UNITED STATES DEPARTMENT OF THE INTERIOR
Ray Lyman Wilbur, Secretary

GEOLOGICAL SURVEY
George Otis Smith, Director

Bulletin 819

# THE WASATCH PLATEAU COAL FIELD UTAH

BY

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CANCELLED

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1931

For sale by the Superintendent of Documents, Washington, D. C. - Price $1.30, paper cover

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# THE WASATCH PLATEAU COAL FIELD, UTAH

By Edmund M. Spieker

## INTRODUCTION

The Wasatch Plateau, the northeasternmost of the great group of high plateaus in central and southern Utah, is underlain by a succession of Cretaceous rocks that contain valuable coal beds, and the eastern part of the plateau, in which the coal is accessible, is generally known as the Wasatch Plateau coal field. This field and its continuation east of Price River—the Book Cliffs coal field—contain excellent coal of bituminous rank and together form the largest and most productive coal area in Utah. Coal from these fields has long been highly esteemed by users of western fuels and commands an important position in the fuel markets of the West.

Mining of the coal began in a small way with the earliest settlements in this part of Utah. As population increased and transcontinental railroads were built, large mines were opened and commercial development has advanced until at the present time most of the places accessible by existing railroads are the scenes of large mining enterprises, and the volume of coal passing out to the fuel-consuming centers of the West has reached an annual average of about 4,800,000 tons. The area now undergoing exploitation, however, is small compared with the part yet undeveloped, and the present examination of the field has shown clearly that the great bulk of its coal remains, constituting a reserve of many millions of tons.

### BRIEF HISTORY OF DEVELOPMENT

Coal was discovered in the Wasatch Plateau field in 1874, and mining was started in 1875, when the Fairview Coal & Coke Co. opened a mine in Huntington Canyon, at the site of the present Huntington mine, in sec. 11, T. 14 S., R. 6 E., and established a settlement called Connelsville. In 1876 coal was being mined from 5 openings, 4 in Coal Canyon and 1 in Huntington Canyon near the mouth of Coal Canyon. A railroad was surveyed from Sanpete Valley to this place but was never built. For about three years coke was produced at Connelsville, but the cost of hauling it by wagon to Springville, the nearest market, proved to be too great, and the mine and settlement were abandoned. Since that time the westernmost mine on the north side of the canyon has been operated intermittently as a wagon mine, to supply residents of Sanpete Valley with domestic fuel. The ruins of the coke ovens still remain at this mine (see pl. 1, *A*), but the original settlement disappeared long ago. The coke produced is said to have been of fair quality.

The first large mine to be operated in the field was the Utah or Mud Creek mine, of the Utah Fuel Co., which was opened in 1878 in Pleasant Valley on Pleasant Valley Creek about 3 miles south of Scofield. After being operated for a while it entered a zone of faults that made mining expensive and was temporarily abandoned but was reopened in 1922. In 1884 the Winter Quarters mine was opened in Winter Quarters Canyon, and what is now the Union Pacific mine No. 1 was opened by the Pleasant Valley Coal & Coke Co., near Scofield. When the Union Pacific mine was first opened coke ovens were built and an attempt was made to produce coke from lump coal. According to reports, however, the product was merely devolatilized lump coal. The smaller sizes of coal could not be charged in the ovens, and the process was soon abandoned because of the high cost of using lump coal exclusively. The coal bed at this mine is about 30 feet thick, but the mine was abandoned because of the expense imposed by the numerous faults encountered in it. It has been reopened in recent years by the Scofield Coal Co., which in 1923 was producing coal both from the thick bed and from another bed about 80 feet higher.

The Clear Creek mine, at the head of Pleasant Valley, was opened in 1899, and coal has been produced there by the Utah Fuel Co. without interruption ever since. (See pl. 13, *A*.) In 1915 this mine was extended, by means of a rock tunnel driven through a fault zone to the coal outcrop in Bob Wright Canyon, and two new mines, one on the Castlegate "A" bed and one on the Bob Wright bed, were opened. Small mines and prospect pits have been opened from time to time on nearly all the coal beds in Pleasant Valley.

From 1899 to 1909 no new mines were opened except a few, such as the Winter Quarters No. 5, in extension of operations already begun, and Pleasant Valley continued to produce all the coal shipped from the field. The first mines on the east front of the plateau were those now operated by the United States Fuel Co., which were opened at the sites of old wagon mines in Miller and Cedar Creek Canyons in 1909 and 1910. The Consolidated Fuel Co. built the Southern Utah Railroad, from Price to Hiawatha, in 1909, and opened the Hiawatha mines. In 1910 the Castle Valley Fuel Co.

opened the Mohrland mine and extended the railroad into Cedar Creek Canyon. The Blackhawk mine was opened by the Black Hawk Fuel Co. in 1911. The names of the Blackhawk and Mohrland mines were changed in 1925 to King No. 1 and King No. 2 respectively. All these mines are now under the control of the United States Smelting & Refining Co. and are operated by the United States Fuel Co.

The gradient of the Southern Utah Railroad, which reached 5 per cent in places, was found too high for efficient operation, and a new line, the Utah Railway, was built. This line, which joins the Denver & Rio Grande Western Railroad at Utah Railway Junction, at the mouth of the Price River Canyon, has a maximum grade of 2 per cent and has supplanted the Southern Utah Railroad, which is abandoned. The mines at Hiawatha and Mohrland have grown steadily and are now among the largest in the field. In 1917 the Lion Coal Co. opened a mine at Wattis on the Wattis bed and in 1924 a second mine on a lower bed. In 1924 the Sweet Coal Co. began work on North Fork of Gordon Creek.

## PURPOSE OF INVESTIGATION

The investigation on which this report is based was undertaken primarily for the purpose of obtaining geologic and economic data required in the administration of the coal provisions of the mineral leasing law (41 Stat. 437) and secondarily for the purpose of obtaining such information on the general geology of the field as would best promote efficient mining.

## CHARACTER AND METHODS OF WORK

The field work was done during the summers of 1921, 1922, 1923, and 1924. The geologic and topographic work was done simultaneously by a field party which for the greater part of the time consisted of 8 to 10 men.

During the first year H. I. Smith, at that time a member of the Bureau of Mines, cooperated with the party, giving the field detailed attention from the point of view of the engineer and operator. G. J. Salmon, also of the Bureau of Mines, was associated with Mr. Smith in this work for a short time at the beginning. Mr. Smith has cooperated with the writer throughout the work and has given freely his advice concerning the parts of the report that are of interest to the mining engineer. W. B. Upton, jr., who was associated with the writer, had charge of the preparation of the topographic map of the coal field and was assisted in 1921 by G. F. Harley and F. W. Downey and in 1922 by Mr. Downey and Vaughn Gordon. In 1923 the topographic mapping was done by Mr. Upton and E. B. Hill, assisted by Coy Williams, E. L. Guymon, K. K. Kimball, L. Jensen, and L. H. Wolff. In 1921 the writer was assisted in the geologic work by W. W. Boyer and R. H. Haseltine, in 1922 by J. B. Eby and C. F. Spieker, and in 1923 by A. A. Baker and C. F. Spieker.

In 1924, after the topographic map had been completed, the writer, D. J. Fisher, and W. H. Newhouse mapped the geology of the parts of the four quadrangles that lie east of the plateau front.

The coal-bearing formation was studied closely throughout the area mapped. Complete stratigraphic sections of the formation were measured at many places, and sections including the valuable coal beds were taken in sufficiently close succession to indicate the amount of coal present and the correlation of the coal beds. Individual sections of coal beds were measured wherever possible within the limitations of the work. In the part of the field as far south as the mouth of Huntington Canyon the coal-bearing formation normally forms somewhat smooth-faced slopes and the coal beds are ordinarily poorly exposed or completely hidden. Measurements of the beds in this part of the field must therefore be considered as subject to revision when the full thickness of the beds is made known through prospecting or mining. Most of the thicknesses here recorded were obtained at the cost of much labor with pick and shovel, and they are thus better than simple outcrop measurements, but in many places the beds have weathered and slumped or burned, so that nothing less than a drift dug to fresh coal will show their true thicknesses.

Certain of the coal beds could be traced through their association with prominent sandstones, and the lowest coal was thus identified throughout most of the field. Most of the upper beds, however, are not associated with persistent and distinctive sandstones, and they could not be traced except at the expense of far more time and labor than was available. In parts of the field where such tracing could not be done columnar sections of the coal-bearing rocks were measured at as many places as possible, the lowest coal bed being used as a datum plane, and the upper beds were correlated through a comparative study of the sections.

The detailed study of the coal measures was supplemented by a general study of all the rocks in the Wasatch Plateau, and complete stratigraphic sections were measured at a number of places. The rocks above the coal-bearing zone of the Blackhawk formation were studied in sufficient detail to permit their recognition in places where the coal is underground, and sufficient data were obtained throughout the field to permit drawing the boundaries of the formations.

The structure of the region was mapped in as great detail as exposures permitted. Faults, which are important in their effect upon the coal-bearing rocks, were located and measured with care wherever possible. Near the east front of the plateau the attitude of the coal-bearing beds was determined by obtaining altitudes on key beds in the Mesaverde group. In other parts of the field the determination of structure is entirely dependent on a knowledge of the rocks above the Mesaverde group, and in such places the value of a general stratigraphic study is evident.

The location on the topographic map of the Land Office survey lines has been an important part of the work both for the purpose of land classification and for the outlining of future development. Most of the townships in the field were surveyed many years ago, and many of the original corner stones are not to be found, either because they were never set or because they have been obliterated by landslides, floods, or human agencies. The corners that were found during the work are indicated on the map, and for the most part they appear to have been accurately set. The extension from the located corners of the land lines on the topographic map is therefore probably satisfactory for all uses to which the map may be put.

## ACKNOWLEDGMENTS

The writer desires to express his appreciation of the spirit, energy, and ability displayed by his associates in the work. He is particularly indebted to W. B. Upton, jr., in charge of the topographic work, who spared no pains in the task, often difficult, of coordinating the topographic with the geologic surveys. In the office A. A. Baker, W. W. Boyer, and J. B. Eby have aided in the compilation of results, and Mr. Baker has contributed a large part of the work of assembling the data for the final report. The writer is also indebted to M. R. Campbell, under whose supervision the work was begun; W. C. Mendenhall, both as chief of the land classification board and later as chief geologist; and W. T. Thom, jr., under whose supervision the work was completed, for general criticism of the work and for the generous spirit in which they supervised it. The writer enjoyed the advantage of unusually capable and experienced camp assistants, and of these R. J. Gordon, Otto Carli, and G. K. Hardy contributed more than an ordinary share of the labor involved in operating so large a party.

R. M. Magraw, general superintendent, and J. B. Forrester, chief engineer, of the United States Fuel Co., and C. H. Stevenson, of Price, extended many greatly appreciated courtesies to members of the party and furnished information that was of much value in the work. Valuable information and assistance were given by A. C. Watts, chief engineer of the Utah Fuel Co.; T. A. Stroup, superintendent of the Clear Creek mines; and W. J. Reid, superintendent of the Wattis mine of the Lion Fuel Co. Eugene McAuliffe, president

of the Union Pacific Coal Co., and William Monay, vice president of the Kinney Coal Co., were generous in their interest, and in general all the operators and prospectors in the field volunteered courtesies and information that helped materially.

The residents of the several towns in and near the field were always courteous and helpful in supplying the many material needs of the party and thus smoothing the progress of the work. The officials of the United States Forest Service, in particular Mr. J. W. Humphrey, supervisor of the Manti National Forest, and Messrs. D. H. Williams, B. A. Howard, and P. M. V. Anderson, forest rangers, gave a large amount of assistance and information and placed their field facilities at the disposal of the Geological Survey party.

## EARLIER PUBLICATIONS

The reports of the earlier explorations of the western United States contain but slight mention of the Wasatch Plateau. Captain Gunnison's ill-fated expedition, part of the exploration for a Pacific railway, crossed the divide at the south end of the plateau in 1853, and Lieutenant Beckwith's account of the journey [1] contains a brief description of the country, probably the first to be published. Other early reports [2] of the general region mention the Wasatch Plateau and give scattered bits of geologic information concerning it. The earliest detailed mention of coal in the plateau came in 1877, as a description of the first mines to be opened, near the head of Huntington Canyon.[3] The first organized account of the geology of the Wasatch Plateau was the report by Dutton [4] on the High Plateau region. Minor references to the Wasatch Plateau in these earlier years are cited in the text of the present report.

The Wasatch Plateau coal field is mentioned and briefly described by Forrester [5] and Storrs [6] in their accounts of the coal resources of Utah. The first geologic study of the field, with particular reference to the coal, came in 1905, when Taff [7] made a reconnaissance examination which was part of a rapid survey covering the coal-bearing

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[1] Beckwith, E. G., U. S. Pacific R. R. Repts., vol. 2, pp. 66, 67, 1855.

[2] Howell, E. E., U. S. Geog. Surveys W. 100th Mer. Rept., vol. 3, pp. 235, 265–270, 295, 1875.

[3] Morton, J. H., The coal mines of central Utah: Eng. and Min. Jour., vol. 23, pp. 76–77, 1877.

[4] Dutton, C. E., The geology of the High Plateaus of Utah, pp. 160–168, U. S. Geog. and Geol. Survey Rocky Mtn. Region, 1880.

[5] Forrester, Robert, Coal fields of Utah: U. S. Geol. Survey Mineral Resources, 1892, pp. 511–520, 1893.

[6] Storrs, L. S., The Rocky Mountain coal fields: U. S. Geol. Survey Twenty-second Ann. Rept., pt. 3, pp. 415–471, 1902.

[7] Taff, J. A., Book Cliffs coal field, Utah, west of Green River: U. S. Geol. Survey Bull. 285, pp. 289–302, 1906.

region west of the Green River. In 1906 Taff[8] made a more detailed examination of the northern part of the field, and the results of this work have been the most detailed available until the present work was begun.

During the years 1911 to 1914 Clark[9] studied in great detail the western part of the Book Cliffs coal field, and as the present work began at the place where Clark's work ended, his results were of great value in this study.

The Emery coal field, in southern Castle Valley directly adjacent to the Wasatch Plateau coal field, has been described in detail by Lupton.[10] The area mapped by Lupton overlaps the area covered by the present study.

The stratigraphy of the Wasatch Plateau was described briefly by the writer and J. B. Reeside, jr.,[11] in 1925, and in the same year a short account of the coal field, by the writer, was published.[12] Other publications bearing upon features of the coal field are cited at the proper places in this report.

## GEOGRAPHY

### LOCATION, EXTENT, AND PHYSICAL NATURE OF WASATCH PLATEAU

The Wasatch Plateau is the northeasternmost of the High Plateaus of Utah. It lies in the central part of the State, extending from the Price River southward to White Mountain and Musinia Peak, a distance of about 85 miles. (See fig. 1.)

The plateau is a high table-land, and it forms part of the great highland rim of the Colorado Plateau region, which sweeps in a broad curve from western Colorado to southwestern Utah. It is connected with the other high plateaus on the south by a lower table-land trenched by the valleys of Ivie and Salina Creeks, and on the north it merges with the highland between the Uinta Basin and the Wasatch Mountains. On the east the Wasatch Plateau is bounded by Castle Valley and on the west by the Sevier and Sanpete Valleys. The plateau surface is from 9,000 to 11,300 feet above sea level and 3,000 to 6,500 feet above the lower land on the east and

[8] Taff, J. A., The Pleasant Valley coal district, Carbon and Emery Counties, Utah: U. S. Geol. Survey Bull. 316, pp. 338–358, 1907.

[9] Clark, F. R., Economic geology of the Castlegate, Sunnyside, and Wellington quadrangles, Carbon County, Utah: U. S. Geol. Survey Bull. 793, 1928.

[10] Lupton, C. T., Geology and coal resources of Castle Valley in Carbon, Emery, and Sevier Counties, Utah: U. S. Geol. Survey Bull. 628, 1916.

[11] Spieker, E. M., and Reeside, J. B., jr., Cretaceous and Tertiary formations of the Wasatch Plateau, Utah: Geol. Soc. America Bull., vol. 36, pp. 435–454, 1925.

