DEPARTMENT OF THE INTERIOR
Roy O. West, Secretary

U. S. GEOLOGICAL SURVEY
George Otis Smith, Director

Bulletin 804

GEOLOGY AND COAL AND OIL RESOURCES OF THE HANNA AND CARBON BASINS, CARBON COUNTY, WYOMING

BY

C. E. DOBBIN, C. F. BOWEN, AND H. W. HOOTS

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1929

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
U.S.GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
60 CENTS PER COPY

CONTENTS

	Page
Introduction	1
Location and relations of the area	1
Purpose of the survey	2
Field work	2
Acknowledgments	3
Earlier geologic investigations	3
History of mining development	6
Geography	6
Surface features	6
Drainage	8
Settlements and roads	8
Stratigraphy	9
General relations	9
Pre-Tensleep rocks	11
Pennsylvanian rocks	11
Tensleep sandstone	11
Permian and Triassic rocks	11
Embar (?) formation	11
Chugwater formation	12
Jurassic rocks	12
Sundance formation	12
Cretaceous (?) rocks	13
Morrison formation	13
Cretaceous rocks	14
Cloverly formation	14
Thermopolis shale	15
Mowry shale	15
Frontier formation	16
Carlile shale	16
Niobrara formation	16
Steele shale	17
Mesaverde formation	17
Lewis shale	21
Late Upper Cretaceous and Tertiary (?) rocks	22
General features	22
Medicine Bow formation	23
Tertiary (?) and Tertiary rocks	24
Ferris formation	24
Hanna formation	25
North Park formation	26
Quaternary deposits	26
Terrace gravel	26
Alluvium	27

Page

Structure ... 27
General features ... 27
Folds ... 27
Fort Steele anticline ... 27
Walcott syncline ... 28
Cedar Ridge, St. Marys, and Pass Creek Ridge anticlines ... 28
Saddleback Hills anticline and Carbon Basin ... 29
Flat Top anticline ... 29
Faults ... 30
St. Marys fault ... 30
Cedar Ridge fault ... 31
Minor faults ... 31
Economic geology ... 31
Coal ... 31
General occurrence ... 31
Physical and chemical properties ... 32
Production and uses ... 37
Quantity of coal ... 37
Township descriptions ... 38
General scope ... 38
T. 21 N., R. 85 W ... 39
T. 22 N., R. 85 W ... 40
T. 23 N., R. 85 W ... 42
T. 21 N., R. 84 W ... 42
T. 22 N., R. 84 W ... 44
T. 23 N., R. 84 W ... 45
T. 24 N., R. 84 W ... 48
T. 21 N., R. 83 W ... 50
T. 22 N., R. 83 W ... 51
T. 23 N., R. 83 W ... 56
T. 24 N., R. 83 W ... 59
T. 21 N., R. 82 W ... 62
T. 22 N., R. 82 W ... 62
T. 23 N., R. 82 W ... 66
T. 24 N., R. 82 W ... 67
T. 21 N., R. 81 W ... 68
T. 22 N., R. 81 W ... 68
T. 23 N., R. 81 W ... 73
T. 24 N., Rs. 80 and 81 W ... 76
Tps. 20 and 21 N., R. 80 W ... 76
T. 22 N., R. 80 W ... 79
T. 23 N., R. 80 W ... 81
Tps. 20 and 21 N., R. 79 W ... 82
T. 22 N., R. 79 W ... 84
Oil developments ... 84
History of drilling operations ... 85
Fort Steele anticline ... 85
Cedar Ridge, St. Marys, and Pass Creek Ridge anticlines ... 85
Saddleback Hills anticline ... 85
Allen Lake anticline ... 86
Oil Springs anticline ... 86
Index ... 87

ILLUSTRATIONS

Page

PLATE 1. *A*, Tensleep sandstone in the Flat Top anticline, SE. ¼ sec. 12, T. 23 N., R. 79 W.; *B*, Upper part of the Chugwater formation on Little Medicine Bow River, SE. ¼ sec. 13, T. 23 N., R. 79 W. 26

2. *A*, Sundance, Morrison, and Cloverly formations in Como Ridge; *B*, Morrison and overlying formations on Little Medicine Bow River, SW. ¼ sec. 14, T. 23 N., R. 79 W. 26

3. *A*, Mesaverde formation on North Platte River, NW. ¼ sec. 13, T. 22 N., R. 86 W.; *B*, Transition zone from Steele shale to the Mesaverde formation, NW. ¼ sec. 24, T. 22 N., R. 86 W. 26

4. *A*, Sandstone hogback in the upper part of the Lewis shale, NW. ¼ sec. 2, T. 21 N., R. 84 W.; *B*, Medicine Bow formation on Austin Creek, SW. ¼ sec. 12, T. 24 N., R. 83 W. 26

5. *A*, Upper part of the Ferris formation, NE. ¼ sec. 31, T. 21 N., R. 83 W.; *B*, Vertical beds in the lower part of the Ferris formation, sec. 18, T. 24 N., R. 82 W. 26

6. *A*, Conglomeratic sandstone at base of Hanna formation, near Carbon; *B*, Hanna formation overlapping Mesaverde sandstone and Steele shale, SE. ¼ sec. 4, T. 23 N., R. 80 W. 26

7. *A*, Panorama in sec. 9, T. 23 N., R. 80 W., showing steeply dipping Hanna rocks striking north toward the Freezeout Hills; *B*, Conglomerate in lower part of the Hanna formation, SE. ¼ sec. 5, T. 21 N., R. 81 W.; *C*, North Park formation on North Platte River below Saratoga 42

8. Columnar section of rocks exposed in the Hanna and Walcott quadrangles 42

9. *A*, Mesaverde formation in Saddleback Hills anticline, sec. 17, T. 21 N., R. 80 W.; *B*, Oil Springs anticline in sec. 1, T. 23 N., R. 79 W.; *C*, Wilson coal mine, SE. ¼ sec. 32, T. 21 N., R. 80 W. 42

10. Columnar section of rocks exposed in the Saddleback Hills quadrangle 42

11. Sections of coal beds in T. 23 N., R. 85 W. ..... In pocket.

12. Sections of coal beds in T. 21 N., Rs. 83 and 84 W.; and T. 22 N., R. 84 W. ..... In pocket.

13. Sections of coal beds in T. 23 N., R. 84 W. ..... In pocket.

14. Sections of coal beds in T. 24 N., R. 84 W. ..... In pocket.

15. Sections of coal beds in T. 22 N., R. 83 W. ..... In pocket.

16. Sections of coal beds in T. 23 N., R. 83 W. ..... In pocket.

17. Sections of coal beds in T. 24 N., R. 83 W. ..... In pocket.

18. Sections of coal beds in Tps. 21 and 22 N., R. 82 W. ..... In pocket.

19. Sections of coal beds in T. 23 N., R. 82 W., and T. 24 N., Rs. 80, 81, and 82 W. ..... In pocket.

Page

PLATE 20. Sections of coal beds in T. 22 N., R. 81 W.----In pocket.
21. Sections of coal beds in T. 23 N., R. 81 W.----In pocket.
22. Sections of coal beds in Tps. 20 and 21 N., Rs. 80 and 81W.---In pocket.
23. Sections of coal beds in T. 22 N., R. 80 W.----In pocket.
24. Sections of coal beds in T. 23 N., R. 80 W.----In pocket.
25. Sections of coal beds in Tps. 20, 21, and 22 N., R. 79 W.--In pocket.
26. Logs of wells in the Hanna and Carbon Basins----In pocket.
27. Geologic map and structure sections of the Hanna and Carbon Basins----In pocket.

FIGURE 1. Map of southern Wyoming showing relation of Hanna and Carbon Basins to other coal and oil and gas fields---- 1
2. Sections of coal beds in T. 21 N., R. 85 W.---- 39
3. Sections of coal beds in T. 22 N., R. 85 W.---- 41

GEOLOGY AND COAL AND OIL RESOURCES OF THE HANNA AND CARBON BASINS, CARBON COUNTY, WYOMING

By C. E. Dobbin, C. F. Bowen, and H. W. Hoots

INTRODUCTION

Location and relations of the area.—The Hanna and Carbon Basins lie in south-central Wyoming (see fig. 1), and are due to the existence of great basin-shaped depressions in the earth's crust that have been filled by layers of sandstone and shale interbedded with many

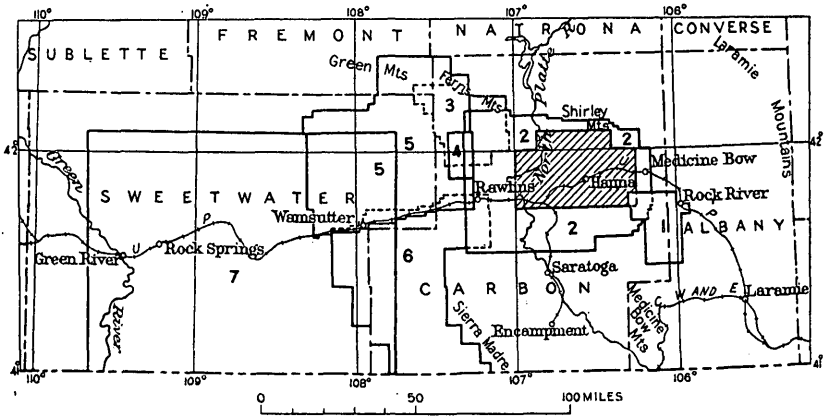


FIGURE 1.—Map of southern Wyoming, showing relation of Hanna and Carbon Basins to other coal and oil and gas fields. 1. Rock Creek oil field (U. S. Geol. Survey Bull. 806); 2, east central Carbon County (Bull. 316); 3, Lost Soldier-Ferris district (Bull. 756); 4, Bell Springs gas field (Bull. 796); 5, Great Divide Basin coal field (Bull. 341); 6, Little Snake River coal field (Bull. 341, 381); 7, Rock Springs district (Bull. 341, 381, 702, 751, 781)

layers of coal. Extensive coal-mining operations have long been in progress in these basins, and their coal-bearing areas are traversed by the main line of the Union Pacific Railroad, their great remaining reserves of coal being thus made readily available at such future times as they may be in greater demand.

The two basins are really subdivisions of a single major downwarp of the granitic basement rocks of the region that lies between the Rawlins uplift on the west, the Ferris, Seminoe, Shirley, and Freeze-out uplifts on the north, and the Medicine Bow uplift on the south.

This depression is not closed on the east by any definite structural feature but represents the accentuated northwestward extension of the broad intermontane syncline known as the Laramie Basin. The depth of the depression is such that it contains about 35,000 feet of sedimentary rocks ranging in age from Carboniferous to late Tertiary.

The Hanna and Carbon Basins are almost wholly covered by the topographic maps of the Walcott, Hanna, and Saddleback Hills quadrangles, but they also include about one tier of townships north of these quadrangles, which has not been mapped topographically. The Union Pacific Railroad crosses the three quadrangles, and all of the area described, except the northern portions of T. 24 N., Rs. 82 to 84 W., and T. 23 N., R. 85 W., is within 15 miles of the railroad.

Purpose of the survey.—The geologic investigations that form the basis for this report were undertaken primarily for the purpose of classifying and valuing the public land with regard to coal. In order to do this it was necessary to locate accurately with respect to land lines the outcrops of all coal beds that were considered to be of workable thickness. The thickness and the character of the coal beds were determined in all accessible mines and prospects, and in the absence of openings sufficient prospecting was done to obtain the desired information. The quality of the coal was determined by analyses of fresh samples taken from working mines, or from prospects that had been recently opened. The geologic structure of the field was worked out with considerable accuracy in order to determine the depth of the coal beds below the surface and their availability for mining.

Field work.—The investigations forming the basis for this report were made during the field season of 1913 by C. F. Bowen, assisted by F. A. Herald, F. A. Hinkley, L. H. White, Fritz Aurin, and for a time by J. B. Reeside, jr., and in 1915 by Mr. Bowen with the assistance of C. J. Hares, C. A. Bonine, H. M. Robinson, O. L. Brace, and V. O. Wood. A brief inspection of the field was made by C. E. Dobbin in 1924, and was followed by a more thorough field review and slight revision of the geologic data by Mr. Dobbin and H. W. Hoots in 1925. Statistics of development were revised to include all explorations for coal and oil to the end of 1925. The present report was then prepared by Mr. Dobbin with the assistance of Mr. Hoots.

The original mapping was done by means of plane table and telescopic alidade, used in conjunction with a topographic base having a horizontal scale of 1:48,000 and a contour interval of 25 feet. This base and a system of triangulation established during the topographic survey served as both horizontal and vertical control except for that portion of the area lying north of the quadrangles, which

was mapped on a flat base, on which horizontal control was obtained by expanding the triangulation net established in the quadrangles.

During the season of 1913 altitudes were determined at all locations made on coal outcrops but not on geologic boundaries, as it was found that the topography is sufficiently precise to give the altitude of these boundaries. In general, the altitudes of coal beds computed from the topographic contouring vary less than 25 feet from the true altitude, and the variation rarely exceeds 50 feet.

During the progress of the topographic mapping the land survey was adjusted to the triangulation control by the location of many of the land corners. The topographic base, therefore, serves as well for the determination of cadastral position as for the determination of surface altitudes. During the geologic examination many of the land-corner stones were located for the purpose of "tying" coal beds to them. Most of the corners thus located harmonize with the land net on the topographic map. Only a few of the corners for which careful search was made could not be found.

Acknowledgments.—The writers wish to acknowledge the efficient aid rendered by all assistants during the prosecution of the work. They also wish to tender especial thanks to Eugene McAuliffe and G. B. Pryde, officials of the Union Pacific Coal Co., for maps, drill-hole records, and development data in the Hanna district; to Elfred Beck, of the Producers & Refiners Corporation for logs of wells on the Saddleback Hills and St. Marys anticlines; to Albert Cronberg, of Medicine Bow, for information concerning the geology and oil developments near that town; to T. W. Stanton, F. H. Knowlton, and J. B. Reeside, jr., for their identification and interpretation of fossils; and to M. R. Campbell and W. T. Thom, jr., for their supervision of the investigations and for suggestions and criticisms offered during the preparation of this report.

Earlier geologic investigations.—The earliest geologic investigations in the Hanna and Carbon Basins were made by Hadyen in 1868, and in describing the country along the Union Pacific Railroad west of Como Ridge he wrote:[1]

> From a point about 10 miles east of Como to St. Marys Station, a distance of about 50 miles, the Tertiary formations occupy the country with the peculiar sands and sandstone and clays and numerous coal beds. The most marked development of the coal beds is at the Carbon station, about 80 miles west of Laramie station. The rocks incline nearly southeast, or south and east. Three entrances have been made to the mine, and the bed is 9 feet thick. The openings follow the dip and consequently descend. The mines are about 3,000 yards from the railroad, but a sidetrack has already been laid to them. More than 1,000 tons of coal have already been taken, and the Union Pacific Railroad Co. is ready to contract for any amount that

[1] Hayden, F. V., U. S. Geol. Survey Terr. Second Ann. Rept., pp. 95–96. 1873.

can be supplied to them. The coal at Carbon is of the best quality of Tertiary splint, very compact and pure. It is not as hard as anthracite, but the miners informed me that it was more difficult to work than the bituminous coals of Pennsylvania. * * *

From St. Marys to Rawlings Springs, a distance of about 30 miles, the railroad passes over rocks of Cretaceous age. * * * The railroad, from a point about 8 miles east of Benton to Rawlings Springs, passes through one of the most beautiful anticlinal valleys I have seen in the West. On either side the rusty-gray sands and standstones dip away from the line of the road at an angle of 10° to 15°. This anticlinal valley is most marked near Fort Steele, at the crossing of the North Platte.

In the early surveys of the fortieth parallel King[2] subdivided the Cretaceous into four major "groups"—Dakota, Colorado, Fox Hill, and Laramie. The Colorado group was in turn subdivided into the Fort Benton, Niobrara, and Fort Pierre groups, corresponding respectively, to Meek and Hayden's Cretaceous Nos. 2, 3, and 4. The Fort Pierre, now known as Pierre shale, was later excluded from the Colorado group when the Montana group was defined.

In his report King states:

The whole Colorado group, composed of these three members, is bounded on the upper surface by the heavy sandstones of the Fox Hill and below by the still more compact sandstones of the Dakota.

It is evident from King's description of the Fox Hill "group" that sandstones of the Hanna Basin region now included in the Mesaverde formation were considered by him and other early workers as at least a part of that "group." King states further:[3]

In the region of Carbon the Fox Hill sandstones are very well developed and dip from every direction inward toward the town. To the southwest they are well exposed in Simpsons Ridge [Saddleback Hills], where they rise 800 feet above the village. * * *

A section across the ridge on the western side of the Platte, south of Fort Steele, shows that the lower 2,000 feet are pricipally beds of massive sandstone, 50 or 100 feet thick, with but very little shale. Above these are about 1,500 feet of more thinly bedded sandstones, whose individual members vary from 5 to 15 feet in thickness and contain a great many interlaminated shales, which are often bituminous, and thin seams of coal. In the valley south of the ridge, south of Fort Steele, the younger sandstones are decidedly ferruginous, show a considerable change of character, and are supposed to represent the bottom of the Laramie. The entire Fox Hill here is estimated at about 3,500 feet.

It appears that the thick marine shale above the Mesaverde formation now known as Lewis shale was not recognized by the early workers in this region as being in that position.

In the period between 1867 and 1873 Arnold Hague,[4] geologist of the Fortieth Parallel Survey, examined and described the Carbon

[2] King, Clarence, Systematic geology: U. S. Geol. Expl. 40th Par. Rept., vol. 1, pp. 305–306, 1878.

[3] Idem, pp. 322–323.

[4] Hague, Arnold, Descriptive geology: U. S. Geol. Expl. 40th Par. Rept., vol. 2, pp. 142–155, 1877.

Basin and adjoining mountains, foothills, and plains regions, from Como station westward to the vicinity of Fort Steele. At about this time Lesquereux identified fossil plants collected by Hayden in Carbon Basin and interpreted them as lower Miocene.[5] Lesquereux was largely responsible for our first knowledge of the fossil plants of the western Tertiary formations. He was early occupied in the identification of fossils collected and submitted by Hayden in his earliest explorations, but later, in 1872, at the direction of Hayden, he took the field for the purpose of obtaining sufficient fossil plants to determine the age of the lignitic formations. He visited Carbon and collected numerous specimens, which he tabulated.[6] Newberry[7] also examined and identified fossil plants collected by geologists of the early surveys.

F. B. Meek, intimately associated with Hayden in early explorations of the West, acted as paleontologist for the Geological Survey of the Territories and was one of the recognized authorities on invertebrate fossils of North America. Working actively in a virgin field, Meek collected and described great numbers of invertebrate fossils from formations of the West ranging in age from early Paleozoic to the Tertiary. Accompanied by H. M. Bannister in 1872 he examined coal-bearing rocks exposed along the Union Pacific Railroad in southern Wyoming for the purpose of collecting fossils. Invertebrate forms were collected from localities east and west of the Carbon and Hanna Basins, but with the exception of some specimens of *Ostrea* found in the Niobrara shale near Fort Steele, no invertebrates were collected from the area described in this report.

One of the first reports on the Tertiary coals of the West was that by James T. Hodge, geologist on Hayden's early survey. The introduction to this report gives the following historical account[8] of the conditions prevalent in the West at about the time of the first coal mining in this region:

> The occurrence of coal in the Rocky Mountains was observed and reported on by most of the early explorers on the different routes they traversed across the continent. Little importance, however, was attached to these discoveries, and, as the coal beds were seen only in their outcrop, little knowledge was acquired of their real character. It was understood that they belonged, not to the true coal formation, but either to the Lower Tertiary or Upper Cretaceous, and the coal was consequently classed among the lignites or brown coals and generally considered to be far inferior in quality to the genuine coals of the

[5] Lesquereux, Leo, Tertiary flora of North America: U. S. Geol. Survey Terr. Fifth Ann. Rept., pt. 3, p. 306, 1872.

[6] Lesquereux, Leo, Lignitic formation and fossil flora: U. S. Geol. Survey Terr. Sixth Ann. Rept., pp. 410–417, 1873.

[7] Newberry, J. S., The later extinct floras of North America: U. S. Geol. Survey Mon. 35, 1898.

[8] Hodge, J. T., On the Tertiary coals of the West: U. S. Geol. Survey Terr. Fourth Ann. Rept., pt. 4, p. 318, 1871.

Eastern and Middle States. As the country began to be settled, the scarcity of timber soon caused these deposits of fuel to be looked up and mines of coal to be opened and worked in Utah and in Colorado. The construction of the Union Pacific and Central Pacific Railroads created a still greater demand for fuel for the supply of their locomotives, and new mines were opened along the line of the former road in Wyoming Territory, which, with those worked on the eastern border of Utah, near the same road, supply both these long lines of road with all the coal they require. No mines have been found near the Central Pacific Railroad, either in Utah, Nevada, or California, so that this road is wholly dependent for fuel upon the coals brought to it from the Union Pacific. Though it is scarcely three years since these coal mines began to be developed, they have already produced large quantities of coal, and several among them have the appearance of thriving collieries, well furnished with powerful machinery for pumping and hoisting and all the appliances of first-class establishments.

More recently Veatch [9] located and collected samples from the coal mines of the Hanna and Carbon Basins and prepared a reconnaissance geologic map covering these basins and some adjacent territory.

History of mining development.—The first coal-mining development in the Hanna and Carbon Basins was that at and near the town of Carbon in 1868. Seven mines were ultimately opened at this place, and the production up to and including 1902, when the mines were abandoned, was about 4,680,000 tons. The immediate cause for the abandonment of these mines was the shifting of the main line of the Union Pacific Railroad farther north to its present route through the town of Hanna. Mines at Dana were opened in 1889 and abandoned in 1891, according to reports, on account of the unsuitability of the coal for locomotive use. The mines at Hanna were opened in 1890.

Five mines, known as Nos. 1, 2, 3, 3½, and 4, have been opened by the Union Pacific Coal Co. at Hanna, and of these, Nos. 2 and 4 are actively operated at the present time. These two mines employ 250 men and have an average daily production of 2,200 tons of coal.

GEOGRAPHY

Surface features.—The plains type of topography prevails in the Hanna and Carbon basins but is broken around their margins by low ridges composed, in most places, of the resistant sandstones of the Mesaverde formation. These ridges reach a maximum altitude in Pass Creek Ridge, in the Hanna quadrangle, of 7,905 feet above sea level. High plains in various stages of erosion, terraces formed by streams when they flowed at higher levels than now, alluvial flats as much as half a mile wide, and valleys of moderate extent all occur within these basins. The extreme range of relief within the

[9] Veatch, A. C., Coal in east-central Carbon County, Wyo.: U. S. Geol. Survey Bull. 316, pp. 244–260, 1907.

area is about 1,600 feet, between the crest of Pass Creek Ridge and North Platte River at the point where it leaves the area.

The plains, which occupy the greater part of the area, have locally been carved into prominent isolated hills, the most conspicuous of which occur in the vicinity of Hanna, and striking examples of badland topography are developed along the coulees leading down to Medicine Bow River.

Pass Creek, St. Marys, and Cedar Ridges form a nearly continuous chain of hills, separated into three parts, which extend from northwest to southeast across the southwestern parts of the Walcott and Hanna quadrangles. In previous publications these hills have been described under a single name, chosen from one or another unit of the chain, but to avoid confusion local names applied to the individual units are here adopted. These ridges are bold rocky features that rise rather abruptly, in places almost precipitously, from the surrounding plains. The maximum altitude is attained in Pass Creek Ridge, whose highest point rises about 750 to 900 feet above the adjacent plains.

Rattlesnake Ridge lies southwest of St. Marys and Cedar Ridges, to which its trend is approximately parallel. This ridge rises by a series of southwestward-facing escarpments from the valley of North Platte River to a maximum height of nearly 1,100 feet above the river level. On the northeast it descends by a more gentle and uniform slope to the broad valley which separates it from St. Marys and Cedar Ridges.

The Saddleback Hills, in the southern part of the Saddleback Hills quadrangle, form a bold, narrow ridge, which rises to a maximum altitude of 7,843 feet, or about 500 to 600 feet above the surrounding plain, and part of a similar but broader ridge, known as Medicine Bow Ridge, occupies the extreme southeast corner of the same quadrangle.

With the exception of the series of prominent hogback ridges east of Medicine Bow River in the northeast corner of the Saddleback Hills quadrangle and some of the high ridges along the northern margin of the Hanna Basin, the remainder of the area described is featured by undulating plains from 6,500 to 7,500 feet above sea level. In their higher portions, as in the northeast quarter and along the north edge of the Hanna quadrangle, they are rough and broken, and the descent to the valley of Medicine Bow River is extremely abrupt and rugged.

Flat-topped gravel terraces, remnants of a former more extensive terrace system, border the valleys of North Platte and Medicine Bow Rivers in many places, and a series of lower terraces occur within the present river valleys.

Alluvial flats as much as half a mile in width occur along North Platte and Medicine Bow Rivers and to a lesser extent along some of the larger intermittent drainage channels.

Drainage.—The Hanna and Carbon Basins lie wholly within the drainage basins of the North Platte and of its tributary Medicine Bow River, and the perennial streams joining these rivers within the basins are Little Medicine Bow River and Austin, Troublesome, and Difficulty Creeks, which rise in the Shirley Mountains, on the north. The surface drainage reaches the permanent streams through intermittent stream channels locally known as ditches. Hanna Ditch rises in the hilly area northeast of Hanna and pursues a northeastward course to Medicine Bow River. Walcott Ditch begins in the southwestern part of the Saddleback Hills quadrangle and follows a general westward course past Dana and Walcott to North Platte River at Fort Steele. St. Mary's Ditch rises in the east-central part of the Walcott quadrangle and follows a northwestward course to North Platte River. The best known and most prominent of these ditches is Big Ditch and its two tributaries, North and Middle Ditches. Big Ditch rises near the eastern boundary of the Hanna quadrangle east of Hanna, and follows a general northwestward course to North Platte River, which it enters 3 miles south of the north boundary of the Walcott quadrangle. Middle Ditch and North Ditch have general westerly courses. These three ditches drain approximately three-fourths of the area of the Walcott and Hanna quadrangles.

Settlements and roads.—The Union Pacific Railroad crosses the Hanna and Carbon Basins and is the principal cause of their settlement. The town of Hanna has been built around the coal mines opened to provide locomotive fuel and now (1926) has a population of about 1,800. Medicine Bow, with a population of about 200, is also on the railroad about 3 miles east of the area, and Walcott and Fort Steele contain about 75 and 150 people, respectively, and serve principally as supply points for near-by ranches. A branch railroad extends southward from Walcott to Saratoga and Encampment. With the exception of the towns and of the ranches on the alluvial flats of North Platte and Medicine Bow Rivers and Austin Creek, the area is sparsely settled, largely because of the scarcity of water.

The Lincoln Highway traverses the southern portion of the area, and well-traveled roads lead from it both north and south to distant towns, ranger stations, and ranches in the well-watered mountainous areas adjoining the basins. One such road traverses the northeast corner of the Saddleback Hills quadrangle, crosses Medicine Bow River, and leads to Difficulty post office, in the Freezeout Hills. Difficulty is also reached by a well-traveled road that leads north from

Hanna. Another good road leads from Medicine Bow southwestward across the southeast corner of the Saddleback Hills quadrangle to the Johnson ranch, on Medicine Bow River, and thence to the town of Elk Mountain. Another well-traveled road leads north from Walcott, skirts the east end of St. Marys Ridge, crosses Medicine Bow River in sec. 26, T. 24 N., R. 83 W. and proceeds northward to the Freeze-out Hills and Casper. Other roads and trails exist within the area, and some are fairly well traveled at certain times of the year, though they are as a rule in poor condition.

STRATIGRAPHY

GENERAL RELATIONS

The consolidated formations exposed in the Hanna and Carbon Basins are all of sedimentary origin and range from Triassic to Tertiary in age. They include marine, fresh-water, and brackish-water deposits having an aggregate thickness of about 33,650 feet, although some of the formations are separated by pronounced unconformities. Unconsolidated deposits of small extent and of fluviatile and eolian origin also occur.

Beneath the strata that crop out in the area mapped are older formations of sandstone, shale, and limestone, which date back to Carboniferous and possibly to Cambrian time. These formations are upturned and exposed by erosion along the mountain ranges surrounding the Hanna and Carbon Basins and rest unconformably on pre-Cambrian crystalline rocks, including granite, gneiss, and schist, which constitute the cores of most of the mountain ranges.

Geologic formations in the Hanna and Carbon Basins, Wyo.[a]

Age	Formation	Thickness (feet)	Characteristics
Quaternary.	Alluvium.		Worked-over material from surrounding formations.
	Terrace gravel.	[b] 0–25	Waterworn pebbles of older sedimentary and crystalline rocks.
Miocene (?).	North Park formation.	[b] 0–400	Whitish unconsolidated sand and clay with thin intercalated beds of limestone in some places; locally conglomeratic at base.
	—Unconformity—		
Eocene.	Hanna formation.	[b] 7,000	Alternating beds of dark-gray, yellowish, and carbonaceous shale; white, gray, and brown sandstones, massive to thin bedded and commonly cross-bedded; conglomerate and conglomeratic sandstone containing pebbles of chert, granite, quartzite, sandstone, Mowry shale, Cloverly conglomerate, etc.; and numerous beds of coal. Contains fish scales, bones of turtles and mammals, fresh-water shells, and an abundance of leaves.
	—Unconformity—		

[a] Bowen, C. F., Stratigraphy of the Hanna Basin, Wyo.: U. S. Geol. Survey Prof. Paper 108, pp. 228-229, 1917. [With some changes.]
[b] Approximate.

Geologic formations in the Hanna and Carbon Basins, Wyo.—Continued

Age	Formation	Thickness (feet)	Characteristics
Eocene (?).	Ferris formation.	[b] 6,500	Light-colored, dark-gray, and carbonaceous shale; buff to brown sandstone, in places extremely cross-bedded and showing great irregularity of deposition; and numerous beds of coal. Pockets, lenses, and thin beds of conglomerate composed of pebbles of older rocks are distributed through a zone about 1,000 feet thick at the base of the formation. Contains fresh-water invertebrates, land plants, and in lower 1,400 feet bones of dinosaurs, including *Triceratops*.
Upper Cretaceous.	Medicine Bow formation.	[b] 4,000–6,200	Light-colored to gray and carbonaceous shale; gray to brown sandstone showing cross-bedding, ripple marks, and other features of irregular deposition; thin irregular beds of coal and sandstone containing marine Cretaceous fossils in lower part. Fresh and brackish water invertebrates, land plants, and bones of dinosaurs, including ceratopsians.
	Lewis shale.	[b] 3,300	Predominantly dark-gray shale with thin intercalated beds of shaly sandstone and some beds of light-colored massive to heavy-bedded sandstone. About 600 feet below the top of the formation is a persistent ledge-making gray sandstone about 270 feet thick. Marine.
	Mesaverde formation.	2,200–2,700	An upper member of white to gray sandstone alternating with gray and carbonaceous shale with a conspicuous, resistant white sandstone at the top; contains thin irregular beds of coal in some places. A middle member of brown to gray sandstone, gray to carbonaceous shale, and thin irregular beds of coal; differs from upper member in its prevailingly brown color; fresh and brackish water fauna. A lower member of gray to white sandstone and gray shale; contains a marine fauna and is not coal-bearing; grades into the Steele shale through a zone of transition beds.
	Steele shale.	[b] 4,000–5,000	Dark-gray shale with intercalated beds of sandy shale and sandstone, some of which form conspicuous ledges near top of formation. Shale contains concretions of calcareous sandstone, dark limestone, and white crystalline calcite. Marine fauna. At top a transition zone of interbedded sandstone and shale.
	Niobrara formation.	[b] 700	Dark calcareous shale with several harder chalky beds which crop out as conspicuous light-colored ridges.
	Carlile shale.	[b] 460	Dark shale with some thin sandy layers and many large concretions.
	Frontier formation.	[b] 725	Dark-gray to black shale with Wall Creek (?) sandstone member at top.
	Mowry shale.	120	Hard, compact dark-brown to black fissile shale weathering to silver-gray.
	Thermopolis shale.	180	Dark-gray to black shale with thin sandy beds.
Lower Cretaceous.	Cloverly formation.	128	An upper member of hogback-forming sandstone, a middle member of green shale and sandstone, and a lower member of conglomeratic sandstone.
Cretaceous (?).	Morrison formation.	350	Variegated shale alternating with sandy shale and sandstone. Contains dinosaur bones.
Upper Jurassic.	Sundance formation.	350	Gray and green shale alternating with gray sandstone and sandy shale.
Triassic.	Chugwater formation.	1,300	Red shale with intercalated red and gray sandstone and sandy shale; some limestone and gypsum. Beds of variegated colors are present.
Permian.	Embar (?) formation.	150	Red shale, limestone, gypsum, and some thin sandstones.
Pennsylvanian.	Tensleep sandstone.	[b] 250	Massive to thin-bedded and cross-bedded light-gray sandstone.

