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THE GEOLOGICAL SURVEY OF WYOMING
S. H. KNIGHT, State Geologist

BULLETIN No. 25

THE GEOLOGY OF THE NORTH END OF THE MEDICINE BOW MOUNTAINS, CARBON COUNTY, WYOMING

BY

JOSEPH NEELY

UNIVERSITY OF WYOMING
LARAMIE, WYOMING
MAY, 1934

STATE OF WYOMING

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F O R E W O R D

The broader aspects of the geology of the Medicine Bow Mountains were first made known through the work of the geologists of the United States Geological Exploration of the Fortieth Parallel in 1878. The work of this survey was necessarily of a reconnaissance nature. This bulletin is the first detailed report on the geology of the area. The report contains important contributions to the geology of south-central Wyoming.

The writer of this report was assigned the problem for his Master's thesis and it affords an 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

ILLUSTRATIONS

THE GEOLOGY OF THE NORTH END OF THE MEDICINE BOW MOUNTAINS

CARBON COUNTY, WYOMING

by

Joseph Neely

I N T R O D U C T I O N

LOCATION

The area described in this report includes approximately 260 square miles of the northern end of the Medicine Bow Mountains in the east-central portion of Carbon County, Wyoming (Fig. 1). The nearest station on the Union Pacific railroad is Hanna, which is located 25 miles north of the northern edge of the area. The borders of the area are accessible by improved

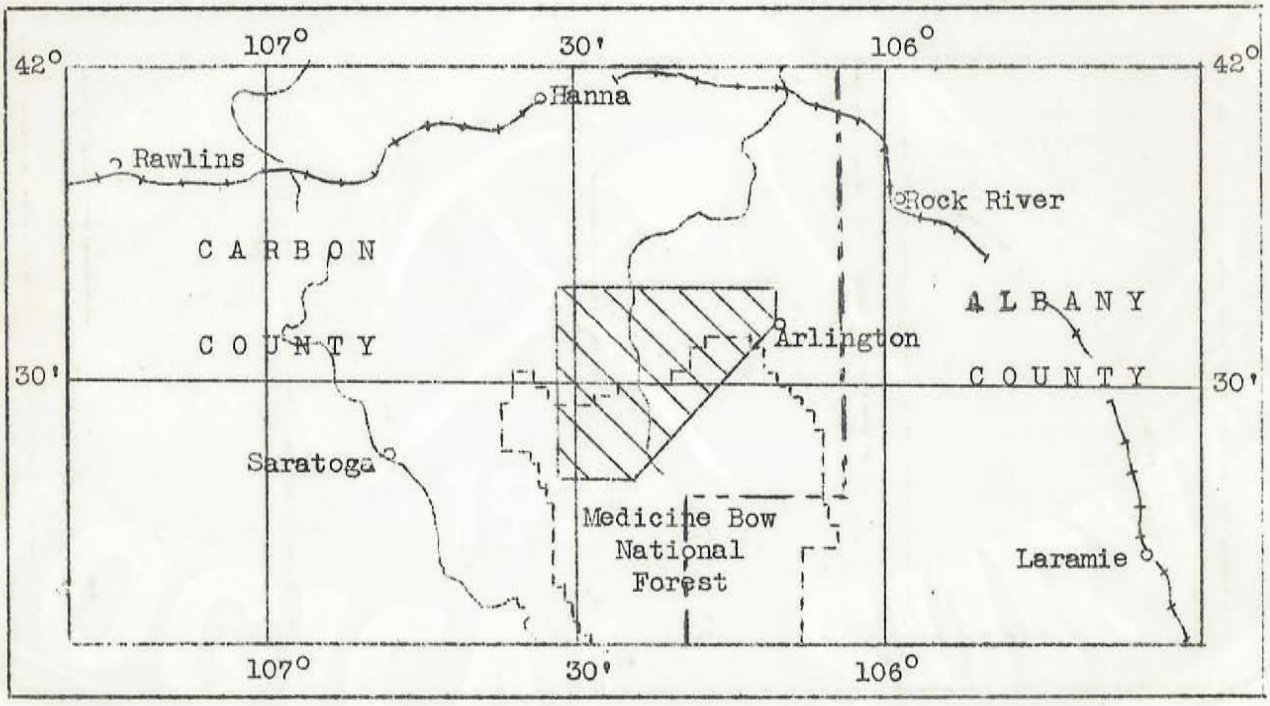


Figure 1. Index map showing the area described in this report.

roads from the east by way of Arlington, from the north by way of the town of Elk Mountain and from the south by the way of the Centennial-Saratoga highway. Much of the area is mountainous and heavily timbered and travel is confined to native trails, old logging roads and U. S. Forest trails in the part within the Medicine Bow National Forest.

RELIEF

The area includes a broad, relatively flat, basin-like depression which is referred to in this report as the Upper Pass Creek-Medicine Bow Basin. The basin is encircled on its east, south and west sides by mountains. On its north side it merges into a larger depression known as the Carbon Basin. The Upper Pass Creek-Medicine Bow Basin is separated by a low divide into two minor basins. The region to the east of this low divide is drained by the Medicine Bow River, which flows to the north and joins the North Platte River in north-central Carbon County. The region to the west of the low divide is drained by Pass Creek, which flows to the northwest and enters the North Platte River. Both the Medicine Bow River and Pass Creek flow in relatively narrow valleys which have been entrenched 200 feet or more below the general level of their drainage basins. The Upper Pass Creek-Medicine Bow Basin slopes gradually from an elevation of 8500 feet at its southern extremity to an elevation of 7500 feet at the northern edge of the area.