[12] Analyses of Utah coals: Bur. Mines Tech. Paper 345, pp. 13–22, 1925.

west. An excellent description of the broader features of the High Plateaus will be found in Dutton's account of the region.[13]

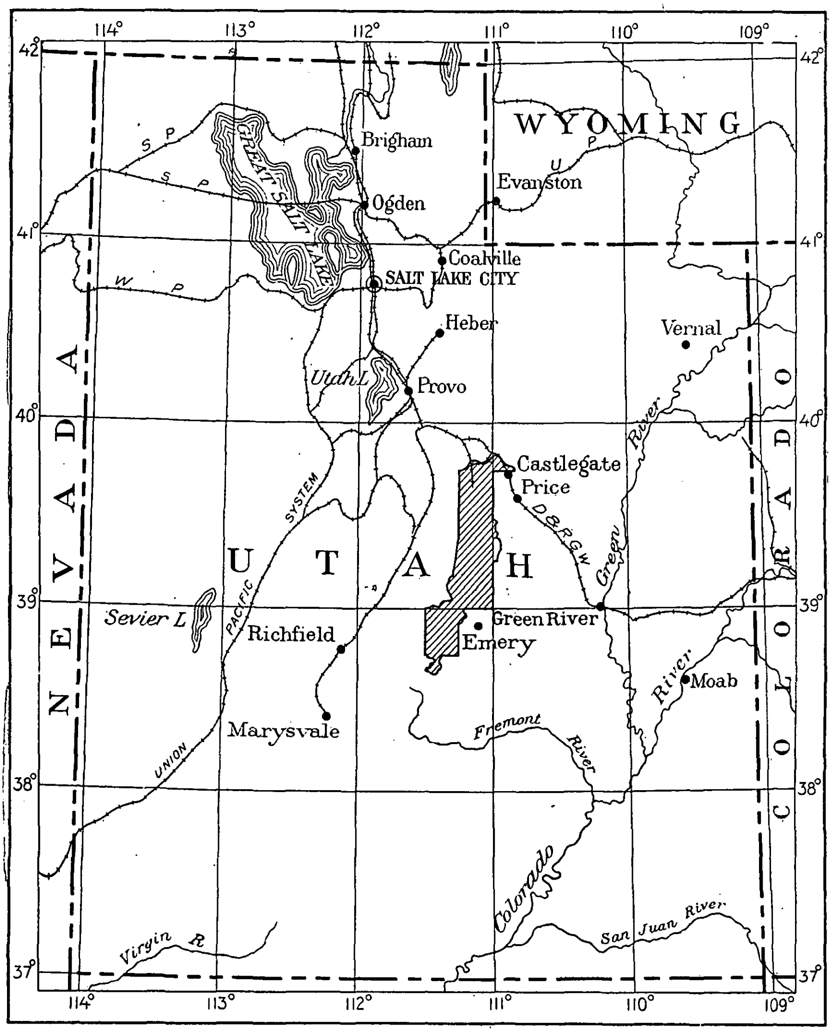



FIGURE 1.—Index map of Utah, showing location of Wasatch Plateau coal field (shaded area)

## GENERAL SURFACE FEATURES

The geologic maps accompanying this report (pls. 31 and 32) show the surface features of the eastern part of the plateau. The following description is intended to emphasize some of the salient features of the plateau and to point out the relation of its surface features to the geology of the region.

The eastern margin of the plateau is formed by an abrupt wall of barren cliffs and steep slopes, broken only by the V-shaped mouths

[13] Dutton, C. E., The geology of the High Plateaus of Utah, U. S. Geog. and Geol. Survey Rocky Mtn. Region, 1880.

of large canyons. (See pls. 2, *A;* 4, *B;* 20, *B.*) In the northern part of the plateau the barren aspect of the cliffs is in places relieved by brush-covered slopes (see pl. 11, *B*), but south of Huntington the front rises precipitously from Castle Valley in a sharp series of cliffs from 2,500 to 3,300 feet high. The front of the plateau partakes of the physical nature of the desert region to the east. The main body of the plateau is protected from erosion by a succession of rocks consisting predominantly of sandstone, which overlies a great shale formation. These rocks lie nearly flat or dip at slight angles, and the rugged, sharply dissected cliffs of the eastern escarpment have resulted from the cutting back of the edges of the strata by erosive processes characteristic of semiarid regions. During the summer heavy rainstorms break suddenly on the plateau and in a short time pour large volumes of water on the top. Within a few minutes after such a storm the water is concentrated into the stream channels leading to the valleys below, and the raging torrents thus formed carry along immense loads of débris, gouging out their channels at clearly visible rates. These torrents cut very rapidly into the soft shale, and as they sweep the shale away from beneath the overlying sandstone the sandstone breaks off along joint planes in great blocks, leaving bare vertical cliffs and block-strewn slopes. Vegetation never gains sufficient foothold to protect the surface, and the process of erosion goes on at rates far more rapid than those which prevail in regions where equal amounts of rainfall are more evenly distributed and where vegetation can become established, forming a protective covering and preventing the washing away of the softer rocks.

At the base of the cliffs on the east front long, sloping terraces extend downward to Castle Valley. The form of these terraces is well shown on Plates 31 and 32. The terraces are remnants of a great sloping plain, like a huge apron which formerly extended continuously along the base of the cliffs but which has been deeply trenched by recent drainage channels until at present only remnants of the original surfaces are preserved.

The higher levels of the plateau present a striking contrast to the barren cliffs and rugged canyons of the east front. Here are broad stretches of attractive parklike country, whose rolling hills and gentle swales are covered with the restful green of abundant grassy vegetation and beautified by large areas of spruce and aspen forest. These higher lands, which lie between 8,000 and 11,000 feet above sea level, normally receive abundant rain and support a rich growth of varied grasses, plants, and shrubs which make them a valuable summer pasture for horses, cattle, and sheep.

On the west the descent to Sanpete and Sevier Valleys is hardly less abrupt than that to Castle Valley on the east, but the aspect of the west front of the plateau is entirely different, and forested slopes prevail instead of barren cliffs. This difference is due to the fact that the hard rocks of the western margin of the plateau, instead of lying flat, bend downward toward the valley in a great monoclinal fold. The slopes of the plateau front correspond with the dip of the rocks, and at only a few places do the edges of the strata protrude in cliffs.

## BOUNDARIES OF WASATCH PLATEAU COAL FIELD

The entire Wasatch Plateau is underlain by the coal-bearing formation, and the limits of the coal field are approximately the same as those of the plateau. At its north and south ends, however, the coal field departs somewhat from the natural boundaries of the plateau.

On the north the best natural boundary for the coal field is the Price River, but to accept it as a boundary would divide the Castlegate mining district into two parts and would separate the mining district of Spring Canyon from those of Castlegate and Kenilworth, with which the Spring Canyon district is intimately associated. To avoid this difficulty the meridian of 111° west longitude has been adopted as an arbitrary boundary between the Wasatch Plateau and Book Cliffs coal fields, and the northern boundary of the Wasatch Plateau field west of the one hundred and eleventh meridian is placed at the Price River.

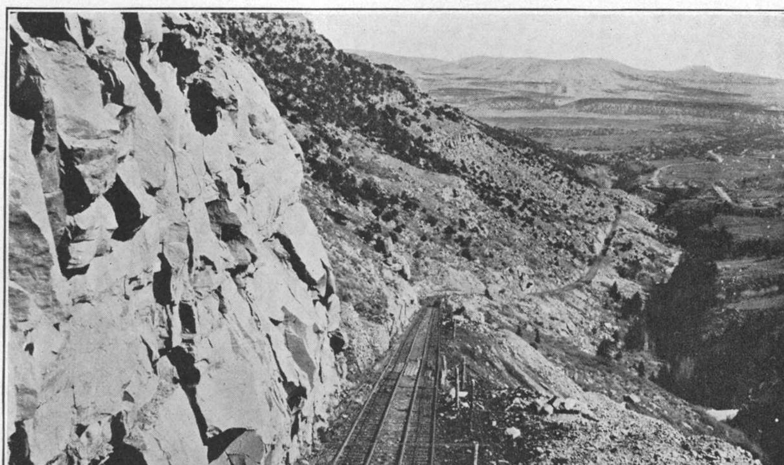
The southern part of the coal field extends beyond the limits of the Wasatch Plateau, but the extensions are considered part of the field because they are geologically inseparable from it and because they do not form in themselves an area sufficiently large to require recognition as a separate field. The coal-bearing rocks extend unbroken across the lower table-land between the Wasatch Plateau and the Fish Lake Plateau, and the southern limit of the coal of the Wasatch Plateau field, as here described, lies in the northern part of the Fish Lake Plateau, where the coal-bearing rocks pass under a thick mantle of basaltic igneous rock.

## DRAINAGE

The eastern part of the Wasatch Plateau is part of the Colorado River Basin, and it is drained by small streams tributary to the Price, San Rafael, and Fremont Rivers, branches of the Green and Colorado. The west slope of the plateau, a smaller part of the total area, is drained by tributaries of the Sevier River, which flows into Sevier Lake, one of the numerous sinks of the Great Basin. The crest of the plateau is thus part of the divide between the Colorado Basin and the Great Basin.

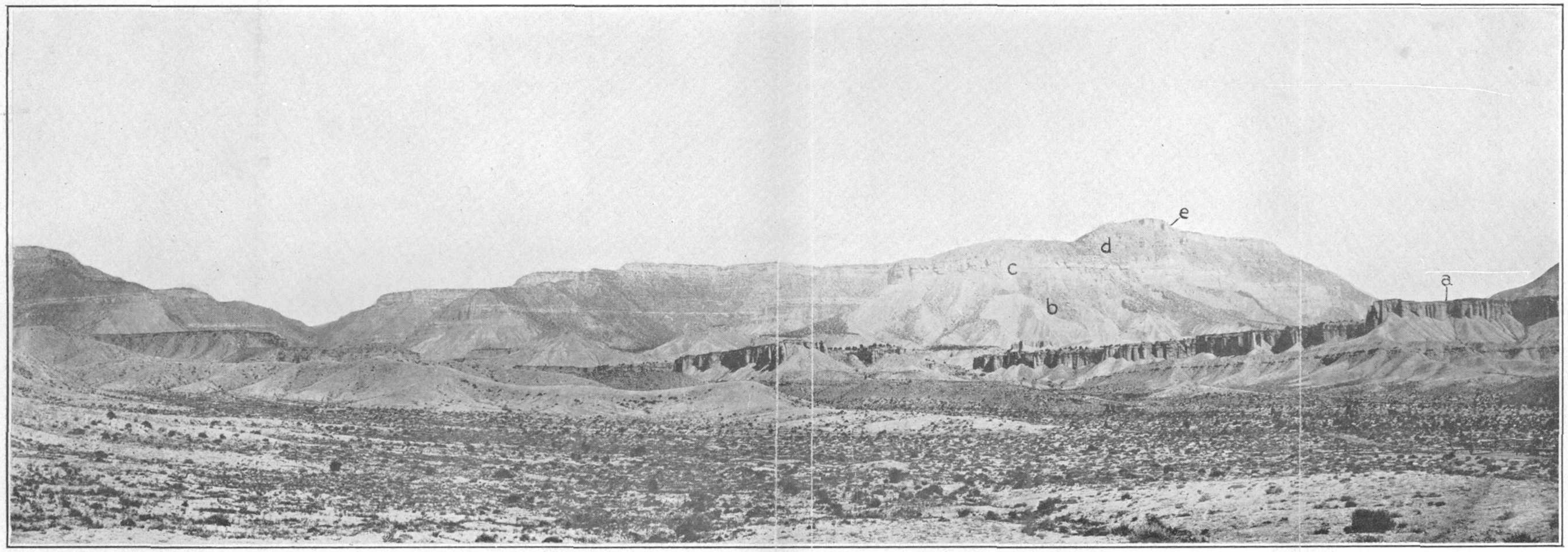
The Price River is the largest stream in the plateau and drains about 500 square miles in the northeastern part, rising in the gen-

*A*. RUINS OF OLD COKE OVENS AT SITE OF CONNELSVILLE, NEAR THE MOUTH OF COAL CANYON, T. 14 S., R. 6 E.



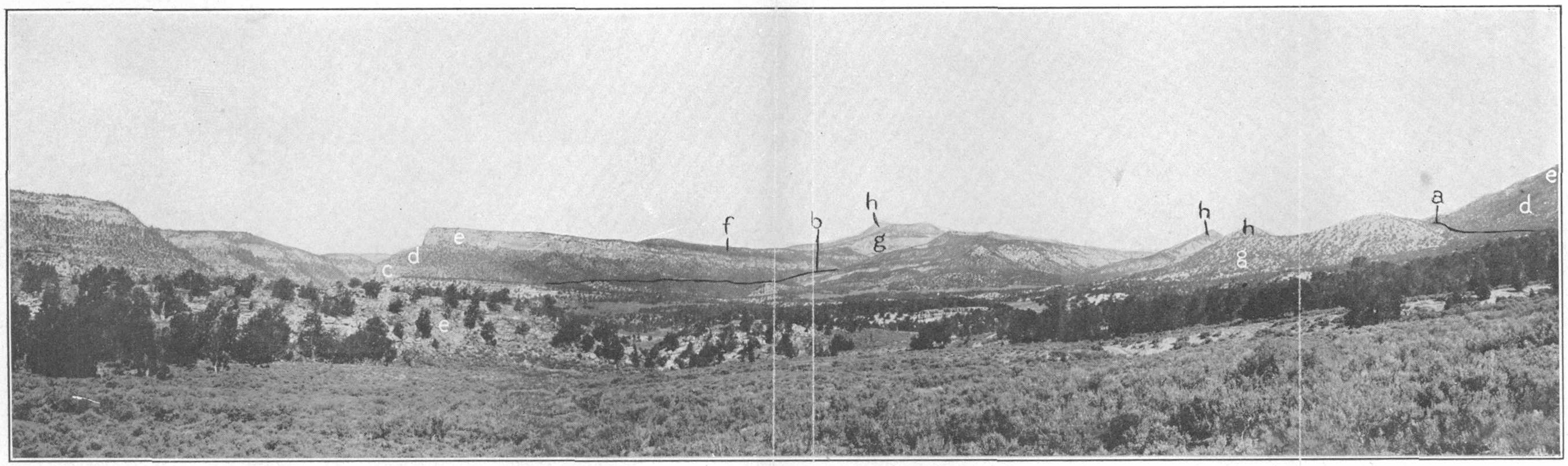
*B*. TRAMWAY AT WATTIS MINE

From trestle above mine mouth. Town of Wattis in right distance; Castle Valley beyond.



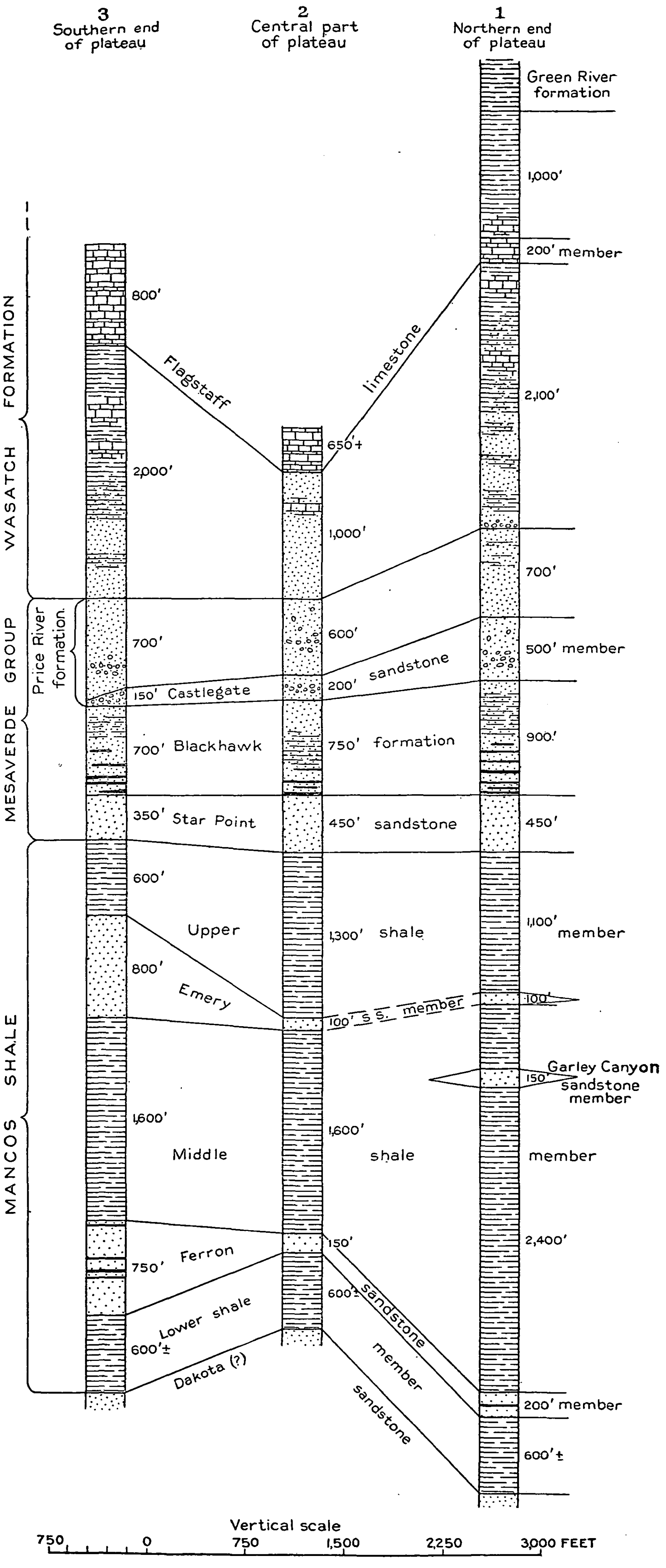

*A.* EAST FRONT OF WASATCH PLATEAU AT MOUTH OF ROCK CANYON

A characteristic view of the plateau front in the southern half of the field, showing tongue of Emery sandstone member (a) and upper shale member (b) of Mancos shale; Star Point sandstone (c); Blackhawk formation (d); and Castlegate sandstone member (e) of Price River formation. Small remnants of gravel-capped terraces appear near the center.




*B.* THE DRAGON, SHOWING JOES VALLEY FAULT ZONE

Upper canyon of Ferron Creek on left; Wagon Road Ridge in center distance; The Dragon in general foreground; west slope of South Horn Mountain at extreme right. The fault zone lies between the Joes Valley fault (a) and the Upper Ferron fault (b); c, Star Point sandstone; d, Blackhawk formation; e, Castlegate sandstone member of Price River formation; f, upper part of Price River formation; g, lower member of Wasatch formation; h, Flagstaff limestone member of Wasatch formation.