[b] Approximate.

PRE-TENSLEEP ROCKS

The oldest sedimentary formation in this general region is a well-bedded rusty quartzite which is conspicuously exposed in the Rawlins uplift. At Rawlins this quartzite is 412 feet thick and is considered to belong to the lower part of the Middle Cambrian.

The name Casper formation was proposed by Darton[10] for the limestone, dolomite, and sandstone of Carboniferous age, which range from 500 to 1,000 feet in thickness and constitute the greater part of the sedimentary rocks in the Casper and Laramie Mountains. These rocks, according to Darton, represent the southeastward extension of the Amsden and Tensleep formations of central Wyoming but are so changed in character and indefinite in stratigraphic limits that a new name was given to them. Darton recognized, however, that in some places, as in the Freezeout Hills, the Madison, Amsden, and Tensleep formations can be differentiated. According to Darton, the Casper formation rests unconformably on pre-Cambrian crystalline rocks in the Laramie Basin. At Rawlins, however, it is in contact with the Madison limestone, which rests on Cambrian quartzite.

PENNSYLVANIAN ROCKS

TENSLEEP SANDSTONE

The Tensleep sandstone is conspicuously exposed in sec. 12, T. 23 N., R. 79 W., and vicinity, where it is the central formation in the Flat Top anticline. It is at least 250 feet thick and consists of massive to thin-bedded and cross-bedded light-gray sandstone, which stands about 500 feet above the surrounding country and bears a growth of pine trees. (See pl. 1, *A*.)

PERMIAN AND TRIASSIC ROCKS

EMBAR (?) FORMATION

Excellent exposures of the Embar (?) and the overlying Chugwater formation occur on the south limb of the Flat Top anticline in sec. 13, T. 23 N., R. 79 W., and vicinity, where the moderately inclined rocks have been deeply dissected by Little Medicine Bow River and its tributaries. Here as elsewhere in this general region the line of demarcation between the Embar (?) and Chugwater formations is not a sharp one, and for present purposes it was drawn at the top of the uppermost thin but persistent limestone above the Tensleep sandstone. This limestone probably corresponds to the

[10] Darton, N. H., Paleozoic and Mesozoic of central Wyoming: Geol. Soc. America Bull., vol. 19, p. 418, 1908.

Forelle limestone, and the beds below it to the Satanka shale.[11] The following section illustrates the character of the Embar (?) formation at this locality:

Section of Embar (?) formation in sec. 13, T. 23 N., R. 79 W.

	Feet
Base of typical red beds of Chugwater formation.	
Embar (?) formation:	
Forelle (?) limestone—Limestone, lavender-colored	3
Satanka (?) shale—	
Shale, red	85
Limestone, gray, slabby	10
Shale, green and brown	30
Gypsum	6
Shale, grayish brown	6
Sandstone, gray, calcareous; contains thin laminae of asphalt and gives a strong odor of petroleum	2
Shale, gray	4
Top of Tensleep sandstone.	
	146

CHUGWATER FORMATION

The most characteristic feature of the Chugwater formation is its predominantly red color, but other light colors, including purple, pink, blue, green, and buff, occur. The formation consists chiefly of shale, in part sandy, in which occur beds of sandstone, limestone, and gypsum. Beds of sandstone are most abundant in the upper part of the formation, and at the top there is a zone 150 feet thick consisting almost wholly of sandstone which contains an abundance of cross-bedding, ripple marks, and other features characteristic of stream, wave, or wind action. (See pl. 1, *B*.) Gypsum occurs chiefly in the lower half of the formation in beds 1 to 19 feet thick. In a stratigraphic section measured in the northeast corner of the Saddleback Hills quadrangle it is estimated that the Chugwater formation consists of 69 per cent shale, 22 per cent sandstone, 6 per cent gypsum, and 3 per cent limestone. Its thickness in this area is about 1,300 feet.

JURASSIC ROCKS

SUNDANCE FORMATION

In the Saddleback Hills quadrangle the Sundance formation consists chiefly of gray and green shale with beds of sandstone of varying thickness in its basal and middle portions. In near-by areas, however, it contains a greater proportion of sandy beds, including

[11] Darton, N. H., and Siebenthal, C. E., Geology and mineral resources of the Laramie Basin, Wyo.: U. S. Geol. Survey Bull. 364, pp. 20–22, 1909.

thin sandstones and arenaceous shales, and thin beds of limestone, some of which are rather sandy.

The following section measured at Como Ridge, 5 miles east of Medicine Bow, where exposures are excellent, shows the general character of the Sundance formation in this general region. (See pl. 2, *A*.)

Section of Sundance formation at Como Ridge

	Feet
Base of Morrison formation.	
Sundance formation:	
Sandstone, gray, cross-bedded	2
Sandstone, green, shaly	5
Sandstone, light gray, cross-bedded	5
Shale, green, sandy, and thin limestones	34
Sandstone, buff, thin-bedded	5
Shale, green, containing *Belemnites*	68
Sandstone, grayish-brown, thin-bedded	12
Shale, gray, sandy	29
Sandstone, light gray, cross-bedded	7
Sandstone, gray, massive to thin-bedded and cross-bedded	70
Shale, green	15
Shale, red, and thin-bedded red sandstone	36
Sandstone, gray, massive, friable	15
Shale, green, and shaly sandstone	12
Sandstone, light gray, massive, with brown sandstone concretions, cross-bedded in upper part	35
Top of Chugwater formation.	
	[12] 350

The following marine Jurassic fossils were collected from the Sundance formation in the SW. ¼ sec. 13, T. 23 N., R. 79 W., Saddleback Hills quadrangle, locality 9357:

Penatcrinus asteriscus Meek and Hayden.
Serpula sp.
Eumicrotis curta (Hall).
Trigonia quadrangularis Hall and Whitfield.
Tancredia sp.
Pleuromya subcompressa Meek.
Cardioceras cordiforme var. distans Whitfield.
Belemnites densus Meek and Hayden.

CRETACEOUS (?) ROCKS

MORRISON FORMATION

The Morrison formation consists of alternating beds of shale and sandstone. The sandstone is most abundant in the lower part of the

[12] Darton (op. cit., p. 26) obtained 119 feet for the thickness of the Sundance formation in Como Ridge, drawing the base of the formation considerably higher than in the section given here.

formation, and at its base there is white sugary massive sandstone 143 feet thick. Not far above this is another sandstone containing conglomerate pebbles at the base and numerous clay balls above. It is cross-bedded and ranges from 10 to 34 feet in thickness within a few hundred feet along the strike. The shales vary in color from green to gray and drab. In other places they show a great variety of color and contain maroon members, which make the formation difficult to distinguish from the Chugwater. On lithologic evidence it is difficult in some places to locate the boundary between the Morrison and the Sundance, and in deciding on what shall be taken as the boundary it is necessary to be guided by the character of the contained fossils. Two species of marine invertebrates—*Belemnites densus* and *Pentacrinus asteriscus*—are very common in the Sundance, whereas the Morrison contains fresh-water mollusks and bones of dinosaurs.

Section of Morrison formation on Little Medicine Bow River in sec 14, T. 23 N., R. 79 W.

	Feet
Base of Cloverly formation.	
Morrison formation:	
Shale, gray to drab, becoming darker at top	63
Calcareous concretionary layer	3
Shale, pale green	24
Sandstone, brown, coarse, cross-bedded	12
Shale, green	24
Sandstone, brown, thin bedded; contains many clay balls and bones; locally cross-bedded and variable in thickness	34
Shale, green, sandy, and thin beds of sandstone	45
Sandstone, white, shaly; in places sugary, elsewhere platy	143
Top of Sundance formation.	
	348

At Como Ridge the Morrison formation is 222 feet thick and is made up almost entirely of variegated shale with thin sandstones. (See pl. 2, *A*.)

CRETACEOUS ROCKS

CLOVERLY FORMATION

The Cloverly formation is 128 feet thick on Little Medicine Bow River in sec. 14, T. 23 N., R. 79 W., and is made up of three members. The uppermost member is a heavy sandstone 85 feet thick which makes a prominent hogback. (See pl. 2, *B*.) The middle member, which is 33 feet thick, consists of green shale and sandstone, and the basal member is a conglomerate 10 feet thick.

Section of Cloverly formation in sec. 14, T. 23 N., R. 79 W.

Base of Thermopolis shale.

Cloverly formation:	Feet
Sandstone, light gray, hard, sugary, fine grained, locally both massive and cross-bedded; conglomeratic; makes the prominent hogback shown on Plate 2, *B*	85
Largely concealed but shows scattered exposures of green shale	25
Sandstone, conglomeratic and very hard	2
Green shales and greenish-gray sandstone; both soft	6
Sandstone, light gray, cross-bedded, conglomeratic, the pebbles consisting of chert and jasper	10
	128

As no fossils were obtained from the Cloverly formation in this area no new evidence can be presented regarding its age. According to Darton [13] it is equivalent to the Lakota, Fuson, and Dakota formations of the Black Hills region.

THERMOPOLIS SHALE

The Thermopolis shale consists chiefly of dark-gray to black shale but also contains some thin sandstone layers which commonly show markings resembling worm trails. Dark siliceous concretions or concretionary bands are also present. The total thickness, as determined at the locality shown on Plate 2, *B*, is 180 feet.

Section of Thermopolis shale in sec. 14, T. 23 N., R. 79 W.

Base of Mowry shale.

Thermopolis shale:	Feet
Shale, gray to black with several thin papery sandstones	130
Sandstone, brown, cross-bedded	4
Shale, gray, sandy	10
Sandstone, rusty, hard; makes small hogback (see pl. 2, *B*)	10
Shale, black	26
Top of Cloverly formation.	180

MOWRY SHALE

The Mowry shale is a hard, highly compact deep-brown to black fissile shale, 120 feet thick, which has a silver-white color when weathered and contains an abundance of fossil fish scales. The fact that samples of the shale yield a small amount of oil on distillation may have an important bearing on the source of the oil found in many places in the Frontier formation.

The Mowry is much more resistant than the shales above and below it and usually crops out in a prominent pine-clad ridge. This char-

[13] Op. cit., p. 31.

acteristic, together with those enumerated above, makes it the most easily recognizable and useful horizon marker among the formations exposed in the area. It is especially used as a datum plane in establishing correlations between different fields, but it is seldom recognized by well drillers and consequently is of little present value in the correlation of well records.

FRONTIER FORMATION

The Frontier formation consists of dark-gray to black shale, about 625 feet thick, overlain by about 100 feet of beds consisting chiefly of sandstone with some interbedded shale, that are locally called Wall Creek sandstone. This sandstone makes a prominent hogback ridge that trends parallel to the Cloverly hogback and is separated from it by a broad valley, which is eroded in the intervening less resistant shale. (See pl. 2, *B*.) In the Salt Creek oil field the Wall Creek sandstone is the chief source of oil, and it is also oil-bearing in the Lost Soldier district, but within the area here described the sandstone that is doubtfully correlated with the Wall Creek has so far yielded only minor quantities of oil.

A fossil collection from the Wall Creek (?) sandstone member in the SW. ¼ sec. 10, T. 23 N., R. 79 E. (lot 9358), included the following Colorado fauna:

Ostrea sp.
Inoceramus fragilis Hall and Meek.
Callista tenuis Hall and Meek(?).
Gyrodes conradi Meek(?).
Prionocyclus wyomingensis Meek.

CARLILE SHALE

The Carlile shale consists of about 460 feet of very dark shale containing some thin sandy layers and many large concretions. It usually crops out in areas of low relief and is consequently nowhere well exposed.

NIOBRARA FORMATION

The Niobrara formation consists of about 700 feet of dark and buff calcareous shale which in places contains some thin layers of sandstone. In this particular region the Niobrara contains three chalky beds of variable thickness which crop out as conspicuous light-colored ridges standing above subdued areas of soft dark shale. The upper part and to some extent also the lower part of the formation are characterized by thin layers of white crystalline calcite which occurs parallel to the bedding planes. This calcite and the color of the formation constitute its most marked lithologic features.

It contains large numbers of *Ostrea congesta*, many of which occur attached to the shells of large *Inoceramus* similar to *Inoceramus deformis* Meek. These are its most characteristic fossils.

STEELE SHALE

The Steele shale consists of dark-gray shale with some interbedded sandstone and sandy shale. The most conspicuous sandstone beds occur near the top of the formation and in places form conspicuous ridges that are difficult to distinguish from similar ridges in the Mesaverde formation. (See pl. 3, *B*.) The shale contains calcareous concretions which, in its upper part, are somewhat arenaceous, but lower in the formation they consist of a more or less pure limestone. In some places on the weathered outcrop of the formation considerable quantities of white crystalline calcite occur in heaps, which seem to have resulted from the disintegration of concretions, though no concretions of this material were observed intact. The thickness of the Steele is estimated to be 4,000 to 5,000 feet (see pl. 26) but can not be accurately determined because of poor exposures.

The contact between the Steele and Mesaverde is gradational, and the sandstones mentioned above (see pl. 3, *B*) have, in some places, been included by previous writers in the Mesaverde, whereas in other places where they are less conspicuous they have been included in the Steele. The writers include in the Steele all sandstones that are overlain by thick beds of shale or sandy shale containing a marine fauna. It has been found that these sandstones beneath the marine shales are variable and can not be recognized everywhere, whereas the thick marine sandstones above the highest marine shale form a more definite mappable unit, and were included in the Mesaverde formation. By this method the Steele is made to include beds of marine origin only, and the Mesaverde to include beds of both freshwater and marine origin, the marine beds consisting of heavy sandstones occurring in the lower part of the formation.

Because of its nonresistant character the Steele shale produces areas of low relief. It occupies the crest of the Fort Steele anticline in the southwest corner of the Walcott quadrangle, where it is inclosed by high ridges of the Mesaverde formation. (See pl. 3, *B*.)

MESAVERDE FORMATION

For purposes of description the Mesaverde formation in this area may be divided into three members. The lower member is about 700 feet thick near Fort Steele and consists of indurated white to gray massive to thin-bedded and cross-bedded sandstone alternating with thinner beds of shale. This member is of marine origin, as

indicated by the prescence in it of numerous impressions of the marine plant *Halymenites major* and of the marine shells *Inoceramus pertenuis*, *Callista* sp., *Ostrea* sp., *Anomia* cf. *A gryphorhynchus*, *Placunopsis hilliardensis*, *Solen?* sp., *Cardium speciosum*, *Pyropsis* sp.?, and *Serpula* sp., indicating a Pierre fauna.

The lower member is separated from the middle member by a narrow but very pronounced strike valley in which transition beds occur. The middle member consists of gray to brown sandstone alternating with beds of gray carbonaceous shale and thin irregular beds of coal. (See pl. 3, *A*.) The sandstones range from thin-bedded and somewhat flaggy to massive varieties and show more or less cross-bedding. On the weathered surface they are prevailingly brown, and in weathering they do not give rise to such pronounced vertical cliffs and hogbacks as the sandstones of the lower division. The coal beds that occur in the member are thin and irregular and in many places contain a high percentage of earthy matter. This member contains fresh and brackish water invertebrates, which, together with its prevailing brown color and the presence of carbonaceous material, serve to distinguish it from the lower member.

The upper member is lithologically similar to the lower member in that it consists of white to gray sandstones alternating with beds of shale. The sandstone is more resistant to weathering than that of the middle division and produces ledges with nearly vertical faces, and at the top of the formation there is a prominent white ledge-making sandstone. In some parts of the field the upper member contains thin beds of carbonaceous shale and coal. At other places, notably in the railroad cut about 4 miles northeast of Walcott, it contains, near the top, numerous *Halymenites* and *Inoceramus* remains, which indicate marine conditions.

The aggregate thickness of these three members is about 2,700 feet near Fort Steele and about 2,200 feet near Allen station, west of Medicine Bow The thinning of the formation toward the east seems to be at the expense of the lower member, which is not well developed in the Saddleback Hills quadrangle.

Because it is more resistant to erosion than the other formations in this field, the Mesaverde usually forms the most prominent topographic features. Its distribution is therefore indicated in a general way by the distribution of the long, narrow chains of hills A single exception to this rule occurs in the outcrop extending diagonally across the northeastern part of the Saddleback Hills quadrangle. Here the outcrop of the Mesaverde rises but little above the surrounding surface. This approximation of hard and soft rocks to a uniform plain, the surface of which is somewhat generally covered with terrace gravel, indicates a partial peneplanation in this part of the field.

Ripple marks and cross-bedding are common features throughout the Mesaverde. The sandstone beds, which are much more highly indurated than in the overlying formations, have been considerably fractured and in places even brecciated by the deformation to which they have been subjected. On Pass Creek, St. Marys, and Cedar Ridges, and in the Saddleback Hills, slickensided surfaces are common and are probably due, in part at least, to the slipping of the beds on one another in the process of folding.

Section of Mesaverde formation measured in Rattlesnake Hills, north of Fort Steele

Upper member:	Feet
Sandstone, white, with interbedded shale	20
Shale, carbonaceous	3
Sandstone, white	8
Talus, probably sandstone	16
Shale, carbonaceous	2
Sandstone, white, granular, ripple marked	33
Talus, chiefly sandstone	42
Sandstone, white, platy, indurated	9
Shale, gray	3
Sandstone, white, platy, indurated	2
Shale	3
Sandstone, white, platy, indurated	2
Shale	7
Shale, indurated	5
Shale, gray	3
Sandstone, white, platy, indurated	4
Shale	4
Sandstone, thin, indurated; makes top of ridge	22
Talus slope; thin sandstone ledges alternating with dark shale	197
Sandstone, coarse, gray	11
Shale and shaly sandstone	13
Sandstone, thin, brown	4
Sandstone, white, massive	13
Shale, carbonaceous at top	4
Sandstone, white, coarse	4
Shale, drab	22
Sandstone, grayish brown, alternating with thin beds of shale	39
Shale, gray	6
Sandstone, white, coarse	11
Shale, sandy, and sandstone, gray	45
Sandstone, gray, platy	7
Shale and sandstone, alternating	56
Shale, brown, ferruginous	16½
Shale and sandstone, alternating	28
Sandstone, white, platy	2½
Shale, sandy	9
Sandstone, brown, concretionary, bedded	11
Shale, black	4

Upper member—Continued.	Feet
Sandstone, brown, slabby	10
Shale and thin beds of sandstone	25
Sandstone, brown, thin bedded	7
Shale, gray	8
Sandstone, white, shaly at base	18
Sandstone, massive, concretionary, ferruginous	10
Sandstone and shale, brown and white alternating	100
Sandstone, brown, shaly	10
Sandstone, white, massive; weathers pockety	8
	887
Middle member:	
Shale, with thin sandstone beds, partly covered	43
Sandstone, brown, coarse	16
Shale, with thin sandstone layers	53
Sandstone, shaly at top, gray to brown	19
Sandstone, brown, thin, and shale, drab, alternating in about equal proportion	35
Shale, buff to gray	15
Sandstone, cross-bedded	32
Shale, gray	10
Sandstone, gray, cross-bedded	5
Sandstone, grayish brown, thin bedded, slabby	65
Shale, sandy	42
Sandstone, gray, thin bedded	8
Shale	25
Sandstone, weathers brown, fresh grayish brown, fine grained	2
Shale, gray, sandy	25
Sandstone, brown, ferruginous	1
Shale, gray	10
Sandstone, brown, fine grained	14
Shale, gray	19
Sandstone, brown, thin bedded, ripple marked	5
Shale, gray	9
Sandstone, brown, thin bedded	8
Shale, carbonaceous	2
Shale	9
Sandstone, brown	4
Shale, sandy	23
Sandstone, thin bedded	17
Talus slope (sandstone, shaly?)	34
Shale, sandy	130
Sandstone, thin bedded	2
Shale, sandy, partly covered	78
	760
Lower member (marine):	
Sandstone, gray, thin bedded	93
Sandstone, thin bedded, white	19
Sandstone, grayish white, massive; contains *Halymenites major*	25

Lower member (marine)—Continued.	Feet
Talus (shale?)	28
Sandstone, grayish white, massive	17
Sandstone, gray, thin bedded	75
Sandstone, gray, heavy bedded	22
Shale	115
Sandstone	10
Talus (probably shale or shaly sandstone)	42
Sandstone, grayish brown, thin bedded at base, massive above	74
Talus (shale?)	75
Sandstone, gray, with thin beds of shale at base	15
Sandstone, grayish brown, very shaly, cross-bedded, thin bedded	12
Sandstone, grayish brown, thin bedded	10
Steele shale.	
	632
Total thickness of Mesaverde	2,279

LEWIS SHALE

The Lewis shale consists for the most part of dark-gray marine shale with numerous intercalated beds of sandy shale and sandstone of variable thicknesses. Prominent sandstones near the base of the formation are exposed in the west side of Pass Creek Ridge and in the gap between that ridge and St. Marys Hill. The most persistent sandstone is 250 feet thick and occurs 600 feet below the top of the formation, forming a prominent hogback ridge in places more than 100 feet high and separated by a broad valley from the basal sandstones in the Medicine Bow formation. (See pl. 4, *A*.) The sandstones are prevailing gray, ripple marked and cross-bedded, and in some places very massive. The shale is dark gray and contains a few fossiliferous concretions. The formation is as a rule poorly exposed because it occupies areas of low relief and is commonly covered with detrital matter or overlapped by the North Park formation. All data obtained suggest that it is about 3,300 feet thick in this area.

The Lewis as defined herein includes all of the typical dark-gray marine shale lying above the conspicuous white sandstone at the top of the Mesaverde formation and below a group of massive brown sandstones arbitrarily selected as the base of the Medicine Bow formation.

The fauna of the Lewis in this area is of late Montana age and is similar to the Bearpaw shale fauna of Montana. *Sphenodiscus lenticularis* (Owen) and a gastropod doubtfully referred to *Cominella*, characteristic Fox Hills species, were collected near the top of the formation in the NW. ¼ sec. 18, T. 21 N., R. 80 W.

LATE UPPER CRETACEOUS AND TERTIARY (?) ROCKS

GENERAL FEATURES

All the Upper Cretaceous rocks in this area from the Thermopolis shale to the Lewis shale, inclusive, are marine except a part of the Mesaverde formation. In the first 400 or 500 feet above the Lewis shale there are a few marine beds with invertebrate fossils of Fox Hills types intercalated in the basal part of the succession of late Cretaceous and early Tertiary continental deposits, which has the enormous total thickness of about 20,000 feet. These intercalated marine Cretaceous beds with some associated brackish-water deposits are important in that they show that the change from marine to land and fresh-water conditions was gradual and that no great time hiatus is represented between the marine and continental deposits.

In his reconnaissance work in the Hanna and Carbon Basins Veatch [14] recognized the conformable relations between the Lewis and the overlying coal-bearing formation, which he called "Lower Laramie," and placed the most pronounced break in the entire section between the "Lower Laramie" and the overlying rocks, which he called "Upper Laramie." The rocks referred to the Fort Union in Veatch's section and placed above the "Upper Laramie" have proved to be a part of the "Upper Laramie" and probably some distance below its top.

The more detailed work of Bowen [15] has shown that the great unconformity which Veatch believed to be at the base of his "Upper Laramie" is really in the middle of that aggregate. It therefore became necessary to recognize two formations within the "Upper Laramie," and inasmuch as the various kinds of fossils obtained from them and from the "Lower Laramie," as interpreted, gave somewhat discordant indications of age and correlation, so that the correlations suggested by Bowen could not be fully established, it was decided to give new local names to the three formations, as follows:

The Medicine Bow formation is essentially the same as the "Lower Laramie," though its upper boundary is a few hundred feet lower than the boundary between "Lower Laramie" and "Upper Laramie" as mapped by Veatch in part of the area. The Ferris formation is the lower half of the "Upper Laramie" and is characterized in its lower 1,000 feet by conglomeratic beds whose pebbles are only of the most resistant kinds of rock, apparently derived from some

[14] Veatch, A. C., Coal in east-central Carbon County, Wyo.: U. S. Geol. Survey Bull. 316, pp. 244–260, 1907; On the origin and definition of the geologic term "Laramie": Jour. Geology, vol. 15, pp. 526–548; Am. Jour. Sci., 4th ser., vol. 24, pp. 18–22, 1907.

[15] Bowen, C. F., Stratigraphy of the Hanna Basin, Wyo.: U. S. Geol. Survey Prof. Paper 108, pp. 227–235, 1918.

distant source rather than from the near-by mountains, and without recognized fragments of the underlying Cretaceous formation. There is no evidence of an unconformity at its base other than the presence of irregularly conglomeratic beds. The upper half of the "Upper Laramie" was named the Hanna formation. It rests unconformably on the Ferris formation and is lithologically very different from the Ferris in that it is highly feldspathic and its conglomerate contains an abundance of local material, notably granite, Mowry shale, and Cloverly conglomerate. On account of the overlap of the Hanna formation in part of the area the conglomerate at its base was not recognized in the earlier work as distinct from the one at the base of the Ferris formation.

When these continental deposits of the Hanna Basin are compared on the one hand with the Lance Creek section [16] in eastern Wyoming, 150 miles to the northeast, and on the other with the section of the eastern part of the Rock Springs field,[17] 100 miles to the west, the following correlations are suggested by the stratigraphic succession and by balancing the paleontologic evidence:

The Fox Hills sandstone of eastern Wyoming is almost certainly represented in the uppermost part of the Lewis shale, in the lower 500 feet of the Medicine Bow formation, and in the basal member of the Black Buttes coal group of the Rock Springs field, to the west.

The Lance formation is apparently represented in the major part of the Medicine Bow formation, in the lower 1,000 feet of the Ferris formation, and in the major part of the Black Buttes coal group. The fossil plants seem to indicate that the equivalent of the Laramie formation of the Denver Basin is also present in the Medicine Bow formation, but if distinct from the representative of the Lance formation the boundary between them has not been recognized. The Fort Union formation is probably represented by all of the Ferris formation except the conglomeratic 1,000 feet at the base. The Hanna formation probably represents the Black Rock coal group, of Wasatch age, of the Rock Springs field.

The formal descriptions of the three local formations follow.

MEDICINE BOW FORMATION

The Medicine Bow formation ranges from 4,000 to 6,200 feet in thickness and consists of yellow, gray, and carbonaceous shale, beds of coal, and gray and brown sandstone. (See pl. 4, *B*.) The lower

[16] Stanton, T. W., and Knowlton, F. H., Stratigraphy and paleontology of the Laramie and related formations in Wyoming: Geol. Soc. America Bull., vol. 8, pp. 128–137, 1897. Stanton, T. W., Fox Hills sandstone and Lance formation ("*Ceratops* beds") in South Dakota, North Dakota, and eastern Wyoming: Am. Jour. Sci., 4th ser., vol. 30, pp. 184–187, 1910.

[17] Schultz, A. R., The southern part of the Rock Springs coal field, Sweetwater County, Wyo.: U. S. Geol. Survey Bull. 381, pp. 222–237, 1910.

part of the formation is made up of massive to cross-bedded brown sandstones, which usually form a conspicuous group of ledges and contain numerous beds of coal. These sandstones are overlain by an intermediate group of dark-colored shales and thin-bedded fine-grained brown sandstones, with some beds of massive white sandstone. The sandstones at the top of the formation are coarse, massive, friable, and easily eroded and are interbedded with thick beds of dark-gray shale.

The area occupied by the formation is usually characterized by numerous shallow parallel valleys separated by low sandstone ridges surmounted by numerous jutting crags and ledges of indurated brown sandstones. As a rule the formation is not well exposed in this area, but at its type locality, near the mouth of Medicine Bow River, in T. 24 N., R. 84 W., all details of it are laid bare.

A fresh-water invertebrate fauna with occasional brackish-water elements occurs throughout the formation except in the lower part, where there are sandstone beds with a marine fauna of Fox Hills type. Leaves and bones also occur but are not abundant or, as a rule, well preserved. The fresh-water invertebrates are considered by Stanton to belong to the Lance fauna, and the plants are regarded by Knowlton as belonging to the flora of the Laramie formation of the Denver Basin. The bones are chiefly of dinosaurs and include some recognized as ceratopsian, though not well enough preserved to permit even generic identification.

TERTIARY (?) AND TERTIARY ROCKS

FERRIS FORMATION

The lower 300 feet of the Ferris formation consists of dark shale and coarse, friable massive buff to yellow sandstone containing small scattered pebbles and irregular thin beds of conglomerate. Overlying this lithologic unit is one about 800 feet thick, made up largely of conglomerate, which occurs as pockets, lenses, and thin beds irregularly distributed throughout the sandstone that constitutes the remainder of the unit. The pebbles of the conglomerate are usually less than 1 inch in diameter, are well rounded, and consist of quartzite, black, gray, and yellow chert, jasper, rhyolite, and porphyry. The remaining 5,400 feet of the formation consists of gray, brown, and yellow sandstones interstratified with numerous thick beds of coal.

The sandstones in the Ferris formation are very irregular and lenticular, coarse sandstone wedging out between beds of shale and vice versa within short distances along the strike. Ripple marks and cross-bedding are also features of these deposits. In short, all

the evidence at hand indicates the rapid accumulation of these beds by shifting streams under subaerial or near-shore subaqueous conditions.

The fossils in the Ferris consist of leaves, fresh-water shells, and bones of vertebrates, but the leaves are by far the most abundant. Bones occur chiefly in the lower 1,000 feet of the formation and represent turtles, fishes, and dinosaurs. Several of the bone specimens have been identified as ceratopsian, and one or two as *Triceratops*, thus apparently correlating the lower portion of the formation with part of the Lance formation of Wyoming and Montana, unless perchance they have been derived by erosion from the underlying Medicine Bow formation, as is possible but not probable, because no identifiable ceratopsian remains have been found in the Medicine Bow. The leaves and shells are regarded as Fort Union types.

HANNA FORMATION

The Hanna formation occupies the central portion of the Hanna and Carbon Basins and contains most of the coal mines opened by the Union Pacific Coal Co. in this area. It rests unconformably on the Ferris formation and transgresses across all underlying formations at least down to the Cloverly and possibly down to the granite. (See pls. 6, *B*; 7, *A*.) It consists of alternating conglomerate, sandstone, shale, and coal beds, and its base is marked by a thick conglomeratic sandstone and locally by massive conglomerate. (See pls. 6, *A*; 7, *B*.)

The sandstones of the formation range from coarse-grained massive or thick-bedded varieties to fine-grained thin-bedded sandstones which on weathering assume a brown color and show a tendency to split into thin, slabby masses. The coarse-grained varieties are buff or grayish white and commonly more or less conglomeratic. They are also highly feldspathic. The pebbles of the conglomerate include, besides materials of the same kind as those that occur in the conglomerate at the base of the Ferris formation, an abundance of granitic material and locally large quantities of Mowry shale, Cloverly conglomerate, and soft, sugary sandstone fragments that may have been derived from the Tensleep, Cloverly, or Mesaverde formations.

The Hanna formation is about 7,000 feet thick in this area and contains an abundance of plant remains, all of which are referred to the Fort Union by F. H. Knowlton. The few invertebrates collected are also regarded by T. W. Stanton as chiefly suggestive of Fort Union age, though species found near the top are said to resemble the Wasatch fauna. The few fragmentary remains of vertebrates thus far found in the formation include fish scales, fragments of turtle shells, and a fragmentary mammalian jaw identified by J. W. Gidley

as a creodont, probably *Claenodon*, which may belong to either the Fort Union or the Wasatch.

Ripple marks, cross-bedding, and lenticular bedding are characteristic features of the formation.

NORTH PARK FORMATION

The North Park formation overlies unconformably the Hanna and older formations and consists chiefly of fine white unconsolidated sand, sandy clay, and marl, which are well described by their popular name "mortar beds." (See pl. 7, *C*.) In some places a well-defined conglomerate occurs at the base of this formation; in others the white sand and clay rest directly on the Hanna formation or older rocks. Thin beds of gray limestone are interstratified with the sand and clay, but these limestone beds seem to be of local occurrence. In some localities the attitude of the strata in this deposit is in general accord with that of the underlying beds. In other places these younger beds dip at angles up to 30° or more in directions almost at right angles to those of older and directly adjacent formations.