The mountains which enclose the Upper Pass Creek-Medicine Bow Basin, except on the north, have been formed by two major anticlines which converge in the southern part of the area and continue to the south as the main anticline of the Medicine Bow Mountains. On the eastern side of the main basin the northern end of the main range of the Medicine Bow Mountains slopes to the north from an elevation of 10,000 feet and terminates abruptly three miles south of the northeast corner of the area as shown on the map (Plate No. III). The basinward slope of the Medicine Bow Mountains is comparatively gentle, owing to the low dips on the west flank. Kennaday Peak, locally known as Bald Mountain, borders the Upper Pass Creek-Medicine Bow Basin on the south and attains an elevation of 11,100 feet. The southern face of this mountain descends abruptly to the valley of the North Platte River. The northern face descends with equal abruptness to the basin. The region to the south and west of Kennaday Peak is drained by Cedar Creek, which has formed a depression known as Cedar Pass between Kennaday Peak and a mountain lying to the northwest of the pass, known as Pennock Mountain. Cedar Creek flows westward to the North Platte River. The Upper Pass Creek-Medicine Bow Basin is bounded on the west by three mountain masses arranged along an anticlinal axis extending northwest from the main portion of the Medicine Bow Range. These mountain masses are named, from south to north, Pennock Mountain, Coad Mountain and Elk Mountain. Pennock Mountain and Coad Mountain are separated by a saddle known as Oberg Pass. Coad Mountain and Elk Mountain are separated by a water gap known as Pass Creek Pass through which Pass Creek flows. The summit of Elk Mountain is 11,165 feet above sea level and this mountain stands considerably higher than Coad and Pennock Mountains. All three of the mountains are complex anticlinal uplifts and they slope steeply on all sides.

FIELD WORK

Field work was begun in this area by the writer on July 30 and concluded on August 31, 1933. The United States Geological Survey, on their geological map of Wyoming published in 1925, shows this area as mapped by the geologists of the Geological Exploration of the Fortieth Parallel in 1870 (King, 6, Map I) and no evidence of later publications on the geology of the area has been found by the writer. Available maps of the area include the topographic sheet of

PLATE I

A. A view looking northwest from the summit of Kennaday Peak showing Pass Creek Basin, and from right to left, Elk, Coad and Pennock Mountain.

B. A view looking east near the summit of Kennaday Peak showing a knife-like ridge of Hanna conglomerates.

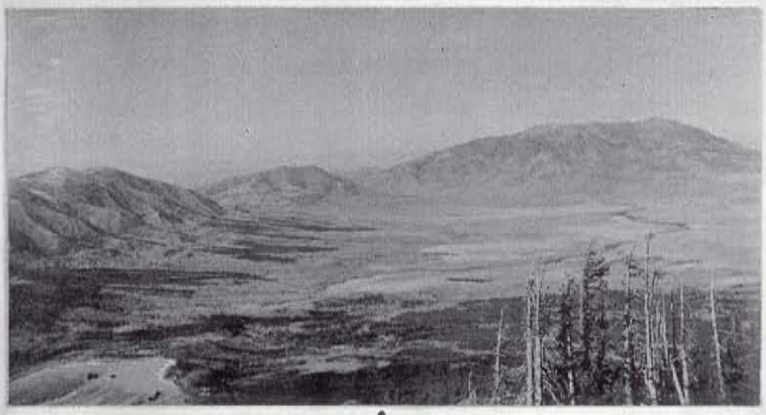
C. Pre-Cambrian rocks in place on the west flank of Kennaday Peak.

D. A prospect hole in an Embar gypsum bed in Oberg Pass between Coad and Pennock Mountains.

E. A view of White Rock Canyon on Wagonhound Creek showing the white sandstone cliffs of the Casper formation. The coarse conglomerate in the immediate foreground is a thin veneer of the Hanna formation lying unconformably on the Tensleep sandstone.

F. A fresh exposure of Hanna conglomerate in a land slip about 2 miles north of the Bow Ranger Station on the east fork of the Medicine Bow River.

G. An outcrop of Tensleep sandstone in Oberg Pass between Coad and Pennock Mountains showing the weathering effects on cross-bedding.



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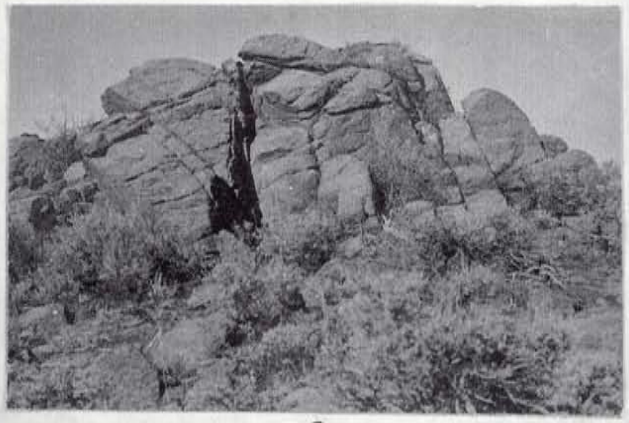