COLUMNAR SECTIONS OF ROCKS IN THE WASATCH PLATEAU COAL FIELD eral vicinity of Soldier Summit and Pleasant Valley and flowing eastward through a narrow canyon in the east front of the plateau, across the northern part of Castle Valley, and north of the Beckwith Plateau to its confluence with the Green River, about 14 miles north of the town of Green River. The Price River is normally a moderate-sized stream, having a mean flow of about 200 second-feet and a minimum flow of 20 to 25 second-feet at Helper, where it emerges from its canyon in the plateau. In the early summer the flow usually reaches a maximum of 800 to 1,200 second-feet, but it varies from year to year, having an extreme recorded maximum of more than 8,000 second-feet.

Huntington Creek is the next large stream south of the Price River. It rises on the well-watered plateau surface, flows through a narrow, deep canyon toward the desert, and joins Cottonwood and Ferron Creeks in T. 19 S., R. 9 E., to form the San Rafael River. Its mean flow, measured near the mouth of Huntington Canyon, is normally about 100 second-feet, its maximum about 600, and its minimum about 30. It drains an area in the plateau of about 160 square miles. The Left Fork of Huntington Creek has been impounded at two places in T. 14 S., R. 6 E., and the reservoirs are used to equalize the seasonal flow of water for irrigation of Castle Valley in the vicinity of Huntington and Cleveland. The main course of Huntington Creek in the plateau is about 30 miles long.

Cottonwood Creek, the next large stream south of Huntington Creek, drains an area in the plateau of about 240 square miles, including Joes Valley, the North Dragon Valley, and the plateau top west of Straight Canyon. Its mean annual discharge is usually about 135 second-feet, and during the summer the mean is about 350 second-feet. In times of flood the discharge may reach 1,900 second-feet. The water of Cottonwood Creek is normally clear and potable.

Between Cottonwood and Ferron Creeks practically no streams flow continuously. Rock Canyon contains, near its mouth, a very small stream of highly alkaline water that is unfit for drinking. Ferron Creek is a vigorous stream of good water, most of which is used for the irrigation of ranches in Castle Valley. Its mean annual flow is about 115 second-feet, but the flow in early summer is much greater than in winter. In the summer the flow is rarely lower than 30 second-feet, and in times of extreme flood it exceeds 1,000 second-feet.

Muddy Creek is similar to Ferron Creek. No exact measurements of its flow are available. It is largely used for the irrigation of ranches near Emery and furnishes a supply of good clear water. Quitchupah Creek is similar to the others described in every way except that its water is slightly alkaline and is not so good for drinking as the usual water of the plateau. The upper part of Convulsion Creek, the central branch of Quitchupah Creek, contains very good water whose source is in a spring near the divide. The lower courses of Water Hollow, Convulsion, and Quitchupah Creeks are fed by numerous springs issuing from the Emery sandstone member of the Mancos shale, and the water from many of these springs is " sweet."

Saleratus Creek, the next south of Quitchupah Creek, contains a small flow of water that is usually alkaline and not desirable for drinking. It flows into Ivie Creek, which contains an abundant flow of very good water that originates largely in the Tertiary rocks on the north face of the Fish Lake Plateau. Practically all the water of Ivie Creek is diverted for the irrigation of the Oak Spring ranch, one of the largest and oldest ranches in the region. Last Chance Creek, the southernmost stream in the coal field, normally contains a moderate flow of good water, some of which is diverted into Paradise Lake for the use of Farrel's (formerly Hogan's) ranch.

As a general rule the water issuing from the rocks above the coal-bearing (Blackhawk) formation is of good quality; the water from the coal-bearing rocks is usually alkaline, but in places it is potable. The water from springs in the Mancos shale is nearly everywhere alkaline, and at some places its content of dissolved salts is so large that the springs are known locally as " poison springs." Nearly all the water is somewhat " hard," particularly the water from the limestone of the higher plateau, but in general the water on the top of the plateau is of excellent quality and is plentiful nearly everywhere west of the plateau front. On most of the outcrops of the coal-bearing rocks on the main front of the plateau water is scarce, and where it is needed for mining it has been necessary to bring it down by ditches or pipe lines from the plateau. In places, however, such as Huntington Canyon, where the coal-bearing rocks extend far into the mass of the plateau, good water is plentiful near the coal outcrops.

## SETTLEMENTS

The coal-bearing area and the directly adjacent territory are but sparsely inhabited and would be even less populous but for the several mining towns. Hiawatha, in Miller Creek Canyon; Mohrland, in Cedar Creek Canyon; Wattis, in Wattis Canyon; and Clear Creek, Scofield, and Winter Quarters, in Pleasant Valley, are the mining towns of the field. Hiawatha is the largest of these, and it has many modern buildings and conveniences. The eastern part of the town is shown on Plate 17. Hiawatha, Mohrland, and Wattis are on the Utah Railway and have daily train connection with the main line of the Denver & Rio Grande Western Railroad, as well as telephone, telegraph, and electric-power service and frequent stage connection with Price.

The largest towns of the general region, including areas outside of the Wasatch Plateau field, are Price and Helper, on the Denver & Rio Grande Western Railroad, and Huntington, about 24 miles south of Price, in Castle Valley. Price, a town of about 3,000 inhabitants, is the county seat of Carbon County and is the commercial center of the area as a whole. Its position on the railroad makes it the point of entrance to Castle Valley, and it is the starting point for stage lines to Emery, in Castle Valley; Sunnyside, in the Book Cliffs coal field; and Duchesne, Roosevelt, and Myton, in the Uinta Basin. Helper was founded primarily as a railroad division point but has grown to be the trading center for the towns in the Spring Canyon district and for Kenilworth, in the adjoining part of the Book Cliffs field. Huntington, a town of about 1,200 inhabitants, is the chief trading point for central Castle Valley and is the center of the largest farming community east of the Wasatch Plateau. South of Huntington, in Castle Valley, are Castle Dale, the county seat of Emery County; Orangeville, a small community about 1½ miles west of Castle Dale; Ferron, a farming town of about 800 inhabitants on Ferron Creek; and Emery, a town of about 650 inhabitants near the south end of the valley. These towns are the chief trading centers near the coal field. Smaller communities include Cleveland, Molen, Clawson, and Rochester.

The central part of Castle Valley contains numerous ranches, which support a moderately large population. In and near the high plateau, however, ranches are few, and those few are found in the broader parts of the canyons and in valleys such as Joes Valley. The population of the plateau, apart from mining towns, is small.

## TRANSPORTATION AND TRAVEL ROUTES

*Railroads.*—The main line of the Denver & Rio Grande Western Railroad crosses the Wasatch Plateau coal field at its northern margin, and branch lines extend to the mining towns on the east front and in Pleasant Valley. The branch in Pleasant Valley leaves the main line at Colton and supplies the towns of Scofield, Winter Quarters, and Clear Creek. The Utah Railway extends from Utah Railway Junction, near Castlegate, along the base of the cliffs to Hiawatha and Mohrland. Spurs extend to the several mines near Spring Canyon and to Wattis, and in 1925 a branch line was being constructed to reach prospective coal mines on north fork of Gordon Creek.

*Roads and trails.*—The mining towns are all accessible by good automobile roads, and the "wagon mines" by wagon roads, but elsewhere in the coal field good roads are rare, and travel is difficult. An automobile road connects Price with Huntington, Castle Dale, Ferron, and Emery, and a daily stage runs between Price and Emery. Three automobile roads cross the plateau; one, a part of the Midland Trail, follows the general trend of the railroad up the Price River Canyon to Soldier Summit and on to Salt Lake City; another connects Orangeville, a hamlet 11 miles southwest of Huntington, with Ephraim, in the Sanpete Valley, by way of Straight Canyon and Seely Creek; the third, a part of the Pikes Peak-Ocean to Ocean Highway, connects Emery with Salina, in the Sevier Valley, by way of Ivie and Salina Creeks and is said to be the only one of the three that remains open throughout the winter. At the mouth of Ivie Creek Canyon a road branches southward from this highway, connecting with the towns of Fremont and Loa, in Rabbit Valley. This road was opened to automobile traffic in 1922, and it affords a good direct route from Castle Valley to points in Wayne County. Well-graded automobile roads connect Price and Huntington with Mohrland, Hiawatha, Wattis, and the several towns in Spring Canyon and Pleasant Valley, and a first-class concrete road connects Price and Castlegate.

Many secondary roads exist in the plateau proper, and these are put in repair as they are needed or become impassable through disuse and the ravages of floods. No road in this region lasts long without attention, and therefore road conditions change so rapidly that no description will be sure to hold good for more than a short time, and the only way to ascertain the accessibility of parts of the plateau top is to inquire locally at the time travel is contemplated. The general condition of the roads when the topographic map was made is shown on Plates 31 and 32, but even this will have changed materially in places by the time of publication of this report. It should be noted, however, that road conditions on the plateau in general are rapidly improving, largely owing to the work of the Forest Service in the Manti National Forest.

Many trails exist on the top of the plateau, and horseback travel is possible almost throughout. Only on the eastern front in the belt of cliffs, is travel afoot or horseback seriously obstructed.

## CLIMATE AND VEGETATION

In Castle Valley and on the east front of the Wasatch Plateau the rainfall is low and the prevailing temperatures are in general moderate, but on the top of the plateau the rainfall is more than twice as great as it is on the front, and the average temperatures are much lower. The following table shows the comparative precipitation and temperature of places in Castle Valley, Sanpete Valley, and Pleasant Valley:

*Precipitation and temperature in the Wasatch Plateau, Utah* [a]

| Place | Annual precipitation (inches) | Annual temperature (°F.) | | |
|---|---|---|---|---|
| | | Mean | Maximum | Minimum |
| Emery | 8 | 45 | 89 | —12 |
| Castle Dale | 11.8 | 47 | 95 | —2 |
| Price | 13.5 | 49 | 95 | —7 |
| Manti | 13.5 | 46 | 95 | —14 |
| Scofield | 19 | 37 | 86 | —37 |

[a] Compiled from U. S. Weather Bureau climatologic data for United States, 1914, 1915, 1916, and 1921.

The figures for Emery, Castle Dale, and Price, which are in Castle Valley, show the range for the east front; the figures for Manti are typical for the west front; and those for Scofield, although down in Pleasant Valley, give some indication of conditions in the northern part of the plateau. It is believed that the rainfall in the central part of the plateau exceeds that of Scofield, and the temperature ranges are doubtless different, but no published records are available.

The marked difference between the vegetation of the east slope and that of the top of the plateau is clearly reflective of the difference in precipitation. In Castle Valley vegetation is scant, and only the hardier plants common in arid regions are found. Shad scale, salt bush, scrub cedar, sagebrush, greasewood, piñon, and galleta grass prevail in the lowlands and on the cliffs, and in places scrub oak is abundant. On the top of the plateau vegetation is plentiful, and in places the growth of underbrush in the forests is actually rank. There some larger conifers grow, and the quaking aspen flourishes. Wild flowers are abundant, and because of the cooler temperature many of them bloom until late in the summer. On the plateau frosts commonly occur throughout the summer, and ordinary agriculture is impossible. The native grasses, however, grow in profusion, and many of the higher parts of the plateau afford rich pasturage for cattle, horses, and sheep.

## GEOLOGY

### STRATIGRAPHY

#### GENERAL SECTION

The geologic formations of the Wasatch Plateau coal field proper range in age from the lower part of the Upper Cretaceous to the lower part of the Eocene. The exposed formations include many varieties of sandstone, conglomerate, shale, and limestone, and their total thickness in the plateau and Castle Valley exceeds 10,000 feet.

A summary of the formations that constitute this column is given in the following table:

*Formations exposed in the Wasatch Plateau coal field*

| Age | Group and formation | | Member | Character of beds | Thickness (feet) Eastern part | Thickness (feet) Western part |
|---|---|---|---|---|---|---|
| Eocene. | Wasatch formation. | | | Shale, variegated, similar to lower member. | – | 1,000-1,200 |
| | | | Flagstaff limestone member. | Limestone, blue, gray, and white; forms massive cliff. | | 800-1,000 |
| | | | | Shale, variegated, chief colors red, chocolate, purple, gray; limestone, drab, white, and gray; sandstone, steel-gray and cream-colored; conglomerate. | 1,000 | 2,000 |
| Unconformity. | | | | | | |
| | Mesaverde group | Price River formation. | | Sandstone, gray to white, gritty; gray conglomerate; very little shale. | 600 | 1,000 |
| | | | Castlegate sandstone member. | Sandstone, very massive, coarse, white to gray; weathers buff; conglomeratic. | 150-500 | 150-200 |
| | | Blackhawk formation. | | Sandstone, buff to gray, medium to fine grained; shale; and coal; of continental origin. | 700-950 | 1,000+ |
| | | Star Point sandstone. | | Sandstone, massive, buff to gray, of marine to brackish-water origin; in places penetrated by tongues of marine Mancos shale. | 300-450 | 1,000+ |
| Upper Cretaceous. | Mancos shale. | | Upper shale member. | Shale, marine, blue-black to gray, sandy. Of Montana age. | 300-1,300 | (?) |
| | | | Emery sandstone member. | Sandstone, massive to thin bedded; forms steplike cliffs; contains Eagle fossils. | 50-800 | (?) |
| | | | Middle shale member. | Shale, marine, blue-gray; contains Niobrara fossils and includes the Garley Canyon sandstone member. | 1,650-2,400 | (?) |
| | | | Ferron sandstone member. | Sandstone, buff, brown, and white, coal-bearing; contains Carlile fossils. | 50-800 | (?) |
| | | | Lower shale member. | Shale, marine, blue-gray; contains lower Colorado fossils. | 600 | (?) |
| | Dakota (?) sandstone. | | | Sandstone, brownish gray, cross-bedded, conglomeratic. | 20 | |
| Cretaceous (?). | Morrison formation. | | | Shale, variegated; sandstone, gray to brown; limestone, gray and green; conglomerate. | 300+ | |

A preliminary description of the major features of the stratigraphy of the plateau, in which the formation names here used are defined, has recently been published.[14] The relations of the formations exposed on the plateau are shown graphically on Plate 3.

[14] Spieker, E. M., and Reeside, J. B., jr., Cretaceous and Tertiary formations of the Wasatch Plateau, Utah: Geol. Soc. America Bull., vol. 36, pp. 435–454, 1925.

The following descriptions are intended to present only the principal features of formations other than the Blackhawk formation, which contains the coal of the field, as attention is centered in this report on those details of the stratigraphy that bear in some way upon the occurrence and discovery of the coal.

## CRETACEOUS (?) SYSTEM

### MORRISON FORMATION

*Distribution of outcrop.*—The lowest rocks exposed in the area covered by the present work belong to the Morrison formation. They are exposed only in the southeast corner of the Castle Dale quadrangle, in and near Molen Seep Wash. The outcrop here is part of the great band of Morrison rocks which encircles the San Rafael Swell.

*Lithologic character.*—Approximately the upper 300 feet of the Morrison formation appears in the Castle Dale quadrangle. No section of these rocks was measured within the quadrangle, but the following section, which was measured by the writer on the Castle Dale-Green River road, east of the quadrangle, shows the varied character of the beds constituting the formation:

*Section of upper part of Morrison formation on Castle Dale-Green River road about 7 miles east of Castle Dale*

| | Feet |
|---|---|
| 1. Shale, green, gray, and red, containing scattered polished pebbles | 33 |
| 2. Limestone, dark green, coated at the outcrop with dense desert varnish | 12 |
| 3. Shale, gray clay, containing bands of calcareous gray sandstone, some red shale, and geodal concretions of jasper | 50 |
| 4. Sandstone, light gray, thin-bedded and cross-bedded, fine-grained | 8 |
| 5. Sandstone, light gray, coarse; weathers brown; in places copper-stained | 7 |
| 6. Conglomerate, gray; pebbles of gray sandstone; matrix coarse, friable gray sandstone | 4 |
| 7. Shale, gray | 20 |
| 8. Shale, green | 3 |
| 9. Shale, yellow, sandy | 1 |
| 10. Shale, purple to maroon; contains nodules of jasper and chalcedony, many of which are geodes lined with quartz crystals | 10 |
| 11. Shale, gray to variegated, nodular; contains irregular beds of gray limestone | 30 |
| 12. Sandstone, brown | 2 |
| 13. Shale, like No. 11 | 15 |
| 14. Limestone, nodular, gray | 2 |

| | Feet |
|---|---|
| 15. Shale, like No. 11 | 15 |
| 16. Shale, dark red-brown to dark maroon; contains nodules of gray limestone | 20 |
| 17. Limestone, gray | 3 |
| | 235 |

### CRETACEOUS SYSTEM

#### DAKOTA (?) SANDSTONE

*Distribution of outcrop.*—Between the uppermost shale beds of the Morrison formation and the lower member of the Mancos shale is a thickness of sandstone that has commonly been assigned to the Dakota. This sandstone crops out in the same locality as that mentioned for the Morrison formation.

*Lithologic character and thickness.*—Lupton[15] has described the Dakota (?) sandstone for this region, giving several measured sections to show its variation in thickness and character. Where it is exposed in the Castle Dale quadrangle the formation consists of about 20 feet of coarse light brownish-gray nodular cross-bedded and conglomeratic sandstone.