This formation, according to Veatch,[18] attains a maximum thickness of 4,500 feet, but in this area its thickness is believed not to exceed a few hundred feet. So far no fossils have been found in the North Park formation, but to judge from its stratigraphic relations and physical character it is almost certainly of middle or late Tertiary age. It is tentatively classified as Miocene(?).

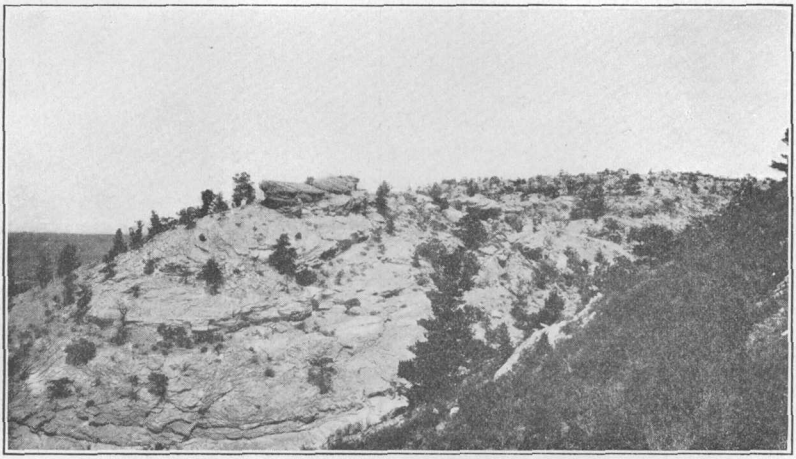
The North Park is separated from the older formations by an unconformity as shown by the fact that it overlaps underlying formations of Cretaceous and Tertiary age exposed in the field. It occurs chiefly in the valleys eroded in the Lewis and Steele shales but also overlaps other formations in areas of low relief.

QUATERNARY DEPOSITS

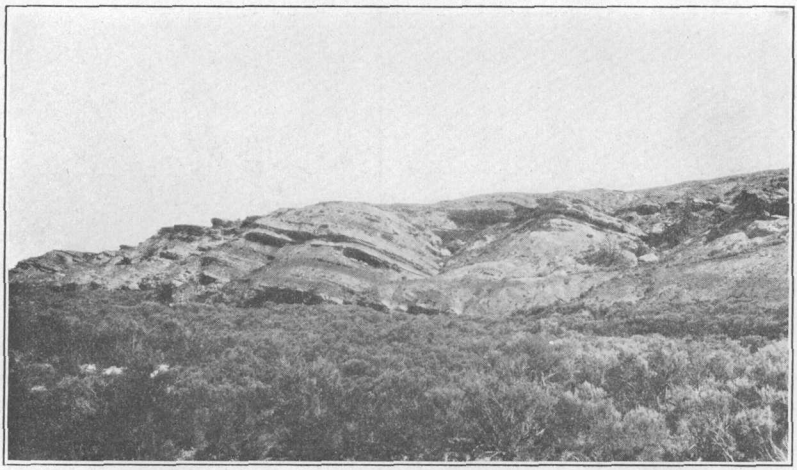
TERRACE GRAVEL

Terrace gravel, containing well-rounded pebbles from all the underlying rocks down to the pre-Cambrian, covers considerable areas along the present valley of North Platte River and also in the eastern part of the Saddleback Hills quadrangle. The gravel beds occur at altitudes up to 350 or 400 feet above the present level of North Platte and Medicine Bow Rivers, and in some places they overlie the North Park formation and are therefore obviously more recent than that formation. They are assumed to be of Quaternary age, though there is no direct proof that they may not be somewhat older.

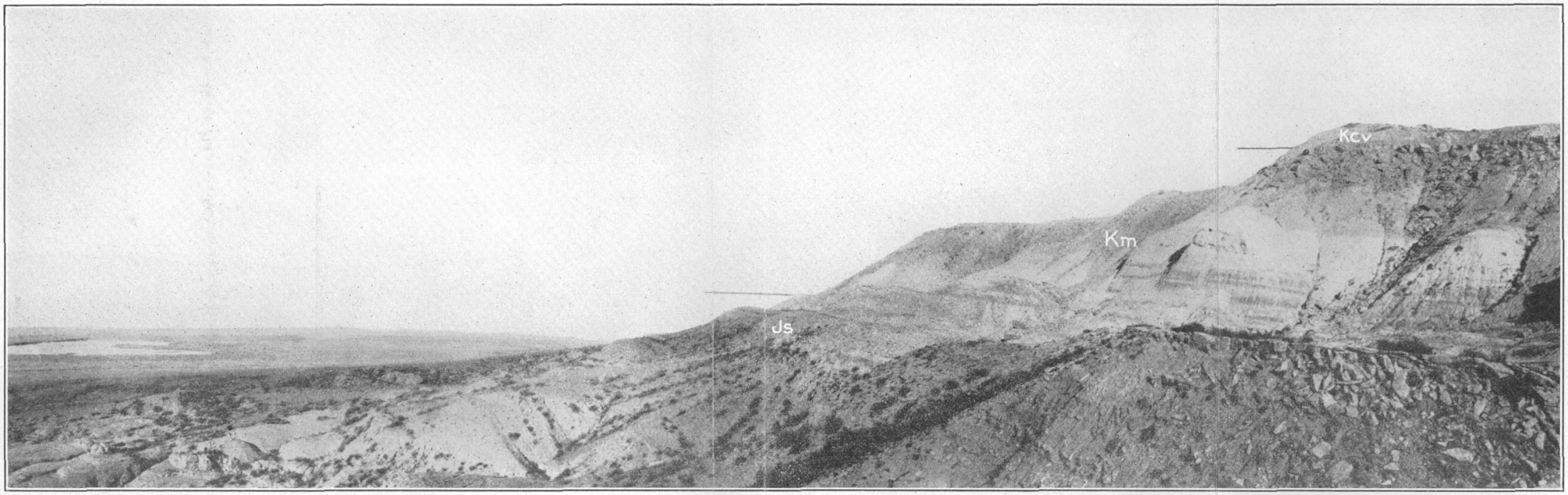
[18] Veatch, A. C., Coal fields of east-central Carbon County, Wyo.: U. S. Geol. Survey Bull. 316, p. 246, 1907.



A. TENSLEEP SANDSTONE IN THE FLAT TOP ANTICLINE, SE. ¼ SEC. 12, T. 23 N., R. 79 W.

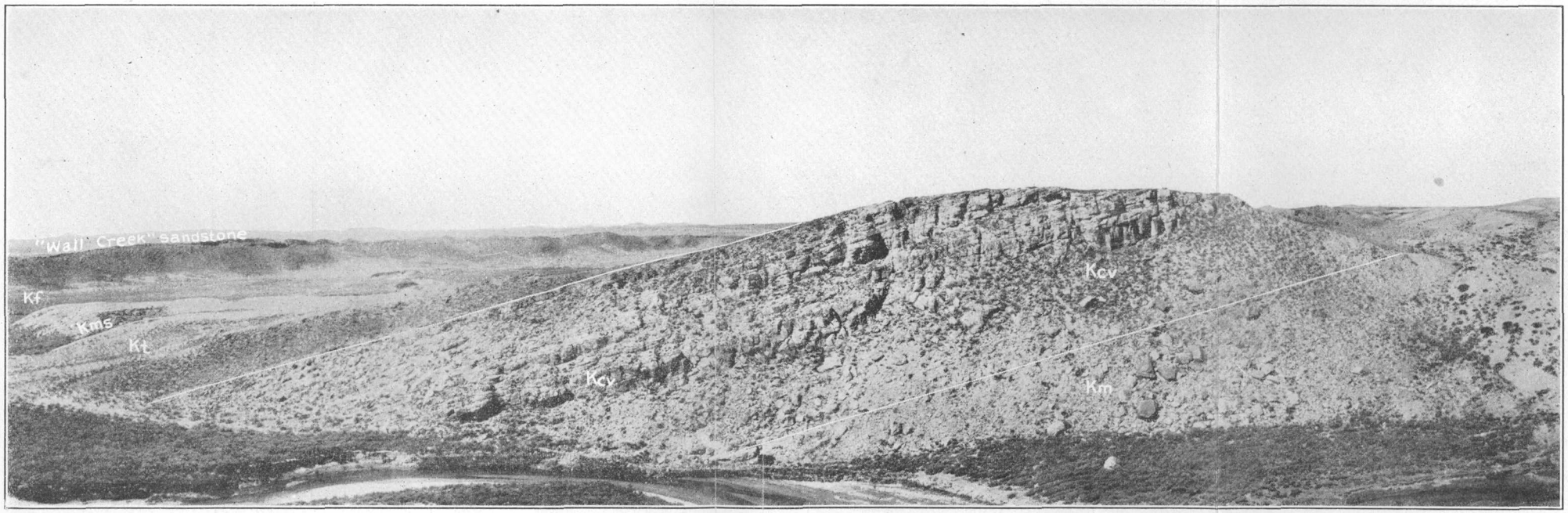


B. UPPER PART OF THE CHUGWATER FORMATION ON LITTLE MEDICINE BOW RIVER, SE. ¼ SEC. 13, T. 23 N., R. 79 W.



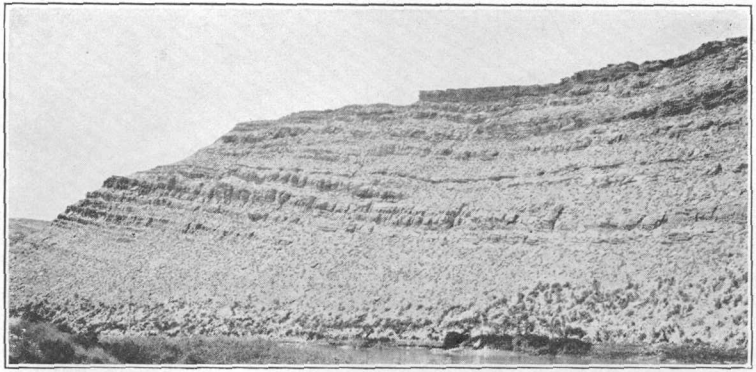
A. SUNDANCE, MORRISON, AND CLOVERLY FORMATIONS IN THE WEST FACE OF COMO RIDGE 5 MILES EAST OF MEDICINE BOW

Js, Sundance; Km, Morrison; Kcv, Cloverly

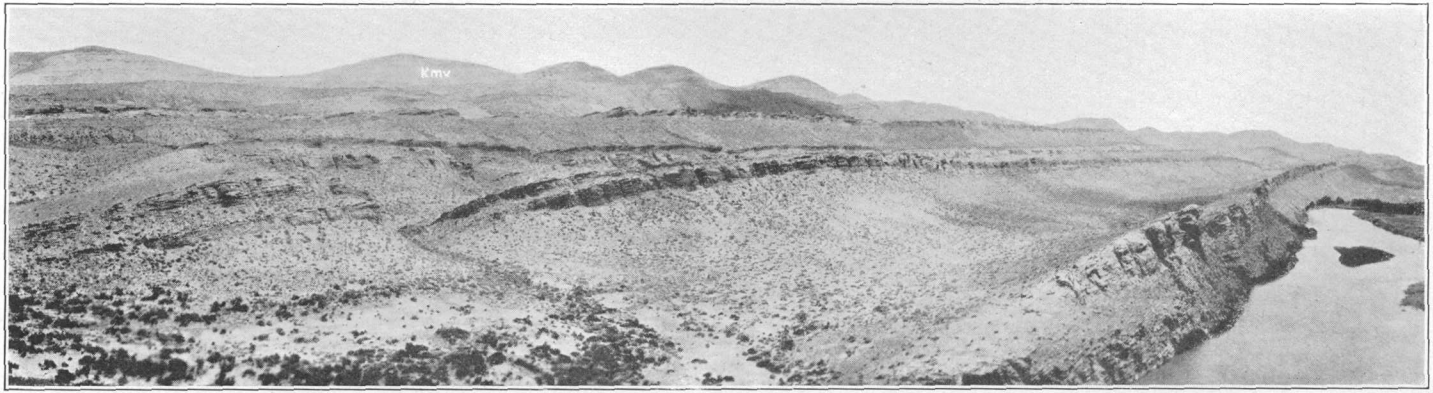


B. MORRISON, CLOVERLY, AND OVERLYING FORMATIONS ON LITTLE MEDICINE BOW RIVER, SW. ¼ SEC. 14, T. 23 N., R. 79 W.

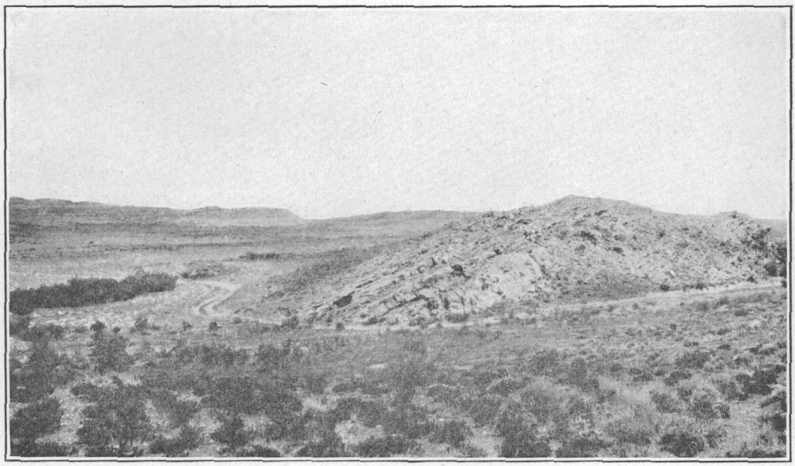
Looking west from Cloverly hogback on Little Medicine Bow River. Km, Morrison formation; Kcv, Cloverly formation; Kt, Thermopolis shale; Kms, Mowry shale; Kf, Frontier formation with Wall Creek (?) sandstone member at the top



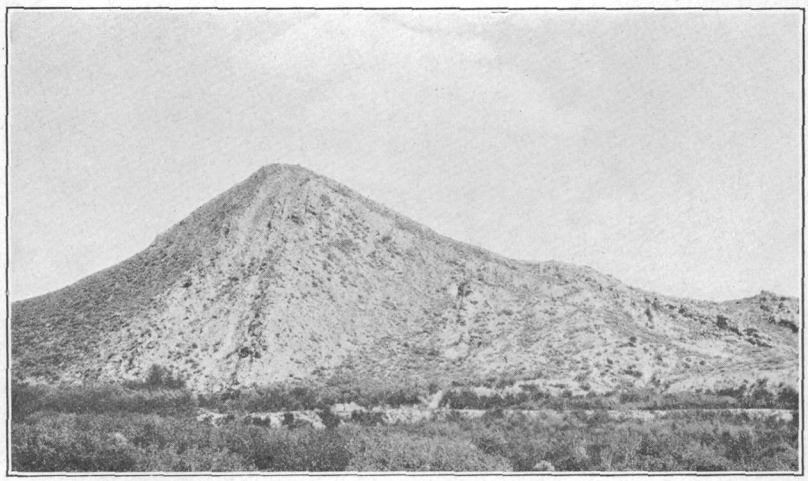
A. MESAVERDE FORMATION ON NORTH PLATTE RIVER, NW. ¼ SEC. 13, T. 22 N., R. 86 W.



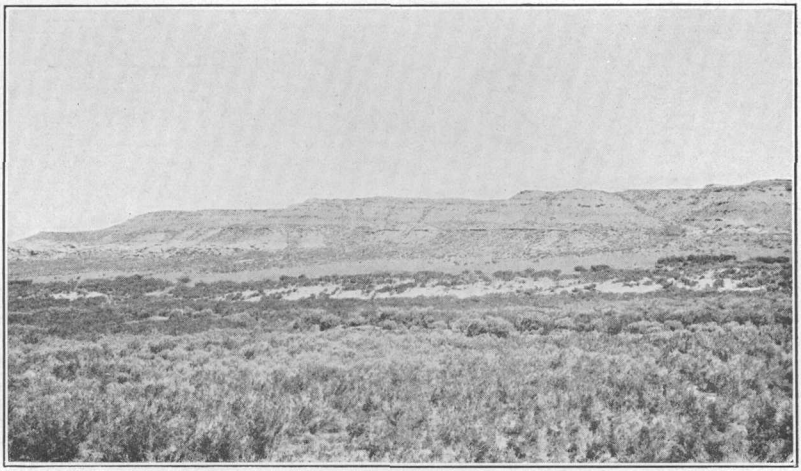
B. TRANSITION ZONE FROM STEELE SHALE TO MESAVERDE FORMATION, NW. ¼ SEC. 24, T. 22 N., R. 86 W.



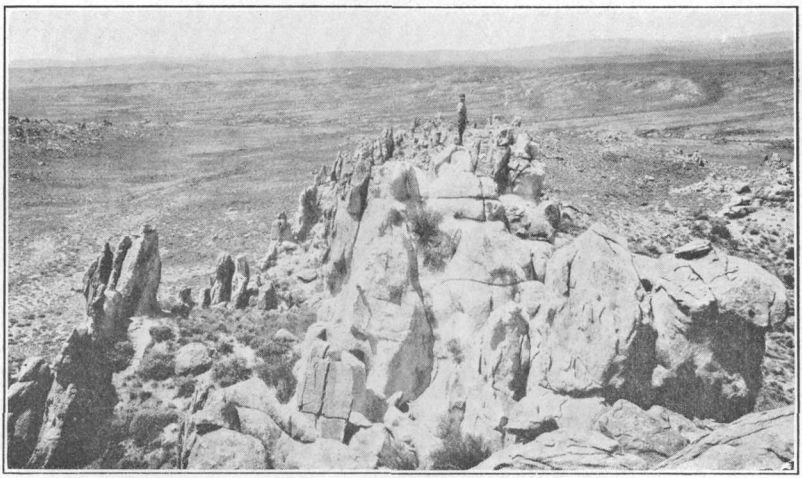
A. SANDSTONE HOGBACK IN THE UPPER PART OF THE LEWIS SHALE, NW. ¼ SEC. 2, T. 21 N., R. 84 W.



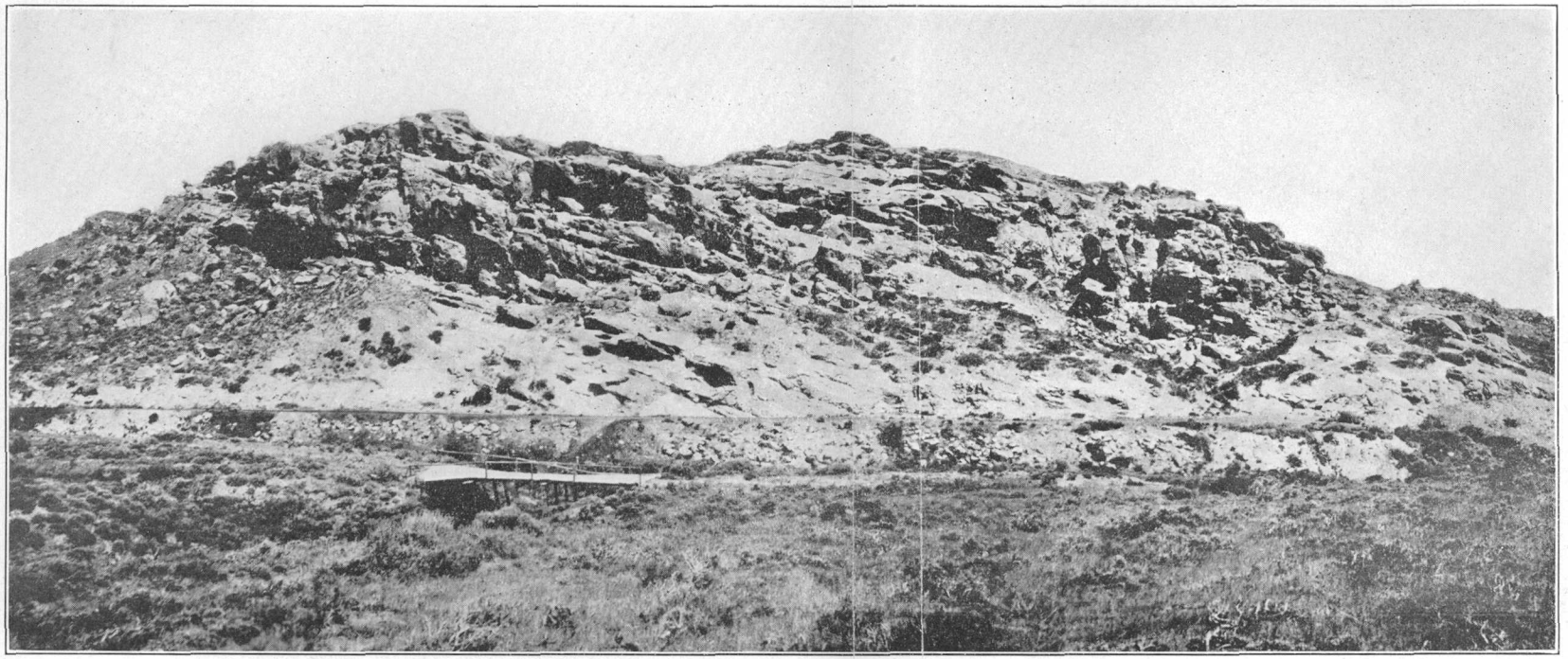
B. MEDICINE BOW FORMATION ON AUSTIN CREEK, SW. ¼ SEC. 12, T. 24 N., R. 83 W.



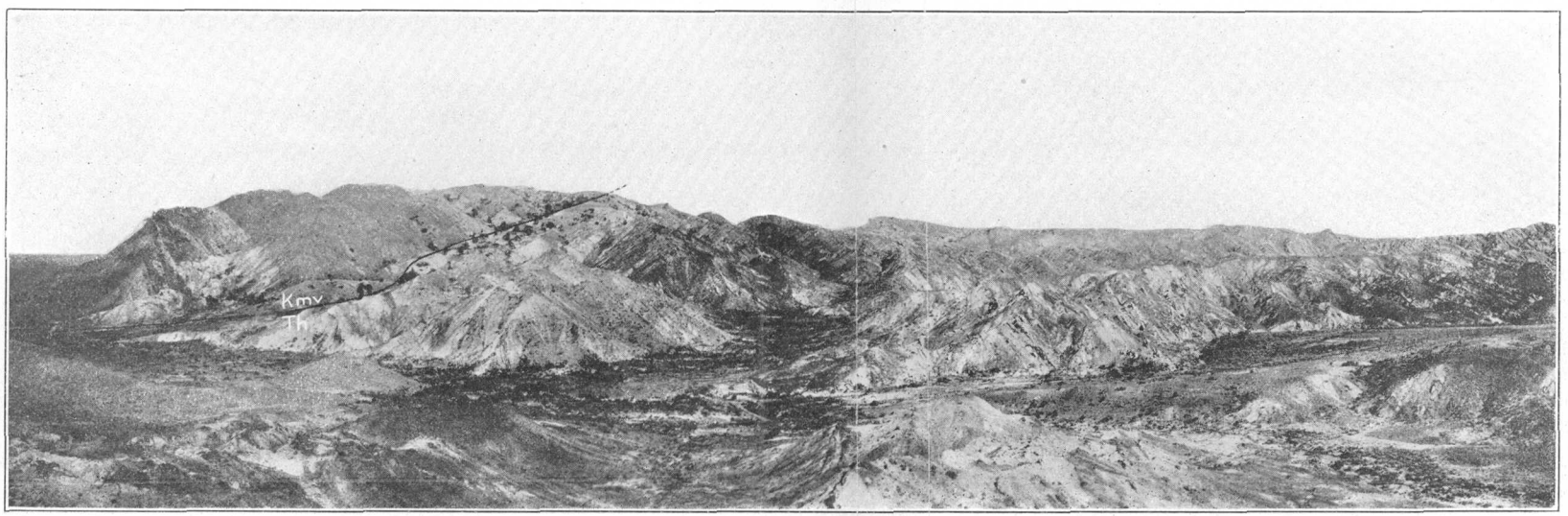
A. UPPER PART OF THE FERRIS FORMATION, NE. ¼ SEC. 31, T. 21 N., R. 83 W.



B. VERTICAL BEDS IN THE LOWER PART OF THE FERRIS FORMATION, SEC. 18, T. 24 N., R. 82 W.



A. CONGLOMERATIC SANDSTONE AT BASE OF HANNA FORMATION, NEAR CARBON



B. HANNA FORMATION (Th) OVERLAPPING MESAVERDE SANDSTONE (Kmv) AND STEELE SHALE, SE. ¼ SEC. 4, T. 23 N., R. 80 W.

ALLUVIUM

Along the valleys of North Platte and Medicine Bow Rivers and some of the larger "ditches" there are deposits of alluvial material derived from the older formations, some of which afford the sites for the ranches and farms which have been established wherever small level tracts can be irrigated with river water.

STRUCTURE

GENERAL FEATURES

The dominant structural features of the Hanna Basin region are the Hanna Basin proper and the subsidiary Walcott and Carbon Basins. The partial isolation of the Walcott and Carbon Basins is due to the existence of sharp plunging anticlines projecting northwestward and northward from the Medicine Bow Mountain uplift on the south.

Faults, or breaks in the surface beds, are much in evidence in certain parts of the area, though most of the visible faults are of small displacement. Two of them, one on the southwest side of St. Marys Ridge, and the other on the northeast side of Cedar Ridge, respectively designated for convenience the St. Marys and Cedar Ridge faults, are of greater magnitude, and a buried fault of profound displacement is believed to limit the Hanna Basin on the north and form the boundary between the basin and the Shirley Mountains. The general line of this fault is marked by a zone of faults in the Hanna formation, though the downthrow of these faults is toward the mountains, suggesting a recent reversal of the movements that caused the Hanna Basin depression.

FOLDS

FORT STEELE ANTICLINE

The Fort Steele anticline, named from the near-by town of Fort Steele, is the southeastward extension of the Rawlins uplift and crosses the southwest corner of the Walcott quadrangle. The anticline is a rather symmetrical fold which plunges toward the southeast. In that direction it rapidly narrows and loses much of its significance, probably not far beyond the southern margin of the Walcott quadrangle, though it is there covered by the North Park formation. The Mesaverde formation, which forms conspicuous rims on the opposite limbs of the fold, dips away from the axis at angles of 30° to 50°.

WALCOTT SYNCLINE

The Walcott syncline, named from the town of Walcott, is the structural trough separating the Fort Steele anticline from the Cedar Ridge, St. Marys, and Pass Creek Ridge anticlines to the northeast. The axis of this syncline enters the Walcott quadrangle near the northwest corner of sec. 28, T. 22 N., R. 85 W., and plunges southeastward, passing just east of the old Buckley & Ryan mine and disappearing beneath the overlapping North Park formation near the southeast corner of the Walcott quadrangle. Throughout most of the course in the area mapped the beds forming the northeast limb of the Walcott syncline are overturned from the northeast, locally with the result that both limbs of the fold dip in the same direction near its axis, though the beds of the northeast limb are much more steeply inclined than those of the southwest limb. Northwestward from the Buckley & Ryan mine, however, the overturn gradually decreases and the syncline becomes an asymmetric fold with steep dips on its northeast limb and more gentle dips (35°) on its southwest limb.

CEDAR RIDGE, ST. MARYS, AND PASS CREEK RIDGE ANTICLINES

The general position of the Cedar Ridge, St. Marys, and Pass Creek Ridge anticlines are indicated by the ridges of the same names, which extend chain-fashion southeastward from T. 22 N., R. 85 W., to T. 21 N., R. 82 W. According to the interpretation of the structure of these features shown in structure sections E–F and G–H, Plate 27, they are complexly faulted, first by thrusting and then by subsidence, and it is believed to be probable that the principal upfold in the Cloverly beds lies deeply buried northeast of the surface ridges, rather than beneath them. At its northwest end the Cedar Ridge anticline is a broad, slightly asymmetric open fold, whose axis lies at about the crest of the ridge and rises to the southeast. The east limb of the fold is cut obliquely by the Cedar Ridge fault, which, on passing southeastward from North Platte River, gradually cuts across the axis of the anticline, leaving only the western limb exposed. The strata are slightly overturned in some places, as at the southeast end of the ridge, and at other places they are closely compressed and wrinkled into minor folds and broken by numerous minor faults.

In the St. Marys anticline the beds are in many places considerably overturned on the southwest limb, except at the extreme ends of the anticline. This overturning is doubtless due, in part at least, to the drag effects of differential movement along the thrust fault that borders the southwestern edge of the ridge. Toward the northwest end of the anticline, where the overturning and faulting gradually give way to normal folding, individual beds can be traced for

several hundred feet along their outcrop, and in that distance their attitude changes southeastward along the strike from steep normal southwestward dips to vertical and then to slightly overturned positions.

At the southeast end of St. Marys Ridge the northeast flank of the anticline has been cut off by faulting, and it appears that this same faulting continues northwestward along the northeast edge of the ridge, for in this direction the resistant Mesaverde sandstones, which should compose the northeast flank of the anticline, are absent for nearly 3 miles and are replaced by a low area covered by the nearly flat-lying North Park formation. As shown by the geologic map and structure section along line E–F, Plate 27, a high-angle fault is believed to border the northeast side of St. Marys Ridge. This fault may represent a southeastward extension of the Cedar Ridge fault or may merely have resulted from stresses similar to those which provided that fault.

The dips are moderate near the west end of the Pass Creek Ridge anticline and become progressively steeper near the southeast end. Some overturning of the folded beds is visible both southwest of the anticline in T. 21 N., R. 83 W., and probably more markedly along the north limb of the anticline in T. 21 N., R. 82 W., though exposures are poor in this locality, and the observed dips may be due to obscured faulting rather than to overturned folding.

SADDLEBACK HILLS ANTICLINE AND CARBON BASIN

The Saddleback Hills anticline is a long, narrow uplift in T. 21 N., R. 80 W., its position being marked by the conspicuous topographic feature of the Saddleback Hills or Simpson Ridge, formed by heavy sandstones of the Mesaverde formation cropping out along the anticlinal axis. The dips on the flanks of the anticline for the most part range from 25° to 60°, though the east flank of the anticline is somewhat overturned north of the fault that cuts across the crest of the fold near the north line of sec. 16. The zones of maximum dip along the flanks of the fold occur about 1 mile from the anticlinal axis. West of the anticline steeply dipping Lewis and Medicine Bow strata are locally concealed beneath the gently dipping Hanna formation, whereas on the east side tilted beds of the Hanna formation partly overlap the Lewis and flatten eastward toward the center of the Carbon Basin, rising gradually thence eastward toward the Medicine Bow anticline.

FLAT TOP ANTICLINE

The western part of the Flat Top anticline extends into the northeastern part of the Saddleback Hills quadrangle, causing the expo-

sures of the Chugwater formation near the eastern margin of the quadrangle and of the Tensleep sandstone, half a mile farther east. In contrast with folds previously described, the Flat Top anticline trends about due east. It is a markedly asymmetric fold with relatively steeper dips on its north flank than on the south, as is shown by cross section O–P, Plate 27.

FAULTS

Two major faults or fault systems are developed in the Hanna Basin, and numerous normal faults of moderate displacement cut the coal-bearing rocks of the area. One of the major faults separates late Cretaceous beds from Archean granite in T. 24 N., R. 82 W., and presumably continues beneath the cover of the Hanna formation to connect with faults in the southwestern part of T. 24 N., R. 80 W., and with the fault that lies just south of the crest of the Oil Springs anticline in T. 23 N., R. 79 W. The vertical displacement of the crystalline basement rocks on this fault is believed to reach a maximum of 30,000 feet, or about 6 miles. The dropping of the area southwest of this fault formed the Hanna Basin, and erosion of the uplifted region northeast of the fault yielded much of the material of which the coal-bearing formations within the basin are composed.

The second major fault series includes the group of faults that parallel to St. Marys and Cedar Ridges and may be a part of a continuous fault system including the Arlington thrust fault, which bounds the Medicine Bow Range on its northeast side. The Cedar Ridge fault is the westernmost fracture belonging to this series and forms the northeast limit of the Cedar Ridge anticline. This fault may be continuous with the fault that bounds St. Marys Ridge on the northeast, or more probably with the St. Marys fault, which follows the southwest base of St. Marys Ridge and continues thence southeastward as a fault or strongly overturned fold that follows the Lewis-Medicine Bow line of contact southwest of Pass Creek Ridge and perhaps extends as far as the north flank of Elk Mountain, in T. 20 N., R. 81 W.

