Green River sediments in sec. 8, T. 7 N., R. 5 W., Wind River Meridian.

Megascopic description: The specimen is a hard green rock with felsitic texture and porphyritic structure. The phenocrysts are pink, brown, gray and black. In addition, the specimen contains rock fragments up to three fourths of an inch in diameter embedded in a matrix of the same general composition.

Microscopic description: The predominant mineral present is andesine showing distinct zonary banding. There are also minor amounts of brown and green hornblende. The groundmass is felsitic or glassy. Most of the feldspar and hornblende grains are broken fragments and in addition there are numerous larger fragments of porphyritic andesite with andesine and hornblende phenocrysts embedded in a glassy groundmass. The mineral and rock fragments indicate that the rock is either a tuff or a flow rock in which movement of the magma broke up a crust and engulfed portions of it. The rock has been subjected to fracturing and deposition of silica in veinlets cutting across both groundmass and grains.

PLATE VII

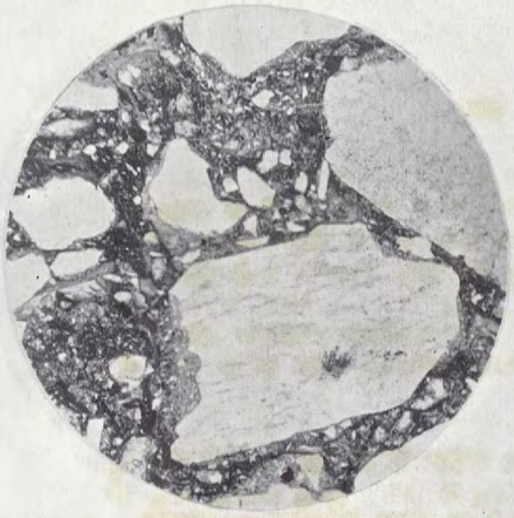
A. Wasatch rhyolite. Taken with ordinary light, x 30. The large grain below and to the right of the center of the field is microcline. The large grain at the top of the field and the two large ones at the lower right edge are quartz. The small white angular grains embedded in the glassy groundmass are both quartz and microcline.

B. Wasatch rhyolite. The same view as A but taken between crossed niccols, x 30. The small black angular grains embedded in the glassy groundmass are both quartz and microcline.

C. Post-Green River rhyolite (?) talus breccia. Taken with ordinary light, x 10. This photomicrograph shows the angular fragments (dark) and the colloform banding in the cement.

D. Post-Green River rhyolite (?) talus breccia. The same view as C but between crossed niccols, x 10. This photomicrograph shows the fibrous and radiating structure in the siliceous cement.

THE GEOLOGICAL SURVEY OF WYOMING BULLETIN NO. 24 PLATE NO. VII



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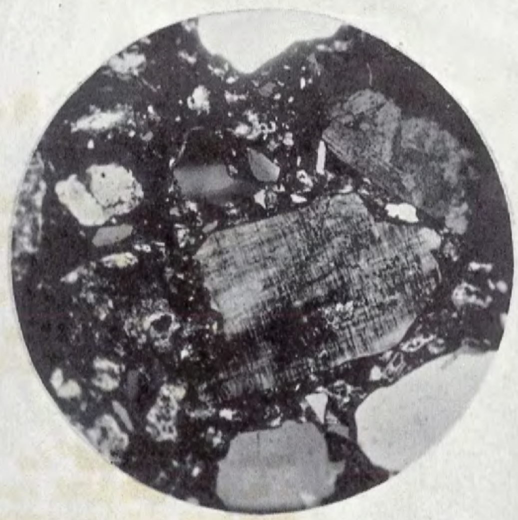