#### MANCOS SHALE

*General character.*—The Mancos shale forms the lowland east of the Wasatch Plateau and south of the Book Cliffs. It consists of blue-black to gray marine shale, with several prominent sandstone members, and at the north end of Castle Valley it is probably not less than 5,000 feet thick. The greater part of its exposure in Castle Valley has been described by Lupton,[16] and its exposure in the area between Castlegate and Sunnyside has been described by Clark.[17]

*Generalized section of Mancos shale at north end of Castle Valley*

| | Feet |
|---|---|
| Star Point sandstone. | |
| Mancos shale: | |
| Shale, blue-gray, sandy | 1,100 |
| Sandstone, buff-gray (Emery sandstone member) | 50 |
| Shale | 500 |
| Sandstone, buff-gray (Garley Canyon sandstone member) | 140 |
| Shale | 2,400± |
| Sandstone, sandy shale, and coal beds (Ferron sandstone member) | 210 |
| Shale | 600± |
| Dakota (?) sandstone. | |
| | 5,000± |

[15] Lupton, C. T., Geology and coal resources of Castle Valley in Carbon, Emery, and Sevier Counties, Utah: U. S. Geol. Survey Bull. 628, pp. 26–30, 1916.
[16] Idem, pp. 30–34.
[17] Clark, F. R., op. cit., pp. 13–15; 112–115.

The units outlined in this section are recognizable throughout Castle Valley, with the exception of the Garley Canyon sandstone, which disappears in the southwestern part of the Castlegate quadrangle.[18]

At the south end of Castle Valley the Mancos shale is somewhat thinner and the constituent members are considerably different in thickness, as is shown by the following section:

*Generalized section of Mancos shale on Quitchupah Creek, as measured in the southern part of Castle Valley*

| | Feet |
|---|---|
| Star Point sandstone. | |
| Mancos shale: | |
| Shale, blue-gray | 600 |
| Sandstone, buff (Emery sandstone member) | 800 |
| Shale, blue-gray | 1,650 |
| Sandstone, sandy shale, and coal beds (Ferron sandstone member | 500 |
| Shale, dark blue-gray | 600± |
| Dakota (?) sandstone. | |
| | 4,150± |

The fossil content of the Mancos shale shows it to range in age from lower Colorado to lower Montana. The fossils collected in the present work occur in well-defined zones of the shale and permit the satisfactory correlation of all parts of it with similar parts of the Mancos shale in regions farther east and north and the assignment of the zones to definite places in the standard Cretaceous section of the Western Interior.

*Members of the Mancos shale.*—The five members of the Mancos shale, shown in the table of formations on page 16, are fairly constant in appearance throughout the area mapped.

The lower shale member consists largely of dark blue-gray to black fissile shale and is considerably darker in color than the other shale members. It normally forms a slope beneath the low escarpment of Ferron sandstone, and its outcrop follows in general the eastern edge of Castle Valley, fronting the San Rafael Swell.

The Ferron sandstone member has been described in detail for Castle Valley by Lupton.[19] It forms an escarpment which follows the eastern edge of Castle Valley and gains in prominence southward as the sandstone of the member thickens from 75 feet at the north end of the valley to about 800 feet at the south end. South of T. 21 S., R. 7 E., the Ferron member contains coal, much of which is valuable. At the north end of the valley it contains no coal at the outcrop, but a bore hole near Price, in the NE. ¼ SE. ¼ sec. 28,

[18] Clark, F. R., op. cit., p. 112.
[19] Lupton, C. T., op. cit., pp. 31–33.

T. 14 S., R. 10 E., shows it to be over 200 feet thick and to contain a coal bed reported to be 7 feet 6 inches thick.

The middle shale member forms a large part of the floor of Castle Valley, and because of its great width of outcrop its thickness is somewhat difficult to measure. It is at least 2,400 feet thick near Price, in the northern part of Castle Valley, and about 1,650 feet thick near Emery, in the southern part. South of Emery its exact thickness is not known because of faults that cut out the upper part. It consists of blue-gray shale and contains many sandy layers, some of which change laterally into thin beds of sandstone. In the northern part of Castle Valley it contains the Garley Canyon sandstone member, which is lenticular at the outcrop but is probably part of a great tongue connecting toward the west with a large body of sandstone.

The Emery sandstone member forms a steplike series of cliffs at the base of the Wasatch Plateau, which are prominent near Emery, the type locality of the sandstone, and decrease in prominence toward the northern part of the valley. North of Emery the sandstone splits into two tongues (see pl. 2, *A*), separated by marine shale; the upper tongue continues north as far as the Castlegate quadrangle,[20] but the lower one dies out at the outcrop north of Hiawatha. Near Emery the member is about 800 feet thick, and farther south it becomes thicker but its complete thickness is difficult to ascertain because of faults. It thins rapidly north of Emery, and the two tongues into which it splits average about 50 feet in thickness in the plateau front near Ferron. The upper tongue is much thicker in the Castlegate quadrangle; and in the Bob Wright embayment, in the Scofield quadrangle, it thickens further in a westward direction, becoming at least 550 feet thick. At this place it may include the lower tongue, which is not continuous with it at the outcrop but which may connect with it underground.

Fossils collected from the Emery sandstone near Emery by Reeside, Thom, and the writer show it to be of lower Montana (Eagle) age.

The upper shale member of the Mancos forms the slope at the base of the Wasatch Plateau, beneath the lowermost sandstone of the Mesaverde group. (See pl. 27, *A*.) In the northern and central parts of the plateau front this member is 1,000 to 1,100 feet thick, but in the southern part it thins considerably, being about 600 feet thick west of Emery and possibly as little as 300 feet thick at its southernmost exposures in the region. It consists of blue-

[20] Clark, F. R., op. cit., pp. 113-114.

gray shale, much like that of the middle member, but it is normally sandier.

## MESAVERDE GROUP

### NOMENCLATURE AND SUBDIVISION

The rocks in the Wasatch Plateau here designated the Mesaverde group were originally considered to belong to the Laramie.[21] They were first assigned to the Mesaverde formation by Taff,[22] who followed Richardson's nomenclature[23] applied in the Book Cliffs, the coal-bearing rocks of which are continuous with those of the Wasatch Plateau. Richardson's application of the name Mesaverde was based on the use, by Fenneman and Gale,[24] of the name Mesaverde for the coal-bearing rocks in western Colorado which immediately overlie the Mancos shale, and which he regarded as equivalent throughout the region between western Colorado and the Wasatch Plateau.

Clark,[25] who carried on the first highly detailed work in the region, subdivided the Mesaverde formation into three members and discovered the fact that the lower sandstones of the Mesaverde of the west end of the Book Cliffs are equivalent to an upper part of the Mancos shale of areas farther east, the change eastward from sandstone to shale taking place by intertonguing of the Mesaverde and Mancos. Clark's original subdivisions have been recognized and followed by the writer, but, for reasons already published[26] in part, the rocks earlier designated the Mesaverde formation are now called the Mesaverde group, and the "members" are now set apart as separate formations, as shown in the table on page 16. This nomenclature has also been used in Clark's report,[27] which was not published until after the field work for this report had been done.

### STAR POINT SANDSTONE

*Type locality, distribution, and type of outcrop.*—The Star Point sandstone, the basal formation of the Mesaverde group in the

[21] Dutton, C. E., Geology of the High Plateaus of Utah, pp. 155–158, U. S. Geog. and Geol. Survey Rocky Mtn. Region, 1880. Taff, J. A., The Book Cliffs coal field, Utah: U. S. Geol. Survey Bull. 285, pp. 291–292, 1906.

[22] Taff, J. A., The Pleasant Valley coal district, Utah: U. S. Geol. Survey Bull. 316, pp. 340–341, 1907.

[23] Richardson, G. B., The Book Cliffs coal field: U. S. Geol. Survey Bull. 316, p. 305, 1907; Reconnaissance of the Book Cliffs coal field: U. S. Geol. Survey Bull. 371, pp. 16–19, 1909.

[24] Fenneman, N. M., and Gale, H. S., The Yampa coal field, Routt County, Colo.: U. S. Geol. Survey Bull. 297, pp. 19, 23, 1906.

[25] Clark, F. R., op. cit., pp. 15–16; pls. 4, 15.

[26] Spieker, E. M., and Reeside, J. B., jr., Cretaceous and Tertiary formations of the Wasatch Plateau, Utah: Geol. Soc. America Bull., vol. 36, pp. 441–448, 1925.

[27] Clark, F. R., op. cit., pp. 115–116.

Wasatch Plateau, was so named[28] because the lower part of it is prominent in Star Point, the northeasternmost headland of Gentry Mountain, in the northern part of T. 15 S., R. 8 E. It includes the rocks between the Mancos shale below and the Blackhawk formation above. It crops out in the east front of the plateau, usually forming the lowermost cliff in the escarpment (see pls. 20, *B*, and 2, *A*) and in Pleasant Valley. It is almost continuously exposed for about 100 miles in the barren front of the plateau, and it may be traced and studied in detail throughout its outcrop. In the central and southern parts of the field the Star Point sandstone forms vertical cliffs which bar the ascent of the plateau except where it is breached by large stream courses.

*Lithologic character and thickness.*—At its type locality and in the northeastern part of the field the Star Point sandstone consists of three prominent sandstone beds, in some places separated by shale and in others merely set off by partings of thin-bedded sandstone. These sandstone beds are equivalent in downward succession to the Spring Canyon, Storrs, and Panther tongues described by Clark.[29] The following section shows the character and thickness of these units at the north end of the field:

*Section of Star Point sandstone in Coal Canyon, sec. 16, T. 13 S., R. 8 E.*

| | Feet |
|---|---|
| Spring Canyon tongue: | |
| Sandstone, white, fine grained, massive | 20 |
| Sandstone, buff, medium grained, massive | 80 |
| Concealed (probably marine Mancos shale) | 80 |
| Storrs tongue: Sandstone, locally white, normally buff, medium grained | 50 |
| Concealed (probably largely Mancos shale) | 120 |
| Panther tongue: | |
| Sandstone, buff, fine to medium grained, massive, forming individual bench | 23 |
| Sandstone, as above, forming bench | 30 |
| Sandstone, buff; weathers away readily, grading to shale in places | 5 |
| Sandstone, hard, buff, medium grained | 1 |
| Shale, sandy, brown-gray | 1 |
| Shale, dark gray | 25 |
| Sandstone, hard, gray; weathers buff | 5 |
| Mancos shale (main body). | |
| | 440 |

In this section the tongues of Mancos shale between the tongues of Mesaverde sandstone are plainly evident. (See pp. 24–25.) Farther south the shale diminishes, as is shown by the following section, which represents the Star Point sandstone in the central part of the field:

[28] Spieker, E. M., and Reeside, J. B., jr., op. cit., pp. 442–443.
[29] Clark, F. R., op. cit., pp. 17, 116.

*Section of Star Point sandstone on east side of Grimes Wash, south of Anderson mine*

| | Feet |
|---|---|
| Hiawatha coal bed (base of coal-bearing Blackhawk formation). | |
| 1. Sandstone, white, massive | 24 |
| 2. Sandstone, buff, medium grained, massive at top, considerably split by bedding planes in lower half | 108 |
| 3. Sandstone, buff to gray, medium grained, platy and somewhat friable | 36 |
| 4. Shale, sandy, dark gray, marine (tongue of Mancos shale) | 60 |
| 5. Sandstone, platy, friable (like No. 3) | 24 |
| 6. Concealed (probably shale with thin beds of sandstone) | 66 |
| 7. Sandstone (like No. 3) | 42 |
| 8. Sandstone, buff, massive | 140 |
| Mancos shale (main body). | |
| | 500 |

In this section Nos. 1 and 2 constitute the Spring Canyon tongue, No. 5 is probably the Storrs tongue, and No. 8 is the Panther tongue of the section at the western edge of the Book Cliffs coal field.

Between Rock Canyon and Ferron Canyon the basal (Panther) tongue of the Star Point sandstone gradually loses its identity. South of Straight Canyon it becomes more and more split by bedding planes, and in Rock Canyon it is less prominent than usual, though still clearly definable. South of Rock Canyon the lower part of the sandstone appears to give place to shale, and the upper part changes from the massive sandstone that is characteristic in the northern part of the field to platy, thin-bedded sandstone that grades downward into the Mancos shale and upward into the massive sandstone of the upper part of the Star Point formation. At the southern end of the Wasatch Plateau the basal part of the Star Point sandstone is probably represented entirely by sandy shale. A section of the Star Point sandstone in the southern part of the field is as follows:

*Section of Star Point sandstone on south side of Mill Hollow, in sec. 25, T. 23 S., R. 4 E.*

| | Feet |
|---|---|
| Sandstone and shale of coal-bearing Blackhawk formation. | |
| 1. Sandstone, white at top, very massive, forming vertical cliff | 100 |
| 2. Sandstone, largely in thin massive beds separated by thinner partings of shale | 128 |
| 3. Shale, very sandy, harder than main body of Mancos shale, containing increasing number of thin sandstone beds toward top | 160 |
| Mancos shale (main body). | |
| | 388 |

South of this place No. 1 thickens, becoming about 150 feet thick and displacing the upper part of No. 2. There the details of the remainder of No. 2 and No. 3 are as follows:

*Section of lower part of Star Point sandstone on south face of Old Woman Mountain, in sec. 36, T. 23 S., R. 4 E.*

| | Ft. | in. |
|---|---|---|
| Sandstone, gray-buff; breaks to sharp sparlike fragments, containing shale partings 1 inch to 4 inches thick | 13 | |
| Shale, gray, massive, with many thin bands of sandstone in upper part | 33 | 6 |
| Sandstone, buff, platy, containing 1-foot band of shale 2 feet above base | 8 | |
| Shale, containing many hard sandy bands | 20 | |
| Sandstone; weathers yellow-brown; bedding planes prominent | 52 | |
| Shale, containing sandy bands | 78 | |
| Sandstone, platy | 1 | 6 |
| Shale, blue-gray, marine, very evenly bedded, sandy | 10 | |
| Sandstone, evenly bedded; weathers yellow-brown | 6 | |
| Mancos shale. | | |
| | 222 | |

In the eastern part of the field the Star Point sandstone is remarkable for its consistency in thickness and appearance. The interval between the top of the formation and the top of its basal (Panther) tongue is very regularly 350 to 360 feet throughout the front of the plateau between North Fork of Gordon Creek and Ferron Canyon. The Panther tongue ranges in thickness between 50 and 100 feet, but its top is very even and approximates a perfect plane more closely than any other geologic horizon in the field.

In Pleasant Valley and the northern part of Huntington Canyon the Star Point sandstone is considerably thicker than on the eastern front of the plateau. In the central part of Huntington Canyon it is 600 feet or more thick, and in Pleasant Valley, where exposures do not show its entire extent, it is probably more than 1,000 feet thick. On the west side of Pleasant Valley between Clear Creek and Scofield, where the Star Point sandstone crops out in forested hills, at least 1,000 feet of sandstone has been noted beneath the horizon of the Hiawatha coal bed, and the base of the sandstone is not exposed. No shale is evident at any of the exposures of the Star Point in Pleasant Valley.

*Relation to adjacent formations.*—The intertonguing relation between the Star Point sandstone and the Mancos shale, described by Clark and referred to above, is not fully displayed in the Wasatch Plateau, but the shale tongues that penetrate westward into the Star Point sandstone may be clearly recognized, as shown in the section on page 22. The downward thickening of the sandstone between the east front and Pleasant Valley, mentioned on page 24, doubtless also takes place by intertonguing, but if so, the tongues are buried beneath younger formations and are not observable. The southward replacement of the basal (Panther) tongue by shale, on the other hand, appears not to be due to intertonguing but to a gradual lateral change, such as is natural in going seaward, from sandstone to marine shale.

The actual boundary between the Star Point sandstone and the Mancos shale is thus somewhat complicated and spread out over a considerable vertical range. The contact between the base of the sandstone and the underlying shale in the Wasatch Plateau, which would normally be recognized as the boundary, shows a simple transition from shale upward into sandstone, and at most places the transition is so gradual that to fix a boundary precisely is a purely arbitrary matter. The boundary selected in the preceding sections is placed as nearly as possible in the middle of the transition beds, or perhaps a trifle above it.

The upper boundary of the Star Point sandstone, which involves the passage from littoral or marine sandstone to continental beds, is much sharper, and in most parts of the field it is a smooth, clear-cut surface, easily recognizable and usually well exposed. (See pl. 5, *B*.) The Star Point sandstone is normally succeeded upward, either directly or within a few feet, by the lowest coal bed of the Blackhawk formation, and the contrast between the massive hard white sandstone and the softer overlying beds is strong.