ST. MARYS FAULT

The St. Marys fault follows the southwest base of St. Marys Ridge, and along it the Mesaverde formation has been thrust over the Lewis shale (see cross section E–F, pl. 27) and locally rests upon the Medicine Bow formation. The plane of the fault is nowhere clearly exposed, and the presence of the fault is indicated solely by stratigraphic relations and by the slickensided surfaces commonly displayed by the Mesaverde rocks that form St. Marys

Ridge. The fault plane appears to dip gently northeastward, and the horizontal movement upon it may attain a maximum of over half a mile. The fault can be traced with reasonable certainty for about 5 miles and may merge laterally into sharp folds or may be directly continuous with the Cedar Ridge fault and with a possible fault following the zone of overturning that marks the Lewis-Medicine Bow contact southwest of Pass Creek Ridge.

CEDAR RIDGE FAULT

The Cedar Ridge fault follows the northeast base of Cedar Ridge, and its plane is exposed in a small gully in the NW. ¼ sec. 15, T. 22 N., R. 85 W., where it is nearly vertical and strikes N. 58° W. The fault conforms to the definition of a normal fault, as its hanging wall has dropped with respect to its footwall. The amount of the displacement, however, is undetermined, although it is at least 500 feet in the NW. ¼ sec. 25, T. 22 N., R. 85 W., and may amount to much more than that. At the southeast end of Cedar Ridge the fault seems to curve southward and pass between Cedar and St. Marys Ridges, distinct evidence of faulting being observable in this gap. No trace of the fault was observed south of the gap, however, and it may die out southward or, more probably, connect with the St. Marys fault along the southwest base of St. Marys Ridge.

MINOR FAULTS

Numerous small faults of more or less local extent and of relatively small displacement occur at several places in the field but most notably in the Rattlesnake Hills, in the northeast corner of the Walcott quadrangle, near Hanna, and in the vicinity of Carbon. These faults are all believed to be of the normal type in the sense that the hade is toward the hanging wall. It is believed, however, that in many of the faults the principal movement has been horizontal rather than vertical. This belief is based on the fact that in several places there is a well-marked horizontal drag along the fault zone.

ECONOMIC GEOLOGY

COAL

GENERAL OCCURRENCE

The coal in the Hanna and Carbon Basins occurs in the Mesaverde, Medicine Bow, Ferris, and Hanna formations, and the relative position of the several coal beds within these formations is shown in Plates 8 and 10. There are at least 4 coal beds in the Mesaverde formation which are more than 3 feet thick, 15 in the Medicine Bow

formation, 20 in the Ferris formation, and 30 in the Hanna formation, besides numerous lenses of coal that could not be traced because of poor exposures.

The coal beds in the Mesaverde formation are principally of low bituminous rank and attain a maximum observed thickness of about 8 feet in T. 24 N., R. 84 W., near the north rim of the Hanna Basin, though elsewhere they are thin and irregular in extent. Most of the Mesaverde coal is very impure, the impurities occurring as partings in the bed or intimately mixed with the coal.

The coal beds in the Medicine Bow formation are also thin and irregular but not so much as those in the Mesaverde formation. In many places the Medicine Bow coal is fairly pure and can no doubt be utilized for fuel, though no large mines have yet been opened on Medicine Bow coals in this area. The coal of the Medicine Bow formation is not uniformly distributed either horizontally or vertically. It occurs in a 1,500-foot zone in the lower part of the formation. In some places, as in T. 23 N., R. 85 W., this zone contains a dozen or more beds; in other places, as north of Pass Creek Ridge and south of St. Marys Hill, only a few beds are present; and in still other places no coal of economic importance is known to occur within the coal-bearing zone. The coal beds are 11 feet or less in thickness, and are very irregular in extent. There seems to be no systematic increase or decrease in thickness in any direction. These coals, though of subbituminous rank, are probably of more value than the coals in the Mesaverde formation, but because of the presence of thicker and more persistent coal beds in the overlying formations the Medicine Bow coal has thus far been little developed in this area.

Both the Ferris and Hanna formations contain numerous beds of subbituminous coal which range from a few inches to 25 feet or more in thickness and are more extensive and regular in thickness than those in either the Mesaverde or the Medicine Bow formations. The coal that is being mined at Hanna by the Union Pacific Coal Co. occurs in the Hanna formation and is extensively used by the Union Pacific Railroad as well as for domestic purposes. The old Dana mine, west of Hanna, and the No. 5 mine, at Carbon, were opened on coal beds within the Ferris formation, but at the present time there are no working mines on the coals in that formation.

PHYSICAL AND CHEMICAL PROPERTIES

The coal of the Mesaverde formation is black, shows a tendency to prismatic jointing or cleavage, and does not break up into flakes parallel to the bedding planes on weathering. Because of lack of development of Mesaverde coals in this area only one strictly fresh sample was obtained—at the Wissler mine, in sec. 22, T. 22 N., R.

79 W. This particular coal bed occurs near the top of the Mesaverde formation, and its analysis indicates that it is of subbituminous rank, though heretofore Mesaverde coals in this area have been considered of bituminous rank. Analyses of samples collected by Veatch [19] in 1906 show that the Mesaverde coal in this general area after air drying averages about 6 per cent in moisture, the ash ranges from 2 to 6 per cent, averaging about 3.5 per cent, and the heating value averages slightly more than 12,000 British thermal units.

The coals in the Medicine Bow, Ferris, and Hanna formations are of subbituminous rank, are black and shiny, contain a rather high percentage of moisture, and disintegrate rapidly when exposed to the air. With the loss of their moisture they check and break along irregular lines and finally crumble to powder or to thin laminae.

Two samples of coals from the Medicine Bow formation show after air-drying average moisture, 8.3 per cent; ash, 3.4 per cent; heating value, 11,605 British thermal units. Other analyses of coal in the Medicine Bow formation are listed by Veatch.[20]

No opportunity was afforded to the writers to collect fresh samples of coal from the Ferris formation, because of lack of development. Veatch,[21] however, lists three apparently fresh samples taken in secs. 25 and 36, T. 23 N., R. 84 W., which after air-drying gave average moisture, 10.4 per cent; ash, 5.0 per cent; heating value (one sample only), 10,881 British thermal units.

Analyses of representative samples of coals from the Hanna formation have been given by Veatch.[22] The analyses of two of these samples and of others collected by the writers and representatives of the Bureau of Mines are shown on pages 35–36. Analyses of these samples after air-drying show average moisture, 8.5 per cent; ash, 6.4 per cent; heating value, 11,360 British thermal units.

The figures given above may be considered representative of the chemical qualities of the better grades of coal occurring in the several coal-bearing formations of the Hanna Basin.

In order to compare the coals of the Hanna and Carbon Basins with those of other fields with which they must compete, analyses are also given of coals from the Rock Springs and Kemmerer fields, farther west in Wyoming, from the Castlegate district, Utah, and from the Denver Basin, Colorado.

The analyses are given in four forms, marked A, B, C, and D. Analysis A represents the sample as it comes from the mine. This form is not well suited for comparison, because of accidental irregularities in the amount of moisture in the coal as it comes from the mine. Analysis B represents the sample after it has been dried

[19] Veatch, A. C., op. cit., pp. 253–258.
[20] Idem, pp. 254–258.
[21] Idem, p. 255.
[22] Idem, pp. 255–258.

under standardized conditions. Analysis C represents the constitution of the coal after all of its moisture has been eliminated, and analysis D represents its calculated composition after all moisture and ash have been theoretically removed. Form A of the analyses represents, with fair accuracy, the composition of the coal as it is shipped from the mine; forms B, C, and D are useful for engineering calculations of various sorts.

Analyses of coal samples from the Hanna and Carbon Basins and of representative samples from competing fields

[Made by the United States Geological Survey and the Bureau of Mines]

Source	Formation	Location				Laboratory No.	Air-drying loss	Form of analysis	Proximate			Ultimate						Heating value	
		Quarter	Sec.	T. N.	R. W.				Moisture	Volatile matter	Fixed carbon	Ash	Sulphur	Hydrogen	Carbon	Nitrogen	Oxygen	Calories	British thermal units
Wissler mine	Mesaverde	NE	22	22	79	A-14124	5.5	A	14.1	36.5	41.6	7.8	1.1	-------	-------	-------	-------	5,717	10,290
								B	9.2	38.7	43.9	8.2	1.2	-------	-------	-------	-------	6,050	10,890
								C	-------	42.5	48.4	9.1	1.3	-------	-------	-------	-------	6,656	11,980
								D	-------	46.8	53.2	-------	1.5	-------	-------	-------	-------	7,322	13,180
Local prospect	Medicine Bow	NE	11	24	83	22972	7.2	A	14.1	32.8	48.6	4.5	1.03	-------	-------	-------	-------	5,930	10,670
								B	7.5	35.3	52.4	4.8	1.11	-------	-------	-------	-------	6,385	11,500
								C	-------	38.2	56.6	5.2	1.20	-------	-------	-------	-------	6,905	12,430
								D	-------	40.3	59.7	-------	1.27	-------	-------	-------	-------	7,280	13,100
Ryan mine	do	SW	14	21	84	93541	2.4	A	11.4	33.8	51.7	3.1	.6	5.6	65.5	2.2	23.0	6,350	11,430
								B	9.2	34.6	53.1	3.1	.7	5.5	67.1	2.2	21.4	6,506	11,710
								C	-------	38.1	58.4	3.5	.7	4.9	73.9	2.4	14.6	7,167	12,900
								D	-------	39.5	60.5	-------	.8	5.1	76.5	2.5	15.1	7,422	13,360
Johnson mine	Hanna	NW	6	20	79	22800	2.7	A	13.3	37.9	41.9	6.9	.85	-------	-------	-------	-------	6,005	10,810
								B	10.9	38.9	43.1	7.1	.87	-------	-------	-------	-------	6,170	11,100
								C	-------	43.7	48.4	7.9	.98	-------	-------	-------	-------	6,925	12,460
								D	-------	47.5	52.5	-------	1.06	-------	-------	-------	-------	7,520	13,530
Do	do	SE	32	21	80	93486	3.5	A	9.5	39.3	42.8	8.4	.5	6.0	62.8	1.1	21.2	6,200	11,160
								B	6.2	40.7	44.4	8.7	.5	5.8	65.0	1.2	18.8	6,422	11,560
								C	-------	43.4	47.3	9.3	.6	5.4	69.3	1.2	14.2	6,850	12,330
								D	-------	47.9	52.1	-------	.6	6.0	76.5	1.4	15.5	7,556	13,600
Wilson mine	do	SE	32	21	80	A-14123	3.7	A	10.9	37.9	47.7	3.5	.7	-------	-------	-------	-------	6,406	11,530
								B	7.4	39.3	49.7	3.6	.8	-------	-------	-------	-------	6,650	11,970
								C	-------	42.5	53.6	3.9	.8	-------	-------	-------	-------	7,183	12,930
								D	-------	44.2	55.8	-------	.8	-------	-------	-------	-------	7,478	13,460
Hanna No. 1 mine (abandoned).	do	NW	20	22	81	3605	2.2	A	10.1	41.0	41.9	7.0	.49	5.5	62.7	1.3	23.1	6,280	11,300
								B	8.1	41.9	42.9	7.1	.50	5.4	64.1	1.3	21.6	6,420	11,560
								C	-------	45.6	46.6	7.8	.54	4.9	69.7	1.4	15.7	6,985	12,570
								D	-------	49.5	50.5	-------	.59	5.3	75.6	1.5	17.0	7,570	13,630

Analyses of coal samples from the Hanna and Carbon Basins and of representative samples from competing fields—Continued

[Made by the United States Geological Survey and the Bureau of Mines]

Source	Formation	Location				Laboratory No.	Air-drying loss	Form of analysis	Proximate				Ultimate					Heating value	
		Quarter	Sec.	T. N.	R. W.				Moisture	Volatile matter	Fixed carbon	Ash	Sulphur	Hydrogen	Carbon	Nitrogen	Oxygen	Calories	British thermal units
Hanna No. 2 mine	Hanna	NW	19	22	81	3396	3.8	A	12.4	39.8	41.1	6.7	0.26	6.4	61.6	0.88	24.7	5,975	10,760
								B	8.9	41.3	42.7	7.1	.27	6.2	64.0	.90	23.2	6,115	11,010
								C		45.4	46.9	7.7	.30	5.7	70.3	.99	16.6	6,735	12,130
								D		49.2	50.8		.33	6.2	76.2	1.08	18.0	7,340	13,220
Hanna No. 4 mine (composite of 3 samples, 1925).	do					A-13215	2.5	A	10.5	40.3	44.1	5.1	.4	5.9	63.5	1.1	24.0	6,228	11,210
								B	8.1	41.4	45.2	5.3	.4	5.8	65.1	1.1	22.3	6,389	11,500
								C		45.0	49.3	5.7	.5	5.3	70.9	1.2	16.4	6,956	12,520
								D		47.8	52.2		.5	5.7	75.2	1.2	17.4	7,578	13,280
Rock Springs, Wyo. (average of 4 analyses).							3.6	A	10.6	35.2	50.4	3.7	.82	5.6	66.8	1.2	21.8	6,635	11,940
								B	7.2	36.5	52.3	3.9	.85	5.4	69.3	1.3	19.2	6,890	12,400
								C		39.4	56.4	4.2	.91	4.9	74.8	1.4	13.8	7,430	13,370
								D		41.1	58.9		1.20	5.1	77.8	1.4	14.4	7,755	13,960
Kemmerer, Wyo. (average of 4 analyses).						18612	1.8	A	3.9	40.1	49.0	7.0	.60	5.5	72.2	1.2	13.5	7,160	12,890
								B	2.2	40.8	49.9	7.1	.61	5.4	73.6	1.3	12.1	7,290	13,120
								C		41.7	51.0	7.3	.62	5.3	75.2	1.3	10.4	7,455	13,420
								D		45.0	55.0		.67	5.7	81.0	1.4	11.3	8,035	14,470
Castlegate, Utah (average of 7 analyses).							1.8	A	4.3	43.5	45.8	6.4	.46	5.8	72.4	1.4	13.5	7,210	12,690
								B	2.7	44.1	46.7	6.5	.69	5.7	73.5	1.4	12.2	7,345	13,440
								C		45.7	47.5	6.8	.70	5.4	75.5	1.4	10.1	7,530	13,550
								D		49.0	51.0		.77	5.9	80.9	1.6	10.8	8,070	14,520
Denver Basin, Colo. (average of 4 analyses).						6593	14.7	A	21.5	31.2	41.9	5.4	.44	5.8	54.2	1.0	32.9	5,154	9,280
						6837		B	7.9	36.5	49.1	6.3	.51	5.2	63.7	1.1	23.2	5,999	10,888
						6841		C		39.7	55.9	6.9	.56	4.7	71.5	1.5	17.6	6,616	11,817
						6840		D		42.7	57.2		.60	5.2	74.1	1.4	18.9	7,025	12,687

From a comparison of the analyses in the foregoing table it appears that the coals of the Medicine Bow, Ferris, and Hanna formations of the Hanna and Carbon Basins are somewhat higher in moisture and lower in heating value than the coals of the Rock Springs, Kemmerer, and Castlegate districts, whereas they surpass those of the Denver Basin in some respects. Such of the Mesaverde coals of the Hanna and Carbon Basins as are of a purity equal to those of the Medicine Bow, Ferris, and Hanna coals are believed to be slightly higher in heating value than those younger coals, but the Mesaverde coals are of little present commercial interest because of their relative inaccessibility and irregularity.

Production and transportation costs, as well as the quality of competing coals, determine the markets which each can successfully enter, and the future demand for Hanna Basin coal and the direction of its movement will be governed by these factors. Presumably, however, its principal markets will lie near the Hanna Basin and eastward and southeastward along the lines of the Union Pacific Railroad.

PRODUCTION AND USES

The coal production in Carbon County amounted to 496,104 tons in 1926. Practically all of this came from the mines of the Union Pacific Coal Co. at Hanna, though small amounts are produced by other mines that supply near-by towns and ranches.

About 90 per cent of the coal mined is used by the Union Pacific Railroad for raising steam. The coal is light and makes many sparks when burned under forced draft but otherwise gives satisfactory results in locomotives. The use of the coal for domestic purposes is almost wholly confined to the towns along the railroad.

QUANTITY OF COAL

Good topographic maps and reliable information on the position, dip, and thickness of the coal beds and overlying strata make it possible to estimate with a fair degree of accuracy the amount of coal present 3,000 feet or less below the surface in the Hanna and Carbon Basins. The area was divided into a number of narrow strips running perpendicular to the outcrop, the total thickness of coal at the outcrop and the area were obtained for each strip, and on the assumption that an acre-foot contains 1,800 tons of coal the tonnage was calculated for each strip. The sum of these amounts gives the coal beneath 3,000 feet or less of cover as 4,264,675,000 tons. As some beds undoubtedly are not exposed and escaped observation, the estimate is not unwarrantedly high.

Sufficient data are not yet available concerning the area in which the coal lies deeper than 3,000 feet to estimate the quantity, but it is probable that at least as much coal is present below that depth as there is above it.

Total estimated quantity, by townships, of coal 3,000 feet or less below the surface in the Hanna and Carbon Basins

Township	Mesaverde formation	Medicine Bow formation	Ferris formation	Hanna formation	Total
T. 21 N., R. 85 W.	200,000				200,000
T. 22 N., R. 85 W.		710,000			710,000
T. 23 N., R. 85 W.		15,600,000			15,600,000
T. 21 N., R. 84 W.	500,000	1,635,000			2,135,000
T. 22 N., R. 84 W.		5,000,000	33,800,000		38,800,000
T. 23 N., R. 84 W.			313,000,000		313,000,000
T. 24 N., R. 84 W.	4,158,000	17,119,000	8,023,000		29,300,000
T. 21 N., R. 83 W.		1,000,000			1,000,000
T. 22 N., R. 83 W.		2,400,000	527,000,000		529,400,000
T. 23 N., R. 83 W.			385,000,000	7,000,000	392,000,000
T. 24 N., R. 83 W.	1,000,000	47,500,000	90,400,000		138,900,000
T. 21 N., R. 82 W.			13,000,000		13,000,000
T. 22 N., R. 82 W.			468,000,000	95,000,000	563,000,000
T. 23 N., R. 82 W.			93,300,000	4,150,000	97,450,000
T. 24 N., R. 82 W.		13,420,000			13,420,000
T. 21 N., R. 81 W.	2,160,000	30,000,000			32,160,000
T. 22 N., R. 81 W.				529,732,000	529,400,000
T. 23 N., R. 81 W.					766,650,000
T. 24 N., R. 81 W.				19,250,000	19,250,000
T. 20 N., R. 80 W.				20,000,000	20,000,000
T. 21 N., R. 80 W.	31,000,000	6,000,000		222,000,000	259,000,000
T. 22 N., R. 80 W.	6,500,000	51,500,000	8,700,000	12,000,000	78,700,000
T. 23 N., R. 80 W.		200,000		287,000,000	287,200,000
T. 24 N., R. 80 W.				700,000	700,000
T. 20 N., R. 79 W.				8,500,000	8,500,000
T. 21 N., R. 79 W.	8,200,000	1,000,000		101,000,000	110,200,000
T. 22 N., R. 79 W.	1,000,000	4,000,000			5,000,000
					4,264,675,000

TOWNSHIP DESCRIPTIONS

GENERAL SCOPE

In the following township descriptions particular emphasis is laid on the location and character of the coal beds, though the topography and geology are mentioned in a general way. The outcrops of the coal beds are shown on Plate 27, and the localities at which coal sections were measured are marked on the map by numbers. The coal sections, correspondingly numbered, are shown in the illustrations or given in the text. In general the coal beds numbered 1 to 89 are numbered consecutively from the lowest to the highest. (See pl. 8.) The coal beds numbered 90 to 130 are undoubtedly equivalent to some of the lower numbered coal beds, but as they occur in isolated localities no precise correlations could be made. The townships are described in order from south to north and west to east, starting in the southwest corner of the Walcott quadrangle.

T. 21 N., R. 85 W.

Rattlesnake Ridge, capped by the resistant sandstones of the Mesaverde formation, crosses the northeastern part of T. 21 N., R. 85 W., and rises about a thousand feet above the valley of North Platte River, which follows the southwestern base of the ridge. Owing to

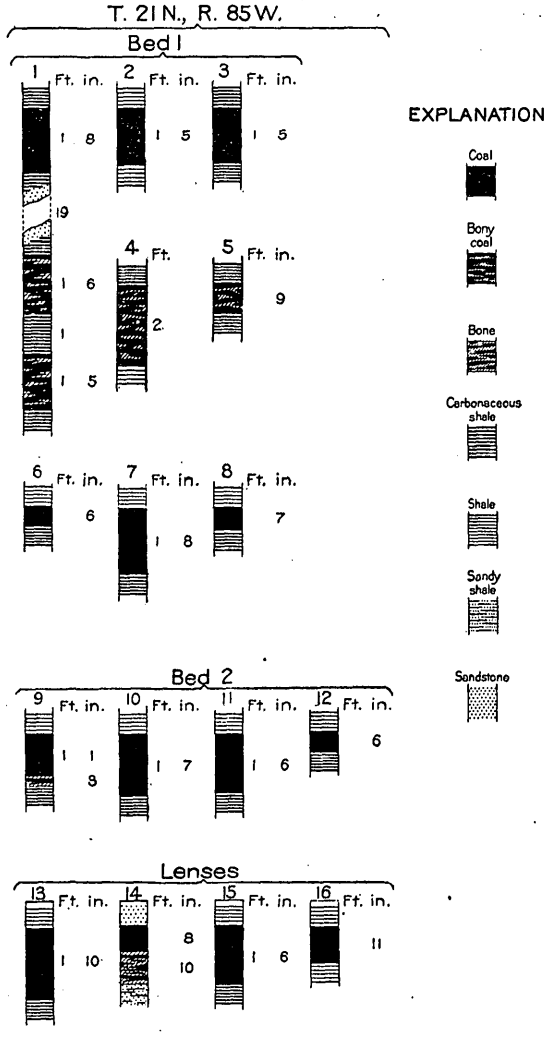


FIGURE 2.—Sections of coal beds in T. 21 N., R. 85 W.

the influence of the Fort Steele anticline, which crosses the southern part of the township (see pl. 27), the Steele shale is exposed over the central and southwestern parts, and the Mesaverde beds of Rattlesnake Ridge dip northeastward beneath the Lewis shale, which is the surface formation in the northeast corner except in a small part of

sec. 1, in which the basal beds of the Medicine Bow formation are present.

The Mesaverde formation is 2,300 to 2,700 feet thick in this township, and a detailed section of it is given on pages 17–21. The Steele shale is between 4,000 and 5,000 feet thick, and some 2,500 to 3,000 feet of it is exposed within the township along the Fort Steele anticline. This fold plunges toward the southeast, and the average dip of its northern limb is about 30° as compared with 50° for its southern limb.

The small amount of coal in the township is contained in the Mesaverde formation and occurs in thin beds, which are irregular in character and extent. Bed 1 crops out in the eastern part of sec. 13 and is represented in Figure 2 by graphic sections 1 to 3. At locations 2 and 3 bed 1 is 1 foot 5 inches thick, and at each place a small pit has been opened. At location 1 bed 1 is 1 foot 8 inches thick and another bed 19 feet below it consists of two benches of bony coal, each about 1 foot 6 inches thick, separated by 1 foot of carbonaceous shale. A coal probably equivalent to bed 1 contains 2 feet of shaly coal at location 4, in the SW. ¼ sec. 11, and 9 inches of coal at location 5, near by. Coal occurs at this horizon at locations 6 to 8, near the southwest corner of sec. 3, with a maximum observed thickness of 1 foot 8 inches at location 7.

Bed 2 is 50 feet above bed 1 in the eastern part of sec. 13 and has a maximum thickness of 1 foot 7 inches at location 10. Smaller measurements of bed 2 are shown graphically in Figure 2, by sections 9, 11, and 12. Northwest of location 9 bed 2 is represented by carbonaceous shale and thin streaks of coal.

At location 13, in the NE. ¼ sec. 13, a coal bed 1 foot 10 inches thick is exposed in an old prospect. In sec. 11 a coal bed at about the same horizon as the one measured at location 13 has a maximum thickness of 1 foot 6 inches at locations 14 to 16.

T. 22 N., R. 85 W.

Cedar Ridge, an anticline developed in the resistant sandstones of the Mesaverde formation, and its southeastward extension, St. Marys Ridge, crosses T. 22 N., R. 85 W., diagonally from southeast to northwest and attains a maximum height of about 750 feet above the North Platte. The land on both sides of these ridges is an undulating, grass-covered plain which stands 150 to 300 feet above the river level and becomes rougher toward the river. On the northeastern limb of the Cedar Ridge anticline the Lewis shale and Medicine Bow formations are largely concealed by the overlapping North Park formation but where exposed dip 2°–31° NE. On the southwestern limb of the anticline the Mesaverde sandstones dip 25°–70°

SW., into a syncline of Lewis shale lying between Cedar and Rattlesnake Ridges, which crosses the southern boundary of the township. The Cedar Ridge fault is exposed a little west of the water tank at the Miller ranch, north of North Platte River, and also in a small ravine half a mile southeast of the Miller ranch. The fault plane is

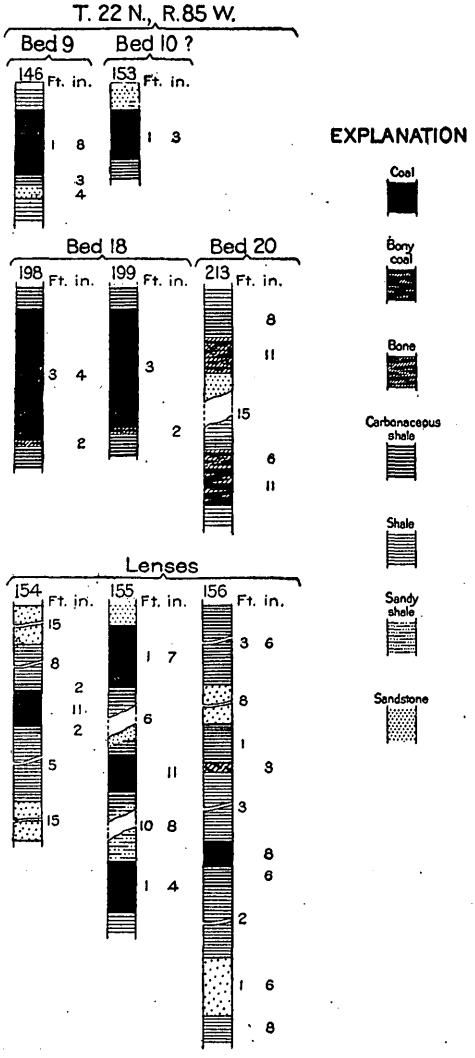


FIGURE 3.—Sections of coal beds in T. 22 N., R. 85 W.

nearly vertical at these places, and the Lewis formation probably has been dropped about 1,650 feet with reference to the Mesaverde sandstones in Cedar Ridge.

The amount of coal in the part of the township mapped is exceedingly small and occurs in the Medicine Bow formation. Some

thin beds occur in the Mesaverde formation north of North Platte River and outside the Walcott quadrangle, but none occur within the quadrangle itself.

Bed 9 is the lowest-numbered coal bed exposed in the township and contains 1 foot 8 inches of coal at location 146, in the NE. ¼ sec. 3. Another coal bed lying just above bed 9 contains 1 foot 3 inches of coal at location 153, in the NE. ¼ sec. 3, and may be bed 10 of T. 23 N., R. 85 W. Beds 18 and 20, the only other numbered coal beds mapped in the township, occur in the northern part of sec 2. Bed 18 contains about 3 feet of coal at locations 198 and 199, and bed 20 about 1 foot of bone and shale at location 213.

At location 155 in the SE. ¼ sec. 3, the lowest of three coal beds is 1 foot 4 inches thick and may be bed 7 of T. 23 N., R. 85 W. The two higher beds at this location are less than 2 feet thick, as shown in Figure 3.

Beds of carbonaceous shale and coal crop out at locations 154 and 156, in the SE. ¼ sec. 3, but the coal in none of these sections exceeds 1 foot in thickness, as shown by the corresponding graphic sections in Figure 3.

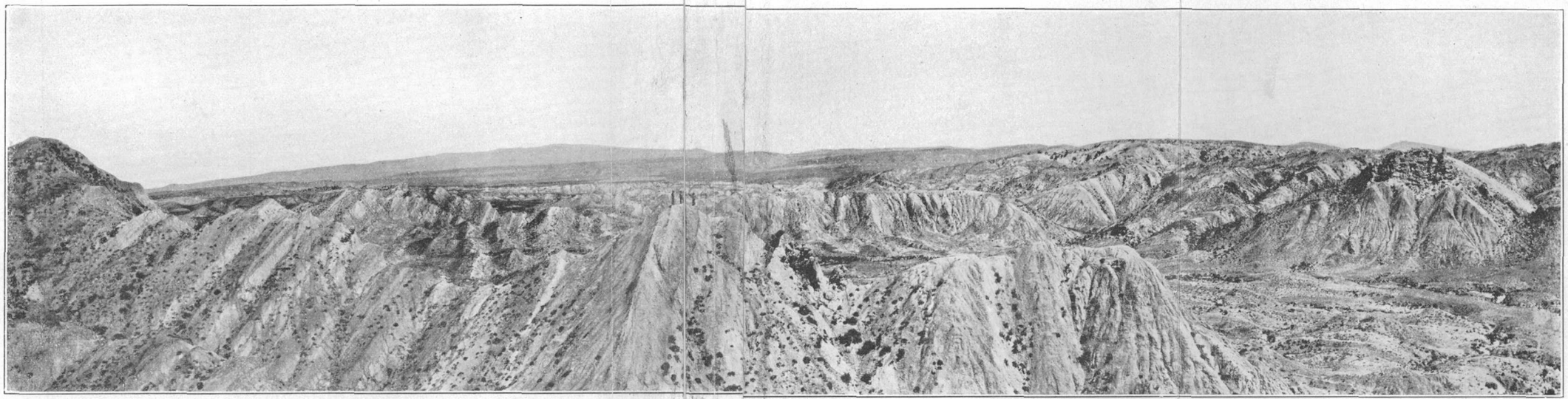
T. 23 N., R. 85 W.

The Lewis and Medicine Bow formations occupy the part of T. 23 N., R. 85 W., that was mapped, and dip 15°–25° E., as shown by structure section A–B, Plate 27. A series of parallel sandstone ridges and shale valleys trending nearly north characterize the outcrop of the Medicine Bow formation, whereas the Lewis shale crops out in a rather broad, open valley.

There are numerous thin beds of coal in the lower 2,000 feet of the Medicine Bow formation in this township, none of which were found to contain as much as 3 feet of clean coal. The correlation of coal outcrops is rendered difficult because of the variable character of the coal beds, the small stratigraphic range between them, and the comparatively long horizontal distances between exposures. The correlation shown on the map represents the best judgment of the writers after a study of the beds in the field and a careful compilation of all the data procured. It is probable, however, that many of the beds are lenticular and may vary considerably in thickness between points of sectioning, especially where such points are half a mile or more apart. The lines of outcrop of the several beds measured and their observed thicknesses are shown, respectively, by Plates 27 and 11.

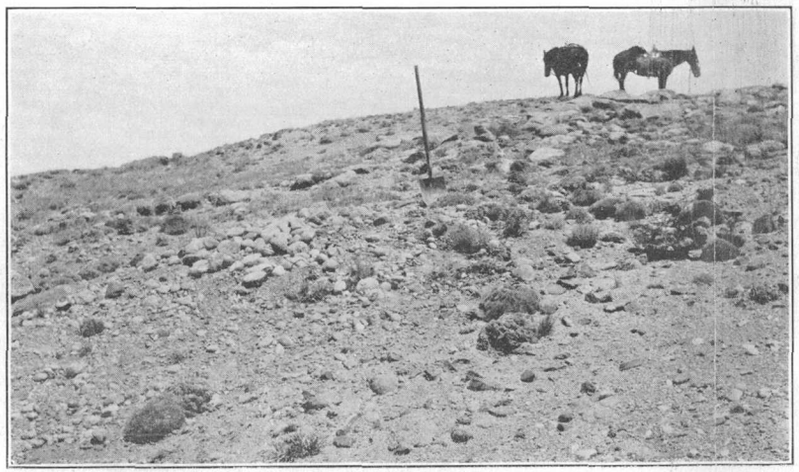
T. 21 N., R. 84 W.