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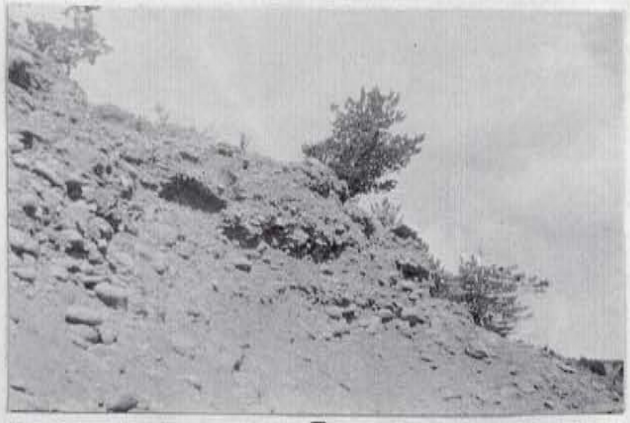

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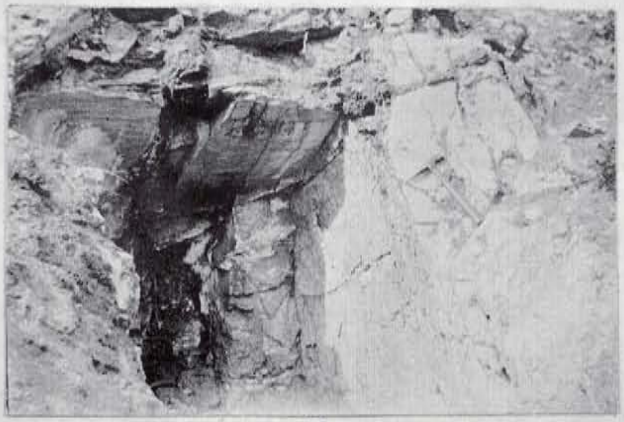

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the Medicine Bow Quadrangle published by the U. S. Geological Survey, topographic sheets of the Medicine Bow Forest, published by the U. S. Forest Service and a map of the Medicine Bow National Forest published by the U. S. Forest Service in 1928. No topographic maps of that portion of the area lying to the north of the Medicine Bow Forest Reserve have been published. Mapping was done with the aid of a Brunton compass and distances were determined by pacing, intersection from prominent points located on the base map and in some cases by estimation. Locations were obtained from section-corner stones where they could be found. When section-corner stones could not be found, outcrops were located approximately by reference to the base map.

Along the mountain fronts, the upturned edges of the sediments afford good exposures with the exception of the glaciated portion along the southwest side of the area. There are only a few exposures in the central portion of the area because of a covering of alluvium and a heavy growth of timber in some places. Excellent exposures occur in the northeast corner along Wagonhound Creek.

ACKNOWLEDGMENTS

The writer wishes to thank Dr. S. H. Knight, State Geologist, for making this report possible. Thanks are also due Dr. R. H. Beckwith and Mr. H. D. Thomas for suggestions rendered by them during the writing of this report. The writer wishes to acknowledge the assistance rendered by the U. S. Forest Service for supplying him with copies of the Medicine Bow National Forest Map and the kindness shown by Ranger Martin Olson stationed at the Bow Ranger Station. The writer wishes to give especial thanks to the ranchers in this area for the kind and generous hospitality extended him while field work was being done.

STRATIGRAPHY

GENERAL RELATIONSHIPS

Approximately 13,000 feet of clastic marine and continental sediments ranging in age from Mississippian to Pliocene are present in the area. There are nine stratigraphical breaks which demonstrate that deposition was interrupted from time to time and that the formations do not represent a complete geological section.

PRE-CAMBRIAN ROCKS

Pre-Cambrian crystalline rocks occur in the cores of the anticlines which form the mountainous portion of the area. These rocks are exposed along the west, south and east borders of the area with the exception of small strips between Coad and Pennock Mountains, between Pennock Mountain

SYSTEM	SERIES	FORMATION	SYMBOL	COLUMNAR SECTION	THICKNESS	CHARACTER
TERTIARY	PLIOCENE (?)	NORTH PARK	Tnp		0-400(?)	CONGLOMERATES & VOLCANIC ASH
	L.EOCENE	WASATCH FORMATION	Tw		0-400(?)	RED SHALES & ARKOSIC SANDSTONES
	PALEOCENE	HANNA FORMATION	Th		0-7000	COARSE CONGLOMERATES, ARKOSIC SANDSTONES AND SHALES
CRETACEOUS	U CRETACEOUS	STEELE SHALE	Ks		4000-5000	BLACK SHALES
		NIOBRARA FORMATION	Kn		600(?)	GREY LIMESTONES & BLACK SHALES
		BENTON GROUP	Kb		1485	BLACK SHALES & GREY SANDSTONES
		DAKOTA FORMATION	Kd		130	CROSS-BEDDED SANDSTONE & SHALES
	L.CRET (?)	MORRISON FORMATION	Km		200	VARICOLORED SHALES, SANDSTONES & LIMESTONES
JURASSIC	U.JURAS.	SUNDANCE FORMATION	Js		190	WHITE SANDSTONE & SHALE
	U.TRIAS	JELM FORMATION	Rj		75	RED CONGLOMERATE
TRIASSIC	TRIASSIC (?)	CHUGWATER SHALE	Rc		1200	RED SHALES & SANDSTONE
CARBONIFEROUS	PERMIAN	EMBAR FORMATION	Ce		300	RED SHALES & GYPSUM BEDS
	PENN	TENSLEEP FORMATION	Ct		140	WHITE CROSS-BEDDED SANDSTONE
	MISS.	MADISON FORMATION	Cm		75	PURPLISH LIMESTONE
PRE-CAMBRIAN			pre-C			GRANITES, DIABASES & METAMORPHICS