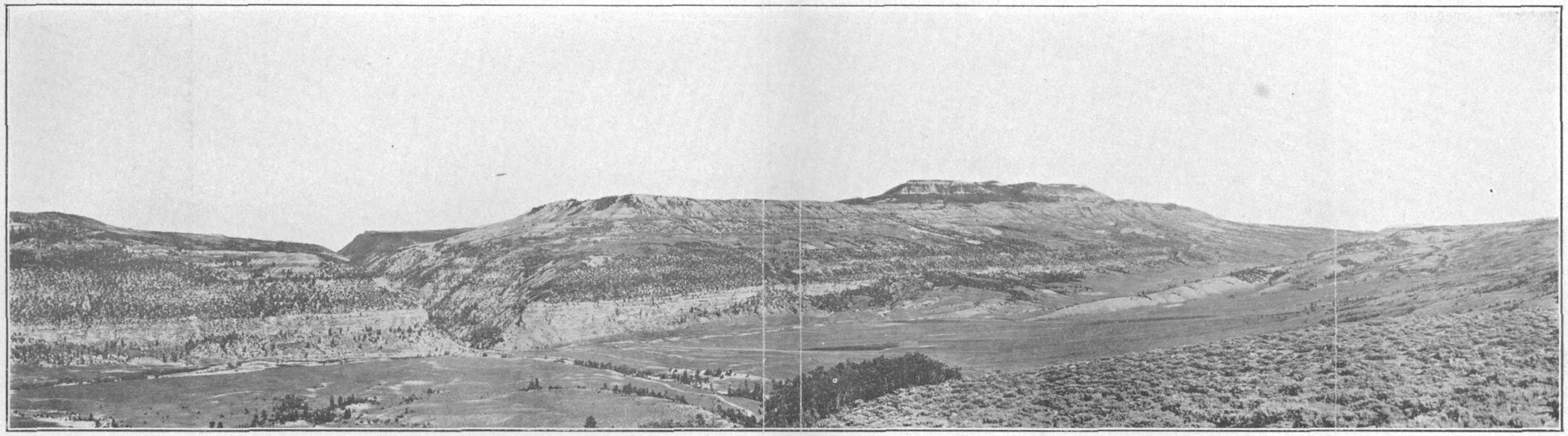
*Key beds.*—All the subsidiary units of the Star Point sandstone are good horizon markers, or key beds, particularly the basal (Panther) tongue and the upper (Spring Canyon) tongue, the top of either of which serves remarkably well as a horizon for the detailed determination of structure. The interval between these two horizons is relatively constant, and the top of the Spring Canyon tongue is of special value as a key to the position of the basal (Hiawatha) coal bed of the Blackhawk formation. The upper 10 to 50 feet of the Spring Canyon tongue is normally either pure-white or grayish-white sandstone, and wherever it is exposed it strikes the eye more readily than any other bed in the Star Point formation. (See pl. 5, *B*.) In the more rugged parts of the plateau front the Spring Canyon tongue invariably forms a vertical cliff. In places where the Mesaverde group yields broken slopes instead of cliffs the Spring Canyon tongue is usually beveled off, but the only places at which it does not appear are the forested slopes in the northern part of the plateau, and there the white sandstone at the top of the tongue may be traced from point to point, across the concealed areas, with little trouble. The white sandstone is overlain directly by the Hiawatha coal bed and has long been used by prospectors as a guide in their search for this coal.

The only other sandstone of considerable extent in the Mesaverde group that is similar to the white sandstone at the top of the Star Point formation and might be confused with it is the Aberdeen sandstone member of the Blackhawk formation, which underlies the Castlegate "A" coal bed. This sandstone, described by Clark[30] as it occurs in the Book Cliffs coal field, has been traced throughout the part of the Wasatch Plateau coal field north of Gentry Mountain. The characteristic appearance of the two white sandstones in the slopes of the plateau front in the Bob Wright embayment is shown in Plate 5, *A*.

*Conditions of origin.*—The sandstone of the Star Point was laid down on the beach and near the shore of the sea in which were deposited farther east the finer-grained sands and muds now constituting the Mancos shale. The intertonguing relation between the Star Point and the Mancos has resulted from the oscillation back and forth of the seashore, the tongues of sandstone representing partial withdrawal or eastward movement of the sea, with attendant eastward migration of the shore zone of sand and offshore zone of mud, and the tongues of shale representing the intervening advance or westward movement of the sea, resulting from depression of the shore, during which the zone of sand moved farther west and the zone of finer mud, following in its wake, occupied areas previously covered with sand. Repetition of this process, once for each tongue of sandstone and its overlying tongue of shale, with sufficient subsidence of the sea bottom to allow accumulation and preservation of the sediments, produced the succession of tongues here described. After the Spring Canyon tongue was formed the sea did not again invade the Wasatch Plateau, although it doubtless came very near at the time when the Aberdeen sandstone of the Blackhawk formation was being laid down. As it withdrew farther and farther east, it continued its oscillation, forming the higher tongues described by Clark[31] During this time land conditions existed in the Wasatch Plateau, and the Blackhawk formation was laid down as a continental and fresh-water swamp deposit.

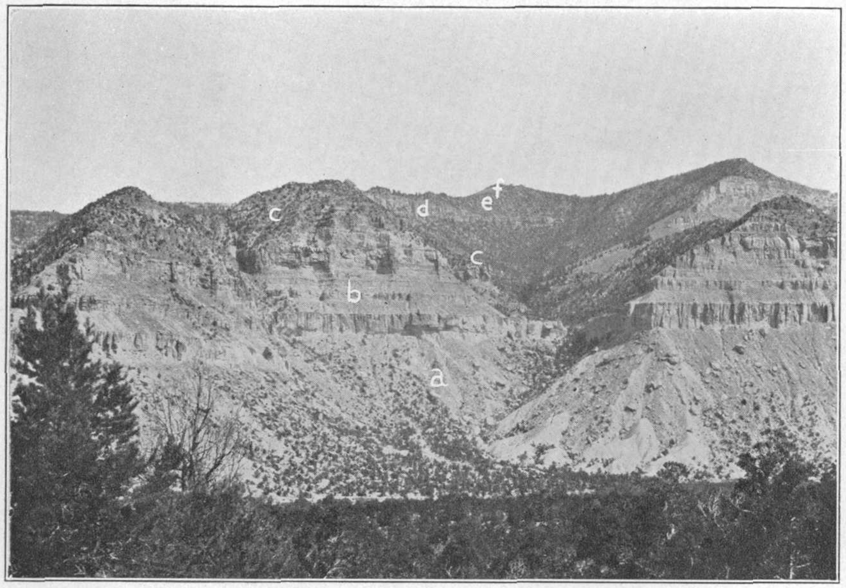
Obviously, the cross section that will show the tongues is one at right angles to the shore of the ancient sea; this is the type of cross section afforded by the Book Cliffs east of Castlegate. A cross section parallel to the ancient shore will not show the interwedging of the tongues but will show them as parallel bands of sandstone separated by bands of shale; with slight variations, this is the type of

[30] Clark, F. R., op. cit., pp. 11, 18.
[31] Idem, pp. 18–19.



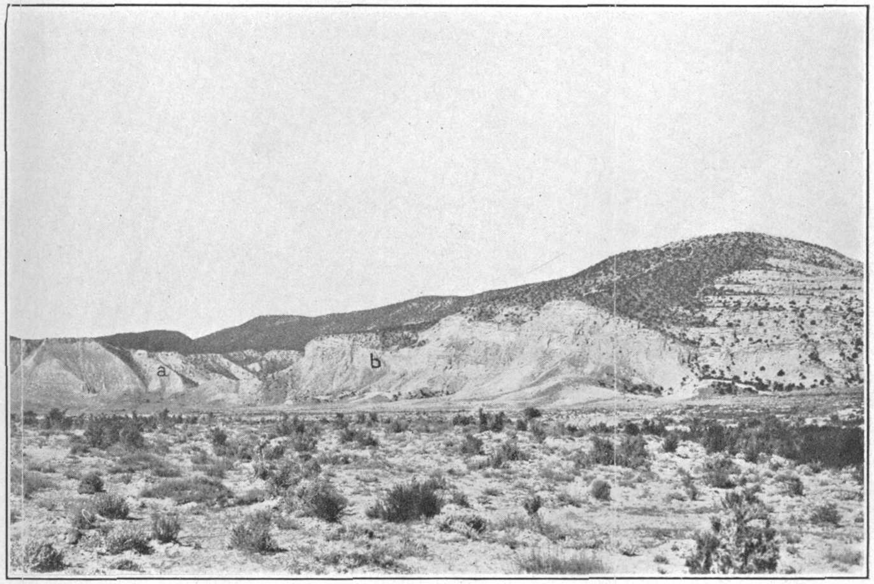
*A.* JOES VALLEY AND THE WEST FACE OF NORTH HORN MOUNTAIN

The type locality of the Joes Valley fault zone, seen from the brink of the western valley wall. Trail Mountain on left, North Horn Mountain in center, Straight Canyon between them. Joes Valley in left foreground, the North Dragon on left, top of South Horn Mountain on right sky line. The Castlegate sandstone forms the cliff, and above are the sandstones of the overlying part of the Price River formation, the lower shales of the Wasatch, and, on the Cap (right center sky line), the Flagstaff limestone member of the Wasatch. The low gray ridge in the valley on the right is Flagstaff limestone in a downthrown block of the fault zone.



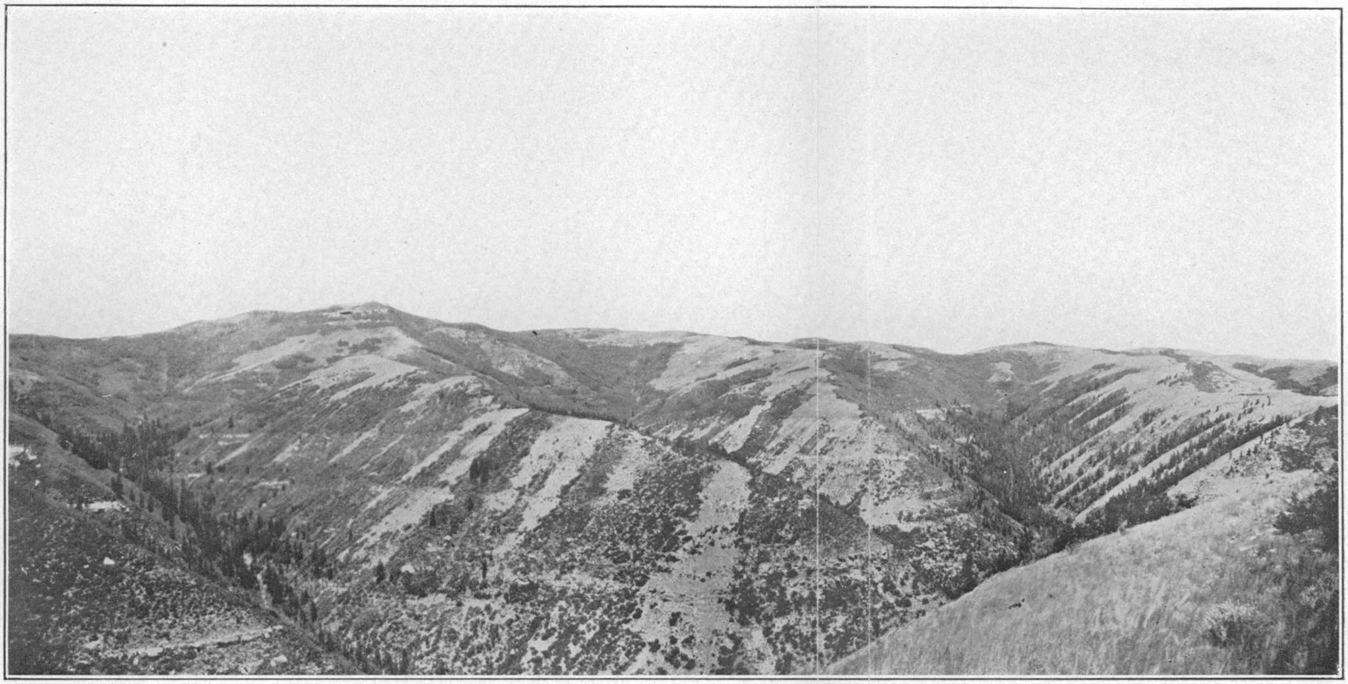

*B.* EAST WALL OF HUNTINGTON CANYON NEAR ITS MOUTH

a, Mancos shale; b, Star Point sandstone; c, Blackhawk formation; d, Castlegate sandstone member of Price River formation; e, upper part of Price River formation; f, Wasatch formation. The Bear Canyon fault is visible on the left.




*C.* PARADISE FAULT IN HILL EAST OF OAK SPRINGS RANCH, 13 MILES SOUTHWEST OF EMERY

Looking west from highway. a, Middle member of Mancos shale; b, Emery sandstone member of Mancos. The characteristic steplike outcrop of the Emery sandstone is visible at the right.



*A*. HEAD OF BOB WRIGHT CANYON, SHOWING WHITE SANDSTONES BENEATH HIAWATHA AND CASTLEGATE "A" COAL BEDS
The lower white sandstone is at the top of the Star Point sandstone; the Blackhawk formation forms the hills and ridges.

*B*. WHITE SANDSTONE AT TOP OF STAR POINT SANDSTONE, EXPOSED IN NORTH WALL OF CANYON SOUTH OF MILL FORK CANYON, IN T. 16 S., R. 7 E.

cross section afforded by the eastern front of the Wasatch Plateau. The cliffs of the Wasatch Plateau, however, do not follow strictly the shore of the ancient sea, and this may clearly be seen by comparison of the sections of the Star Point sandstone given on pages 22–24. In the northernmost section the shale tongues are evident, but in the next section south they have disappeared; this indicates that the lines of farthest advances of the sea (producing the shale tongues) did not follow the present line of cliffs, but crossed it at an angle, bearing more nearly due north than the cliffs, which trend northeast.

The uppermost sandstone of the Star Point originally formed the beach of the last retreating sea, and on it encroached, as the sea withdrew, the coastal swamps in which the coal of the Blackhawk formation was formed.

### BLACKHAWK FORMATION

*Type locality, distribution, and type of outcrop.*—The Blackhawk formation, the middle and coal-bearing division of the Mesaverde group, consists of the rocks between the top of the Star Point sandstone and the base of the Castlegate sandstone member of the Price River formation. The formation was named [32] from the locality of the Blackhawk mine (now King No. 1), on the east front of the plateau near Hiawatha. Its area of outcrop in the eastern part of the plateau is shown on Plates 31 and 32. It forms, normally, the middle slopes of the plateau front and the walls of the deeper canyons dissecting the plateau, and in the part of the field bordering Pleasant Valley it forms much of the plateau top. The Blackhawk slopes on the plateau front are as a rule sharply distinct from the pronounced cliffs of the underlying Star Point sandstone and the overlying Castlegate sandstone member, and in general the slope between the two cliffs is a good guide to the identity of the Blackhawk formation. (See pl. 20, *B*.) In the northern part of the field the formation is commonly covered with soil, and only its thicker and more resistant sandstone beds stand out in scattered exposures, but throughout the part of the plateau south of an east-west line through Mohrland the slopes are largely barren of soil, and the rocks are very well exposed. In some of the steep-walled gulches of the southern half of the field even the shale and softer sandstone beds are clearly exposed, but in the northern part perfect exposures of this sort are very rare.

*Lithologic character and thickness.*—The Blackhawk formation consists of sandstone, shale, and coal and ranges in thickness be-

[32] Spieker, E. M., and Reeside, J. B., jr., op. cit., p. 443.

tween 700 and 1,000 feet. The lower half of the formation contains thick and valuable coal beds, and in places thin beds of coal are distributed throughout the formation. The sections on Plate 6 show graphically the constitution and thickness of the formation at selected localities in the field.

The sandstone beds are for the most part fine to medium grained, buff to gray, and composed largely of quartz grains, in places intermixed with a considerable sprinkling of weathered feldspar. Many of them do not differ much in appearance from the Star Point sandstone, but some contain a higher percentage of iron than any part of the Star Point and are hence darker yellow or even red-brown. On the whole the sandstone beds of the Blackhawk are more irregular than those of the Star Point, and sandstones really similar to the Star Point sandstone are found only in the lower part of the Blackhawk formation.

The Blackhawk formation contains also a few local beds of white sandstone similar to that at the top of the Star Point sandstone and numerous thin beds of a brilliant orange-yellow sandstone. One white sandstone bed, which lies 160 to 200 feet above the base of the formation and is the same as the Aberdeen sandstone member of the Book Cliffs coal field, is traceable without interruption from the northern part of the field southward to the northeastern slopes of Gentry Mountain, and a similar bed appears intermittently at about the same distance above the Hiawatha coal in lower Huntington Canyon and in the vicinity of Hiawatha and Mohrland. A typical exposure of this sandstone in Bob Wright Canyon is shown in Plate 5, *A*. These white sandstones are well defined, with a clear-cut upper surface, and in that respect they differ from the white sandstone beds in the Castlegate member, which are everywhere more or less irregular. The beds in the Blackhawk formation normally underlie coal beds; but not all the coal beds rest on white sandstone.

The orange-yellow sandstone is very fine grained and is usually associated with coal beds. Similar sandstone is not known to occur in any other part of the Mesaverde group. It is by no means regular in occurrence, but it appears to be present sporadically in all parts of the Wasatch Plateau field.

The cement of these sandstones is in most places either calcium carbonate or secondary silica, but in a few places it seems to consist almost entirely of clay. Iron is also present in the cement of all except the pure-white sandstones, from which the original iron was probably leached by organic acids in the swamps that covered them. The presence of magnesium in many of the sandstone beds of the Blackhawk formation is well known at many places where efflorescent salts, containing a high percentage of magnesium sulphate, completely incrust hollows in the sandstone. The crust of these salts that has collected in some of the larger cavelike hollows in the sandstone is in places a foot or more thick. The leaching out by underground water of these materials from the Blackhawk formation has made many of the springs issuing from the formation extremely alkaline.

In the Blackhawk formation, particularly in the lower part, near the thicker coal beds, are many layers of very fine grained calcareous material that seems to be on the border line between limestone and sandstone. This material is normally light gray, in places white, and it is very homogeneous and solid. It has been interpreted by the writer as a fine-grained form of the same material that makes, in coarser grain, the normal gray sandstone of the formation, although at many places it might properly be called an impure limestone. In places an orange to brown material of probably similar origin occurs in platy beds that contain well-preserved fossil plants.