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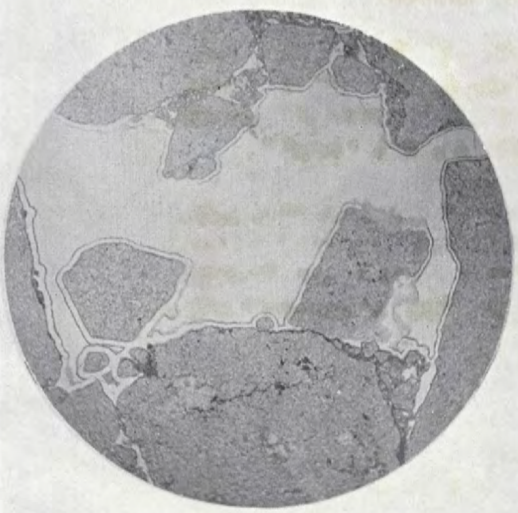

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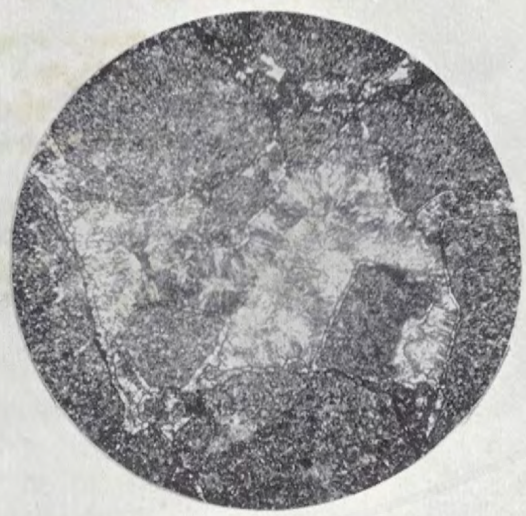

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Photomicrograph: (Pl. VI B, ordinary light, x 30.) Most of the field is occupied by a fragment of andesite consisting of lath-shaped phenocrysts of clear white andesine embedded in a finer matrix containing abundant iron oxide (black). The lighter portion around the edge of the field is the matrix in which the rock fragment is embedded.

Specimen No. 4. - Andesite flow breccia or tuff from the same locality as specimen No. 3, but from a thin flow higher in the succession.

Megascopic and microscopic description: The description for specimen No. 3 also applies to this rock.

POST-GREEN RIVER ANDESITES

Specimen No. 2. - Porphyritic hornblende andesite from a dike cutting the Green River formation in sec. 13, T. 7 N., R. 5 W., Wind River Meridian.

Megascopic description: This specimen is a dense green rock with felsitic texture and porphyritic structure. The phenocrysts consist of hornblende and pink and white feldspars, most of which are less than one sixteenth of an inch in diameter, embedded in a green matrix. As the dike, from which this specimen was taken, cuts through the Green River formation, there are numerous inclusions of highly altered shale fragments.

Microscopic description: The rock consists of abundant phenocrysts of basic andesine and a few phenocrysts of brown and green hornblende embedded in a glassy or cryptocrystalline groundmass. The feldspar shows pronounced zonary banding. Most of the phenocrysts have a holocrystalline outline, but in certain portions of the thin section the feldspar are broken, jagged fragments. This clastic structure is probably the result of movement during the interval of consolidation of the magma.

Specimen No. 13. - Porphyritic hornblende andesite from a dike approximately 200 feet thick cutting the Green River sediments. The specimen was collected from sec. 7, T. 7 N., R. 4 W., Wind River Meridian.

Megascopic description: The rock is a malachite-green porphyry with dark hornblende and feldspar embedded in a fine groundmass.

Microscopic description: The rock consists of large phenocrysts of brown hornblende and zonary banded andesine embedded in a glassy groundmass. The rock has been fractured and had secondary quartz deposited in the fractures.

Photomicrograph: (Pl. VI F, crossed niccols, x 40). The largest grain is zonary banded andesine. Crystals of hornblende are located to the right of the large andesine grain and near the left side of the field.

Specimen No. 14. - Porphyritic hornblende andesite from a dike several hundred feet thick cutting the Green River formation in sec. 7, T. 7 N., R. 4 W., Wind River Meridian.

Megascopic description: The rock is a light gray porphyry consisting of phenocrysts of hornblende and feldspar up to one-eighth of an inch in diameter.