GENERALIZED COLUMNAR SECTION OF THE ROCKS EXPOSED AT THE NORTH END OF THE MEDICINE BOW MOUNTAINS

EASTERN SIDE OF THE AREA

FORMATIONS ABOVE THE CHUGWATER REMAIN THE SAME OVER THE ENTIRE AREA

FORMATION	SYMBOL	COLUMNAR SECTION	THICKNESS	CHARACTER
CHUGWATER	Rc		1200	RED SHALES & SANDSTONE
FORELLE	Cf		15	PURPLISH LIMESTONE
SATANKA	Gs		150	RED SHALES & GYPSUM BEDS
CASPER	Cc		140	WHITE CROSS-BEDDED SANDSTONE
	pre-C			GRANITES, DIABASES & METAMORPHIC ROCKS

and the south flank of Kennaday Peak, and the glaciated portion on the southwest side. The pre-Cambrian rocks are composed of quartzites, schists, gneisses, meta-diabases and granites. According to Blackwelder (1, pp. 615-658) the metamorphic rocks which were formerly sediments are probably of Algonkian age.

MISSISSIPPIAN ROCKS

Madison formation. - The Madison lies unconformably on pre-Cambrian crystalline rocks in the western half of this area and the steeply dipping outcrops form prominent ridges along the east and south flanks of Elk and Coad Mountains and the southern end of the east flank of Pennock Mountain. Rocks mapped as Madison in this area are a basal purplish to pink massive marine limestone approximately 20 feet thick and an overlying succession of red shales and red to gray sandstones 55 feet in thickness. The red shales and sandstones may represent the Amsden formation of northern Wyoming, but because of their limited areal extent and uncertain identification they are included in the Madison formation. The Madison thickens to the north and is correlated with the Madison of central Wyoming, (Lee, 9, p. 5) where it contains Mississippian fossils (Darton, 4, pp. 403-470). It thins to the south and east so that it wedges out near the center of the area. The Madison is overlain unconformably by the Tensleep sandstone. This unconformable relationship is shown by the fact that the Madison thins rapidly to the south and east and by the fact that the Tensleep formation overlaps it and lies on the pre-Cambrian complex.

PENNSYLVANIAN AND PERMIAN ROCKS

Nomenclature and correlation. - The Pennsylvanian rocks in this area are represented by beds of massive sandstone. In central Wyoming, where similar beds are overlain by the Embar formation, they are known as the Tensleep formation. Therefore, the sandstones have been mapped as Tensleep throughout the western portion of the area, where they are overlain by typical Embar. In the Laramie Basin area, where the sandstone beds are overlain by the Satanka and Forelle formations, they constitute the Casper formation. Therefore, the sandstone beds have been mapped as Casper throughout the eastern portion of the area, where they are overlain by the Satanka and Forelle formations. In order to avoid confusion these massive sandstone beds will be referred to as the Tensleep formation over the entire area.

In central Wyoming the Permian rocks are known as the Embar formation, while in the Laramie Basin area the rocks belonging to this system are known as the Satanka and Forelle formations. The basal portion of the Chugwater formation also belongs to this system. Throughout the eastern portion of the area the Satanka and Forelle formations are recognizable and are therefore mapped as such. In the western portion of the area the Forelle limestone is absent and the beds have been mapped as Embar.

The Embar formation is stratigraphically equivalent to the Satanka, Forelle and the basal 100 to 150 feet of the Chugwater*.

* H. D. Thomas, Personal communication, 1934.

Tensleep formation. - The Tensleep is a medium-grained light gray to white cross-laminated sandstone approximately 140 feet thick in this area, and, due to its resistant character, forms prominent ridges and hogbacks where it flanks the mountains. Although no fossils have been found in this area, a marine fauna of Pennsylvanian age has been reported from the limestone facies to the east (Darton 5, pp. 18-19) which has led to the belief that the sandstone is of marine origin and probably a beach deposit of the Pennsylvanian sea (Knight 7, pp. 49-80). The Tensleep formation occurs over the entire area. Excellent exposures can be found in White Rock Canyon where Wagonhound Creek cuts through the formation.

Embar formation. - The Embar formation is composed of approximately 300 feet of red shales, gypsum beds, and "rotten" purple limestones lying unconformably* on the Tensleep sandstone. The Embar is overlain with apparent conformity by the Chugwater shale. Additional evidence of these interformational relationships have been accurately determined by Mr. H. D. Thomas and will be published in a forthcoming report. The Embar occurs, in general, over the western half of the area and is stratigraphically equivalent to the Satanka, Forelle, and the lower 100 to 150 feet of the Chugwater in the eastern half of the area*. The Embar is marine in origin and contains a Permian fauna*. As the formation is, for the most part, a soft shale, it outcrops in depressions rather than in ridges. The bright red color of the shales and the contrasting white gypsum beds, some of which attain a thickness of many feet, make the formation conspicuous and easily recognized. The contact between the Embar and the overlying Chugwater cannot be readily determined, however. The upper half of the Embar formation is well exposed in Oberg Pass, between Coad Mountain and Pennock Mountain.