Rattlesnake Ridge and St. Marys Ridge, two prominent ranges made up of the heavy sandstones in the Mesaverde formation, break

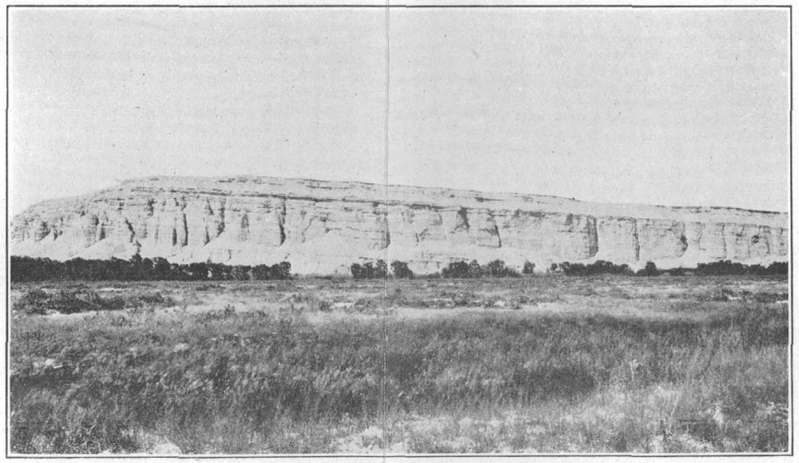


A. PANORAMA IN SEC. 9, T. 23 N., R. 80 W.

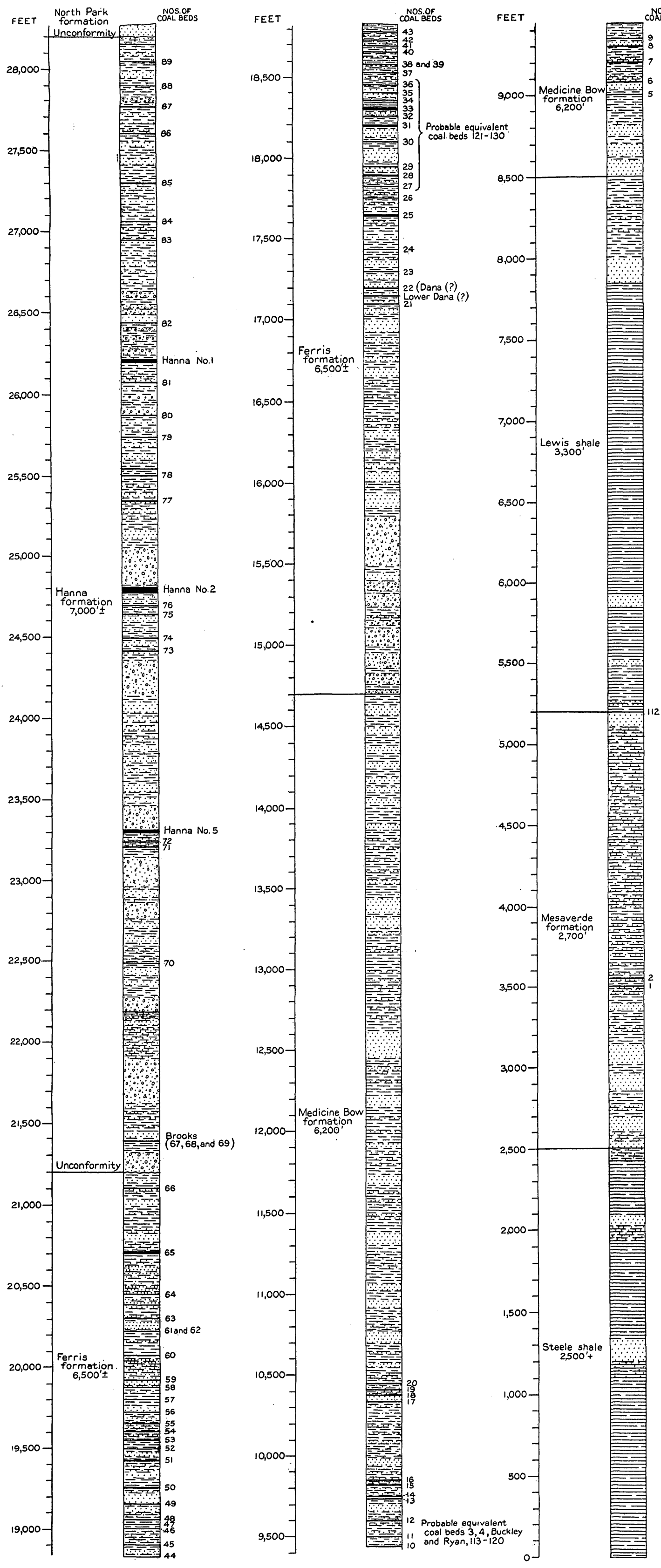
Showing steeply dipping Hanna rocks striking north toward the Freezeout Hills



B. CONGLOMERATE IN LOWER PART OF HANNA FORMATION, SE. ¼ SEC. 5, T. 21 N., R. 81 W.

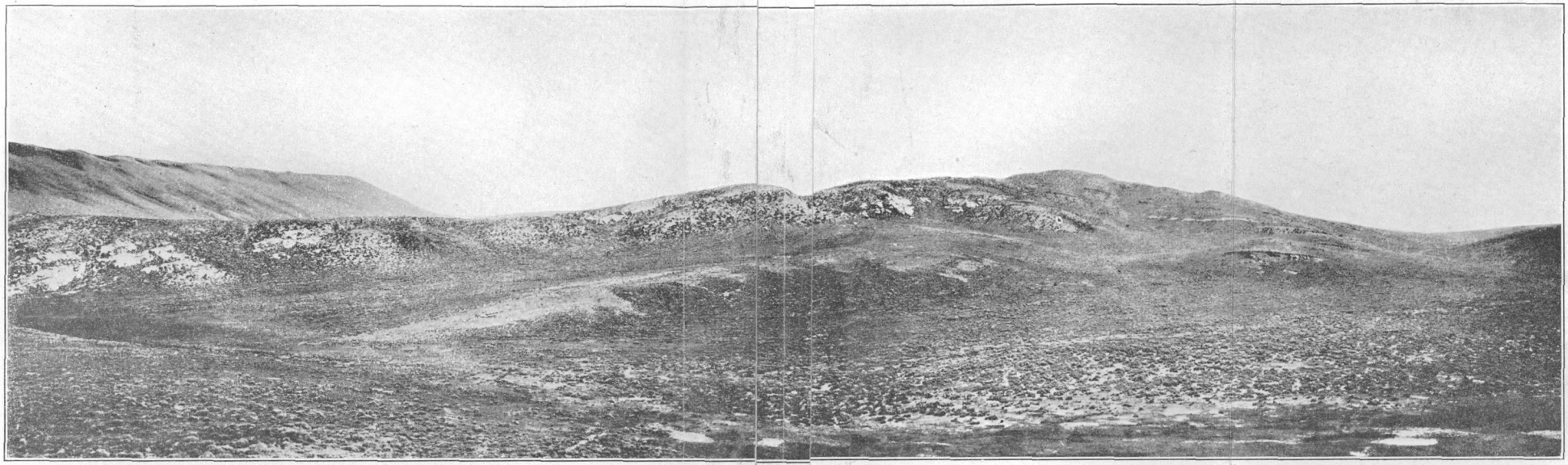


C. NORTH PARK FORMATION ON NORTH PLATTE RIVER BELOW SARATOGA

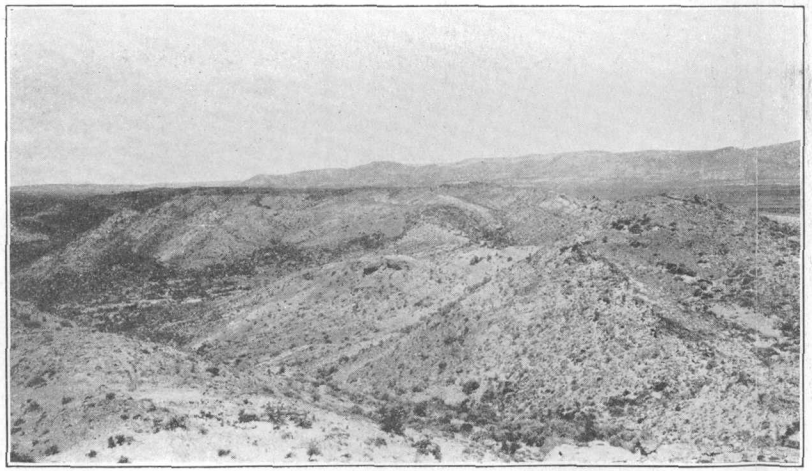


COLUMNAR SECTION OF ROCKS EXPOSED IN THE HANNA AND WALCOTT QUADRANGLES

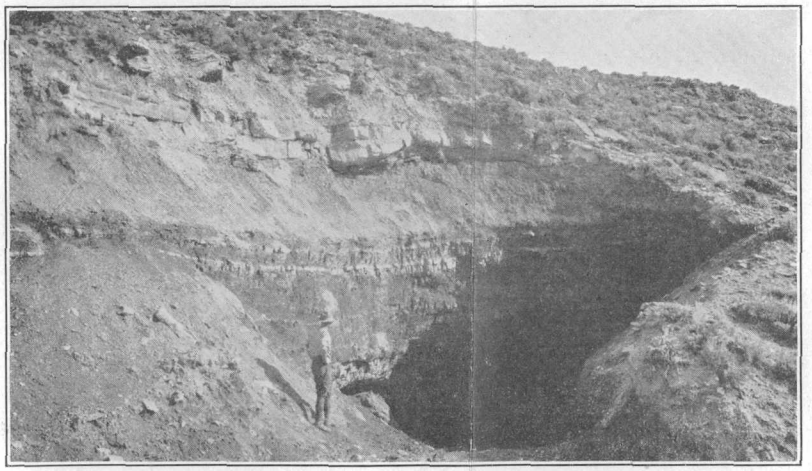
6175—29. (Face p. 42.)



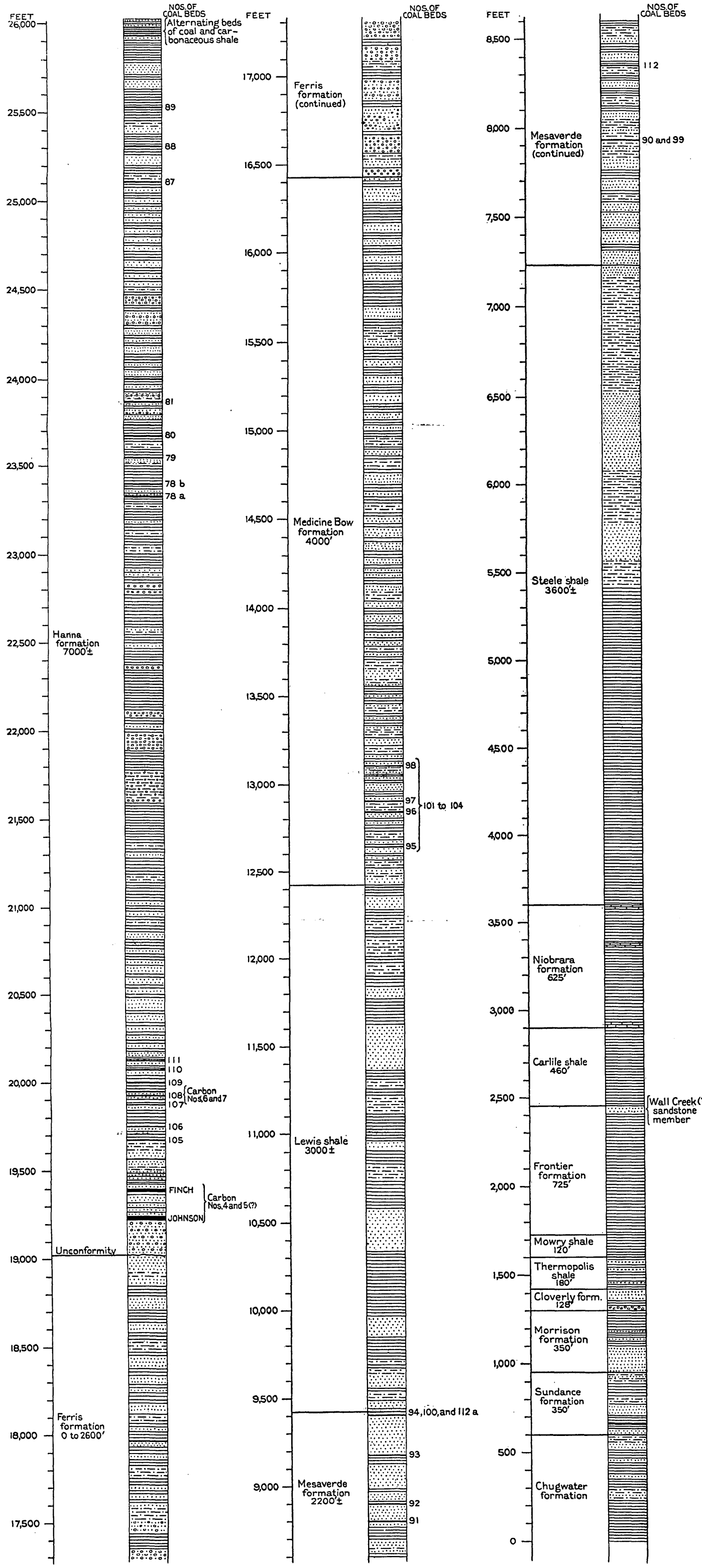
A. MESAVERDE FORMATION IN SADDLEBACK HILLS ANTICLINE, SEC. 17, T. 21 N., R. 80 W.



B. OIL SPRINGS ANTICLINE IN SEC. 1, T. 23 N., R. 79 W.



C. WILSON COAL MINE, SE. ¼ SEC. 32, T. 21 N., R. 80 W.



EXPLANATION

Sandstone | Shale | Limestone | Sandy shale | Conglomerate | Coal bed

COLUMNAR SECTION OF ROCKS EXPOSED IN THE SADDLEBACK HILLS QUADRANGLE

the monotony of the plains in T. 21 N., R. 84 W. Rattlesnake Ridge attains an altitude of 7,350 feet, or 875 feet above North Platte River, in sec. 18 but decreases in altitude southeastward, owing to the plunge of the Fort Steele anticline, and terminates about 1 mile west of Walcott. St. Marys Ridge, which coincides with an anticline by the same name, culminates in St. Marys Hill, which rises to an altitude of 7,496 feet in sec. 14.

The structure is more varied in this township than in any other in the Hanna and Carbon Basins. The Fort Steele anticline crosses the southwestern part of the township and is separated from the St. Marys anticline by the Walcott syncline, which is occupied by the Lewis shale and Medicine Bow formation. The unconformable North Park formation covers much of the surface in the vicinity of Walcott and north of St. Marys Hill.

Bed 1 occurs about 1,000 feet above the base of the Mesaverde formation and is represented in Plate 12 by graphic sections 17 to 19 and by the lowest beds in sections 21 and 22. It averages less than 2 feet in thickness and does not occur east of location 19.

Bed 2 occurs about 50 feet above bed 1 and consists of carbonaceous shale at location 26, in the SE. ¼ sec. 20. Elsewhere in the township it contains from 9 inches to 2 feet 2 inches of coal, as shown by graphic sections 20 to 25 and 27 to 30 in Plate 12.

At locations 31 and 32, in the NW. ¼ sec. 18, a lens of coal, which also occurs in T. 21 N., R. 85 W., exhibits a maximum thickness of 1 foot 9 inches. Another lens contains about 1 foot of coal at location 33, in the NE. ¼ sec. 10. Other Mesaverde coals in the vicinity of location 33 are less than a foot thick and were not mapped.

The Buckley & Ryan bed crops out in both limbs of the Walcott syncline in the eastern part of the township and has been traced from the Buckley & Ryan mine southeastward as far as the railroad. At location 39, in the SW. ¼ sec. 14, it contains 6 feet of undivided coal. Smaller measurements of it in this township are represented graphically in Plate 12 by sections 34 to 38 and 40 to 42, which show from 1 foot to 5 feet of coal. The bed that shows about 2 feet of coal at location 43, in the NE. ¼ sec. 24, may be the Buckley & Ryan bed, but the correlation is uncertain. At the present time a small mine near the old Buckley & Ryan mine yields about 225 tons of coal annually for use in Walcott.

Two beds below the Buckley & Ryan bed in the SE. ¼ sec. 15 average about 2 feet in thickness, as shown by graphic sections 45 to 51 in Plate 12 and by sections 300 feet west of location 48, where there is 2 feet 4 inches of coal; 90 feet south of location 49, 1 foot 8 inches; and 100 feet north of location 49, 2 feet—at each place underlain and overlain by shale.

6175—29——4

At location 53, in the SE. ¼ sec. 24, an old prospect exhibits 4 feet of coal. At location 52, about 300 feet northwest of the prospect, the coal bed is only 10 inches thick, and 400 feet to the southeast it consists of carbonaceous shale.

Coal beds less than 3 feet thick occurring in the NW. ¼ sec. 25 are represented by graphic sections 54 and 55 in Plate 12. Another coal bed 2 feet 7 inches thick crops out at location 56, in the SW.¼ sec. 24.

Bed 3 crosses the northeast corner of the township and averages 2 feet 3 inches in thickness at locations 60 to 63, as shown by the corresponding graphic sections in Plate 12.

T. 22 N., R. 84 W.

In the southwestern part of T. 22 N., R. 84 W., the North Park formation overlaps the Lewis shale and abuts against the Mesaverde formation in St. Marys Ridge, which stands about 400 feet above the rolling plain that occupies the remainder of the township. East of the North Park overlap the Medicine Bow and Ferris formations dip 25° NE., as shown by structure section E–F, plate 27.

The Mesaverde formation contains one bed of coal near the axis of the St. Marys anticline in sec. 31. At location 113 the bed contains 3 feet 7 inches of coal, but at locations 112 and 114 it contains less than 2 feet of coal.

Bed 3 in the Medicine Bow formation crops out in the SW.¼ sec. 36 and is about 2 feet thick at locations 58 and 59. At location 57 it is only 8 inches thick, and in the two coulees between location 57 and the wagon road, nearly 1 mile farther to the northwest, no coal could be found at its horizon. It is believed, therefore, that the bed pinches out a short distance west of location 57.

Bed 4 was traced from the southeast corner of the township northwestward as far as location 90, in the NW. ¼ sec. 35, where it is concealed by the surface wash that covers that part of the township. Between locations 90 and 100 it contains from 2 to 4 feet of coal, but at location 89, in the SE. ¼ sec. 27, not more than 14 inches of coaly material was found.

In the SE. ¼ sec. 36 a thin bed lying just below bed 4 contains less than 2 feet of coal at locations 109 and 110. Farther northwest, at locations 107 and 108, a coal bed at about this horizon is slightly more than 1 foot thick. Another bed overlying bed 4 in the SE. ¼ sec. 36 contains less than 2 feet of coal at location 104 to 106.

Bed 23, the lowest coal bed in the Ferris formation in this township, is represented in Plate 12 by sections 239 and 240, which show a maximum thickness of 2 feet 10 inches of coal. Southeast of location 240, in the SE. ¼ sec. 2, bed 23 is concealed beneath wash in St. Marys Ditch.

Except for the section measured at location 247, in the NW. ¼ sec. 2, which shows only 8 inches of badly weathered coal, bed 24 ranges in thickness from 1 foot 1 inch to 1 foot 7 inches in this township, as shown by graphic sections 246 to 251 in Plate 12.

Bed 25 is about 200 feet above bed 24 and was traced continuously across the northeast corner of the township. Measurements of it in the township are represented in Plate 12 by sections 259 to 263, which show thicknesses ranging between 6 feet 6 inches at location 259, in the NW. ¼ sec. 2, and 11 feet 8 inches at location 263, in the NE. ¼ sec. 12. Usually the bed is broken into several benches by partings, and as a rule the lowest bench contains the best coal.

Bed 25 is overlain in this township by bed 27, which contains 4 feet 5 inches of coal at location 291, in the NE. ¼ sec. 2, and 4 feet 4 inches at location 292, half a mile farther southeast. At location 292 bed 25 passes beneath wind-blown deposits occupying a shallow depression, and it could not be traced farther southeast.

Bed 31, which lies about 200 feet above bed 27 in this township, is over 12 feet thick at location 348, in the NE. ¼ sec. 2, but could not be traced southeastward across the low depression in sec 1. However, as it contains 10 feet of coal in sec. 7 of the township to the east, it is probably present beneath this depression and not less than 10 feet thick.

Bed 33 occurs about 150 feet above bed 31 at location 372, in the NE. ¼ sec. 22, and consists of an upper bed of coal 3 feet 2 inches thick separated from a lower bed 8 feet 4 inches thick by about 50 feet of sandstone and shale. About three-quarters of a mile north of this township these two beds unite to form a single bed of coal about 16 feet thick. However, southeast of location 372 bed 33 evidently thins out, as it was not found in the township to the east.

T. 23 N., R. 84 W.

North Platte River crosses the southern and eastern parts of T. 23 N., R. 84 W., and is bordered by steep bluffs, which rise as much as 200 feet above the flood plain of the river. Away from the river the surface is diversified by hills, ridges, and ditches. The most prominent ridge is the one that extends northward from the Ferris ranch in sec. 23 and rises 475 feet above the North Platte.

The Medicine Bow and Ferris formations occupy the surface of the township and have a monoclinal dip of 6°–20° E., as shown by structure section A–B, Plate 27. The monoclinal structure is modified by several normal faults, most of which are probably of small magnitude, but one designated fault I–I, which dips 70° NE., has a vertical displacement of about 200 feet and a horizontal displacement of about 900 feet. Faults G–G, H–H, and P–P are downthrown to the northeast. The vertical displacement is not more than

50 feet, and the horizontal displacement ranges between 0 and 300 feet. Fault R–R is downthrown to the west, and fault S–S to the east. The block included between these two faults has been shifted relatively southward, but the amount of displacement could not be determined. It seems that the horizontal offsets on opposite sides of the block just about compensate, as the coal bed, measured at location 678, in the SW. ¼ sec. 1, seems to correspond with the one measured at location 674, a quarter of a mile farther northeast.

Because the faulted condition of the strata in the northeast corner of the township prevents the precise correlation of the coal beds in that area with those that occur south of the faulted district, the areas will be described separately. All coal beds exposed in the township occur in the Ferris formation.

Bed 23 is the lowest coal bed exposed in this township and can be traced about a quarter of a mile in the SW. ¼ sec. 35 before it disappears in the shifting sands that border North Platte River. At location 238 it contains 2 feet 8 inches of coal in two benches separated by 1 foot of shale.

Bed 24 has about the same surface extent as bed 23 and is represented in Plate 13 by graphic section 245, which shows 1 foot 1 inch of coal. It was not observed north of location 245.

Bed 25 has a similar distribution to beds 23 and 24 and is represented by graphic sections 256 to 258 in Plate 13, which show a maximum thickness of 4 feet 3 inches of coal.

Bed 27 overlies bed 25 and has been traced by intermittent exposures nearly across the township. Between locations 286, in the SE. ¼ sec. 14, and 290, in the NW. ¼ sec. 35, its thickness ranges between 4 feet 1 inch and 5 feet, but at location 285, in the NW. ¼ sec. 14, it is only 9 inches thick. About half a mile farther north, at location 284, it is 10 feet 8 inches thick. From location 283, in the NW. ¼ sec. 11, bed 27 can be traced northward to location 282, in the SW. ¼ sec. 2, where an excellent exposure in a small ravine leading down to North Platte River shows 6 feet 8 inches of undivided coal underlain by 5 feet of bony coal.

Bed 28 has been traced almost continuously from the central part of sec. 26 northward to sec. 11, where it passes beneath terrace gravel. At location 297, in the NW. ¼ sec. 11, it has a maximum thickness for this township of about 18 feet. Other measurements of it in this township are shown graphically in Plate 13 by sections 298 to 301.

Bed 31 shows a general though not altogether regular decrease in thickness from south to north in this township. At location 347, in the SE. ¼ sec. 35, it is 19 feet thick and unbroken by partings. Another bed about 4 feet below it is 3 feet 5 inches thick and may represent bed 29 of T. 22 N., R. 83 W. At location 346, near the center of sec. 35, bed 31 is nearly 15 feet thick, and at locations

339 to 341, 344, and 345 it is over 10 feet thick. At location 343, in the SE. ¼ sec. 26, an old prospect on this bed shows 6 feet of coal with the base not exposed. Another abandoned prospect on this bed was found at location 342, in the SE. ¼ sec. 26, but the workings were so badly caved that it could not be entered. At location 336, in the southern part of sec. 11, bed 31 contains only 1 foot 3 inches of coal.

Bed 32 crops out in secs. 11 and 14 and probably does not extend much farther either north or south. At location 363, in the SE. ¼ sec. 14, it contains 2 feet 5 inches of coal split by a 3-inch parting of shale. Another coal bed about 30 feet lower is 4 feet 6 inches thick and may be a part of bed 31. Bed 32 could not be traced north of location 361, in the SE. ¼ sec. 11.

Bed 33 was traced continuously from a point just south of this township northward to fault I–I. At location 371, in the SE. ¼ sec. 35, it is separated into two benches by a wedge of shale and carbonaceous shale 27 feet thick. The main part of the upper bench is 5 feet 10 inches thick, and that of the lower bench 7 feet 2 inches thick. At location 369, in the NE. ¼ sec. 35, bed 33 contains almost 25 feet of coal, split by three shale partings, each less than 1 foot in thickness. Other measurements of bed 33 in the township showing from 9 to almost 20 feet of coal are represented in Plate 13 by graphic sections 364 to 368 and 370.

At location 671, in the SE. ¼ sec. 11, a coal bed 3 feet 6 inches thick occurs a short distance above bed 33, but it could not be traced beyond this point.

Bed 35 occurs in the eastern part of sec. 35 and contains less than 2 feet of coal at locations 380 and 381.

Bed 41 crops out in secs. 13 and 14 and averages 1 foot 9 inches in thickness at locations 404 to 407, as shown by the corresponding graphic sections in Plate 13.

So far as known, bed 42 occurs only in the NW. ¼ sec. 13. It is 3 feet 8 inches thick at location 408 and 2 feet 5 inches thick at location 409.

Bed 42–A overlies bed 42 and has been traced with more or less certainty between the north side of sec. 25 and fault I–I in sec. 13. At location 410, in the NW. ¼ sec. 13, it contains 1 foot 4 inches of bony coal, but it increases in thickness to the south and at location 415, in the SW. ¼ sec. 24, contains 3 feet 8 inches of coal in its lower bench, and 10 inches in its upper bench, separated by 10 inches of shale. Smaller sections of bed 42–A in this township are represented in Plate 13 by graphic sections 411 to 414 and 416.

Bed 43 has the same distribution as bed 42–A, which it directly overlies, and ranges from 1 foot 6 inches to 2 feet 8 inches in thickness at locations 417 to 423.

Bed 44 has about the same surface distribution as bed 43 and ranges in thickness from 11 inches at location 429, in the NW. ¼ sec. 25, to 6 feet 4 inches at location 431, in the NW. ¼ sec. 36. Other measurements of bed 44 in this township are shown in Plate 13 by graphic sections 424 to 428, 430, and 432.

Measurements of bed 45 in secs. 24 and 25 of this township are represented in Plate 13 by graphic sections 433 to 437, which show from 1 foot 3 inches to 2 feet 2 inches of coal. A bed tentatively correlated with bed 45 contains 1 foot 7 inches of coal at locations 438 and 439, in the NW. ¼ sec. 36.

Bed 46 is represented south of fault G–G in sec. 25 by graphic sections 444 and 445, in Plate 13, which show from 2 to 5 feet of impure coal. North of the fault it is represented by graphic sections 440 to 443, which show one or more coal beds from 6 inches to over 5 feet thick, interstratified with beds of shale and bony coal.

Bed 47 is a thick bed of carbonaceous shale containing several thin beds of coal. At location 447, in the SE. ¼ sec. 24, the thickest of these coal beds contains 1 foot 6 inches of coal.

Bed 49 overlies bed 47 and attains a maximum thickness for the township of 2 feet 3 inches at location 452, near the center of sec. 25. Other measurements of bed 49 in this township are represented graphically in Plate 13 by sections 451 and 453 to 455.

Bed 50–A occurs in the eastern part of sec. 25 and may be equivalent to bed 50 of T. 22 N., R. 83 W. Its thickest measurement was obtained at location 491 and shows 8 feet 6 inches of coal separated into two benches by a shale parting 10 inches thick. Smaller measurements of bed 50–A in this township are represented in Plate 13 by graphic sections 490 and 492.

Bed 51, which has been traced for several miles in the townships southeast of this one, occurs along the eastern border of this township south of Big Ditch. Its maximum thickness of coal for this township is 4 feet 6 inches at location 496, in the NE. ¼ sec. 36, and its minimum thickness 1 foot 7 inches at location 495, in the NE. ¼ sec. 25.

Bed 52 has about the same surface distribution as bed 51 and was measured in this township at locations 508 and 509, in the SE. ¼ sec. 25, where it is 1 foot 1 inch and 2 feet 2 inches thick, respectively.

Measurements of the coal beds exposed in the faulted areas in secs. 1 and 2 exhibit from 1 foot 2 inches to 7 feet 4 inches of coal, as shown by the corresponding graphic sections in Plate 13.

T. 24 N., R. 84 W.

In the northeastern part of T. 24 N., R. 84 W., vertical or slightly overturned beds in the Mesaverde and Medicine Bow formations

form conspicuous parallel ridges separated by a valley of Lewis shale about half a mile wide. The remainder of the township east of North Platte River is occupied by the Ferris formation, which is unevenly eroded and in places deeply trenched by North Platte and Medicine Bow Rivers. In the southeast corner of the township the beds dip about 10° SE.

Bed 112–B, at the top of the Mesaverde formation, has been traced from a point about half a mile east of this township westward to North Platte River. At location 1475, in the NW. ¼ sec. 2, it contains 15 feet 7 inches of coal separated into three benches by partings of shale and sandstone. The thickest bench contains over 9 feet of coal, as shown by the corresponding graphic section in Plate 14. Other measurements showing no individual coal bench over 3 feet thick are represented graphically in Plate 14 by sections 1474 and 1476 to 1478.

Three beds of coal dip 80° S. in a cut bank on the west side of the North Platte in the NW. ¼ sec. 4. The lowest of these beds contains 4 feet of coal at location 1484, the middle one 6 feet of coal at location 1485, and the upper one 4 feet of coal at location 1486. Other lenses in the Mesaverde formation showing from 1 foot 8 inches to 4 feet of coal were measured at locations 1480 and 1482 to 1483.

Bed 113, the lowest coal in the Medicine Bow formation in this township, ranges in thickness from 1 foot 6 inches at location 1494, in the SW. ¼ sec. 3, to 1 foot 10 inches at location 1495, 1 mile farther east. At location 1496, in the NE. ¼ sec. 12, it contains 2 feet of carbonaceous shale.

Bed 114 contains about 1 foot of coal at location 1502, in the NE. ¼ sec. 11, and 5 feet of coal at location 1500, in the SW. ¼ sec. 3. Intermediate measurements of it in this township are shown in Plate 14 by graphic sections 1501 and 1503.

Measurements of bed 116 in this township are represented in Plate 14 by graphic sections 1520, 1520a, 1521, and 1521a. Each of these sections, except 1521, contains an upper bed of coal about 4 feet thick and a lower bed from 1 foot to 1 foot 10 inches thick, separated by 4 to 7 feet of shale. At location 1521, however, it contains only 1 foot 3 inches of coal.

Only two sections were obtained on bed 117 in this township. At location 1532, in the NE. ¼ sec. 12, it is made up of two benches of coal separated by 20 feet of sandstone and shale. The upper bench is 1 foot 6 inches thick, and the lower one 3 feet 4 inches thick, with a 2-inch parting below the middle. At location 1531 bed 117 is only 8 inches thick.

Measurements of bed 118–A in this township are represented in Plate 14 by graphic sections 1542 to 1544, which show about 3 feet of

coal. At location 1543 a bed of coal 3 feet thick occurs 16 feet below bed 188–A.

Sections 1555 to 1557 on bed 119 show a nearly constant thickness of about 3 feet 9 inches of coal.