The shale of the Blackhawk formation is of three general kinds. Ordinary clay shale, gray or green, granular, and normally soft at the outcrop, is most abundant. Carbonaceous shale, massive to laminated and brown to black, is next in order of abundance, and a tough, leathery smoke-gray shale, which is usually associated with coal, occurs less commonly. The smoke-gray shale is generally found in thin layers, either separating the coal from sandstone, as roof or floor material, or forming partings within the bed. In an unweathered state it is hard, homogeneous, and very much like the type of fire clay commonly associated with coal beds in the Appalachian region.

All the shale of the Blackhawk formation is of continental origin, and although most of it shows the structure characteristic of true shale none of it is bedded as evenly as the marine shale of the Mancos. Some of the Blackhawk shale is very compact and totally structureless, and at the outcrop such shale weathers to clay.

The Blackhawk formation contains all gradations from slightly carbonaceous shale to pure coal. In places carbonaceous shale and dull or bony coal intergrade so closely that it is difficult to discriminate between them by mere inspection. The hard, even-grained material known as bone is common in coal beds of the field, and rarely has it been noted in separate beds not associated with coal.

Types of sedimentary rock in the Blackhawk formation are not greatly different from one end of the field to the other. The proportion of shale is greater in the northern part of the field than in the southern part, and the sandstone beds are more prominent in the southern part, but on the whole the change in character of rocks from place to place is relatively slight. The character of the beds composing the formation is shown in the following section, which was measured in Corner Canyon in a small stream channel where the rocks are unusually well exposed and which affords a practically complete record of the formation. The section shows the distribution of the coal beds almost throughout the formation, which is characteristic of the northern part of the field.

*Section of Blackhawk formation in Corner Canyon (locality 123), T. 15 S., R. 8 E.*

| | Ft. | in. |
|---|---|---|
| Castlegate sandstone member of Price River formation: Sandstone, coarse to medium grained, buff to pink, irregularly bedded. | | |
| Blackhawk formation: | | |
| Sandstone, massive, medium grained | 11 | |
| Shale, gray clay | 33 | |
| Sandstone, yellow | 1 | 6 |
| Shale, gray, fissile | 17 | |
| Concealed | 27 | |
| Shale, clay, solid | 16 | |
| Sandstone, buff, blocky to platy | 15 | |
| Shale, dark blue | 6 | |
| Sandstone, fine grained, and shale, dark blue, alternating in thin layers | 25 | |
| Sandstone, massive | 7 | |
| Shale, gray clay | 3 | |
| Sandstone, massive | 12 | |
| Sandstone, containing thin seams of coal | 6 | |
| Shale, hard, sandy | 1 | |
| Shale, dark-gray clay, firm | 4 | |
| Shale, black, highly carbonaceous | 1 | |
| Shale, dark-gray clay, soft | 2 | 6 |
| Shale, light-gray clay, soft | 2 | |
| Sandstone, buff, irregularly bedded | 15 | |
| Clay, gray | 6 | |
| Sandstone, massive; makes cliff | 45 | |
| Shale, sandy, hard | 5 | |
| Sandstone, fine grained, gray | 2 | |
| Shale, clay, ranging between dark blue-gray and light yellow-gray | 2 | |
| Sandstone, medium grained, buff | 1 | |
| Coal | | 1 |
| Shale, clay, as above | 5 | |
| Sandstone, white | 2 | |
| Sandstone, medium grained, gray, hard | 2 | |
| Coal | | 2½ |
| Shale, dark blue | | 8 |
| Sandstone, yellow and dark blue alternating | 12 | |
| Sandstone, massive, buff | 10 | |
| Shale, light-gray clay | 5 | |
| Sandstone, massive, buff | 14 | |

| Blackhawk formation—Continued. | Ft. | in. |
|---|---|---|
| Shale, black | 1 | 3 |
| Coal | 2 | 1 |
| Shale, black to gray, thin bedded | 4 | |
| Sandstone, platy, with spheroidal ferruginous concretions | 2 | |
| Shale, black, with lenses of coal | 3 | 6 |
| Shale, gray clay | 1 | |
| Sandstone, massive, ledge maker, brown at top | 15 | |
| Sandstone, platy | 20 | |
| Sandstone, massive; makes cliff | 15 | |
| Sandstone and shale, friable, partly concealed, showing thin streaks of coal | 12 | |
| Sandstone, very massive, resistant | 50 | |
| Sandstone, resistant but blocky, not massive | 16 | |
| Sandstone, friable, alternating with thin layers of blue-gray shale | 2 | 6 |
| Sandstone, very massive and solid | 15 | |
| Concealed | 15 | |
| Clay, green-gray | 1 | |
| Sandstone, massive, very fine grained, hard | 7 | |
| Coal, containing much resin | 2 | |
| Shale, massive to thin bedded, gray-black | 3 | |
| Sandstone, massive, gray to buff | 8 | |
| Clay, gray | | 1 |
| Shale, grading laterally to bony coal | | 7 |
| Coal | 1 | 6 |
| Shale, black | | 6 |
| Sandstone, massive, fine grained | 4 | |
| Coal | | 6 |
| Shale, hard, sandy, grading to shaly sandstone | 3 | |
| Shale, black, massive | | 6 |
| Coal | | 8 |
| Shale, clay | 1 | |
| Shale, black; breaks to rectangular blocks and gives odor of sulphur when struck | 1 | 4 |
| Shale, hard, gray | 1 | 6 |
| Shale, clay | 1 | |
| Shale, firm, gray | | 10 |
| Shale, light-gray clay | 2 | |
| Shale, black, fissile | | 7 |
| Shale, massive, blue, hard | 3 | 6 |
| Limestone, lenticular, of fresh-water origin, sandy | | 7 |
| Shale, gray clay | 2 | 6 |
| Shale, sandy, hard | | 4 |
| Coal | 1 | 2 |
| Coal, impure | | 2 |
| Shale, gray clay | 5 | 6 |
| Shale and coal in thin layers | | 6 |
| Shale, hard, massive | 3 | |
| Clay, gray-green | 2 | |

| Blackhawk formation—Continued. | Ft. | in. |
|---|---|---|
| Sandstone, massive, medium grained | 6 | |
| Shale, green-gray, solid | 1 | 6 |
| Shale, blue-black | 1 | 6 |
| Sandstone, with streaks of shale and coal | 21 | |
| Shale and sandstone, alternating, thin bedded | 10 | |
| Clay, light gray to white | 1 | |
| Sandstone, massive, calcareous at top | 6 | |
| Shale, light-gray clay, hard and firm | 1 | 2 |
| Shale, black, lenticular, with streaks of coal | 2 | |
| Sandstone, hard, fine-grained, shaly | 7 | |
| Shale, black, thin bedded, highly carbonaceous | 1 | 6 |
| Sandstone, shaly | 5 | |
| Shale, sandy | 1 | |
| Coal | 1 | 5 |
| Shale, gray clay | 2 | |
| Sandstone, shaly | 1 | |
| Shale, gray clay | 3 | |
| Coal | | 7 |
| Bone | | 1 |
| Coal | | 4 |
| Shale, gray clay | 2 | 6 |
| Sandstone, gray-buff, with lenses of black shale and carbonaceous matter | 18 | |
| Shale, black | 1 | 6 |
| Coal | | 3 |
| Shale | 1 | 6 |
| Coal | | 5 |
| Shale, gray clay | 9 | |
| Sandstone, platy | 1 | 8 |
| Shale, platy | 1 | 6 |
| Sandstone, massive, soft, argillaceous, almost shale | 2 | |
| Concealed | 5 | |
| Shale, sandy | 3 | |
| Shale, clay, with lenses of coal | 2 | |
| Concealed | 17 | |
| Sandstone, as above, almost shale | 15 | |
| Shale; breaks to sparlike fragments | 8 | |
| Shale, massive | 3 | |
| Sandstone, as above, almost shale | 17 | |
| Bone | 1 | 2 |
| Sandstone, massive, irregularly veined with thin seams of carbonaceous matter | 2 | |
| Sandstone, massive, gray | 7 | |
| Sandstone, platy, gray, with lenses of shale and coal, almost shale in places | 11 | |
| Shale | 1 | |
| Coal | | 2½ |
| Shale, massive, dark, grading to sandstone below | 2 | |

| | Ft. | in. |
|---|---|---|
| Blackhawk formation—Continued. | | |
| Sandstone, hard, argillaceous, very fine grained, with lenses of coal | 17 | |
| Shale, black, fissile | 2 | |
| Sandstone, hard, argillaceous, grading to shale below | 3 | |
| Shale, green-gray | 4 | |
| Concealed (coal?) | 6 | |
| Shale, black, soft, platy | 1 | |
| Sandstone, massive, argillaceous | 18 | |
| Coal, with much light-yellow resin | 9 | |
| Shale, thin bedded, sandy lenses at top | 3 | 6 |
| Shale, massive, dark gray | 2 | |
| Sandstone, thin bedded | 11 | |
| Sandstone, massive, buff below, cream-colored above, makes cliff | 15 | |
| Coal, with much dark-red resin at top and bottom | 9 | 4 |
| Sandstone, massive, fine grained, very argillaceous | 3 | 6 |
| Shale, gray clay | 1 | |
| Coal | | 6 |
| Sandstone as above | 2 | 6 |
| Shale, platy | 1 | |
| Sandstone, massive, argillaceous | 1 | 6 |
| Shale, black, massive | 7 | 6 |
| Shale, black, fissile | 4 | |
| Coal | 1 | 8 |
| Shale, black, sandy, with lenses of coal | 2 | |
| Sandstone, massive, yellow-brown to gray, fine grained above, medium grained below | 6 | |
| Shale, very carbonaceous, almost impure coal, sandy | 2 | |
| Coal | | 6 |
| Shale as above | 1 | 6 |
| Sandstone, massive, buff | 8 | |
| Shale, black-gray; breaks to spars | 1 | 6 |
| Sandstone, massive, buff, lenses of black shale | 30 | |
| Coal (Hiawatha bed) | 5 | |
| Total thickness of Blackhawk formation | 937 | 5 |
| Star Point sandstone (upper part): | | |
| Sandstone, white, fine grained | 6 | |
| Sandstone, massive, buff | 48 | |
| Sandstone, thin bedded, gray-buff | 125+ | |
| Total thickness of section | 1,116 | 5 |

This section shows the Blackhawk formation to be composed of about one-third shale and two-thirds sandstone. A casual inspection of the formation gives the impression that it is about half shale and half sandstone, probably because many thin beds of sandstone are covered where the intercalated shale has caused the aggregate to weather into soil-covered slopes. The section contains about 37 feet of coal, 23 feet of which is in three beds. At places in the field where several thick beds of coal are present the total amount is greater; for example, 38 feet of coal divided into two beds is present at Scofield, in Pleasant Valley, and much more is contained in thinner beds. However, the proportion of coal in the Corner Canyon section is fairly representative of the field.

A section measured by W. W. Boyer in Bear Creek Canyon, which is more generalized on account of less complete exposures, shows about the same amount of coal, but that amount is undoubtedly too small because of incomplete measurements on burned beds and beds that are concealed. This section is as follows:

*Section of Blackhawk formation in Bear Creek Canyon, in the SE. ¼ sec. 24, T. 16 S., R. 7 E.*

| | Ft. | in. |
|---|---|---|
| Sandstone and shale | 115 | |
| Sandstone, drab, massive, ledge forming | 30 | |
| Shale, gray | 9 | |
| Sandstone, brown, massive, ledge forming | 17 | |
| Shale and platy sandstone | 17 | |
| Sandstone, gray, massive | 11 | |
| Shale and thin sandstone | 23 | |
| Sandstone, gray-brown, massive, ledge forming | 34 | |
| Coal, partly burned | 1 | 2 |
| Sandstone, shale, sandy shale | 115 | |
| Coal and bone | | 5 |
| Shale, gray | 1 | |
| Coal } (location 193d) | 5 | 6 |
| Coal, bony } (location 193d) | | 4 |
| Coal } (location 193d) | | 10 |
| Sandstone and shale | 26 | |
| Coal | 1 | |
| Sandstone and shale | 29 | |
| Coal and ashes | | 10 |
| Shale and thin sandstone | 13 | |
| Coal, ashes, and burnt shale | | 8 |
| Shale and thin shaly sandstone | 22 | |
| Coal and burnt shale | | 8 |
| Shale, yellow clay, and sandstone | 22 | |
| Coal and carbonaceous shale | 1 | |
| Shale, slightly carbonaceous | 3 | |
| Coal | | 2 |
| Sandstone and shale | 44 | |
| Coal | 1 | 2 |
| Shale and sandstone | 24 | |
| Coal and carbonaceous shale | | 6 |
| Sandstone and sandy shale | 18 | |
| Coal (location 193c) | 8 | 2 |
| Shale and sandy shale | 11 | |
| Coal (Bear Canyon bed, location 193b) | 10 | 2 |

| | Ft. | in. |
|---|---|---|
| Sandstone and thin shale, ledge forming | 81 | |
| Coal and ashes | | 10 |
| Sandstone, gray-brown, massive | 11 | |
| Coal (Hiawatha bed, location 193a) | 2 | 7 |
| Bone (Hiawatha bed, location 193a) | | 1 |
| Coal (Hiawatha bed, location 193a) | 2 | 1 |
| Shale, blue-gray | 2 | 7 |
| | 716 | 9 |

In the southern part of the field the main feature in which the formation differs from the foregoing sections is the comparative absence of shale. The following generalized section shows its major elements:

*Generalized section of Blackhawk formation in the southern half of the Wasatch Plateau coal field*

| | Feet |
|---|---|
| Upper massive sandstones, little or no coal | 280 |
| Blocky sandstone, shale, and thin coal beds | 350 |
| Lower massive sandstone and thick coal beds | 120 |
| | 750 |

The columnar sections on Plate 6 show the thickness of various parts of the formation and the relations of individual beds from place to place throughout the field. The general columnar sections on Plate 3 show the thickness of the formation and its relations to the other geologic formations.

*Relation to adjacent formations.*—The base of the Blackhawk formation is sharply defined by the clear-cut upper surface of the Star Point sandstone, upon which it rests conformably. The Hiawatha coal bed is normally the lowest bed of the Blackhawk formation, but in many places the coal bed is separated from the sandstone by a few inches of shale or fire clay and in some places by several feet of sandstone and shale. The evenness and persistency of this contact is remarkable. It was traced in the present work throughout its extent at the outcrop, without doubt as to its identity anywhere except along the forested canyon walls of the upper part of Huntington Canyon and the similar western wall of Pleasant Valley between Clear Creek and Green Canyon. At very few places does it show any irregularity, but at some, notably in the gulch in sec. 13, T. 19 S., R. 6 E., the upper part of the Star Point sandstone appears to have been channeled out, probably by streams of early Blackhawk time, and the channel has been filled in with cross-bedded sandstone. On both sides of irregularities such as this the normal top of the Star Point sandstone is invariably clearly defined.

The top of the Blackhawk formation, drawn at the base of the cliff-forming Castlegate sandstone member of the Price River formation, is well exposed at few places in the field. It is commonly covered by the talus slope of boulders resulting from the disintegration of the overlying cliff. The difference between the sandstone of the Castlegate member and the Blackhawk formation is sufficiently striking, however, to permit a clear distinction wherever the contact is exposed. The nature of this contact is set forth on page 42, in the description of the Price River formation.

*Key beds.*—Within the Blackhawk formation there is but one consistent key bed of wide extent, and that is the Aberdeen sandstone member,[33] which normally underlies the Castlegate "A" coal bed. This sandstone, which is similar to the white sandstone at the top of the Star Point sandstone, was traced in the present work from Spring Canyon, where Clark identified it, as far south as the northeastern slopes of Gentry Mountain, and a bed which is probably the same was traced through a considerable part of Huntington Canyon. In the northern part of the field this sandstone is the chief guide to the identity of the Castlegate "A" coal bed. In this respect also is it similar to the uppermost sandstone of the Star Point, which is the guide to the Hiawatha coal bed. These horizon markers have been of great importance in the correlation of the coal beds of the field. (See pp. 25–26.) Other sandstones in the Blackhawk formation may be recognized for distances of a few miles, and some of them have aided in the correlation of coal beds.

*Age of the Blackhawk formation.*—The few poorly preserved fossils thus far collected from the Blackhawk formation in the Wasatch Plateau, and Book Cliffs coal fields show that the rocks are of Montana age, and according to the usage discussed on page 21, they are referred to the Mesaverde group. Several collections of fossil plants, made by the writer, were reported by F. H. Knowlton to indicate Montana (Mesaverde) age. A list of these fossils is given below:

7672. Meetinghouse Canyon, near forks, about 1 mile from Huntington Canyon, about 400 feet above base of Blackhawk formation:

Sequoia obovata Knowlton.
Ficus populoides Knowlton.
Ficus rhamnoides? Knowlton.
Ficus leei? Knowlton.
Salix sp.

7673. On spur east of Utah Fuel Co.'s mine in Bob Wright Canyon, T. 14 S., R. 7 E.:

Ficus rockvalensis Knowlton.
Salix sp.?

7675. Huntington Canyon north of Coal Canyon, T. 14 S., R. 6 E.:

Onoclea sp. nearest to O. minima Knowlton.

[33] Clark, F. R., op. cit., pp. 18, 117.

7677. On west side of round hill south of Bear Canyon between trail and road, sec. 15, T. 14 S., R. 6 E.:

Sequoia reichenbachi (Geinitz) Heer.
Sequoia obovata Knowlton.
Salix sp.
Ficus sp.