Satanka formation. - The Satanka formation occurs over the eastern side of the area and is composed of 150 feet of bright red shales containing gypsum beds and thin limestone bands. This formation is of marine (?) origin and Permian age*, and is believed to be the stratigraphical equivalent of the lower part of the Embar formation in the western half of the area. The Satanka rests unconformably upon the Tensleep sandstone*. Due to the soft character of the shales, few prominent outcrops are to be found, but the Satanka is easily recognized by its characteristic color. Good exposures of the Satanka can be found near Wagonhound Creek in the northeast portion of the area.

Forelle formation. - The Forelle formation, which occurs over the eastern half of the area, is a purplish fine-grained finely laminated dolomitic "ribbon" limestone approximately 15 feet thick. The laminae are contrasted from one another by color changes ranging from a bluish gray to a pink or purplish pink. A conspicuous feature of this limestone is a crinkled condition caused by pressure due to increase in volume during dolomitization, according to Dr. S. H. Knight**. The unusual lithologic characters of the

* Mr. H. D. Thomas, Personal communication, 1934.
** Dr. S. H. Knight, Personal communication, 1934.

Forelle limestone are distinctive and readily recognized. The Forelle is of marine origin and Permian age and is correlated stratigraphically by Mr. H. D. Thomas* with the central portion of the Embar formation in the western half of this area. The Forelle is resistant in character and forms low ridges where it is exposed near Wagonhound Creek in the northeastern part of the area.

TRIASSIC (?) ROCKS

Chugwater formation. - The Chugwater is represented over nearly the entire area by from 1000 to 1,200 feet of shales and thin sandstones whose predominant color is red, although a few thin beds of other colors are present. Minor amounts of gypsum occur in the lower part of the formation. In the western half of the area the Chugwater is all of Triassic (?) age. In the eastern half, the basal 100 to 150 feet are Permian and are stratigraphically equivalent to the upper part of the Embar*. No fossils were collected from the Chugwater in this area. Exposures exist in the northeastern portion of the area and are characterized by depressions rather than ridges.

TRIASSIC ROCKS

Jelm formation. - The Jelm formation of Upper Triassic age (Knight 8, p. 168) exists over the greater part of the area. The formation is approximately 75 feet thick and is composed of red sandstones containing lenses of typical red, relatively fine-grained conglomerates. It is probably of continental origin (Knight 8, p. 168) and usually forms low ridges where it is exposed in the northeast portion of the area and between Coad and Pennock Mountains.

JURASSIC ROCKS

Sundance formation. - The Sundance occurs over the entire central portion of the area and is composed of approximately 190 feet of light gray to greenish shales and thin buff to white argillaceous sandstones. The formation, which lies unconformably on the Jelm formation, is of Upper Jurassic age and marine origin (Lee 9, pp. 15-16). Belemnites densus occurs in the Sundance in great abundance where the formation is exposed in the SW $\frac{1}{4}$ sec. 5, T. 19 N., R. 79 W. near Wagonhound Creek.

CRETACEOUS ROCKS

Morrison formation. - The Morrison shale, of Lower Cretaceous age (Darton 5, pp. 27-30) lies unconformably on the Sundance (Lee 9, p. 16) and consists of 200 feet of variegated shales containing thin beds of white to gray sandstone. The formation is continuous over the central portion of the are and is exposed in the SE. $\frac{1}{4}$ sec. 5, T. 19 N., R. 79 W. The Morrison formation is of continental origin and well known for the vertebrate fossils which it has yielded.

* Mr. H. D. Thomas, Personal communication, 1934.

Dakota formation. - The Dakota, which occurs over the greater part of the area, is composed of three members: a basal coarse white to gray conglomerate, a middle black shale, and an upper ferruginous sandstone containing limonite concretions. The Dakota is 130 feet thick and lies unconformably on the Morrison (Lee 9, p. 17). According to Darton (4, pp. 403-470) the Dakota is of Upper Cretaceous age and marine origin. Fish remains are found in the shale member. Due to the resistant character of the sandstone members, outcrops form hogbacks and ridges at the lower Wick ranch on Wagonhound Creek.

Benton group. - The Benton group includes the Thermopolis shale, the Mowry shale, the Frontier sandstone and the Carlile shale. The Thermopolis shale is predominately a soft black carbonaceous shale. The Mowry shale is a hard black to brown platy shale which weathers to silvery gray. It usually forms low ridges where exposed and is easily recognized. The Frontier consists of black shales capped by a thick bed of gray sandstone containing shark teeth in abundance. The Carlile shale is a black carbonaceous shale.

The Benton group is approximately 1485 feet thick and occurs over most of the area. It outcrops in areas of low relief except where the Mowry shale and Frontier sandstone are exposed. The members forming the Benton group are all of marine origin and of Upper Cretaceous age (Darton 5, p. 11). The Benton is well exposed along the Medicine Bow River in the central portion of the area.