Bed 120, the highest workable coal bed in the Medicine Bow formation in this township, contains an upper bench of coal about 5 feet thick and a lower bench with a maximum thickness of 2 feet 10 inches, as shown by graphic sections 1562 to 1564 in Plate 14. At location 1562, in the NW. ¼ sec. 11, a third bench 2 feet 1 inch thick occurs 20 feet below the middle bed.

At location 1569, in the NE. ¼ sec. 36, bed 121 in the Ferris formation contains about 6 feet of coal separated into three benches by beds of shale. Section 1568, between faults R–R and S–S in the SW. ¼ sec. 36, probably represents this bed and exhibits over 10 feet of coal.

Bed 125 contains 7 feet of coal at location 1572, in the NE. ¼ sec. 36, and 4 feet 2 inches of coal, broken by 4 inches of shale, at location 1571, half a mile to the southwest. However, at locations intermediate between these points, no coal was found at the horizon of this bed.

Sections 1576 and 1577, on bed 126 in the SE. ¼ sec. 36, show about 3 feet of coal.

At location 1570, in the NW. ¼ sec. 36, a carbonaceous shale bed below bed 121 contains 1 foot 3 inches of coal, but beyond that point it consists chiefly of shale. Coal beds that probably represent numbered beds in T. 23 N., R. 84 W., crop out in the west bank of the North Platte in sec. 35. One of these beds contains 12 feet of coal at location 293 and another one 10 feet of coal at location 294. A third bed contains 5 feet of coal in a lower bench and about 2 feet in an upper bench at locations 295 and 296, the intervening interval being made up of shale, bone, and some coal.

T. 21 N., R. 83 W.

Pass Creek Ridge, a prominent anticline developed in the heavy sandstones of the Mesaverde formation, crosses the central part of T. 21 N., R. 83 W., in a southeasterly direction and rises about 900 feet above the broken country occupied by the Lewis shale, Medicine Bow formation, and North Park formation on each side of the ridge. Southwest of the ridge the beds dip as much as 90° into the Walcott syncline, the axis of which is covered by the overlapping North Park formation, and in some places are slightly overturned. North of the ridge the beds dip about 40° NE., as shown by cross section G–H, Plate 27.

All coal beds in this township occur in the Medicine Bow formation. At locations 81 to 84, in sec. 36, the lower of two coal beds,

which dip about 75° SW., contains about 3 feet of coal, and at locations 85 to 87 the upper one contains from 1 to 3 feet of coal.

Bed 3 was traced from the northwest corner of the township southeastward to the NW. ¼ sec. 11, where it passes beneath the overlapping North Park formation. Throughout this distance it contains from 5 inches to 3 feet 8 inches of coal, as shown by graphic sections 64 to 80 in Plate 12.

Bed 4 lies about 475 feet above bed 3 in this township and is less than 2 feet thick at locations 102 and 103, in the NE. ¼ sec. 6.

A coal bed 3 feet 5 inches thick crops out at location 88, in the NE. ¼ sec. 6, but could not be traced beyond that point.

T. 22 N., R. 83 W.

In the northeastern part of T. 22 N., R. 83 W., Big Ditch has intrenched itself in a valley about 500 feet deep, the north side of which is so much dissected by tributary gulches that the descent to stream level is very abrupt and in places precipitous. South of Big Ditch the land rises gently to the smooth grass-covered divide that separates Big Ditch from Walcott Ditch, to the south. The structure in this township is monoclinal, the Medicine Bow, Ferris, and Hanna formations dipping to the northeast at an angle which decreases from 40° along the southern boundary of the township to about 10° in its northeast corner.

Except for two thin beds of coal in the Medicine Bow formation in sec. 31, all the valuable coal in this township occurs in the Ferris formation. In general the Ferris coals are thin, but one of them is as much as 23 feet thick, and several others are more than 5 feet thick.

Bed 4, in the Medicine Bow formation, crosses the extreme southwest corner of sec. 31 and is about 2 feet thick, as shown by graphic section 101, Plate 15. At location 111 all but 9 inches of a coal bed below bed 4 has been eroded.

Bed 21, the lowest mappable coal bed in the Ferris formation, was traced between locations 220, in the SE. ¼ sec. 17, and 228, in the NE. ¼ sec. 26, and shows a rather uniform thickness of about 1 foot 4 inches of coal except at locations 222 to 224, where it is almost 3 feet thick.

Bed 22 occurs about 100 feet above bed 21 in secs. 22 and 23 and consists of alternating beds of sandstone, shale, and coal with a maximum thickness of about 15 feet. No individual coal bed exceeds 3 feet in thickness, as shown by graphic sections 232 to 237, Plate 15. A bed which probably represents bed 22 contains about 2 feet of coal at locations 229 to 231, in secs. 7 and 18.

Bed 23–A occurs in the SE. ¼ sec. 23 at about the same horizon as bed 23 of T. 22 N., R. 84 W. It contains 1 foot of coal at location 241 and 1 foot 6 inches of coal at location 242.

Bed 24 was measured in this township only at location 253, in the SW. ¼ sec. 7, where it contains 1 foot 2 inches of dirty coal.

Bed 24–A occurs in the southern part of sec. 23 and is probably the same as bed 24 of the township to the west. Measurements of it made at locations 254 and 255 show no single bed of coal over 1 foot 5 inches in thickness.

Bed 25 was traced from the northwest corner of sec. 17 northwestward into T. 22 N., R. 84 W. Measurements of it at locations 264 and 265 (see pl. 15) show a maximum thickness of 8 feet of coal.

Bed 25–A contains about 12 feet of coal at location 266, in the SW. ¼ sec. 24, and is probably equivalent to bed 25 in sec. 17.

Bed 26 was traced less than 2 miles northwestward from the southeast corner of sec. 24 and ranges in thickness from 7 feet 6 inches at location 270 in the SW. ¼ sec. 24, to 11 feet at location 269 a quarter of a mile farther west. (See pl. 15.)

At location 273, in the SW. ¼ sec. 7, bed 26–A consists of about 7 feet of alternating beds of shale and coal.

Bed 28–A occurs about 125 feet above bed 26 and has been traced almost across the township. Except at location 307, in the NW. ¼ sec. 22, where it consists of 2 feet 9 inches of shale and streaks of coal, its thickness ranges between 1 foot 3 inches and 4 feet, as shown by graphic sections 302 to 306 and 308 to 313, Plate 15.

Bed 29 lies about 50 feet above bed 28–A and appears to be an offshoot of bed 31. In the eastern part of the township these two beds are about 250 feet apart, but in the center of sec. 7 the interval between them is only 10 feet. At locations 320 and 327, bed 29 is about 1 foot 6 inches thick, but at locations 317 to 319, in the western part of the township, it contains from 5 to 13 feet of coal. Sections 317 to 319 are shown in Plate 15 under graphic sections 349 to 351 on bed 31.

Bed 30 crops out in secs. 23 and 24, where it ranges in thickness from less than 2 feet at location 333, in the center of sec. 24, to over 7 feet at locations 329 and 330, in the NW. ¼ sec. 23. This great variation in thickness in less than 2 miles suggests that bed 30, like bed 29, is an offshoot from bed 31, and that farther northwest they unite to form one thick bed.

Bed 31 contains over 23 feet of coal, separated into four benches at location 352, in the SE. ¼ sec. 16. Other sections of the bed showing smaller thicknesses of coal are represented graphically in Plate 15 by sections 349 to 351 and 353 to 357. At location 349, in sec. 7, the lower of two beds of coal, each 5 feet thick, is probably equivalent to bed 29, and the upper one probably corresponds to one of the lower benches shown in section 350.

Bed 34 was mapped from the southwest corner of sec. 15 southeastward to and beyond the township boundary. Measurements of it in this township are represented graphically in Plate 15 by sections 373 to 377, which exhibit a maximum thickness of 2 feet 3 inches of coal.

Bed 35 was found in this township only at location 382, in the NW. ¼ sec. 7, and contains 2 feet 7 inches of coal separated into two benches by partings 1 foot 4 inches thick.

Bed 36 occurs in secs. 15 and 16 and is less than 2 feet thick at locations 383 to 386.

Bed 37 lies about 60 feet above bed 36 and is usually too thin and dirty to be of any economic value. Measurements of it showing a maximum thickness of 7 feet 8 inches of coal are shown graphically in Plate 15 by sections 387 to 392.

Bed 38 is 50 feet above bed 37 and contains less than 4 feet of bony coal in this township, as shown by graphic sections 393 to 399, Plate 15.

Bed 39 occurs in the northern parts of secs. 23 and 24 and contains a maximum thickness of 2 feet 3 inches of coal at locations 400 to 403.

Bed 40 crops out in secs. 8 and 16 and contains less than 1 foot of coal in any unbroken bench.

Bed 48 is 3 feet 5 inches thick at location 448, in the SE. ¼ sec. 14, but contains less than 2 feet of coal at locations 449 and 450, in the NW. ¼ sec. 24.

Bed 49 was traced across the township and usually contains coal of good quality. At location 467, in the SW. ¼ sec. 14, it exhibits 3 feet 5 inches of coal unbroken by partings. Smaller measurements of it in this township are shown graphically in Plate 15 by sections 456 to 466 and 468 to 471.

Bed 49–A lies just above bed 49 and at location 475, in the NW. ¼ sec. 6, contains 1 foot 7 inches of coal. A bed at about this same horizon contains less than 2 feet of coal at localities 476 and 477, in the SE. ¼ sec. 8 and the NE. ¼ sec. 16, respectively.

Bed 50 was traced northwestward across the township as far as the northwest corner of sec. 8, where it is covered by surface wash. Throughout this distance it ranges in thickness from 14 feet 6 inches to 3 feet 4 inches and contains numerous partings of shale and bone, as shown by graphic sections 478 to 484, Plate 15.

Bed 51 has been traced northwestward from a point near the east side of sec. 15 to the north side of sec. 6 and into the township to the north. Although it is practically worthless in the eastern portion of the township, it increases in thickness and improves in quality toward the northwest, so that at locations 498 to 500, in secs. 6 and

8, it contains about 5 feet of coal, as shown by the corresponding graphic sections in Plate 15.

Bed 52 is about 50 feet above bed 51 and has about the same horizontal extent. Like bed 51, it shows an increase in thickness and improvement in quality of the coal from southeast to northwest. Measurements of it showing thicknesses ranging from 1 foot to 2 feet 5 inches are shown in Plate 15 by graphic sections 511 to 515.

Bed 53 is about 50 feet above bed 52 in secs. 8 and 9 and is so badly broken by shale partings that it is of little or no economic value. Detailed measurements of this bed are shown graphically in Plate 15 by sections 516 to 518.

Bed 54 has about the same distribution as bed 53 and is of little value at the east end of its outcrop. At locations 520 to 522, in sec. 9, it is badly split by shale partings, which increase in thickness to the southeast, as shown by the corresponding graphic sections in Plate 15. At location 519, in the SE. ¼ sec. 5, it contains 4 feet 6 inches of coal in its lower part, separated by 7 inches of shale from 11 inches of coal at the top. The bed could not be found northwest of this place.

Bed 56–A was traced a little more than a mile in secs. 9 and 10. At location 531, in the SW. ¼ sec. 10, it contains 2 feet 11 inches of coal, with an 8-inch parting near the middle, but at locations 528 to 530 it contains less than 2 feet of coal.

Bed 57 occurs only in secs. 13 and 14 and contains about 1 foot 6 inches of coal, with a thin parting of bone or shale near the middle at locations 537 to 540. At location 538, however, it contains 3 feet of hard bony coal.

As a rule, bed 58 contains one bench of coal about 3 feet thick and several thinner benches separated by partings of shale or bone, as shown by graphic sections 549 to 556 in Plate 15.

Bed 59 occurs only in sec. 13 and lies about 40 feet above bed 58. At location 562 it contains about 2 feet of shaly coal. At the other places it contains about 1 foot 6 inches of coal with an inch of bony material near the bottom. At locations 559 and 560 another bed about 4 or 5 feet below bed 59 contains less than 2 feet of coal.

Bed 60–B overlies bed 59 and was traced from the east side of sec. 13 to the west side of sec. 11, where it enters the alluvium bordering Big Ditch. In most places where a complete section of the bed was obtained it consists of a lower bench made up of alternating beds of coal and shale, above which occurs an unbroken bench of coal about 2 feet thick. Measurements of the bed are represented on Plate 15 by graphic sections 588 to 593.

Bed 61 was traced from the north side of sec. 4 to the southwest corner of sec. 3, where it passes beneath the alluvium of Big Ditch.

Its maximum observed thickness in this township is 3 feet 8 inches at location 608, in the NW. ¼ sec. 4.

Bed 63 is less than 50 feet above bed 61 and has about the same horizontal extent. It is about 2 feet thick in this township, as shown by sections 628 to 631 in plate 15.

Bed 64 was traced from the north side of sec. 4 nearly to the east side of sec. 11 and increases in thickness from southeast to northwest. Its thickest bench contains 6 feet 7 inches of coal at location 638 in the SW. ¼ sec. 3. Other measurements of the bed in this township are shown graphically in Plate 15 by sections 636, 637, and 639 to 642.

Bed 65 is not exposed in this township southeast of location 649 in the SW. ¼ sec. 3, but in sec. 7 of the township to the east it contains 12 feet of coal. At location 649 it consists of three benches that have a total thickness of 3 feet 11 inches of coal separated by thin partings of shale. At location 648 it exhibits an unbroken bed of coal 6 feet 9 inches thick.

Several disconnected exposures of coal occur above bed 65 in the northeast corner of the township. As most of these exposures have not been correlated they are treated as lenses. At locations 801 and 802, in the NE. ¼ sec. 12, a bed of bony coal 1 foot 6 inches thick is exposed at approximately the same horizon as that represented in the NE. ¼ sec. 11 by section 800, which may be correlatable, as suggested on the map, with the bed represented by sections 797 to 799 in secs. 2 and 3. This bed nowhere exceeds 2 feet 1 inch in thickness.

Near the north side of sec. 12 a bed of coal 1 foot 1 inch thick is exposed at location 803. This same bed is 1 foot 3 inches thick about one-eighth of a mile east of this township.

A section measured at location 804, in the NE. ¼ sec. 11, shows 11 inches of coal overlain by alternating beds of coal, bone, and shale.

A coal bed exposed at location 806, in the SE. ¼ sec. 2, contains 1 foot of bony coal. At location 805, about half a mile farther west, this bed contains 11 inches of coal and 11 inches of bone and shale with streaks of coal.

In sec. 14 the lower of two thin coal beds is 1 foot 3 inches thick at location 811 and 1 foot 6 inches thick at location 812. The upper bed is 1 foot and 1 foot 3 inches thick, respectively, at locations 813 and 814.

At locations 815 and 816, in the north-central part of sec. 13, the lower of two coal beds above the two beds just described contains about 2 feet of bony coal in two benches. The upper bed consists of alternating layers of coal and shale having an aggregate thickness of about 5 feet, of which 2 feet 2 inches is coal.

At location 274–A, in the NE. ¼ sec. 25, a bed about 3 feet thick crops out. This bed continues eastward but can not be traced west-

ward. At location 818, in the NE. ¼ sec. 26, another isolated exposure shows 1 foot 6 inches of bony coal. At locations 820, in the NW. ¼ sec. 26, and 819, in the SW. ¼ sec. 22, 1 foot 2 inches and 1 foot 3 inches, respectively, of coal is exposed. At location 821, in the western part of sec. 22, 1 foot 8 inches of coal crops out.

An isolated exposure of coal in the eastern part of sec. 18 contains 1 foot 3 inches of bony coal at location 822. Another lens in the SW. ¼ sec. 13 contains about 2 feet of coal and bone at locations 835 and 836.

Bed 67 occurs just above the base of the Hanna formation in the northern part of sec. 3 and is represented in Plate 15 by sections 772 and 773, which show about 2 feet of coal. This bed could not be traced east of location 773.

Several lenses of coal occur adjacent to fault U–U in secs. 1 and 2. Sections of these beds showing a maximum thickness of 2 feet 6 inches of coal are represented in Plate 15 by sections 807 to 810.

T. 23 N., R. 83 W.

The surface of T. 23 N., R. 83 W., is occupied by the Ferris and Hanna formations, which, except for the bad lands along Medicine Bow River, in the northeast corner of the township, have been eroded into a broken and uneven plain. In the southern part of the township the beds dip about 10° NE., and in the northern part about 10° E. and SE., forming a broad, shallow syncline that occupies the area north of Middle Ditch. This simple structure is complicated in the western part of the township by many small normal faults, which have a general northwest trend and are of local extent. In the absence of key beds it was not possible to determine the displacement caused by all the faults or to correlate the coal beds on opposite sides of them.

Fault I–I is largely inferred in this township because of the fact that no coal beds can be traced across its assumed position, as shown on the map. If coal bed 60–A south of the fault is represented north of it by the coal bed sectioned at location 583, in the SE. ¼ sec. 19, as is believed, the horizontal displacement along the fault at this locality is about 1,200 feet, and the beds on the north side of the fault have been shifted northwestward relative to those on the south side.

Faults J–J, K–K, and L–L are thought to be of small magnitude, Faults J–J and K–K are nearly vertical, and the strata on the northeast side have been shifted to the northwest relative to the strata on the southwest side. Fault M–M dips 83° NE., and probably has caused only a small horizontal displacement of the strata.

Fault N–N dips 84° SW. If coal sections 740 and 749 represent the same bed, as is believed, the horizontal displacement along this fault is about 2,400 feet.

Fault O–O is nearly vertical, and may be a continuation of faults U–U to the southeast and T–T to the northwest.

The Ferris formation contains nearly all the coal beds exposed in this township. The coal beds attain a maximum thickness of about 10 feet, but most of them are thin and lenticular and show a marked decrease in thickness from south to north.

The coal beds south of fault I–I are described by numbers, beginning in the southwest corner of the area with the lowest bed, and taking each bed up in ascending order. The beds north of fault I–I could not be correlated, and the descriptions therefore will deal largely with isolated outcrops.

Bed 50–A was measured at locations 489, in the SW. ¼ sec. 19, and contains two benches of coal about 2 feet thick separated by about 2 feet of shale.

Bed 51 is represented in this township at locations 493, in the SW. ¼ sec. 19, and 497, in the SW. ¼ sec. 31, which show respectively 2 feet 8 inches and 7 feet 10 inches of coal. The intervening sections on this bed are shown in Plate 13.

Bed 52 was measured in this township at locations 504 to 507 and 510. At all these locations it contains less than 2 feet of coal.

Bed 60–A is represented south of fault I–I at locations 584 to 587, in secs. 30 and 32, where it has an average thickness of about 4 feet. North of fault I–I it is probably represented at locations 581 to 583, where there is also about 4 feet of coal.

Bed 61 was traced from the southern boundary of the township as far north as fault I–I and is probably the bed found at locations 598 to 601 north of the fault in the eastern part of sec. 19. Sections 598 to 607, Plate 16, show a marked thickening of the bed as traced northward, its maximum thickness of 6 feet 3 inches occurring at location 604, in the SW. ¼ sec. 29.

Bed 63–A is an offshoot of bed 63, which is split by a shale parting 8 feet thick at location 625, in the NE. ¼ sec. 32. Bed 63–A is over 5 feet thick at locations 619 and 620, in the western part of sec. 20, and 6 feet thick at location 621, in the NW. ¼ sec. 29. At location 622, in the SW. ¼ sec. 29 it contains two benches of coal, each about 4 feet thick, separated by 6 feet 2 inches of shale.

Bed 63 was traced from fault I–I southward into T. 22 N., R. 83 W. At location 626, in the SE. ¼ sec. 32, it contains 4 feet 4 inches of coal, and at location 625, in the NE. ¼ sec. 32, it is split into two beds, the upper of which, bed 63, is 4 feet 3 inches thick, and the lower, bed 63–A, is 7 feet 10 inches thick, with a 4-inch parting in the lower part. North of location 625 it decreases in thickness and contains less than 3 feet of coal at locations 623 and 624, in sec. 29.

Bed 64 ranges in thickness from 5 feet 11 inches at location 634, in the NE. ¼ sec. 32, to 4 feet 10 inches at location 635, in the

SW. ¼ sec. 33. In most places, however, it contains a small amount of bony coal.

Bed 65 is not well exposed in this township and can be traced with reasonable certainty only as far north as fault I–I. Locations 643 to 645, between faults L–L and M–M, in secs. 20 and 29, are probably on this bed. Its maximum thickness for this township is about 9 feet at location 647, in the SW. ¼ sec. 33, and its minimum thickness 3 feet 5 inches at location 643, in the SE. ¼ sec. 20.

The lowest coal lens in the township is represented at location 676, in the NW. ¼ sec. 6, where there is 2 feet 6 inches of coal. Other lenses in secs. 6 and 7 exhibit from 1 to 4 feet of coal at locations 681, 685, 688, 699, and 700 to 711. Measurements of the coal at almost all these locations are shown graphically in Plate 16.

The lowest lens of coal in sec. 18 contains less than 2 feet of bony coal at locations 716 to 718. The overlying lens contains no workable coal at locations 714 and 715 but is over 3 feet thick at locations 712 and 713. Sections 722 and 723 represent two small lenses exposed between faults K–K and M–M in the SE. ¼ sec. 18. The maximum amount of coal in any one bench at these locations is less than 3 feet. Within the same fault block is another lens of coal represented by sections 719 to 721, which show from 2 feet 4 inches to about 7 feet of coal. (See pl. 16.)

At location 724, in the southern part of sec. 19, a lens contains 1 foot 4 inches of coal. Another lens contains 1 foot 2 inches of bony coal at location 725, in the NE. ¼ sec. 19. At location 726, in the SW. ¼ sec. 30, 4 feet of clean coal crops out south of fault H–H, but the bed could not be traced either north or south of this location.

At locations 727 to 730, in sec. 8, a lens contains from 1 foot to 2 feet 3 inches of coal. An overlying lens extends southward into sec. 17 and shows a minimum thickness of 1 foot 8 inches of coal and a maximum thickness of 4 feet 5 inches at locations 731 to 735.

The lens of coal represented by sections 736 and 737 in sec. 17 and 738 in sec. 20 ranges in thickness from 1 foot at location 737 to 4 feet 1 inch at location 738. An overlying lens contains 5 feet of coal at location 739 and 4 feet 3 inches at location 740. Sections exhibiting 1 foot 6 inches were measured on a still higher lens at locations 741 and 742.

Sections 743 and 745 represent uncorrelated exposures of coal between faults K–K, L–L, and M–M in the western part of sec. 20. These sections show from 4 to 5 feet of coal.

North of North Ditch four coal lenses included between faults M–M and N–N show a maximum thickness of 4 feet 8 inches of coal at locations 746 to 752, as shown by the corresponding graphic sections in Plate 16. South of North Ditch two lenses exposed west of

fault K–K in the SW. ¼ sec. 20 shows 4 feet and 5 feet 9 inches of coal, respectively, at locations 753 and 754. Other lenses exposed south of North Ditch in sec. 20 range in thickness from a foot or less of bony coal to over 5 feet of coal at locations 755 to 759. (See pl. 16.) At locations 760 and 761 only carbonaceous shale is exposed.

At location 762, in the NE.¼ sec. 29, a coal lens contains 2 feet 8 inches of coal.

Bed 67, the lowest coal bed in the Hanna formation in this township, is represented by several isolated outcrops which are intersected by faults. Measurements of it made at locations 763 to 771 and represented graphically in Plate 16 show an average thickness of about 3 feet in this township.

Bed 67–A occurs 15 feet above bed 67 and ranges in thickness from less than 1 foot to almost 5 feet, as shown by graphic sections 774 to 778, Plate 16.

Bed 68 is the lowest of two closely associated beds which were mapped east of fault O–O in the central part of the township. It has a minimum thickness of less than 1 foot and a maximum thickness of over 3 feet, as shown by graphic sections 779 to 786, Plate 16.

Bed 69 directly overlies bed 68 and is less than 2 feet thick, as shown by graphic sections 787 to 791, Plate 16.

Measurements of lenses in secs. 34 and 35 which show less than 3 feet of coal are represented in Plate 16 by graphic sections 792 to 796.

T. 24 N., R. 83 W.

In the northern part of T. 24 N., R. 83 W., two hogbacks formed by the vertical sandstones in the Mesaverde and Medicine Bow formations rise several hundred feet above an intervening valley of Lewis shale. In the central and southern parts of the township the Ferris and Hanna formations dip 5°–20° SE. and have been deeply trenched by Medicine Bow River and its tributaries.

Bed 112–B, the only numbered coal bed in the Mesaverde formation in this township, is represented in Plate 17 by a single section, measured at location 1479, in the NE. ¼ sec. 6, which shows 6 feet of coal. The bed could not be traced east of this locality.

A coal lens just below bed 112–B contains 4 feet of coal at location 1493 and 5 feet 6 inches at location 1492. A still lower bed contains about 4 feet of good coal at location 1491, but is too bony to be of any value at locations 1489 and 1490. The lowest bed in the Mesaverde contains about 2 feet of coal at locations 1487 and 1488.

Bed 113, the lowest bed in the Medicine Bow formation in this township, is not well exposed, as it occurs at the base of the steep ridge which marks the base of the formation. Measurements of it

made at locations 1497 to 1499 show from 1 foot 8 inches to 3 feet 5 inches of coal.

Bed 114 is about 150 feet above bed 113. At location 1509, in the NE. ¼ sec. 11, it contains three benches of coal having thicknesses of 1 foot 10 inches, 3 feet 8 inches, and 4 feet 6 inches, separated by beds of shale and sandstone 5 feet and 3 feet thick. At locations 1504 to 1508 and 1510 it contains from 10 inches to 3 feet 10 inches of coal.

Bed 115 was not recognized west of sec. 3. In each of the three sections measured at locations 1514 to 1516, in secs. 10, 11, and 12, respectively, it is about 2 feet thick, but at location 1514 1 foot 3 inches of coal occurs 30 feet lower in the section.

Bed 116 is the thickest bed of coal in the Medicine Bow formation in the township and is mined for local use at location 1526, in the NE. ¼ sec. 11. An analysis of a sample taken from the mine at this location is given on page 35. Measurements of bed 116 made at locations 1522 to 1527 and shown graphically in Plate 17 exhibit several benches of coal separated by partings of shale and sandstone. The thickest individual bench contains 6 feet of coal at location 1524, in the NE. ¼ sec. 4.

From location 1537, in the SE. ¼ sec. 12, westward to location 1535, in the NW. ¼ sec. 11, bed 117 ranges from 5 feet to 7 feet 4 inches in thickness, as shown by the corresponding graphic sections in Plate 17. At locations 1533 and 1534, in the SE. ¼ sec. 6 and the SW. ¼ sec. 4, respectively, it is about 2 feet thick.

Bed 118 contains 1 foot 8 inches of coal at location 1549, in the NE. ¼ sec. 11, and 5 feet 2 inches of coal at location 1547, in the SW. ¼ sec. 4. These and intermediate measurements are shown graphically in Plate 17. A bed designated bed 118–A overlies bed 118 in the SE. ¼ sec. 6 and contains 1 foot of coal at location 1545.

Bed 119 crops out between location 1558, in the SW. ¼ sec. 5, and location 1561, in the NW. ¼ sec. 11. Measurements made of these and intermediate locations exhibit from 1 foot 4 inches to 3 feet 10 inches of coal, as shown in Plate 17.

Bed 120 has about the same distribution as bed 119 and contains about 2 feet of coal at locations 1565 to 1567.

At locations 1582 and 1583, in secs. 5 and 7, two beds of coal each about 1 foot 6 inches thick are separated by about 22 feet of shale and sandstone.

The coals in the Ferris formation in this township are equivalent to the lower Ferris coals mapped in T. 23 N., Rs. 83 and 84 W., but it is impossible to correlate the beds between the two places. These beds are more or less irregular and show a tendency to split up into several benches or be replaced by shale.

Bed 122 is the lowest numbered Ferris coal in the township and crops out for a distance of about 2 miles in secs. 21 and 29. At location 1585, in the NW. ¼ sec. 29, it has a maximum thickness of 17 feet 8 inches of coal. Smaller measurements of it are shown graphically in Plate 17.

Bed 123 has about the same distribution as bed 122 and likewise is concealed by terrace gravel east of sec. 21. At location 1590, in the SW. ¼ sec. 29, it contains over 15 feet of clean coal, and the base of the bed is cut off by a small fault. Smaller measurements of it are shown graphically in Plate 17 by sections 1591 to 1596.

Between locations 1603, in the SE. ¼ sec. 21, and 1608, in the NE. ¼ sec. 22, bed 124 is from 2 to 4 feet thick. West of location 1603, however, it becomes thicker, and at location 1598, in the SE. ¼ sec. 30, it contains about 15 feet of coal. Other sections of this bed are shown graphically in Plate 17.

Bed 125 is an offshoot from bed 124 between locations 1597 and 1598, in secs. 31 and 30, respectively. Measurements of it made at locations 1573 to 1575 show a maximum thickness of over 8 feet of coal.

Bed 126 crops out in secs. 30 and 31 and contains less than 3 feet of coal at locations 1578 to 1581.

Bed 127–A apparently represents the upper part of bed 127, with which it unites in the western part of the township. Sections of it given in Plate 17 show a maximum thickness for this township of 16 feet of coal at location 1615, in the NW. ¼ sec. 28, and a minimum thickness of about 1 foot at location 1618, in the SE. ¼ sec. 22.

At location 1612, in the SE. ¼ sec. 29, bed 127 contains 3 feet of coal, but at points on both sides of this location no coal was found at its horizon. A coal bed over 8 feet 6 inches thick at location 1611, in the SW. ¼ sec. 29, probably respresents bed 127–A.

So far as known, bed 128 occurs only in sec. 31. Sections of it at locations 1619 to 1621 show a maximum thickness of 6 feet of coal.

Bed 129 is thin and bony, as shown by sections 1622 to 1629, Plate 17. Its maximum thickness of 3 feet 10 inches occurs at location 1627, in the NE. ¼ sec. 28.

Bed 130 contains 5 feet 7 inches and 5 feet 6 inches of coal, respectively, at locations 1630 and 1631, in the SE. ¼ sec. 31. A mile farther east it consists of carbonaceous shale.

At location 1632, in the NW. ¼ sec. 32, a lens between beds 129 and 130 contains 8 feet of coal. No coal was found, however, at this horizon elsewhere. At location 1633, in the SW. ¼ sec. 31, another lens is over 3 feet thick.

A lens between 122 and 123 contains 5 feet 7 inches of coal at location 1635, in the NW. ¼ sec. 29, and 10 feet of coal at location 1634.

A lens below bed 122 in secs. 20 and 29 contains less than 2 feet of coal in any individual bench at locations 1636 to 1638. A still lower lens contains 3 feet 9 inches of coal at location 1639, in the SE. ¼ sec. 20, and 2 feet of coal broken by a bone parting 6 inches thick at location 1640.

At location 1642, in the SE. ¼ sec. 20, a bed of coal 3 feet thick, 4 inches of which is bone, crops out in the east bank of Medicine Bow River. At location 1641 a bed somewhat higher in the section contains 3 feet of coal.

T. 21 N., R. 82 W.

In Pass Creek Ridge, which crosses the southwest corner of T. 21 N., R. 82 W., the heavy sandstones in the Mesaverde formation dip westward beneath the Lewis shale at angles ranging between 30° and 70° and are overlapped on the north side of the ridge by the North Park formation, which occupies a syncline lying between the ridge and the outcrops of the Ferris and Hanna formations along the northern boundary of the township. Except for Pass Creek Ridge, where a maximum altitude of 7,905 feet is attained, the surface of the township is for the most part comparatively level and has an altitude ranging between 6,800 and 7,100 feet.

All the coal in this township occurs in the Ferris formation along the northern boundary of the township. The coal beds are poorly exposed, and most of the outcrop lines shown on the map have been projected from the township to the north. The coal sections measured in this township are exhibited graphically in Plate 18.

The Lower Dana bed occurs about 50 feet below the Dana bed at the old Dana mine, in the NE. ¼ sec. 5. A section of the Dana bed measured here by Veatch in 1906 shows 11 feet 2 inches of coal, with a thin parting of shale near the middle. North of this location it becomes thinner and more broken.

The only other coal beds exposed in the township are beds 61–A and 65, which show 3 feet and 8 feet 6 inches, respectively, of coal at locations 618 and 655, in the northern part of sec. 3. Bed 65, however, is split by a shale parting 4 feet 6 inches thick.