7682. Near top of round hill south of Bear Canyon, sec. 15, T. 14 S., R. 6 E.:

Dryophyllum falcatum? Ward.

7680. Huntington Canyon near Bear Canyon, sec. 14, T. 14 S., R. 6 E., about 150 feet above base of Blackhawk formation:

Ficus tessellata Lesquereux?

7679. Main forks in Eccles Canyon, Pleasant Valley district, about 200 feet above base of Blackhawk formation:

Dryophyllum falcatum? Ward.
Ficus trinervis Knowlton.
Ficus eucalyptifolia Knowlton.
Viburnum montanum Knowlton?
Phyllites vermejoensis Knowlton.
Cinnamomum linifolium? Knowlton.
Juglans sp.

7683. Huntington Creek, west side, near mouth of Coal Canyon:

Sequoia obovata Knowlton.
Onoclea sp. nearest to O. minima Knowlton.
Ficus planicostata? Lesquereux.
Laurus cf. L. baueri Knowlton.

*Conditions of origin.*—The sediments that have become the rocks of the Blackhawk formation were probably laid down on a broad flood plain or coastal plain, of very low relief, which lay approximately at sea level. They were probably distributed by streams, at times over the broad surface of the plain and at times possibly into coastal lagoons, into which the salt water of the sea occasionally had access. The alternation of these conditions is shown by the presence in the rocks of both fresh-water and brackish-water fossils. At successive stages this broad plain was covered by extensive swamps bordering the sea, in which the most persistent coal beds were formed, and farther inland other swamps, more local in character, produced the vegetal growth for the formation of the lesser coal beds. The abundance of plant fossils in the rocks throughout the formation shows clearly the existence of land conditions sufficiently stable to permit the growth of vegetation, and the beds composing the formation afford a record of the alternation of areas of sandy beach, lowland swamp, forest-covered flood plain, and coastal lagoon. The swamps in which the coal beds were formed presumably existed on the coastal flood plain during times of very gradual subsidence, while the streams draining the land were comparatively free of sediment, and these swamps were most extensive in the area nearest to the sea in which the Mancos shale was deposited. Consequently, the most persistent coal beds are without exception those which were laid down nearest the shore line, and hence the coal beds of the part of the Mesaverde still preserved are chiefly in the lower part of the Blackhawk formation, or in other words only a little above the Star Point sandstone, which represents in large part the accumulation of sand on the beaches of the receding sea. As the sea withdrew farther east and the present site of the Wasatch Plateau became farther inland, the higher beds of the Blackhawk formation were laid down, and the swamps that existed on these parts of the flood plain were neither so extensive nor so long-lived as those nearer to the shore. This condition is also known to be true in the western part of the Book Cliffs coal field,[34] where the upper limit of the Mancos shale and the sandstone immediately overlying it, which marks the position of the old shore appear at higher and higher stratigraphic positions in eastward progression from Castlegate to Sunnyside and beyond, and the extensive coal beds are those nearest to the sandstone immediately above the Mancos shale.

It is difficult to imagine, in terms of present-day conditions, the extent of the flood plains and coastal swamps in which the sediments of the Blackhawk formation and equivalent formations in other regions were laid down. None of the wide area in which these sediments are now found can have been very far above sea level at any time during the deposition of the sediments, and the thickness of the rocks now included in the Blackhawk formation shows clearly that the conditions under which they were formed must have lasted a very long time. The materials forming the shale and sandstone were probably washed onto the flood plain by sluggish waters of broad, intercommunicating rivers, the sand accumulating on the shores and higher parts of the area and the shale probably within lagoons. The swamps in which the coal was formed came into existence at periods when the subsidence of the land, necessary for the accumulation of appreciable thicknesses of sediments such as shale and sandstone, kept pace with the formation and accumulation of large amounts of peat, the mother substance of coal.

Authorities differ in their estimate of the amount of peat necessary to form a given amount of coal, but the estimates that have been most widely accepted[35] seem to show that a foot of ordinary unconsolidated vegetable débris such as is ordinarily visible at the surface of a swamp would form about half an inch of bituminous coal. The amount varies according to the degree of loss of the original constituents of the vegetable matter through decay, compression, and other causes. The original vegetable matter was com-

[34] Clark, F. R., op. cit., pl. 4.
[35] White, David, The origin of coal: Bur. Mines Bull. 38, p. 89, 1913.

pacted in the swamp to peat that represents possibly one-tenth of the original volume, and the peat was further compacted, in the formation of coal, to about one-third of its volume. A coal bed in the Wasatch Plateau 10 feet thick thus probably represents 300 feet of original plant growth and 30 feet of peat. The amount of vegetable matter necessary to form the thick beds of coal in this and other fields of the western United States must have been enormous, and when the purity of the coal in many of these thick beds is taken into account it is plain that the coal beds represent a remarkably stable set of conditions. To allow the accumulation of pure peat and hence the formation of pure coal it was essential that very little sediment be washed into the swamp; in places where sediments were washed in, the coal beds are either impure or contain partings of bone, sandstone, or shale.

### PRICE RIVER FORMATION

*Type locality, subdivisions, distribution, and type of outcrop.*— The Price River formation was so named [36] from exposures in Price River Canyon northwest of the town of Castlegate. The formation includes at the base the Castlegate sandstone member. The Castlegate sandstone has long been locally known by that name, which is peculiarly appropriate because the massive sandstone forms the gate-like passage, popularly known as the Castle Gate, in Price River Canyon 2 miles above the town of Castlegate. Clark [37] first used the name in a published report and defined the unit.

The surface distribution of the Price River formation is shown on Plates 31 and 32. On the east front of the plateau the cliff of Castlegate sandstone consistently forms the upper rim of the escarpment, where it stands out in bold outlines which can be recognized at considerable distances. (See pls. 2 and 20, *B*.) The overlying part of the formation either forms a slope above the cliff or is spread out over hilly areas of the plateau top. Farther west in the plateau the distribution of the formation is somewhat irregular, owing to the displacement of the rocks by faults, but the characteristic surface expression of the Castlegate sandstone may be recognized wherever it is well exposed, and many of the minor surface features of the interior of the plateau owe their origin to the resistant character of this sandstone. The most notable appearance of the Castlegate member in this part of the field is in the long lines of cliffs forming the walls of Joes Valley and its southern extension. Parts of these outcrops are shown in Plates 2, *B*, and 4, *A*.

[36] Spieker, E. M., and Reeside, J. B., jr., op. cit., p. 445.
[37] Clark, F. R., op. cit., pp. 20, 119.

*Lithologic character and thickness.*—The Price River formation consists predominantly of sandstone, much of which is coarse and conglomeratic, but in places the upper part of the formation contains some shale. The formation as a whole is distinguishable from the Blackhawk formation by the coarser grain and predominantly gray to white color of the sandstone and by its content of conglomerate. The Blackhawk formation is not known to contain conglomerate in the Wasatch Plateau, and coarse gray sandstone occurs in it rarely if at all. The appearance at the outcrop of the characteristic rocks of the Price River formation is shown in Plate 7, *B*. The character of the formation at the type locality is shown by the following section:

*Section of Price River formation in Price River Canyon between the Castle-gate and Crandall Canyon*

| | Feet |
|---|---|
| Upper part: | |
| 1. Sandstone, massive, gray, medium to coarse grained; forms cliff similar in appearance to that of Castlegate member | 100 |
| 2. Shale, gray to brown, sandy, somewhat carbonaceous | 10 |
| 3. Sandstone, massive, like No. 1; forms cliff with solution caves at base; is notably coarser near top | 150 |
| 4. Sandstone, massive in lower part, thin bedded above, brown-gray, medium grained; hard layers alternate with soft | 60 |
| 5. Sandstone, somewhat friable; weathers to rounded outcrop; medium grained, light buff, argillaceous | 90 |
| 6. Sandstone, massive, medium grained, roan-brown | 4 |
| 7. Shale, gray to brown, granular | 26 |
| 8. Sandstone, irregularly platy and thin bedded, medium grained, roan-brown | 5 |
| 9. Covered (probably shale and friable sandstone) | 15 |
| 10. Sandstone, brown, medium grained | 3 |
| 11. Sandstone, friable, and shale (largely covered) | 11 |
| 12. Sandstone like No. 10 | 10 |
| 13. Shale, gray, sandy | 4 |
| Total upper part | 488 |
| Castlegate sandstone member: | |
| 14. Sandstone, irregularly bedded, predominantly pinkish gray to white, some layers gray mottled with brown, a few brown layers; medium coarse near base, coarse and sugary above, containing carbonaceous matter in some layers | 102 |
| 15. Shale, very sandy and hard, gray | 4 |
| 16. Sandstone, medium to fine grained, pinkish brown | 5 |
| 17. Shale like No. 15 | 2 |
| 18. Sandstone, fine grained, containing fragmentary molluscan fossils | 2 |
| 19. Shale like No. 15 | 10 |
| 20. Sandstone, very fine grained, gray; weathers brown | 1 |

| Castlegate sandstone member—Continued. | Feet |
|---|---|
| 21. Shale like No. 15, containing scattered fresh-water and brackish-water fossils | 10 |
| 22. Sandstone, buff, medium grained (the top of this sandstone is at the roadside near point where pipe line crosses Price River), about | 25 |
| 23. Sandstone, massive, forming northern wall of Castle Gate; much like No. 14; containing conglomerate, matrix gray grit, pebbles, 1 inch or less in diameter, of white quartzite and black chert; scattered lenses of coal ¼ inch thick; the cliff of this sandstone has a pinkish cast when seen from moderate distances | 350 |
| Total Castlegate member | 511 |
| Total Price River formation | 999 |

The description in this section of the lowermost unit is somewhat generalized to show the character of the rocks for the entire northern part of the field; otherwise the units are described as they occur in Price River Canyon.

A brief examination of this section will suffice to show that the lithologic characters of the Castlegate member and the overlying Price River beds are much alike. The Castlegate member is separated because of its cliff-forming habit, by which it can be recognized over wide areas. The top of the main cliff, however, which is by definition the top of the Castlegate member, does not everywhere occupy the same stratigraphic horizon. In the Price River Canyon, for example, and in Willow Creek Canyon, where the member is thickest, the upper 200 to 300 feet undoubtedly consists of beds included elsewhere in the overlying part of the Price River formation. Further mention of this characteristic will be found in the description of the Castlegate member as a horizon marker, on page 44.

The Price River formation seems to maintain, in most of the area here described, thicknesses between 700 and 1,000 feet. On Gentry Mountain, however, and north of Muddy Creek it is considerably thinner, probably in part owing to original lack of deposition of as much sediment as at other places and in part owing to the irregular erosion of the upper part of the Price River formation before the overlying Wasatch formation was deposited.

The character of the rocks is fairly constant in the eastern part of the field, except in a few places where the upper part of the formation is shaly, but in the central part of the plateau, notably in the valley south of Cleveland Reservoir, the formation contains much sandstone and shale like that of the Blackhawk formation, and in the northern part, west of Pleasant Valley, it contains distinctive beds of exceedingly coarse grit that is intermediate in texture between coarse sandstone and conglomerate. In the southern part of the field, near the divide on the Pikes Peak-Ocean to Ocean Highway at the head of Ivie Creek, the Castlegate member disappears, and the formation is made up of coarse white sandstone, conglomerate, brown sandstone, and apparently very small amounts of shale.

The position of the formation in the geologic column of selected parts of the field is shown on Plate 3.

*Relation to adjacent formations.*—The base of the Price River formation may be satisfactorily drawn, almost throughout the field, at the base of the massive cliff of the Castlegate member. The rocks of the formation are normally much coarser than those of the underlying Blackhawk formation and are either white or of distinctly grayish hue. The exact line of contact between the two formations is exposed at few places, because of the piles of rock débris that have accumulated at the base of the cliff formed by the Castlegate member.

The abrupt change from fine or medium grained rocks to coarse and conglomeratic sandstones indicates conditions of origin for the Price River formation considerably different from those which produced the Blackhawk formation, and it is possible that the contact between the two is unconformable and that they are separated by a period of erosion representing a considerable lapse of time.[38] Knowledge concerning the Castlegate sandstone gained in 1925 by the writer and Reeside (see p. 44) indicates that unconformity between the formations, if present, does not extend far east of the Wasatch Plateau, but on the west side of the plateau there is an unconformity of considerable magnitude at the base of a succession of conglomerate and sandstone which is probably equivalent to the Price River formation. It seems likely that the contact is unconformable in the Wasatch Plateau, but that the lapse of time represented by the unconformity grows less in eastward progression until it vanishes in the western part of the Book Cliffs.

The top of the Price River formation is almost certainly marked by an unconformity, but in many places the problem of locating the unconformity is not easy to solve. The Price River formation is believed by the writer to be of upper Montana age, and the overlying Wasatch formation is Eocene; a period of uplift and erosion therefore presumably occurred between the deposition of the Price River and that of the Wasatch. On the west side of the plateau the uplift was pronounced, and the Cretaceous rocks were steeply folded and eroded before the lowest Eocene sediments were deposited, but in the

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[38] Spieker, E. M., and Reeside, J. B., jr., op. cit., pp. 445–448.

part of the plateau covered by this report no such disturbance is evident, and the Eocene rocks lie without angular discordance on the Price River rocks.

At many places scattered throughout the length of the field the first rock above the characteristic Price River rocks to show a pronounced change and to indicate unconformity is a conglomerate, the pebbles of which are limestone of the kind peculiar to the Wasatch and later formations. (See p. 46.) This conglomerate, if the pebbles are of Eocene limestone, obviously could have formed only after the beginning of Eocene time. A bare possibility exists that the limestone comes from fresh-water limestone beds in the Morrison formation of the region, but the writer doubts this, and even if it is true, the conglomerate marks the time when the region on the west was sharply folded, bringing the earlier Mesozoic rocks to the surface, and this time the writer believes corresponds to the passage from Cretaceous to Eocene. Where this limestone conglomerate exists, therefore, it is a mark at least of Eocene age. At many places the rocks beneath the lowest bed of limestone conglomerate are such as are characteristic of the Price River formation, and at these places the conglomerate is taken as the base of the Wasatch formation. The actual base of the Wasatch may, however, be lower, as the first sediments of Eocene age to be swept over the eroded surface of the Cretaceous rocks would be the disintegration products of the Cretaceous rocks themselves, and in places where these reworked sediments remained to form the basal Eocene rocks it might be exceedingly difficult if not impossible to detect the passage from Price River to Wasatch rocks.

The limestone conglomerate is not everywhere present, and where it is lacking the best criterion known to the writer for the detection of the base of the Eocene rocks is the appearance of the first highly colored beds. The varicolored shales and sandstones of the Wasatch formation appear to be the reworked products of erosion of the highly-colored rocks of early Mesozoic and Paleozoic age which were folded and exposed to erosion west of the Wasatch Plateau, at the time of mountain building referred to above. The evidence afforded by these colored shales and sandstones, however, is subject to the same reservations as that afforded by the limestone conglomerate, and for the same reasons.

*Key beds.*—The Castlegate sandstone is one of the most persistent and useful horizon markers in central and eastern Utah. It has been traced by the writer throughout the length of the Wasatch Plateau, a distance from north to south of about 60 miles, and on the west side of the plateau, near Mount Pleasant and Fairview, a sandstone identical with it in general appearance and lithologic detail occupies the same apparent stratigraphic position. East of the Wasatch Plateau Clark has traced it in the Book Cliffs as far as Sunnyside, and the writer from Sunnyside to the Green River. In 1925 the writer and J. B. Reeside, jr., traced it eastward from the Green River and found it to become a sandstone tongue projecting into the Mancos shale and extending several miles beyond the Utah-Colorado State line. Its east-west extent is thus known to be at least 135 miles, and its total length of outcrop along the Book Cliffs and the east front of the Wasatch Plateau is over 200 miles.

As a general stratigraphic horizon marker, therefore, the Castlegate sandstone is highly important, but as a key bed for the detailed determination of structure in the Wasatch Plateau it is somewhat unsatisfactory, owing to variations in its thickness and the uncertain nature of its base. Its thickness ranges from 50 to 500 feet, and therefore it can not be used in detailed structure determinations for other than relative results and in local areas. Its base would seem to afford a better horizon than its top for such a purpose, and on the east front of the plateau, where a check may be kept on the interval to the top of the Star Point sandstone, this is true; but farther west this interval is known to vary considerably at localities where it can be determined, and in places where the Castlegate sandstone is the only good horizon marker at the surface and where the interval can not be determined except by drilling some doubt must be attached to any use of the member as an indicator of the detailed structure of the rocks beneath.

The above remarks apply to detailed work only. As a guide to the approximate distance beneath the surface of the coal beds, or at least of the coal-bearing zone of the Blackhawk formation, the Castlegate sandstone is invaluable. In places such as Beaver Creek, Joes Valley, and parts of Ferron Canyon, where the coal beds lie underground, the Castlegate sandstone affords valuable information not only as to the approximate depth to the coal but also as to the probable attitude of the beds.

The Price River formation is regarded by the writer as of upper Montana age[89] and probably accumulated on an area of low relief somewhat similar to that of the Blackhawk formation, with the notable difference that the streams spreading the sediments were in general much more active and were able to transport coarse sand and pebbles. This activity was doubtless due to uplift of the land to the west and consequent increased gradients of the streams. The sea, however, still remained at least vertically near enough to the site of deposition in the plateau to allow the existence there at times

[89] Spieker, E. M., and Reeside, J. B., jr., op. cit., p. 447.

of brackish water, as shown by fossils collected from the shale beds in the upper part of the Castlegate member, some of which belong to genera known only in brackish waters.