Niobrara formation. - The Niobrara consists of approximately 600 feet of soft black shales, containing near the middle, a white chalky argillaceous limestone which forms low bluffs. The Niobrara formation occurs over the central and northern part of the area and has been removed by erosion from the flanks of the anticlines around the borders. Good exposures can be found along the Medicine Bow River in the central portion of the area. The Niobrara contains an abundance of Ostrea congesta and Inoceramus deformis. The formation is of marine origin and Upper Cretaceous age (Bowen 2, p. 229).

Steele formation. - The Steele shale occurs only in the north central portion of the area, having been stripped off the higher lands by erosion. It is exposed over an area of about 18 square miles and forms the basin through which the Medicine Bow River flows. The formation consists of 4000 to 5000 feet of black shales and a few thin sandstone beds. The Steele is marine in origin and of Upper Cretaceous age (Bowen 2, p. 229).

EOCENE ROCKS

Hanna formation. - The Hanna formation rests with pronounced angular unconformity on the Steele shale and transgresses across all of the older rocks including the pre-Cambrian. The Hanna occurs extensively in the northeast and central portions of the area and caps Kennaday Peak. In the basin

area the Hanna formation caps broad flat table lands with a heavy boulder conglomerate and on Kennaday Peak the Hanna capping is composed of a coarse conglomerate containing pebbles and boulders of granite gneisses, diabases and quartzites, some of which measure ten feet in diameter. A fresh exposure in a land slip on the west flank of Kennaday peak reveals smaller, well rounded quartzite pebbles and merely the outline of the disintigrated diabase and granite pebbles. A fresh exposure in a land slip about two miles north of the Bow Ranger Station shows rounded quartzite pebbles as large as 18 inches in diameter with outlines of less resistant pebbles which have almost wholly disintegrated.

Section of the basal Hanna measured on the south-central line of sec. 10, T. 18 N., R. 80 W., on the bluff on the north bank of the East Fork of the Medicine Bow River.

Erosion surface:	Thickness in feet
Hanna formation:	
Coarse quartzite conglomerates containing arkosic sands, molds of decomposed igneous rocks and some shales	110
Yellow arkosic arenaceous shale	25
Gray to yellow arkosic sands grading downward from a medium-grained compact cross-laminated sandstone to coarse friable sands with bands of gray clay nodules. (Strike N. 60° W., Dip 6° N.)	10
Fairly compact conglomerate containing quartzite boulders ranging from 1" to 18" in diameter, decomposed remnants of other rocks, arkosic sand and shale	45
Less compact conglomerates same as above	125
Unconformably contact of the Hanna on the top member of the Dakota.	315
Dakota formation:	

Fragments of Mowry shale and other sediments older than the Hanna are also found in the conglomerate. These boulder conglomerates form ridges because of the resistant character of the quartzite boulders and the high porosity of the sediments. Water seeps through instead of forming streams which might transport material. The conglomerates are lenticular and apparently not basal but rise in the series and become finer as they progress away from the mountain front.

In addition to the conglomerates, the Hanna contains yellow arkosic sands which, in some places, are resistant cross-laminated beds, and in others they are poorly consolidated. Thick beds of gray to yellow shales and also a few thin carbonaceous shales are present. No coal beds are present in this area, although they are numerous in the Hanna Basin. From an exposure at the lower Wick ranch on Wagonhound Creek several well preserved specimens of leaves were collected from a black carbonaceous shale.

The Hanna is a continental deposit of Basal Eocene age. The sediments were apparently deposited by streams flowing from the main mountain range. The formation can be traced without a serious break into the type Hanna formation of the Hanna Basin. It is reported as being from 0 to 7000 feet thick in the Hanna Basin (Bowen, 2, p. 288) but attains only a fraction of this thickness around the north end of the Medicine Bow Mountains.

According to Bowen (2, p. 288) the Hanna formation of the Hanna Basin includes, without an unconformity, the Wasatch formation. However, the Wasatch formation rests unconformably on the Hanna to the south and east of the Hanna Basin.

Wasatch formation. - The Wasatch rests unconformably on the Hanna and older rocks. In the territory mapped it occupies only a small area in sec. 23, T. 19 N., R. 79 W., and lies in a depression eroded in the Hanna. The Wasatch is of Lower Eocene age, and, like the Hanna, is a continental deposit. The Wasatch is composed of red and purplish-red shales and yellow arkosic sandstones and grits. In other areas it is reported to be from 0 to 400 feet thick, but in this area the thickness is probably less than 25 feet.

PLIOCENE ROCKS

North Park formation. - The North Park is exposed on the south flanks of Kennaday Peak and Pennock Mountain. The formation occurs as horizontal beds and rests unconformably on the Hanna, the steeply dipping Chugwater and older rocks. The North Park consists of a basal coarse conglomerate, containing unweathered pebbles and boulders, overlain by a white clay-like bed of stratified volcanic ash. The formation is of Pliocene (?) age and continental origin. It varies in thickness from 0 to approximately 400 feet.

QUATERNARY ALLUVIUM

Much of the area is covered with a few feet of Quaternary alluvium which is fine-grained soil in the stream courses and boulders capping the pediments. Glacial deposits also occur extensively along the southwest border of the area. There is a large terminal moraine about one-half mile east of the Bow Ranger Station on top of which the Forest Service has placed Long Lake Lookout Station. In the heavily forested portions of the area the rocks are almost entirely covered by alluvium.