T. 22 N., R. 82 W.

The surface of T. 22 N., R. 82 W., is occupied by the Ferris and Hanna formations and is very rugged and broken. In the northwestern part of the township the base of the Hanna formation is marked by a conspicuous sandstone escarpment that trends in an east-west direction and rises about 600 feet above Big Ditch, which crosses the central part of the township. This escarpment veers to the south in sec. 10 and becomes inconspicuous in the broken country south of the railroad. In the northwestern part of the township the beds dip

6°–16° N.; elsewhere they dip 8°–25° E. and NE. Faulting on a small scale has occurred in the northeastern part of the township.

The Lower Dana bed, the lowest coal bed in the Ferris formation, occurs at location 277, in the SE. ¼ sec. 32, where it contains 3 feet 1 inch of coal. Farther north, at locations 274 to 276, it averages about 2 feet in thickness, as shown by the corresponding graphic sections in Plate 18. This bed has about the same stratigraphic position as bed 21 of T. 22 N., R. 83 W., but it could not be traced between the two places.

The Dana bed at location 281, about half a mile north of the old Dana mine, is split by several partings of shale, bone, or dirty coal, so that it contains a lower bench of coal 4 feet 6 inches thick and an upper bench 2 feet 10 inches thick. At locations 278 to 280 it is much thinner, as shown by the corresponding graphic sections in Plate 18.

A bed that is probably bed 23–A of T. 22 N., R. 83 W., contains 1 foot 8 inches of coal at location 243, in the NW. ¼ sec. 30. At location 244, 1½ miles farther southeast another bed at about this horizon contains 2 feet 6 inches of coal.

Bed 25–A is about 500 feet above the Dana bed and occurs in a strike valley filled with wash derived from near-by ridges. Only one measurement of the bed was obtained in the township, at location 267, in the SW. ¼ sec. 29, which shows 7 feet of coal.

Bed 26 is about 100 feet above bed 25–A and occurs near the crest of the ridge that forms the northeastern boundary of the valley occupied by bed 25–A. Sections of it measured at locations 271 and 272, in the SW. ¼ sec. 19 and the SW. ¼ sec. 29, respectively, contain between 8 and 9 feet of coal broken by one or two thin partings.

Bed 28–A is represented in this township by sections 314 and 315, each of which contains about 1 foot 6 inches of coal.

Bed 30 contains 1 foot 7 inches of coal at location 334, in the SW. ¼ sec. 19, but at location 335, half a mile farther east, it consists chiefly of carbonaceous shale.

Bed 31 crops out only in sec. 19, of this township and contains from one to three benches of coal, each about 3 feet thick, as shown by graphic sections 358 and 359, Plate 18.

Bed 34, like beds 30 and 31, occurs only in sec. 19 and contains 1 foot 6 inches of coal at location 378. At location 379, less than half a mile farther east, it is less than 1 foot thick.

Bed 49, which ranges from 1 foot to 3 feet 5 inches in thickness in the township to the west, contains 1 foot 5 inches of coal at locations 472 and 473, in secs. 19 and 20, respectively. At location 474, in the NE. ¼ sec. 29, it contains chiefly of shale.

Bed 50 is a thick bed of coal that is commonly split by numerous shale partings and associated with thick beds of carbonaceous shale.

At location 486, in the NE. ¼ sec. 20, it contains 19 feet 6 inches of coal separated into three benches by shale partings 2 inches thick. Above this, thin layers of coal alternate with beds of shale through a vertical distance of 20 feet. Smaller measurements of bed 50 in this township are shown graphically in Plate 18 by sections 485, 487, and 488. Between location 485 and the western edge of the township, bed 50 is concealed beneath alluvium and gravel in the valley of Big Ditch.

Bed 56 occurs about 100 feet above bed 55 and consists of several benches of coal split by shale partings. Altogether it contains over 15 feet of coal at location 535, in the SW. ¼ sec. 21, but is thinner elsewhere in the township, as shown by the graphic sections in Plate 18.

Bed 57 contains 1 foot 3 inches of coal at location 548, in the NE. ¼ sec. 28. North of this location it increases regularly in thickness and becomes almost 4 feet thick at location 542, in the SW. ¼ sec. 18. West of location 542 it thins rapidly until at location 541, in the SW. ¼ sec. 18, it contains about 1 foot of coal.

Bed 58 has its principal development in the township to the west and contains less than 2 feet of coal at locations 557 and 558, in the western part of sec. 18.

Bed 59 usually consists of two benches of coal, each about 2 feet thick, separated by a shale parting about 1 foot thick. Measurements of the bed in this township are shown graphically in Plate 18 by sections 563 to 575.

Bed 60 was traced about 3 miles north of Big Ditch. At location 580, in the NE. ¼ sec. 21, it contains 3 feet 8 inches of coal, below which are several thinner coal beds alternating with beds of shale. Elsewhere in the township it is less than 2 feet thick and much split up by partings, as shown by graphic sections 576 to 579, Plate 18.

Bed 60–B occurs a short distance above bed 60 and may be equivalent to bed 60–A of areas farther west. Its average thickness in this township is about 2 feet, as shown by graphic sections 594 to 597, Plate 18.

Bed 61–A is about 150 feet above bed 60 and at about the horizon of bed 61 of the township to the west. Measurements of it ranging between 1 foot 8 inches and 5 feet are shown graphically in Plate 18 by sections 611 to 618.

Bed 65 is commonly concealed in a valley lying between resistant beds of sandstone. It is well exposed, however, in the railroad cut at location 654, in the NW. ¼ sec. 34, and is about 12 feet thick; the lower 5 feet 6 inches is free from partings, and the remainder is split by several thin partings. Other measurements of it showing from

1 foot 7 inches to 12 feet of coal are shown in Plate 18 by graphic sections 650 to 653 and 655.

Bed 66 occurs near the top of the Ferris formation in the central part of the township. Measurements of it made at locations 661 to 670 average about 2 feet in thickness.

A lens just below bed 66 in secs. 15 and 22 contains a maximum thickness of 2 feet of coal at locations 656 to 658. Another lens showing about 2 feet of coal crops out at locations 659 and 660, in the western part of sec. 34.

The Brooks bed is about 175 feet above the base of the Hanna formation and extends northward from location 834, in the NE. ¼ sec. 27, as far as the fault in sec. 6. Measurements of it in this township, represented graphically in Plate 18 by sections 824 to 834, show from 3 feet to almost 7 feet of coal.

Bed 70 consists of two coal beds each about 2 feet thick, separated by about 7 feet of shale, as shown by graphic sections 837 to 841 in Plate 18.

Bed 71 lies a short distance below the Hanna No. 5 bed in the faulted area in the northeastern part of the township. Sections of it measured at locations 842 to 844 show about 2 feet of coal.

Bed 72 immediately overlies bed 71 and is very variable in thickness, as shown by graphic sections 849 to 855, Plate 18. Its maximum thickness of 4 feet occurs at location 854, in the SW. ¼ sec. 24.

The Hanna No. 5 bed is the lowest thick bed of coal in the Hanna formation and has been extensively prospected by the Union Pacific Coal Co. In the faulted area in the northeast corner of the township the partings that are present in the bed farther south become thicker and give rise to several coal beds. This splitting up of the bed, together with the faulted structure, makes it difficult to correlate exposures correctly. However, it is certain that the bed deteriorates in thickness and quality toward the north and is finally replaced by shale and sandstone. At location 878, in the NW. ¼ sec. 25, it consists of three benches of coal, the upper of which is 12 feet thick and contains only one thin parting. This bench is separated by 5 feet of shale from the middle bench, which is 7 feet thick. This is followed by 3 feet 5 inches of shale, below which is 1 foot 4 inches of coal. North of location 878 as far as fault W–W it maintains a total thickness of 29 to 34 feet and is commonly divided into three benches, the upper of which is 10 to 14 feet thick and is in some places broken by one or more thin partings. At locations 866 and 867, in sec. 12, 7 feet 4 inches and 5 feet 2 inches, respectively, of coal was found, but it seems probable that these sections represent only a part of the bed. At location 865 its total thickness is 2 feet, but a considerable proportion of this thickness consists of carbonaceous shale, and the thickest bench of coal is 3 feet 3 inches thick.

North of location 865, in the SE. ¼ sec. 1, it is broken into several distinct benches.

At locations 879 and 880, in the SW. ¼ sec. 6, a coal lens contains about 3 feet of coal. Another lens traced northward from the central part of sec. 14 contains as much as 2 feet 9 inches of coal at locations 881 to 886. At location 887, in the SW. ¼ sec. 1, a lens which may possibly represent bed 70 contains 1 foot 6 inches of coal. At location 888, in the SE. ¼ sec. 1, four benches of coal are exposed which in descending order have thicknesses of 4 feet 2 inches, 2 feet 2 inches, 1 foot, and 1 foot 6 inches. These benches are separated by beds of sandstone and shale ranging from 4 to 10 feet in thickness.

Measurements of a thick carbonaceous shale bed above the Hanna No. 5 bed at locations 889 to 893, in this and the adjoining township on the east, show from 11 inches to 7 feet of coal, but the thicker coal beds are considerably broken by partings.

At location 896, in the SE. ¼ sec. 13, two coal beds less than 2 feet thick are separated by 3½ feet of shale.

At location 897, in the eastern part of sec. 24, an upper bed of coal 1 foot 6 inches thick is separated from a lower bed 1 foot 3 inches thick by 5 feet 6 inches of shale. These beds may represent bed 74, which has been traced northward for several miles but which is of no value south of the railroad.

T. 23 N., R. 82 W.

Except for the small amount of alluvium along North and Middle Ditches and Medicine Bow River, the surface of T. 23 N., R. 82 W., is occupied by the Hanna formation, which dips 6°–12° E. or NE. Picturesque badlands characterize a belt about 2 miles wide south of the Medicine Bow, and a similar though less marked type of topography occurs in the southeast corner of the township.

The two thick benches of the Hanna No. 5 coal bed mapped in townships to the east and south are largely replaced by shale and bone in secs. 24 and 25, as shown by graphic sections 856 to 859, Plate 19. The thickest bench contains 4 feet of coal at location 859, in the SE. ¼ sec. 25.

At location 964, in the SE. ¼ sec. 12, bed 78 contains almost 11 feet of coal split by a shale parting 3 feet thick. At location 962, about a mile to the northwest, it exhibits only shale, bone, and conglomerate.

At location 987, in the center of sec. 12, bed 80 contains two benches of coal, each about 1 foot thick, separated by 8 inches of shale.

At locations 899 to 903, in sec. 32, a lens contains from 1 to 5 feet of coal, as shown by the corresponding graphic sections in Plate 19. Another lens contains 2 feet of coal at its top and three benches of bony coals below at location 898, in the NE. ¼ sec. 24.

T. 24 N., R. 82 W.

Prominent hogback ridges are formed by highly inclined beds in the Mesaverde, Medicine Bow, Ferris, and Hanna (basal part) formations faulted against the rugged granitic masses of the Shirley Mountains, in the northern part of T. 24 N., R. 82 W. Between the southernmost Hanna hogback and Medicine Bow River the Hanna beds flatten out and are eroded into badlands, which become more accentuated toward the river. Formations older than the Mesaverde crop out east of the great fault in the northeastern part of the township, and a conspicuous outlier of the overcapping North Park formation occurs in sec. 11.

Coal occurs in this township only in the Medicine Bow formation. The coal beds in the Mesaverde formation are represented by beds of carbonaceous shale, and those in the Hanna formation by the coarse sediments characteristic of the formation along the northern margin of the Hanna Basin; the Ferris coals are concealed beneath the Hanna overlap.

Bed 114 contains 8 feet of coal at location 1513, in the NW. ¼ sec. 9, and about 3 feet of coal at locations 1511 and 1512, in sec. 8. No coal was found at its horizon east of location 1513.

Bed 115 contains from 2 to 4 feet of coal at locations 1517 to 1519, as shown by the corresponding graphic sections in Plate 19.

Bed 116 is from 5 to 7 feet thick at locations 1528 to 1530, in sec. 8. Another coal bed from 2 to 4 feet thick occurs about 30 feet below bed 116 at locations 1529 and 1530 and has been mined for local use at location 1530.

Bed 117 contains less than 2 feet of coal at locations 1538 to 1541, as shown by the corresponding graphic sections in Plate 19.

Bed 118 is 5 feet thick at location 1553, in the SE. ¼ sec. 8, but is only 8 inches thick at location 1552, in the SW. ¼ sec. 8. Good exposures east of location 1554, in the SW. ¼ sec. 9, show no coal at this horizon.

The lowest isolated exposure of coal in the township occurs at location 1643, in the SE. ¼ sec. 8, and exhibits about 2 feet of coal. Another lens measured at locations 1644 to 1646 has a maximum thickness of 3 feet 6 inches of coal. The bed which contains 7 feet of coal at locations 1647, in the SW. ¼ sec. 3, may also represent this lens.

At locations 1648 to 1650, in secs. 8 and 9, a lens contains from 2 to 6 feet of coal. At location 1651, in the SE. ¼ sec. 8, an upper bed of coal over 10 feet thick is separated by 19 feet of sandstone and shale from a lower bed 6 feet thick. This abnormally thick section is probably a local thickening caused by the squeezing and buckling of the strata.

Sections 1652 and 1653, in secs. 8 and 9, show 3 feet 4 inches and 5 feet, respectively, of coal in a bed occurring just below bed 114. Sections 1655 and 1654, in secs. 7 and 8, are measurements of a bed lying between beds 117 and 118 and exhibit about 1 and 5 feet, respectively, of coal.

T. 21 N., R. 81 W.

The north end of the Elk Mountain anticline is outlined by the steeply dipping sandstones of the Mesaverde formation in the southern part of T. 21 N., R. 81 W., and rises about 500 feet above the surrounding lowlands of Lewis shale. The remainder of the township is occupied by the Medicine Bow, Ferris, Hanna, and North Park formations, all of which, except the North Park, occupy areas of variable relief and dip 10°–86° NW., toward the center of the Hanna Basin.

Bed 94, in the Mesaverde formation, contains 2 feet 6 inches of coal at location 1239, in the NE. ¼ sec. 36, on the west limb of the Saddleback Hills anticline, but was not observed in the Elk Mountain anticline in this township.

Bed 95, in the Medicine Bow formation, averages about 2 feet 4 inches in thickness at locations 1245 to 1248, as shown by the corresponding graphic sections in Plate 22.

Bed 96 contains three benches of coal less than 1 foot thick at location 1252, in the NE. ¼ sec. 13. Sections of this bed farthest southwest, at locations 1249 to 1251, show less than 3 feet of coal.

Bed 97 contains 1 foot 7 inches of coal at location 1267, in the NE. ¼ sec. 13, but at locations 1265 and 1266, in sec. 22, it contains about 4 feet of coal.

Bed 98 is from 6 inches to 2 feet thick at locations 1270 and 1271, in sec. 13, but was not recognized west of the fault in secs. 13 and 14.

T. 22 N., R. 81 W.

North of the railroad in T. 22 N., R. 81 W., the Hanna formation has been much dissected, and nearly all the larger coulees are bordered by one or more conspicuous sandstone rim rocks. Several hills that rise as much as 700 feet above the railroad also characterize this part of the township. South of the railroad the surface is much less rugged.

The main structural feature in the township is the Hanna syncline, which crosses the township in a northeasterly direction and is separated from a larger and more irregular basin to the northeast by a slight transverse upwarp along the northern boundary of the township. The Hanna beds on the west limb of the Hanna syncline dip eastward at angles which gradually decrease from 23° in the western part of the township to horizontality in the center of the depression.

East of the cynclinal axis, however, the beds are sharply upturned to about 35° and then gradually diminish in dip to about 12° at the eastern margin of the township. Besides being tilted and folded, the beds have been displaced by many small faults, and the horizontal displacement on opposite sides of some of the faults amounts to 2,000 feet. The average displacement, however, is not more than a few hundred feet and decreases toward the axis of the Hanna syncline. The following figures, obtained from the mine superintendent at Hanna, represent the displacements observed along faults in the mines and prospects of the Union Pacific Coal Co. at Hanna:

Fault displacements at Hanna

Fault	Dip	Vertical separation (feet)	Horizontal separation (feet)
W-W	35° NE.	174	170
X-X	67° NE.	157	125
Y-Y	NE.	100	103
Z-Z	82° SW.	100	100

Most of these faults show greater horizontal displacement at the outcrop of the coal beds than underground. In addition to the faults designated above, numerous other faults of small displacement have been encountered in the mines at Hanna. At the abandoned mining camp of Sampo, in sec. 2, two small faults inclose a down-thrown block with but little displacement.

The coal beds exposed in this township occur in the Hanna formation and include beds from No. 72 to the Hanna No. 1 bed. Beds exposed farther west are probably within mining depth in the western part of the township. All the Ferris coals are believed to be over 4,000 feet below the surface of this township.

The Union Pacific Coal Co. has extensively prospected the coal beds with the diamond drill in this and adjoining townships, and though the data obtained by it have been available to the writers, they are considered confidential and are not included in this report.

Bed 72 contains 1 foot 6 inches of coal at location 848, in the NW. ¼ sec. 7, but was not measured elsewhere in the township.

The Hanna No. 5 bed crops out in secs. 6 and 7 of this township and consists of five benches of coal, distributed through an interval of about 30 feet and separated by beds of carbonaceous shale and sandstone. Graphic sections of this bed in Plate 20 show that the thickest individual bench contains 6 feet of coal at location 864, in the NE. ¼ sec. 7.

Just below the bed sectioned at location 889, in the NW. ¼ sec. 7, the lower of two other coal beds contains 1 foot 8 inches of coal at location 894 and the upper 7 feet 6 inches of coal at location

895. These beds may represent a part of the Hanna No. 5 bed, but because of faulting and the lack of key rocks this can not be demonstrated.

Bed 73 is offset by each of the faults north of fault X–X but could not be recognized south of this fault. It ranges from 1 foot 5 inches to 5 feet in thickness and is either bony or split by several partings of shale, as shown by graphic sections 906 to 910, Plate 20.

Bed 74 lies about 80 feet above bed 73 and crops out between fault W–W and the northern border of the township. At location 918, in the SW. ¼ sec. 18, it contains about 18 feet of coal split by four partings of shale and sandstone, of which the thickest is 4 feet thick. Smaller measurements of bed 74 in this township are represented graphically in Plate 20 by sections 914 to 917.

Bed 75 lies about 150 feet above bed 74 and extends from the northern border of the township southward as far as the small fault just south of fault Z–Z. Sections of it measured at locations 922 to 924 and represented graphically in Plate 20 show alternating beds of shale and coal distributed through a vertical interval of about 15 feet, but the only valuable coal occurs at location 922, in the NE. ¼ sec. 5.

Bed 76 occurs about 50 feet above bed 75 and is of value only north of Big Ditch. At location 932, in the center of sec. 18, it contains eight coal beds distributed through a vertical interval of 35 feet. The individual beds range in thickness from 7 inches to over 6 feet. Other fairly thick measurements of the bed showing either a greater or less amount of coal in individual benches are shown graphically in Plate 20 by sections 928 to 931, 933, and 934.

The Hanna No. 2 bed is the thickest coal bed in the township. Its outcrop enters the township near the southwest corner of sec. 19 and trends northwestward to and beyond the township border in the NE. ¼ sec. 5. In the Nos. 2 and 4 mines of the Union Pacific Coal Co., in the NW. ¼ sec. 19 and the SW. ¼ sec. 18, respectively, it is about 35 feet thick and contains several shale partings each about 1 foot thick. Two miles south of the No. 2 mine it is reported to be only 12 feet thick. North of the No. 4 mine its outcrop is usually burned, but measurements of part of the bed showing 25 and 30 feet of coal, respectively, at locations 959, in the NE. ¼ sec. 8, and 960 in the NW. ¼ sec. 17, suggest that its thickness remains constant as far as the northern boundary of the township.

The outcrop of bed 77 trends northeastward from fault X–X and leaves the township near the northwest corner of sec. 3. Sections of it measured at locations 944 to 958 and represented graphically in Plate 20 show that it has a variable thickness in this township and

contains many partings of shale. The thickest individual bench contains almost 9 feet of coal at location 948 in the NE. ¼ sec. 17.

Bed 78 is about 150 feet above bed 77 and has been extensively prospected in the vicinity of Hanna by the Union Pacific Coal Co. Between locations 968 in the SW. ¼ sec. 3, and 984 in the SW. ¼ sec. 19, it contains from 6 to 27 feet of coal, as shown by the corresponding graphic sections in Plate 20. In many of these sections the coal is broken into several benches by partings of bone or shale that attain a maximum thickness of 4 feet, but generally one bench of coal 6 to 10 feet thick is present. Between locations 984a and 986, in the southwest corner of the township, bed 78 contains two benches of coal about 2 feet thick separated by a bed of shale of about the same thickness.

Bed 77–A occurs in secs. 10, 11, and 15, in the eastern limb of the Hanna syncline, and is approximately equivalent to bed 77, which crops out in the western limb of the syncline. It contains one bench of coal about 2 feet thick and several thinner ones separated by greater thicknesses of shale, as shown by graphic sections 1089 to 1091, Plate 20.

Bed 78–A is probably the same as bed 78 in the western limb of the Hanna syncline. South of the railroad, at locations 1004 to 1006, it contains about an equal amount of shale and coal distributed through an interval of 6 to 21 feet; the thickest individual coal bed is 6 feet thick at location 1004, in the NE. ¼ sec. 28. Immediately north of the railroad, however, it consists of three beds ranging through an interval of about 170 feet. Still farther northeast these beds merge into one thick bench of carbonaceous shale about 40 feet thick, which contains several benches of coal. North of Sampo the bed again splits into two members, the outcrops of which are rather widely separated because of the smaller dips. The upper member is designated bed 78–B and contains 6 feet of coal in four benches separated by thin partings of shale and bony coal at location 1024 in the SE. ¼ sec. 2. Other measurements showing the characteristics of bed 78–A, as described above, are represented graphically in Plate 20 by sections 1007 to 1013.

Bed 79–A crops out around the north end of the Hanna syncline and is probably equivalent to one of the beds lying between the Hanna No. 1 bed and bed 78 at the south end of the syncline. It averages about 8 feet in thickness and contains from 2 feet 6 inches to 5 feet 6 inches of coal broken in most places by one or more partings of shale, as shown by graphic sections 1035 to 1040, Plate 20.

Bed 80–A has about the same distribution as Bed 79–A and contains from 3 feet 10 inches to 6 feet 11 inches of undivided coal at lo-

cations 1053 to 1057, as shown by the corresponding graphic sections in Plate 20.

Bed 80–B trends approximately parallel to Bed 80–A and contains about 2 feet of coal, as shown by graphic sections 1058 to 1062, Plate 20.

Bed 80–C is about 35 feet above bed 80–B and consists of two benches of coal about 2 feet thick separated by about 8 feet of shale or sandstone. Measurements of this bed are represented graphically in Plate 20 by sections 1063 to 1066.

Bed 83–A lies about 160 feet above bed 80–C and just below the Hanna No. 1 bed. Measurements of it represented graphically in Plate 20 by sections 1067 to 1074 show thicknesses ranging between 1 and 4 feet.

The Hanna No. 1 bed was first opened up at the Hanna No. 1 mine, in the NW. ¼ sec. 20, and later at Nos. 3 and 3½ mines, in the SW. ¼ sec. 16 and the SE. ¼ sec. 17, respectively. It lies about 800 feet above bed 78 and 1,500 feet above the Hanna No. 2 bed and encircles the Hanna syncline with but few interruptions. The workings of the Nos. 1 and 3 mines have been extended completely across the syncline. The bed has an average thickness of about 23 feet and in some places is comparatively free from partings but in others is divided into many benches by numerous thin partings of shale and bony coal. Measurements of the bed in this township are represented in Plate 20 by graphic sections 1079 to 1084 and 1086 and that at the Hanna No. 1 mine.

Bed 79 crops out in secs. 2 and 3 and probably corresponds to beds 79–A and 80–A, which occur 1 mile farther south. At locations 1041 and 1042, in sec. 2, partial exposures show not less than 5 feet 6 inches of undivided coal, but at locations 1039 a and 1040 a, farther northwest, its full thickness of about 34 feet shows at least five coal beds separated by fairly thick benches of shale, the thickest individual bench of coal being only 5 feet thick.

Numerous disconnected outcrops of coal in this township are grouped under the heading of lenses in Plate 20. The lowest of these stands vertical in the Ferris formation at location 1109, in the NE. ¼ sec. 25, and contains two beds of coal, each about 1 foot thick, separated by a bed of carbonaceous shale 2 feet 4 inches thick.

Sections 1107 and 1108 are measurements of a lens about 2 feet thick lying between beds 77 and 78 in sec. 3. Sections 1103 and 1104 are on the lower of two beds lying between bed 78 and the Hanna No. 1 bed in the southwestern part of the township and show about 2 feet of coal. Another bed immediately overlying the one just described is from 3 to 12 feet thick at locations 1095 to 1099 but contains no individual bench of coal over 5 feet thick. Other meas-

urements of lenses in the southwestern part of the township showing from 1 to 10 feet of coal are represented graphically in Plate 20 by sections 1101, 1102, 1105, and 1106.

A lens which may be equivalent to the Hanna No. 2 bed contains 6 feet of coal separated into two benches by a bed of carbonaceous shale 1 foot 6 inches thick at location 1094, in the NE. ¼ sec. 15. Farther northeast, however, it contains 1 foot or less of coal. Another lens contains about 2 feet of coal at location 1110, near the center of sec. 17.

Sections 889, 891, 894, and 895, in the western part of sec. 7, are shown graphically in Plate 18, for T. 22 N., R. 82 W., in order to show their relations to sections on the same bed in that township. The coal in these lenses ranges from about 2 to 8 feet in thickness.

T. 23 N., R. 81 W.

The Hanna formation occupies the surface of T. 23 N., R. 81 W., and dips 15° NE., toward the center of the structural basin in the northeastern part of the township. Ridges formed by the more resistant Hanna beds cross the township in a northwesterly direction in conformity with the strike of the strata, and rise abruptly above parallel valleys, which either lead directly into Medicine Bow River or into its tributary Willow Spring Draw, a small canyon trending northeastward across the township.

The thick coal beds exposed in T. 22 N., R. 81 W., occur also in this township, but as a rule they contain too many thick partings to be of economic value. The deterioration is caused chiefly by the interfingering from the north of sandstone and conglomerate and the replacing of the coal beds by thick beds of carbonaceous shale.

Bed 72 crops out in the western part of sec. 31 and contains several beds of coal less than 2 feet thick separated by thicker beds of shale at locations 846 and 847. Northwest of location 846 it contains no coal.

At locations 860 and 861, in the NW. ¼ sec. 31, the lower bench of the Hanna No. 5 bed contains 5 feet of coal and the upper bench 2 feet 6 inches of coal. A measurement of the upper bench at location 862, in the SW. ¼ sec. 31, shows about 3 feet of coal, which is bony in the upper part.

Bed 73 is the lowest of four coal beds that underlie the Hanna No. 2 bed in the southwest corner of the township. At locations 904 and 905, in the NW. ¼ sec. 29 and the NW. ¼ sec. 32, respectively, bed 73 is as much as 13 feet thick, but all the individual benches of coal are less than 2 feet 6 inches thick.

Bed 74 lies about 80 feet above bed 73 and contains over 4 feet of coal in a lower bench at location 912, in the NW. ¼ sec. 32. Measurements at locations 911 and 913 showing smaller amounts of coal

are represented graphically in Plate 21. This bed contains no coal northwest of location 911.

Bed 75 occurs about 150 feet above bed 74 and contains less than 2 feet of coal in any individual bench at locations 919 to 921, as shown by the corresponding graphic sections in Plate 21.

Bed 76–A is probably equivalent to bed 76 of the township to the south, but this can not be proved. At location 926, in the northern part of sec. 32, it contains four benches of coal from 1 foot 7 inches to over 3 feet thick, distributed through a vertical interval of 16 feet. At locations 925, in the NW. ¼ sec. 29, and 927, in the SE. ¼ sec. 32, it contains only a few inches of coal.

Although the Hanna No. 2 bed is about 30 feet thick in the township to the south, it contains no coal in Willow Springs Draw, in the NW. ¼ sec. 29, where excellent exposures occur. Between the draw and the southern boundary of the township its outcrop is either concealed in the grass-covered slopes or burned, and no measurements of it could be obtained.

Measurements of bed 77 at locations 937 to 943 are represented by corresponding graphic sections in Plate 21 and show thicknesses ranging between 3 and 28 feet. At all these locations, however, beds of shale and bony coal split the bed into benches that contain from 1 to 11 feet of coal.

Bed 78 is about 150 feet above bed 77 and contains over 15 feet of coal at location 966, near the center of sec. 28. At locations 965, in the SW. ¼ sec. 17, and 967, in the NE. ¼ sec. 33, it contains about 10 feet of coal.

Beds 78–A and 78–B cross the southeast corner of the township and are more fully described under T. 23 N., R. 80 W. Bed 78–A was not sectioned in this township, but a section of bed 78–B at location 1025, in the southern part of sec. 36, contains two benches of coal, each about 4 feet thick, separated by 3 feet of shale.

Bed 79 in this township is probably the same as beds 79–A and 80–A of T. 22 N., R. 81 W. At location 1043, in the SW. ¼ sec. 36, it contains 11 feet of coal, but at all other locations except 1044, where it exhibits 8 feet of coal, it consists of several coal beds less than 2 feet thick separated by beds of shale, as shown by the graphic sections in Plate 21.

Bed 80 in this township is probably the equivalent of beds 81–A and 82–A of T. 22 N., R. 81 W. Measurements of it made at locations 988 to 999 and represented graphically in Plate 21, show thicknesses of coal ranging between 3 and 11 feet.

Bed 81 appears to have the same stratigraphic position as the Hanna No. 1 bed in T. 22 N., R. 81 W., but there is no resemblance between the two beds. At locations 1111 to 1119 it exhibits from 1

to 5 feet of coal, as shown by the corresponding graphic sections in Plate 21.

Bed 82 is a lens about 5 miles long. Sections of it exhibiting from about 2 to 5 feet of coal are represented in Plate 21 by graphic sections 1127 to 1132.

Although bed 83 is of considerable thickness in certain portions of its outcrop in this township, it nowhere contains an individual coal bench as much as 3 feet thick, as shown by graphic sections 1140 to 1143, Plate 21.

Bed 84 contains from 4 to 6 feet of coal at locations 1150 to 1152, near the eastern border of the township, but farther northwest it consists of alternating beds of shale, bony coal, sandstone, and coal, and the coal is nowhere over 3 feet thick, as shown by graphic sections 1147 to 1149, Plate 21.

Bed 85 has about the same distribution and characteristics as bed 84. At location 1159, in the SW. ¼ sec. 13, it consists of 30 feet of carbonaceous shale interstratified with several beds of coal less than 1 foot thick. To the northwest, at locations 1153 to 1158, it consists of alternating beds of carbonaceous shale and coal distributed through a maximum vertical interval of 33 feet and nowhere exhibiting individual benches of coal over 4 feet thick.

Bed 86 is essentially a thick bed of carbonaceous shale and bony coal which locally contains beds of coal 1 foot or less in thickness, as shown by graphic sections 1162 to 1163 a, Plate 21.

Bed 87 occupies an interval of about 30 feet, of which approximately 50 per cent is coal distributed in beds not over 4 feet thick, as shown by graphic sections 1164 to 1166, Plate 21.

As shown by graphic sections 1174 to 1177, Plate 21, bed 88 is a thick bed of carbonaceous shale that contains numerous intercalated beds of coal, none of which exceed 4 feet in thickness.

Bed 89 is of no economic value in this township, although in the township to the east it contains some good coal.

A lens between beds 80 and 81 in the northwestern part of the township contains no bed of clean coal over 1 foot in thickness, as shown by graphic sections 1124 to 1126, Plate 21. Another lens just below bed 82 contains from 6 inches to 4 feet 6 inches of coal at locations 1134 to 1138, as shown by the corresponding graphic sections in Plate 21. Measurements of a lens which splits off bed 83 in the NW. ¼ sec. 23 are represented in Plate 21 by sections 1144 to 1146, which exhibit a maximum thickness of 4 feet of coal broken by one or more partings. At location 1171, in the NE. ¼ sec. 10, a lens overlying bed 86 contains 3 feet 6 inches of coal in its upper part and several beds of coal less than 1 foot thick intercalated with thicker beds of carbonaceous shale in its lower part.