Microscopic description: The rock is the same as specimen No. 13 except for the absence of secondary fracturing and silicification.

Specimen No. 15. - Porphyritic hornblende andesite from a widespread flow capping the white tuffs in the Ramshorn series in sec. 7, T. 7 N., R. 4 W., Wind River Meridian.

Megascopic description: The rock is a pink porphyry with phenocrysts of feldspar and hornblende up to one-fourth of an inch in diameter embedded in a pink felsitic groundmass.

Microscopic description: The rock consists of phenocrysts of hornblende and zonary banded andesine embedded in an aphanitic groundmass. Under reflected light the surface of the thin section is reddish. The color is deepest near the hornblende phenocrysts. It is probable that the coloring material is hematite derived from the weathering of hornblende.

Specimen No. 16. - Rhyolite (?) talus breccia from a bed which lies unconformably on the white andesites and just below the Ramshorn volcanic series in sec. 7, T. 7 N., R. 4 W., Wind River Meridian.

Megascopic description: The rock is composed of angular fragments, up to two inches in diameter, of hard white dense material embedded in a finer hard matrix. A quantity of brown chalcedony has been deposited around the fragments and cements them firmly together.

Microscopic description: The rock consists of angular fragments embedded in a fine siliceous cement. The fragments consist of a very fine mosaic aggregate of quartz and partially sericitized orthoclase. The fragments may possibly be a felsitic rhyolite, but ferromagnesian minerals are conspicuously absent. Under ordinary light the siliceous cement shows a pronounced colloform banding parallel to the outlines of the fragments. Between crossed niccols the cement is seen to consist of radiating and fibrous aggregates of crystals.

Photomicrographs: (Pl. VII C, ordinary light, x 10; Pl. VII D, crossed niccols, x 10.) Photomicrograph C, taken with ordinary light shows the angular fragments (dark) and the colloform banding in the cement. Photomicrograph D, taken between crossed niccols, shows the fibrous and radiating structure in the siliceous cement.

Megascopic description: The rock is a light gray porphyry consisting of phenocrysts of hornblende and feldspar up to one-eighth of an inch in diameter.

Microscopic description: The rock is the same as specimen No. 13 except for the absence of secondary fracturing and silicification.

Specimen No. 15. - Porphyritic hornblende andesite from a widespread flow capping the white tuffs in the Ramshorn series in sec. 7, T. 7 N., R. 4 W., Wind River Meridian.

Megascopic description: The rock is a pink porphyry with phenocrysts of feldspar and hornblende up to one-fourth of an inch in diameter embedded in a pink felsitic groundmass.

Microscopic description: The rock consists of phenocrysts of hornblende and zonary banded andesine embedded in an aphanitic groundmass. Under reflected light the surface of the thin section is reddish. The color is deepest near the hornblende phenocrysts. It is probable that the coloring material is hematite derived from the weathering of hornblende.

Specimen No. 16. - Rhyolite (?) talus breccia from a bed which lies unconformably on the white andesites and just below the Ramshorn volcanic series in sec. 7, T. 7 N., R. 4 W., Wind River Meridian.

Megascopic description: The rock is composed of angular fragments, up to two inches in diameter, of hard white dense material embedded in a finer hard matrix. A quantity of brown chalcedony has been deposited around the fragments and cements them firmly together.

Microscopic description: The rock consists of angular fragments embedded in a fine siliceous cement. The fragments consist of a very fine mosaic aggregate of quartz and partially sericitized orthoclase. The fragments may possibly be a felsitic rhyolite, but ferromagnesian minerals are conspicuously absent. Under ordinary light the siliceous cement shows a pronounced colloform banding parallel to the outlines of the fragments. Between crossed niccols the cement is seen to consist of radiating and fibrous aggregates of crystals.

Photomicrographs: (Pl. VII C, ordinary light, x 10; Pl. VII D, crossed niccols, x 10.) Photomicrograph C, taken with ordinary light shows the angular fragments (dark) and the colloform banding in the cement. Photomicrograph D, taken between crossed niccols, shows the fibrous and radiating structure in the siliceous cement.

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