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

Regional Relationships. - The central portion of the area at the north end of the Medicine Bow Mountains is, in general, a syncline plunging northeast. The east, south and west borders are the flanks of the adjoining anticlines. Minor anticlines, synclines and faults also enter into the structure of the area. The anticlines are either markedly asymmetric or completely overturned to the east. The east limbs of the major anticlines are cut by westward-dipping thrust faults.

FAULTS

Elk Mountain Fault System. - For convenience, the name Elk Mountain fault system is applied to the group of thrust faults and tear faults which follows the east flanks of Elk, Coad and Pennock Mountains. The main thrust is covered by alluvium in many places and cannot be traced continuously, but probably is continuous. On the east flank of Elk Mountain the Madison and Tensleep terminate abruptly on the south against a thrust fault. North of the fault they lie in sedimentary contact with the pre-Cambrian and form part of the overthrust block. To the southwest the fault is covered by alluvium. On the south flank of Elk Mountain the outcrops of the Madison and Tensleep terminate against the pre-Cambrian on the north. Here they are part of the overridden block. Farther south the thrust swings back to the eastward and the pre-Cambrian is thrust onto the Embar.

From the eastern extremity of Coad Mountain the thrust continues southwestward for approximately three miles and then turns abruptly to the westward. From the abrupt turn a branch passes off to the eastward and forms the boundary between the south ends of the northeastward trending outcrops of the Madison, Tensleep and Embar, which are thrust here probably onto Sundance or Morrison. The branch turns northward and forms the boundary between the Embar in the overthrust block and the Dakota in the overridden block. Farther to the northeast the fault passes under alluvium and probably dies out in the incompetent Embar and Chugwater shales.

The area at the southeast end of Coad Mountain is thus an area of compound thrust faulting (Pl. III, cross-section GH). In the area to the west of the main thrust the Madison lies in sedimentary contact with the pre-Cambrian and is overlain by the normal sequence of sediments up to the Jelm. This block is thrust onto a block lying between the two thrusts and containing pre-Cambrian, Madison, Tensleep and Embar sheared from an anticline and syncline beneath the main thrust.

From the branch thrust near the center of sec. 1, T. 18 N., R. 82 W., a tear fault passes off to the southeast and offsets the outcrop of the Dakota more than half a mile.

At the north end of Pennock Mountain the main thrust has carried the pre-Cambrian onto the Benton. Along the east flank of the mountain the fault is covered by alluvium.

In the southwest portion of the mapped area the sediments lie in sedimentary contact with the pre-Cambrian and outline the southern extremity of a northeastward plunging syncline. The pre-Cambrian and sediments at least up to and including the Chugwater form part of the overridden block. In the west portion of Kennaday Peak granites are well exposed and along the north flank of the granite mass the Tensleep lies on the granite and dips almost vertically. The granite mass and the Tensleep are part of the overthrust block. The area to the west and south of the granite mass is

covered by alluvium and the North Park formation and consequently it is impossible to tell whether or not the granites continue to the southwest and join the main mass of pre-Cambrian. If the Kennaday Peak pre-Cambrian is eroded off on the southwest, the west end of the peak may be described as a klippe and the displacement along the thrust fault is of the magnitude of three miles.

FOLDS

Elk Mountain anticline. - Elk Mountain is a doubly plunging northeasterly trending anticline overturned to the east. Exposures are poor along the south and east flanks because of the development of large pediments capped in some places with Quaternary alluvium and in other places with Hanna conglomerates. Only the Madison and Tensleep formations are exposed sufficiently well to be mapped. These formations, standing vertically, can be followed for a distance of about three miles from the north end of Elk Mountain to a position where they are truncated by the Elk Mountain fault. They are exposed again on the south flank of Elk Mountain, where the fault apparently runs farther west in the pre-Cambrian rocks.

Coad Mountain anticline. - Coad Mountain, like Elk Mountain, is a doubly plunging anticline overturned to the east and faulted on the east side. The Madison limestone exposed on the south and east sides ranges in dip from 25° to the south and east to the extreme of being overturned so that in one place it dips 33° to the west. Formations from the Madison to the Benton are exposed on the southeast limb and pre-Cambrian is exposed in the core.

Pennock Mountain anticline. - Pennock Mountain is formed by an asymmetric anticline plunging north and faulted along the east limb. Exposures other than the pre-Cambrian core are present only at the southern end of the mountain and here the dips very from 45° to 60° to the east. The Madison, Tensleep and Embar formations are exposed at this location.

Wagonhound anticline. - The Wagonhound anticline, so named for convenience from Wagonhound Creek, is located in the northeast portion of the area. It is an asymmetric anticline trending northwest and plunging from 10° to 12° to the northwest. On the east limb the dips vary from 26° to 48°, while the maximum dip on the west limb is 15°. The fold takes the topographic expression of a valley rather than a ridge because of the soft shales forming its core. All of the Paleozoic and Mesozoic formations, with exception to the Madison and Embar, which are not present in this portion of the area, are exposed and involved in the anticline.

Minor anticline. - There is evidence of a minor anticline approximately four miles east of Coad Mountain where the Dakota, Benton, and Niobrara formations are exposed. This is apparently the small tightly folded anticline which is typically associated with overturned folds and thrust faults in Rocky Mountain structure. Although it is not apparent because of the cover, this fold probably parallels the east flanks of the mountains for some distance

Kennaday Peak.- Although Kennaday Peak is not a structural mountain, it is worthy of mention at this point. The fact that a pre-Cambrian mass has been faulted so that it occupies a position on the west side of the peak, probably bears little relation to its origin. The mountain is an erosional remnant which has survived because it is located at the stream heads and is capped by extremely coarse resistant Hanna conglomerates. The summit of Kennaday Peak is distinctive with knife-like ridges running at right angles to each other. These ridges are probably caused by land slips, which are common on the flanks of the mountain.