6175—29——6

T. 24 N., RS. 80 AND 81 W.

Except for the small asymmetric anticline in the southeast corner of T. 24 N., R. 81 W., the Hanna formation dips from 3° to 90° S. in T. 24 N., Rs. 80 and 81 W.; the steepest dips occur along the northern margin of its outcrop. Along Medicine Bow River the Hanna beds are dissected into picturesque badlands, but north of the river they occupy a rolling plain. Older rocks down to the Carboniferous occupy the foothills in the unmapped portions of these townships and are complexly folded and faulted.

The coal in these townships occurs in the Hanna formation and is associated with too many thick beds of carbonaceous shale to be of any economic value. Bed 86, the lowest coal, contains about 1 foot of coal at locations 1160 and 1161, in secs. 33 and 32, respectively, T. 24 N., R. 81 W. Bed 87 consists of carbonaceous shale and bone at location 1170, in the SW. ¼ sec. 31, T. 24 N., R. 80 W.

Bed 88 contains as much as 100 feet of carbonaceous shale, interstratified with which are coal beds, ranging from a few inches to 11 feet in thickness, as shown by graphic sections 1172, 1173, and 1180, Plate 19.

Bed 89 also consists of about 100 feet of carbonaceous shale with numerous interstratified beds of coal, as shown by graphic sections 1181 to 1183, Plate 19. Other beds of coal ranging in thickness from a few inches to over 4 feet occur interbedded with greater thicknesses of carbonaceous shale at locations 1188, 1656, 1657, and 1660 to 1662.

TPS. 20 AND 21 N., R. 80 W.

The Saddleback Hills, a long, narrow anticline developed in the resistant sandstones of the Mesaverde formation, attain a maximum altitude of 7,843 feet above sea level in the western part of T. 21 N., R. 80 W., and rise about 500 feet above an encircling valley of Lewis shale. East of the anticline the Lewis shale is overlapped by the Hanna formation, the basal sandstone of which forms a prominent escarpment separating the Lewis shale valley from the uneven uplands included in the Carbon Basin.

The Mesaverde, Lewis, and Medicine Bow beds dip about 65° W. in the western limb of the Saddleback Hills anticline, though in places they stand vertical. In the eastern limb the average dip is a little less, though local exposures show vertical and even overturned beds. (See cross section M–N, pl. 27.) The Hanna beds dip from 10° to 20° toward the center of the Carbon Basin in their southern and western exposures, but lie flat in the center of the basin.

The Mesaverde formation contains five coal beds in various parts of the Saddleback Hills anticline. These beds, with the exception of bed 90, occur near the top and bottom of the uppermost group of

sandstones in the formation and can not be traced continuously because of poor exposures.

Bed 90 occurs near the axis of the anticline and contains a rather persistent bench of coal from 1 to 4 feet thick, broken in many places by partings of shale, as shown by graphic sections 1211 to 1222, Plate 22.

Measurements of bed 91 in the north end of the anticline are represented graphically in Plate 22 by sections 1223 to 1228, which show from 6 inches to 2 feet 6 inches of coal.

Bed 92 is less than 100 feet above bed 91 and contains from 1 foot 7 inches to 3 feet 5 inches of coal at locations 1229 to 1234, as shown by the corresponding graphic sections in Plate 22.

Bed 93 crops out in the eastern limb of the anticline in the northern part of T. 21 N. At location 1237, in the SE. ¼ sec. 9 it exhibits over 6 feet of coal, but elsewhere it is thin or bony, as shown by graphic sections 1235, 1236, and 1238, Plate 22.

A measured section of bed 94 at location 1240, in the SE. ¼ sec. 5, T. 21 N., shows less than 3 feet of coal. This bed does not occur in the eastern limb of the anticline.

At location 1253, in the SE. ¼ sec. 6, T. 21 N., bed 96, the lowest coal in the Medicine Bow formation in this township, contains about 2 feet of coal. Other sections of the bed were not obtained in this township.

Measurements of bed 97 at locations 1268, in the SW. ¼ sec. 7, T. 21 N., and 1269, in the SE. ¼ sec. 6, exhibit less than 2 feet of good coal.

Bed 98 consists of two benches of coal which are 30 feet apart at location 1272, in the SW. ¼ sec. 7, T. 21 N., and 15 feet apart at location 1273, in the SE. ¼ sec. 6. The thickest individual bench occurs at location 1273 and contains 4 feet of coal.

The Johnson bed is the lowest coal in the Hanna formation in these townships and is principally developed along the boundary line between them. At the Wilson mine, in the SE. ¼ sec. 32, T. 21 N., it attains a maximum thickness of 22 feet for these townships. The mine has an entry 250 feet long, 30 feet wide, and 15 feet high, and the coal mined is used by settlers in the general vicinity. An analysis of the coal in this mine is given on page 35. Two entries on the Johnson bed at the Kent mines, in the NW. ¼ sec. 2, T. 20 N., were caved in when examined in 1925. The coal is 14 feet thick in these entries and dips 5° NE. According to settlers, coal was last taken from this mine in the winter of 1923 and was hauled to Medicine Bow in trucks. Other measurements of the Johnson bed in these townships show from 9 to 17 feet of coal, as shown by graphic sections 1290 and 1292 to 1296, Plate 22.

The Finch bed is approximately 100 feet above the Johnson bed at location 1319, in the SE. ¼ sec. 34, T. 21 N., but the interval varies

from place to place. Although the bed can be traced continuously around the southern and western sides of Carbon Basin to a point just north of this township, it is thickest in the southwestern part of the basin, its maximum thickness of 32 feet occurring at location 1312, in the NW. ¼ sec. 28. Other measurements of the bed showing thicknesses ranging between 1 and 27 feet are shown graphically in Plate 22 by sections 1305 to 1311 and 1313 to 1321.

The Johnson mine, on the Finch bed in the SE. ¼ sec. 32, consists of a single entry about 250 feet long and 25 feet wide. Two rooms have been driven off the main entry for about 100 feet. The coal bed is about 13 feet thick, of which 9 feet is mined and the rest left for roof. About 500 tons of coal is mined here annually for local consumption. An analysis of the coal in this mine is given on page 35. The West mine, just west of the Johnson mine, is an entry 75 feet long and 25 feet wide on about 10 feet of coal. About 25 tons annually is mined here for use at the West ranch.

Bed 105 contains about 2 feet of coal at locations 1343 to 1346, in secs. 35 and 36, T. 21 N., and sec. 2, T. 20 N.

North of location 1347 a, in the SE. ¼ sec. 16, T. 21 N., bed 106 and the Finch bed unite and were mapped as one bed. South of location 1347 a, bed 106 ranges between 2 and 4 feet in thickness, as shown by graphic sections 1347 a, 1347 b, 1347 c, and 1347 to 1358, Plate 22.

Bed 107 occurs in the southern part of T. 21 N. and contains less than 2 feet of coal at locations 1364 to 1369, as shown by the corresponding graphic sections in Plate 22.

At location 1376, in the NE. ¼ sec. 27, T. 21 N., bed 108 contains four benches of coal, each less than 2 feet thick, separated by thicker beds of shale. Smaller measurements of the bed in this township are represented graphically in Plate 22 by sections 1371 to 1375 and 1377.

Bed 109 was traced from the Carbon No. 7 mine, near the northeast corner of T. 21 N., along the east and south sides of Carbon Basin, but does not occur along the west side. In the southern part of the basin the bed is associated with thick beds of carbonaceous shale, and it is impossible to tell whether the thickest benches of coal in some of the sections represent a continuous stratum or are more persistent lenses. Measurements of the bed made at locations 1379 to 1386 and 1389 to 1392 and plotted graphically in Plate 22 show that it consists of one or more beds of coal, ranging between 1 and 5 feet in thickness, separated by beds of shale.

Bed 110, like bed 109, is cut in two by Second Sand Creek in secs. 23 and 24, T. 21 N., and contains less than 1 foot of coal at localities 1400 and 1401.

South of Second Sand Creek, at locations 1408 to 1411, bed 111 contains less than 4 feet of coal, as shown by the corresponding graphic sections in Plate 22. At locations 1406 and 1407, north of the creek, its thickest bench contains 2 feet 6 inches of coal.

The Carbon No. 6 bed crosses the northeast corner of T. 21 N. and extends around the north and west sides of Carbon Basin as far south as sec. 10. Sections of it at locations 1417, in the SE. ¼ sec. 3, and 1418, in the NE. ¼ sec. 3, show less than 4 feet of coal.

At location 1437, in the NE. ¼ sec. 6, T. 20 N., a lens of coal between the Johnson and Finch beds contains about 2 feet of coal, but at location 1436, in the center of sec. 32, T. 21 N., it is less than 1 foot thick. Sections 1438 and 1439 are measurements of a bench that splits off from the Finch bed near the southeast corner of sec. 29, T. 21 N., and contains less than 3 feet of coal. Another lens at location 1440, in the SW. ¼ sec. 36, shows 1 foot 6 inches of coal. A lens that splits off from bed 106 in the SE. ¼ sec. 21 was measured at locations 1441 to 1444 and exhibits from 6 inches to 4 feet of coal, as shown by the corresponding sections in Plate 22.

The outlier in the center of sec. 33, T. 21 N., shows 4 feet of coal at location 1445 and may represent bed 106. Another outlier in the SW. ¼ sec. 23 probably represents bed 110 and contains less than 2 feet of coal at location 1446. Sections 1447 to 1450 are on outliers in secs. 22 and 27, and all probably represent the same bed. The thickest individual bench at any of these locations contains less than 2 feet of coal. Section 1451 shows 2 feet 8 inches of coal, which crops out in the small hill near the southwest corner of sec. 15.

T. 22 N., R. 80 W.

The Saddleback Hills anticline plunges northward across the central part of T. 22 N., R. 80 W., and is bordered on the east by the Carbon Basin, which is connected with the Hanna Basin to the northwest by a narrow syncline occupying the northeast corner of the township. (See cross section K–L, pl. 27.) Several small faults with a vertical displacement of less than 100 feet occur in the mines at Carbon, but were not detected elsewhere in the township.

Two prominent landmarks rise above all others in this township. One of these is the high hill of Ferris beds that attains an altitude of 7,419 feet, or 400 feet above the surrounding area, in the SW. ¼ sec. 8, and the other is the Mesaverde ridge at the north end of the Saddleback Hills anticline, which just south of the township line attains an altitude of 7,796 feet, or about 900 feet above the adjoining lowlands of Lewis shale. Except for these features and the escarpments formed by the basal sandstones in the Medicine Bow and Hanna formations, the surface of this township is fairly even.

Coal beds occur in all the formations exposed in the township except the Lewis shale. The most valuable beds, however, are in the Hanna formation.

Bed 94 occurs at the top of the Mesaverde formation in sec. 33 and consists of alternating beds of coal, bony coal, shale, and sandstone ranging through an interval 5 to 18 feet thick. No single bench of coal exceeds 3 feet in thickness, however, as shown by graphic sections 1241 to 1244, Plate 23.

The Medicine Bow coals in this township occur near the base of the formation and are inclined from 30° to 60°. Bed 95–A, the lowest coal, ranges between 10 inches and 5 feet 4 inches in thickness in this township, as shown by graphic sections 1274 to 1282, Plate 23.

Bed 96–A is about 100 feet below bed 96 and is confined to the northern exposures of the formation. Measurements of it made at locations 1283 to 1289 and represented graphically on Plate 23 exhibit from 2 to 4 feet of coal.

Bed 96 is the highest and most valuable Medicine Bow coal in this township. At location 1256, in the SW. ¼ sec. 29, it contains 8 feet 6 inches of coal. Smaller measurements of it made at locations 1254, 1255, and 1257 to 1264 are represented graphically in Plate 23.

Measurements of isolated Medicine Bow coals made at locations 1280 and 1461 to 1462 show 2 feet or less of coal.

At locations 1468 to 1470, in the SW. ¼ sec. 12 and vicinity, alternating beds of coal, shale, and sandstone in the Ferris formation occupy a maximum interval of 17 feet. The corresponding graphic sections in Plate 23, however, show no single bench of coal over 4 feet thick.

The Carbon No. 4 and No. 5 beds are the best coal beds in the Hanna formation in the northern part of the Carbon Basin. The Carbon No. 5 bed is fairly well exposed between the SE. ¼ sec. 22 and the NW. ¼ sec. 13 and contains a maximum thickness of 13 feet of coal at location 1466, in the NW. ¼ sec. 14. Smaller measurements of this bed in this township are represented graphically in Plate 23 by sections 1463 to 1465 and 1467. The Carbon No. 4 bed is about 50 feet above the Carbon No. 5 bed and exhibits 6 feet 6 inches of coal at location 1472, in the center of sec. 14. Nothing comparable to this bed was found elsewhere in the vicinity.

The Carbon No. 6 bed is the one formerly exploited in the Carbon No. 6 mine and probably in the Carbon No. 2 mine. Between location 1423 and the Carbon No. 2 mine it averages about 7 feet in thickness, as shown by the corresponding graphic sections in Plate 23. At location 1426, south of the fault that passes through the No. 2 mine, a bed tentatively correlated with the Carbon No. 6 bed exhibits coal, shale, and carbonaceous shale distributed through an interval of

about 55 feet. Other sections measured at locations 1427 to 1429 show from 2 to 7 feet of coal.

The Carbon No. 7 bed was formerly exploited in the Carbon No. 7 mine, in the SE. ¼ sec. 36, where it was measured and sampled in two places by Veatch in 1906. Sections taken by him about 800 feet from the mouth of the main slope exhibit about 8 feet of coal, as shown by the graphic sections in Plate 23.

Isolated exposures of Hanna coal at locations 1473, in the NE. ¼ sec. 34, and 1205, in the NW. ¼ sec. 4, show less than 2 feet of coal.

T. 23 N., R. 80 W.

A very prominent hogback of Mesaverde sandstone rises abruptly above Steele shale badlands in the northern part of T. 23 N., R. 80 W., and is overlapped by the Hanna formation in sec. 4. (See pl. 6, *B*.) Peneplaned surfaces of the Lewis, Medicine Bow, and Ferris formations end abruptly either at the southern edge of the extensive Hanna badlands in the northwestern part of the township (see pl. 7, *A*) or against the prominent escarpment that borders the dissected table-land in the western part of the township. In broad terms the strata in this township occupy the eastern and southern limbs of a syncline which is poorly defined because of the unconformable relations between the Hanna and underlying formations. At the point where the Hanna overlaps the older formations the beds are closely plicated and flexed, but elsewhere they dip about 15° W. The three normal faults mapped in the southwestern part of the township have displaced the strata only a few hundred feet.

Bed 78–A is about 4,300 feet above the base of the Hanna formation and has been traced across the township. Although it is as much as 40 feet thick, it consists largely of carbonaceous shale and bone, the thickest individual bench of coal being about 6 feet thick, as shown by graphic sections 1014 to 1023, in Plate 24.

Bed 78–B lies 35 feet above bed 78–A and has about the same surface distribution. At location 1050, in the SW. ¼ sec. 28, it contains about 15 feet of coal split in the middle by a 6-inch parting of carbonaceous shale. Other sections in this township showing individual benches of coal from 1 to 9 feet thick interstratified with beds of shale and bony coal are represented graphically in Plate 24 by sections 1026 to 1029 and 1031 to 1034.

Bed 79 occurs 125 feet above bed 78–B and resembles it in being badly broken by shale partings in the northern part of the township but becoming cleaner farther to the south. Measurements of it made at locations 1045 to 1052 and represented graphically in Plate 24 show individual benches of coal from 1 to 10 feet thick interstratified with beds of carbonaceous shale and bony coal.

Bed 80 in this township probably represents beds 81–A and 82–A in T. 22 N., R. 81 W. At locations 1000 to 1003 it contains about 6 feet of coal in an upper bench and from 1 to over 6 feet of coal in one or more lower benches, as shown by the corresponding graphic sections in Plate 24.

Bed 81 is 200 feet above bed 80 and may be equivalent to the Hanna No. 1 bed of T. 22 N., R. 81 W. It nowhere contains as much as 5 feet of good coal, as illustrated by graphic sections 1120 to 1123, Plate 24.

Measurements of bed 87 at locations 1167 to 1169 show alternating beds of coal and carbonaceous shale distributed through a maximum interval of 11 feet. No individual bench of coal exceeds 3 feet in thickness. (See pl. 24.)

Bed 88 lies 200 feet above bed 87 and contains four benches of coal, none of which exceeds 4 feet in thickness, distributed through a maximum interval of about 20 feet, as illustrated by graphic sections 1177 to 1179, plate 24.

Bed 89 is the highest coal bed in the township and contains no single bench of coal as much as 3 feet thick at locations 1184 to 1187, as shown by the corresponding graphic sections in Plate 24.

At locations 1189 and 1190, in sec. 28, a bed which may be part of bed 78–A contains 3 feet 4 inches and 5 feet 6 inches, respectively, of coal. Other coal beds occur near the base of the Hanna formation in sec. 15 and vicinity, but are too badly squeezed, crushed, and folded to be of economic value. Measurements of these beds at locations 1191 to 1204 are represented under the heading of lenses in plate 24 by the corresponding graphic sections. The beds measured at locations 1206 and 1207, in the SE. ¼ sec. 33, occupy about the same stratigraphic position as the lenses described above and contain about 2 feet of poor coal.

At locations 1208 to 1210, in secs. 13 and 14, a coal bed in the Medicine Bow formation contains from 2 to 13 feet of coal, but could not be found beyond the points indicated on the map.

TPS. 20 AND 21 N., R. 79 W.

The Medicine Bow anticline, outlined by the resistant sandstones in the Mesaverde formation, occurs in the southeastern part of T. 21 N., R. 79 W., and rises about 500 feet above the surrounding valley of Lewis shale. The dip of the strata increases uniformly away from the axis of the anticline until a maximum inclination of about 30° is reached in the hogback of light-gray sandstone which characteristically marks the top of the formation. The Hanna formation occupies the eastern part of the Carbon Basin in this township and overlaps the Medicine Bow formation. These formations have a

maximum dip of about 45° and occupy broken areas containing many flat-topped buttes.

Bed 99 occurs about 600 feet above the base of the Mesaverde formation in the Medicine Bow anticline and contains no single bench of coal as much as 2 feet thick at locations 1326 to 1328, as shown by the corresponding graphic sections in plate 25.

Bed 100 occurs at the top of the Mesaverde and is about 7 feet thick at locations 1329 and 1330, in secs. 34 and 27, T. 21 N., respectively.

Beds 101 to 104 occur in the Medicine Bow formation in the northeastern part of T. 21 N. and average about 2 feet in thickness, as illustrated by graphic sections 1331 to 1335 and 1338 to 1340, plate 25. Lenses at locations 1341, in the NW. ¼ sec. 11, and 1342, in the NE. ¼ sec. 16, show about 2 feet of coal.

At location 1303, in the SE. ¼ sec. 20, T. 21 N., the Johnson bed, the lowest coal in the Hanna formation in these townships, contains 11 feet of coal. Smaller measurements of it in these townships and in T. 20 N., R. 80 W., are represented graphically in Plate 25 by sections 1297 to 1302 and 1304. The Johnson mine in sec. 6, T. 20 N., is a small entry from which coal is taken to supply the Johnson ranch on Medicine Bow River. An analysis of the coal in this mine is given on page 35.

At locations 1323 to 1325 the Finch bed contains no single bench of coal as much as 3 feet thick, as illustrated in the corresponding graphic sections in Plate 25.

At location 1363, in the center of sec. 16, T. 21 N., bed 106 contains 6 feet of undivided coal in its lowest bench. Elsewhere in these townships it consists largely of carbonaceous shale and bone, as shown by graphic sections 1359 to 1362, Plate 25.

Bed 107 was measured in these townships only at location 1370, in the NW. ¼ sec. 31, T. 21 N., where it contains 5 feet 4 inches of undivided coal.

The Carbon No. 7 bed contains five benches of coal ranging between 1 and 6 feet in thickness at location 1457, in the NW. ¼ sec. 6, T. 21 N. South of this location, however, it is about 2 feet thick, as shown by graphic sections 1453 to 1456, Plate 25.

Graphic sections 1430 to 1435, Plate 25, show the Carbon No. 6 bed in T. 21 N., R. 79 W., to consist of about four benches of coal separated by beds of carbonaceous shale. The thickest single bench contains about 3 feet of coal at location 1433, in the NE. ¼ sec. 17.

Bed 108 contains less than 1 foot of coal at location 1378, in the SW. ¼ sec. 30, T. 21 N.

Bed 109 contains 2 feet 6 inches of undivided coal at location 1396, in the NE. ¼ sec. 17, T. 21 N. Smaller measurements of it in

T. 21 N. are represented graphically in Plate 25 by sections 1387, 1388, 1393 to 1395, and 1397 to 1399.

Bed 110–A contains less than 2 feet of coal at locations 1402 to 1405, in T. 21 N., and is equivalent to either bed 110 or bed 111 of T. 21 N., R 80 W.

Smaller outliers of a bed not far above the Finch bed exhibit less than 2 feet of coal at location 1459, in the NE. ¼ sec. 6, T. 20 N., R. 79 W.

T. 22 N., R. 79 W.

The surface of T. 22 N., R. 79 W., is largely a peneplain, the more resistant Mesaverde and Medicine Bow beds being worn down to practically the same level as the less resistant Lewis and Steele shales. The southwestern part of the township, however, is hilly and is crossed by a small syncline, which pitches to the northwest. Elsewhere in the township the strata have a monoclinal dip to the west ranging between 25° and 50°.

Thin beds of coal occur in the Mesaverde and Medicine Bow formations in this township, but because of their steep inclination, thinness, and irregularity they are of but little economic value at present.

Bed 112 occurs in the middle of the Mesaverde formation and contains less than 2 feet of coal at locations 1412 to 1414. Bed 112–A occurs at the top of the Mesaverde and contains 5 feet and less of bony coal at locations 1415 and 1416. At the Wissler mine, in the NE. ¼ sec. 22, bed 112–A contains 4 feet of coal. When the mine was examined in July, 1925, the shaft was down about 140 feet and the output averaged 2 tons of coal a day. An analysis of the coal from this mine is given on page 35.

At locations 1336 and 1337, in secs. 32 and 33, bed 104 contains about 2 feet of coal. An isolated exposure of coal in the Medicine Bow formation near the southwest corner of sec. 8 contains 1 foot 8 inches of coal.

OIL DEVELOPMENTS

Practically all the folds in the Hanna and Carbon Basins that might serve as reservoirs for oil have been tested, and in only one, the Saddleback Hills anticline, has oil been found in commercial quantities. The general synclinal character of the basins and the great thicknesses and wide distribution of the Tertiary coal-bearing rocks practically preclude the possibility of finding oil in commercial quantity where rocks younger than the Lewis shale crop out, except possibly along the borders of the basins where anticlines may be concealed by the overlapping Hanna and North Park formations.

The folds once considered to hold the greatest promise of oil production in the Hanna and Carbon Basins are the Fort Steele, Cedar Ridge, and St. Marys anticlines, in the Walcott quadrangle; the Pass Creek Ridge anticline, in the Walcott and Hanna quadrangles; and the Saddleback Hills, Allen Lake, Oil Springs, and Flat Top anticlines, in the Saddleback Hills quadrangle. The structure of these folds is described in the section on structure and in the individual township descriptions. Structure sections of the folds are shown in Plate 27, and their oil possibilities are discussed in a Geological Survey press notice.[23] In view of these facts, this part of the report will be devoted only to a history of drilling operations on the folds.

HISTORY OF DRILLING OPERATIONS

Fort Steele anticline.—The Fort Steele anticline, within the limits of the Walcott quadrangle, has been tested by the Ohio Oil Co. in the NW. ¼ sec. 28, T. 21 N., R. 85 W., and by the Fort Steele Petroleum Co. in the NW. ¼ sec. 22 of the same township. The Ohio well, located on the axis of the anticline, was drilled to a depth of 2,250 feet in 1921 and obtained water in the uppermost sand in the Cloverly formation. The Fort Steele well, drilled in 1918, was located about a mile north of the axis of the anticline and encountered several shows of oil and gas before being abandoned at a depth of 3,540 feet.

Cedar Ridge, St. Marys, and Pass Creek Ridge anticlines.—The Producers & Refiners Corporation has drilled three wells on the St. Marys anticline in T. 21 N., R. 84 W., all of which were dry holes. The first well was drilled in the NE. ¼ sec. 10 in 1925 and was abandoned at a depth of 800 feet. The second well, in the NE. ¼ sec. 9, was abandoned in 1926 at a depth of 2,055 feet. The Quealy sand, the oil-producing sand in the Saddleback Hills anticline, was reported to show slight quantities of oil and gas in this well at a depth of 1,059–1,100 feet. The third well, in the NW. ¼ sec. 14, obtained water in the Quealy sand at a depth of 765 feet, was drilled to a depth of 1,012 feet, and was then abandoned in 1926. According to the interpretation of the structure in the St. Marys anticline, as given in structure section E–F, Plate 27, all these wells were located too far to the southwest to strike the crest of the Cloverly upfold, which lies deeply buried northeast of the surface ridges. Furthermore, chances for commercial oil production in the Quealy sand are believed to be slight because of the sharpness of the folding and the shearing, crushing, and faulting to which the rocks have been subjected.

[23] Coal and oil resources of the Hanna Basin, Carbon County, Wyo.: U. S. Geol. Survey press notice 12514, 1922.

Saddleback Hills anticline.—Oil was discovered in the Saddleback Hills anticline (Simpson Ridge) in June, 1923, by the Producers & Refiners Corporation. Oil was encountered in the Quealy sand, which occurs in the transition zone at the base of the Mesaverde formation, at a depth of 680 feet, and for a short time oil flowed over the top of the 15-inch casing. The oil was cased off, and drilling continued to a depth of 6,931 feet. Neither the Wall Creek (?) sandstone nor the sandy shales composing the Cloverly formation contained oil, and the well was plugged back to 680 feet to recover oil from the Quealy sand. The log of this well is shown graphically in Plate 26.

Production in the Saddleback Hills anticline is confined to sec. 20, T. 21 N., R. 80 W., where eight wells produce about 200 barrels of oil a day from the Quealy sand. This oil is transported to the Union Pacific Railroad at Hanna and carried to the refinery at Parco.

Allen Lake anticline.—The first well on the Allen Lake anticline was drilled in 1918 and 1919 by the Cosden Oil & Gas Co., in the NW. ¼ sec. 34, T. 23 N., R. 79 W. Water was struck in the Wall Creek (?) sandstone at a depth of 275 feet, and about 4,000,000 cubic feet of gas between depths of 936 and 1,063 feet. The Muddy sand contained 35,000,000 cubic feet of gas between depths of 1,357 and 1,397 feet. At a depth of 1,419 feet the hole filled up with water from the uppermost sands in the Cloverly formation, and the well was abandoned. A well started in 1923 by the Laramie Oil & Gas Syndicate about half a mile southeast of the Cosden well was reported to have encountered 3,500,000 cubic feet of gas between depths of 1,330 and 1,343 feet. The sands in the upper part of the Cloverly formation were struck at a depth of 1,508 feet and were reported to yield 35,000,000 cubic feet of gas and a strong flow of water. About 7,000,000 cubic feet of gas, with only a small amount of water, was reported to have been struck between depths of 1,685 and 1,691 feet, in a sand probably belonging to the lower part of the Cloverly formation. The well was later taken over by the Kanawha Oil Co. and plugged back to 1,341 feet in an unsuccessful attempt to obtain the gas originally recorded at that depth. The graphic log of this well is included in Plate 26. A well drilled by the Western States Oil & Land Co., in the NE. ¼ sec. 11, T. 22 N., R. 79 W., was abandoned at a depth of 2,035 feet without reaching the Cloverly sandstones.

Oil Springs anticline.—The Oil Springs anticline was tested in the SW. ¼ sec. 20, T. 23 N., R. 79 W., by the Ohio Oil Co. in 1918 and 1919. Shows of gas were encountered between depths of 1,127 and 1,165 feet. Water was found in the uppermost sands of the Cloverly formation at a depth of 1,480 feet, and the well was then abandoned.

INDEX

	Page
Acknowledgments for aid	3
Allen Lake anticline, wells drilled on	86
Alluvium, occurrence of	27
Beck, Elfred, acknowledgment to	3
Carlile shale, features of	16
Casper formation, rocks designated as	11
Cedar Ridge anticline, features of	28
Cedar Ridge fault, features of	31
Chugwater formation, features of	12
plate showing	26
Cloverly formation, nature of	14–15
plate showing	26
Coal, analyses of	33–37
description of beds by townships, scope of	38
formations containing	31–32
production and uses of	37
properties of	32–37
quantity of	37–38
Como Ridge, section of Sundance formation at	13
Cronberg, Albert, acknowledgment to	3
Drainage of the area	8
Embar (?) formation, nature and occurrence of	11–12
Faults in the rocks	30–31
Ferris formation, nature of	24–25
plate showing	26
vertical beds in, plate showing	26
Field work, record of	2–3
Flat Top anticline, features of	29–30
Folds in the area	27–30
Fort Steele, section of Mesaverde formation north of	19–21
Fort Steele anticline, features of	27
wells drilled on	85
Frontier formation, nature of	16
Geography of the area	6–9
Hanna formation, nature of	25–26
plates showing	26, 42
Hanna quadrangle, columnar section of rocks exposed in	42
Hayden, F. V., quoted	3–4
Hodge, James T., quoted	5–6
King, Clarence, quoted	4
Lewis shale, nature and occurrence of	21
sandstone hogback in, plate showing	26
Little Medicine Bow River, section of Morrison formation on	14
Location of the area	1–2
McAuliffe, Eugene, acknowledgment to	3
Medicine Bow formation, nature of	23–24
plate showing	26
Mesaverde formation, nature and members of	17–21
plates showing	26, 42
Mining development, outline of	6
Morrison formation, nature of	13–14
plates showing	26
Mowry shale, features of	15–16
Niobrara formation, features of	16–17
North Park formation, nature of	26
plate showing	42
Oil developments in the area	84–86
Oil Springs anticline, plate showing	42
well drilled on	86
Pass Creek Ridge, anticline, features of	29
Pryde, G. B., acknowledgment to	3
Purpose of the survey	2
Rattlesnake Hills, section of Mesaverde formation in	19–21
Roads and railroads of the area	8–9
Saddleback Hills anticline, features of	29
oil wells on	86
Saddleback Hills quadrangle, columnar section of rocks exposed in	42
St. Marys anticline, features of	28–29
wells drilled on	85
St. Marys fault, features of	30–31
Settlements of the area	8
Steele shale, nature of	17
plates showing	26
Stratigraphy of the area	9–27
Structure of the rocks	27–31
Sundance formation, nature of	12–13
plate showing	26
Surface features of the area	6–8
Surveys, earlier	3–6
Tensleep sandstone, occurrence of	11
plate showing	26
Terrace gravel, occurrence of	26
Thermopolis shale, features of	15
Township descriptions, Tps. 20 and 21 N., R. 79 W., coal beds in	82–84
Tps. 20 and 21 N., R. 80 W., coal beds in	76–79

	Page
Township descriptions, T. 21 N., R. 81 W., coal beds in	68
T. 21 N., R. 82 W., coal beds in	62
T. 21 N., R. 83 W., coal beds in	50–51
T. 21 N., R. 84 W., coal beds in	42–44
T. 21 N., R. 85 W., coal beds in	39–40
T. 22 N., R. 79 W., coal beds in	84
T. 22 N., R. 80 W., coal beds in	79–81
T. 22 N., R. 81 W., coal beds in	68–73
T. 22 N., R. 82 W., coal beds in	62–66
T. 22 N., R. 83 W., coal beds in	51–56
T. 22 N., R. 84 W., coal beds in	44–45
T. 22 N., R. 85 W., coal beds in	40–42
T. 23 N., R. 80 W., coal beds in	81–82
T. 23 N., R. 81 W., coal beds in	73–75
Township descriptions, T. 23 N., R. 82 W., coal beds in	66
T. 23 N., R. 83 W., coal beds in	56–59
T. 23 N., R. 84 W., coal beds in	45–48
T. 23 N., R. 85 W., coal beds in	42
T. 24 N., Rs. 80 and 81 W., coal beds in	76
T. 24 N., R. 82 W., coal beds in	67–68
T. 24 N., R. 83 W., coal beds in	59–62
T. 24 N., R. 84 W., coal beds in	48–50
Walcott quadrangle, columnar section of rocks exposed in	42
Walcott syncline, features of	28
Wall Creek sandstone, features of	16
Wilson coal mine, plate showing	42