G E O L O G I C A L H I S T O R Y

The geologic history of the area at the north end of the Medicine Bow Mountains is by no means completely represented by the rocks occurring there. Rocks of Cambrian, Ordovician, Silurian and Devonian age are entirely absent and the rocks present represent only a part of later geologic time. No attempt will be made to give the pre-Cambrian history of the area.

EARLY PALEOZOIC TIME

According to Darton (5, pp. 403-470) a large portion of the Rocky Mountain province was probably a land mass during early Paleozoic time and stood above transgressing and regressing seas. However, because of the thick series of marine limestones in near-by areas, such as southeastern Idaho, it seems more probable that seas did cover this portion of the Rocky Mountain province and that the sediments deposited in them were stripped off by erosion after regressions of the seas. Either condition could have existed and no positive evidence can be given to support the second theory.

MISSISSIPPIAN TIME

During Mississippian time, or at least part of it, a sea covered this area in which was deposited the Madison limestone. A much greater thickness was probably deposited and subsequent erosion removed all but the small wedge which occurs there now.

PENNSYLVANIAN TIME

The Tensleep formation in this area represents the shore line or beach deposit of the Pennsylvanian sea, according to Knight (7, pp. 49-80). It is highly probable that later Pennsylvanian sediments were deposited and removed by erosion after the retreat of the sea, as indicated by the unconformable relationship of the Tensleep and the overlying rocks.

PERMIAN AND TRIASSIC TIME

During Permian and Triassic time the area, like most of Wyoming, apparently suffered a highly specialized history. Deposition of the Embar, Satanka, Forelle, and basal Chugwater took place in both marine and continental environments due to an oscillatory condition of the sea. The limestone deposits are marine and probably most of the red beds are continental.

JURASSIC TIME

The Sundance formation is marine and is the result of deposition in the Sundance sea (Darton 4, pp. 403-470). Erosion followed deposition of the Sundance, evidently removing part of it as indicated by the unconformity at the base of the overlying sediments.

CRETACEOUS TIME

During early Cretaceous time the area was a flood plain (Darton 4, pp. 403-470) and the Morrison was deposited by sluggish rivers. Dinosaurs were numerous as indicated by the rich fossil content. After Morrison time the area was subjected to erosion, and then to coastal plain conditions (Darton 4, pp. 403-470) and the deposition of the Dakota sandstone took place. Submergence followed and marine sediments of Upper Cretaceous age were deposited. Approximately 15,000 feet of black shales accumulated in the Upper Cretaceous sea. These marine conditions gradually gave way to continental conditions with the retreat of the sea. Although the continental Medicine Bow formation is not present in this area, it was probably deposited here as well as in the Hanna Basin (Bowen 2, p. 231). The Ferris formation, like the Medicine Bow was probably deposited over the entire area, but was completely stripped off by erosion prior to the beginning of Hanna time.

LARAMIDE REVOLUTION

Near the end of Mesozoic time, and continuing into early Tertiary time, the Rocky Mountain region was subjected to folding and faulting. This great orogeny caused the major structural relationships as they now exist in this area. The folds were overturned toward the east, or many times faulted and overthrust toward the east, indicating that the pressure probably came from the west.

TERTIARY TIME

The exact time of the beginning of the Laramide Revolution in the region has not been definitely determined. It is thought probable that both the Medicine Bow and the Ferris formations of the Hanna Basin were derived from a remote source, in which event the Laramide orogenic disturbance did not begin in this area until the close of Ferris time. The sequence of events which characterize the Tertiary history of the Medicine Bow Mountains and adjacent basins is as follows (Knight, 10):

(1) First period of orogeny. - All of the Cretaceous and older rocks were folded and faulted.
(2) First period of erosion. - This was a prolonged period of erosion during which time several thousand feet of rocks were removed from the area adjoining the pre-Cambrian nucleus.
(3) First period of deposition. - The Hanna formation was deposited during Basal Eocene time.
(4) Second period of orogeny. - During this period of mountain making the Hanna formation was folded as well as the underlying rocks.
(5) Second period of erosion. - This erosion took place during Early Lower Eocene time.
(6) Second period of deposition. - The Wasatch formation of Lower Eocene age was deposited unconformably on the Hanna and older rocks.
(7) Third period of erosion. - This period of erosion was of unknown extent.
(8) Third period of deposition. - Oligocene sediments (White River formation) were deposited. Although no Oligocene sediments were found in this area, from their occurrence in the Laramie Basin it is concluded that they were deposited over the area.
(9) Fourth period of erosion.
(10) Fourth period of deposition. - Early Pliocene sediments (North Park formation) were deposited.
(11) Fifth period of erosion. - This period of erosion took place during Late Pliocene time.

QUATERNARY TIME

The presence of glacial debris in the form of morainal deposits in the south-central portion of the area indicates that Pleistocene glaciation took place. The glacial heads were probably higher in the main range to the south. Deposition of terrace gravels and other alluvium brought this area to its present state.

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