## TERTIARY SYSTEM

The Tertiary rocks contained in the part of the Wasatch Plateau covered by this work are all referred to the Wasatch formation. The Green River formation overlies the Wasatch in the mountains north of Colton and Soldier Summit, at the west end of the Uinta Basin, and it is present west of the great monoclinal fold that borders the Wasatch Plateau on the west, but the highest beds in the area here described belong to the Wasatch formation. The entire thickness of the Wasatch formation is not known to be exposed in the eastern part of the plateau.

### WASATCH FORMATION

*Identification and distribution in Wasatch Plateau.*—The Wasatch formation has been identified in the Wasatch Plateau on the basis of lithologic peculiarities shown by the formation at many points in Utah, western Colorado, and southwestern Wyoming and also because it is continuous with the Wasatch formation in the Book Cliffs on the northeast and the west end of the Uinta Basin on the north, which in turn seems to be continuous with the Wasatch formation at its type locality, near Wasatch station, Utah. So far as the writer knows, this evidence has never been rigidly tested for the region, but the lithologic similarity is so strong and some of the peculiarities are so striking that the identification of the formation as Wasatch seems justified.

The Wasatch formation covers the higher levels of the plateau, except at places in the central part, where it has been faulted down to the level of present valleys, and on the western edge, where it descends in the great monoclinal downwarp to the levels of Sanpete and Sevier Valleys. The lower part of the formation, consisting largely of nonresistant rocks, forms gentle slopes and rolling hills, which stand in considerable contrast to the sharper outlines produced by the underlying formations. This feature is clearly shown by the topographic contours on Plates 31 and 32.

*Subdivisions in the Wasatch Plateau.*—The Wasatch formation is subdivided in the Wasatch Plateau into three members. The upper and lower members are roughly of equal thickness and consist of variegated shale, sandstone, and thin-bedded limestone such as characterize the normal Wasatch formation in this region. They are separated by a third member of fresh-water limestone, which has been named the Flagstaff limestone member [40] because of its prominence in Flagstaff Peak. This subdivision will not hold for regions farther east and south, as in those directions the Flagstaff member disappears. How far north and west the Flagstaff member persists is not known, but the presence of similar limestone in the Wasatch formation in both of these directions suggests that it may extend beyond the limits of the Wasatch Plateau. For the present, however, the subdivision here presented is applied to the Wasatch Plateau only.

*Lithologic character and thickness.*—The Wasatch formation contains a highly varied assemblage of rock types. The lower member consists in the central part of the plateau predominantly of varicolored shale, in which the combinations of various shades of red, purple, chocolate-brown, green, and gray are characteristic of the coloring of Wasatch rocks in the general region, but it contains many irregular beds of gray, brown, and cream-colored sandstone of various texture, and thin beds of fresh-water limestone, chiefly steel-gray and cream-colored but in places also white, tan, and dark blue-gray. In the southwestern, central-eastern, and northern parts of the plateau the member contains more sandstone. Beds of conglomerate occur in the member irregularly both as to horizon and locality. Near the base of the formation this conglomerate belongs to this type of limestone conglomerate mentioned on page 43, but conglomerate whose pebbles are chert, quartz, and quartzite occurs at many places. The lower member ranges generally in thickness between 1,000 and 2,000 feet. This great range is doubtless due in part to the varied conditions under which the sediments accumulated and in part also to irregularities in the surface on which they were deposited.

The Flagstaff member consists normally of fresh-water limestone, of many varieties, most of which weather white and form steep, sharply outlined cliffs. This member has resisted erosion much more strongly than the softer rocks beneath it and has literally held up the top of the plateau. The striking forms of The Cap, on North Horn Mountain (pl. 4, *A*), Wagon Road Ridge (pl. 2, *B*), Flagstaff Peak, Ferron Mountain, White Mountain, Musinia Peak—in short, all the higher tabular masses of the plateau—are due to this member, whose brilliant white cliffs can be seen and recognized from long distances. In addition to limestone, the Flagstaff member contains many beds of a dense white chalky material which in the opinion of C. S. Ross, who examined samples for the writer, may be volcanic ash, although its exact character is difficult to ascertain. The limestone of the member is texturally of four kinds (1) dense,

[40] Spieker, E. M., and Reeside, J. B., jr., op. cit., p. 448.

homogeneous, exceedingly fine grained (grain hardly visible under moderate-power microscope); (2) irregularly cellular, suggesting a compacted limy spring deposit; (3) cemented coquina or shell breccia; and (4) limestone formed of the tiny shells of ostracodes. Of these No. 1 is commonly light cream-colored but may be brown, tan, blue-gray, or light gray; No. 2 is normally cream-colored; No. 3 is dark blue-gray; and No. 4 is cream-colored to buff. On the top of the plateau the Flagstaff member appears to range in thickness between 500 and 1,000 feet, being thickest in the central and southern parts of the plateau, and in the southern part, where its upper portion has been removed by erosion, it may have exceeded 1,000 feet in thickness.

The upper member of the Wasatch has been removed by erosion from the area covered by this report. On the west side of the plateau, however, and in the hills north of Colton and Soldier Summit it is present, and there it gives rise to surface features similar to those of the lower member, which it resembles except that on the west side of the plateau it contains much more green, blue-green, and blue-gray shale than the lower member. It is estimated to be about 1,500 feet thick at the north end of the plateau, in the hills north of Colton.

*Key beds.*—Unfortunately the lower part of the Wasatch utterly lacks distinctive and persistent lithologic units that might serve as horizon markers, and hence at many places in the central part of the field where it would be highly desirable to know the depth to the coal beds of the Blackhawk formation, it is not now possible to estimate the depth with accuracy. However, certain zones, 100 to 300 feet thick and of fairly distinctive lithologic character, have been recognized in several parts of the plateau, and extended study of the formation might show that these zones could be used as horizon markers to some extent and within restricted districts.

The Flagstaff limestone member, on the other hand, is in itself an excellent key bed; being easily recognizable, well exposed, and fairly constant in character, it may be used for larger determinations of structure with good results. For detailed determinations, however, it is limited in value by the varying thickness of the underlying lower member of the Wasatch formation and of the Price River formation; and in some areas, where exposures are scattered and poor, limestones in the lower member of the Wasatch might be confused with it.

*Age of the formation.*—The Wasatch formation is generally regarded as lower Eocene. The invertebrate fossils found in the present work are nearly all of species which are common in the

Wasatch formation, but none of them are accurate time markers, and their evidence is only suggestive. No vertebrate fossils have been reported from the Wasatch Plateau.

### TERTIARY OR QUATERNARY SYSTEM

#### TERRACE GRAVEL

The long, sloping plains leading from Castle Valley up to the base of the sandstone cliffs east of the plateau are covered by layers of gravel and boulders derived from the sandstone and limestone of the plateau and are remnants of former surfaces whose nature and extent can easily be reconstructed in the imagination, either from vantage points in the area or from the geologic map, Plate 31.

The gravel cappings normally range in thickness between 5 and 75 feet and locally near the cliffs, where the material is coarsest, exceed 100 feet in thickness. The deposits extend far out across Castle Valley, and where they merge with the surface of the valley the gravel is normally similar in texture to ordinary river gravel, the pebbles being measurable in inches rather than feet. The gravel and boulders capping the plains are locally cemented by calcium carbonate to form an extremely coarse conglomerate. Notwithstanding its normally unconsolidated condition, the gravel has afforded considerable protection to the surfaces it covers, the flat surfaces of these plains presenting a striking contrast to the badlands typical of the shale areas in the region where no gravel cover exists.

Three separate gravel-capped surfaces are distinguishable on the plateau front, each of which was partly destroyed during the production of the next. These sets of gravel-covered terraces are not distinguished by special patterns on Plates 31 and 32, but they may be identified by comparing the relative altitudes of the remnants of the different surfaces. The highest and therefore oldest surface survives for the most part in relatively small isolated areas near the cliffs. Some of these areas continue to the foot of the cliffs, as did all of them originally, but many of them are now isolated from the cliffs by trenches caused by the converging headward erosion of present intermittent streams. The second surface occupies much greater areas than the highest, and it forms the long, narrow "benches" sloping eastward from the cliffs. The lowest surface is represented by the broadest remnants of all; it has been trenched but little by the narrow channels of the present streams. The three surfaces merge eastward, and in the center of Castle Valley they are not separable.

The age of the gravel deposits is not known. No fossils have yet been found in them, and no other certain means of determining their age seems to be available. They are probably not of great antiquity, however; the cliffs of the plateau front have not been cut back very far since the formation of the upper and oldest deposit, and the rapidity with which erosion there goes on under present climatic conditions suggests that no great amount of time has elapsed since the deposition of the gravel.

## QUATERNARY SYSTEM

### RECENT ALLUVIUM

Most of the larger stream channels of the area contain considerable deposits of recent alluvium. In and near the plateau these deposits consist chiefly of narrow belts of coarse material, but in Castle Valley they comprise many broad areas of fine sand and silt which afford the best farming land of Castle Valley.

## IGNEOUS ROCKS

### NATURE AND EXTENT

In the northern part of the field the sedimentary rocks are cut in many places by igneous dikes. Those which were noted in the course of the present work are shown on Plate 31. Most of the known dikes range in thickness between a few inches and 10 feet, but some that are exposed in the mines of Pleasant Valley are more than 100 feet thick. The dominant trend of the dikes is nearly due east, at right angles to the dominant trend of the faults, but a few of diverse trend have been noted.

In weathered outcrops the dike rock is light green or brownish gray, but the color of the fresh rock is very dark gray or black. C. S. Ross, who examined specimens of the rock for the writer, states that it is a basic lamprophyre, somewhat similar to the lamprophyres in the Wasatch Mountains about 30 miles west of Pleasant Valley described by Loughlin.[41]

The age of the intrusions is not exactly known, but it is believed to be rather late in the geologic history of the region. None have been observed in the part of the plateau covered by Tertiary rocks, and positive proof that they are younger than late Cretaceous is lacking. It is believed, however, that they were intruded at a late stage in the uplift of the region, when the rocks were subjected to tensional stresses and when igneous activity was dominant in parts of the region farther south and west.

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[41] Loughlin, G. F., Two lamprophyre dikes near Santaquin and Mount Nebo, Utah: U. S. Geol. Survey Prof. Paper 120, pp. 101–109, 1918.

### EFFECT OF DIKES ON ADJACENT COAL AND ROCKS

The dikes have altered the adjacent rocks, and where they have crossed coal beds they have changed the coal to coke. None of the dikes exposed in the mines of the Pleasant Valley district, however, have coked the coal for more than 8 or 10 feet, and most of them have coked it for 1 or 2 feet only. Two of the dikes in these mines and the thin layers of adjacent coke are shown in Plate 12.

The coke produced by the dikes is much more solid and less porous than artificial coke, and, as shown by Taff,[42] it contains a much higher percentage of volatile hydrocarbons. This Taff explains as due to three causes—(1) the coal was deeply covered, and escape of the volatile hydrocarbons was difficult; (2) the metamorphosed coal, after losing a large part of its volatile matter, became enriched through absorption of the gaseous products of surrounding coal; (3) the formation of coke was arrested by the cooling of the igneous mass before sufficient time had elapsed for the escape of all volatile hydrocarbons. The conditions under which coke forms next to a dike are widely different from those prevailing in the coke oven, as pointed out by Eby;[43] in the oven the coke in process of formation is free to expand, and a highly porous structure results, whereas under the pressures naturally existing at considerable depths in the earth's crust, augmented by those produced by the intrusion of the dike, expansion is prevented. Eby shows further that the effect on the adjacent coal of a dike 25 feet thick is presumably limited to a distance of about 15 feet, as determined by analyses of samples taken at varying intervals from a dike in a prospect entry in Moffat County, Colo., and that the visible effect of the dike on the coal extends only 20 inches. The latter distance is exceeded somewhat by occurrences of natural coke in the Winter Quarters, Utah, and Clear Creek mines, of Pleasant Valley, where dikes 10 to 15 feet thick have produced columnar areas of coke 2 to 3 feet in width.

In order to show quantitatively the penetration of heat from a dike into adjacent coal, C. E. Van Orstrand prepared, at the writer's request, a curve showing the temperatures that will exist both within the dike and in the coal, at various distances from the dike and at time intervals up to 100 years after the intrusion. (See fig. 2.) The diagram shows that after one day from the time of intrusion the temperature within the dike will have decreased but little and that temperatures higher than 10 per cent of the original extend a very short

[42] Taff, J. A., Natural coke in the Wasatch Plateau [abstract]: Science, new ser., vol. 23, p. 696, 1906.

[43] Eby, J. B., Contact metamorphism of some Colorado coals: Am. Inst. Min. Eng. Trans., No. 1401–I, pp. 3, 4, 1925.

distance from the dike. The temperature in the coal in contact with the dike will never have exceeded 50 per cent of the original.

In order to apply this diagram it is necessary to know the temperature of the dike as it is intruded. Igneous rock of the composition of diabase has been found by Sosman[44] to melt at about 1,300° C. The dikes of the Wasatch Plateau probably melt at a similar temperature, and at the time of intrusion they must have been fluid, or at least of pasty consistency. Coal begins to coke between 300° and 400° C., and the temperatures in coke ovens normally range between 900° and 1,290° C.[45] The temperatures in beehive ovens commonly exceed 1,000° C. If the temperature of the freshly intruded dike is 1,300° C., then on application of the data in Figure 2 it is apparent that the maximum temperature acquired by the coal would never exceed 650° C., and that a temperature of 400° C., suffi-

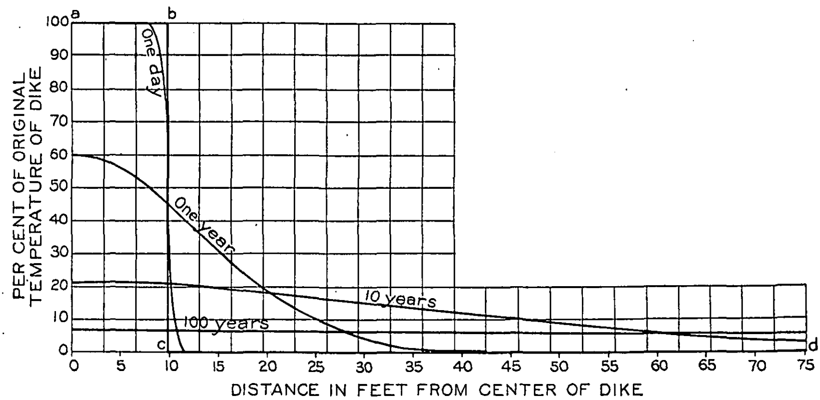


FIGURE 2.—Graph showing rate of flow of heat from igneous dike into coal. The line b–c represents the edge of the dike and a–b–c–d the initial distribution of temperature

cient to fuse the coal and to drive off the first tarry gas, would be found at a distance of about 5 feet from the dike at the end of the first year.

Calculations based on the formula for the flow of heat from a dike show that the greatest distance from the dike at which a temperature of 400° C. will be reached is about 5.1 feet. The temperature gradually rises to this point in about 514 days, after which it immediately begins to fall. At distances less than 5.1 feet from the dike the temperatures rise above 400° C. and subsequently fall below that point.

These facts, however, apply only to a solid body of coal intruded by a mass of molten rock at a temperature of 1,300° C. which came suddenly into contact with the coal and remained in that position.

[44] Sosman, R. B., Data on the intrusion temperature of the Palisade diabase: Washington Acad. Sci. Jour., vol. 3, pp. 389–395, 1913.

[45] For bibliography see Hofman, H. O., General metallurgy, pp. 228, 241, 246, New York, 1913.

The actual conditions of intrusion are somewhat different. The molten material probably moved past the coal for some time, maintaining its temperature until intrusion was complete. The molten rock may have been superheated; this seems very likely where a thin dike was intruded for great distances into relatively cold rocks. Joints or other fissures in the coal, if present, would permit the penetration of highly heated gases perhaps farther than the maximum distances to which the heat would penetrate in solid coal. These conditions would extend the area of heat effect, but how much the writer has not been able to ascertain. On the other hand, as soon as a thin layer of coke formed next to the dike, the change from solid to porous material would increase its insulating power, and the process is therefore obviously complex. However, inasmuch as the maximum temperatures possible probably never quite reach those common in beehive ovens, the reason is plain, despite the conditioning factors mentioned, why the coal has been coked for such short distances.

## STRUCTURE

### GENERAL FEATURES

The Wasatch Plateau lies between the simple, domelike uplift of the San Rafael Swell on the east and the highly faulted, structurally complex region of the Great Basin on the west. Occupying the transition ground between areas showing these different types of structure, it partakes of the nature of both. In the eastern part of the plateau the strata dip gently westward, in continuation of the dip of the west flank of the San Rafael Swell. On the western margin of the plateau the strata bend downward in a great monoclinal fold that is the first of the great displacements bordering the Great Basin, and in many parts of the plateau the rocks are broken by faults of the type which characterizes parts of the Great Basin.

The faults are of great importance in the coal field, because of their effect on the coal beds and because of the mining problems they introduce. Detailed information concerning faults that was obtained in the present work is given on Plates 31 and 32 and in the descriptions of the areas into which the field has been divided. The following description of structure contains general information concerning the field as a whole.

### ATTITUDE OF THE STRATA

The strata of the Wasatch Plateau coal field are for the most part tilted at slight angles, and in many parts of the plateau they lie nearly flat. At a few places, however, where they have undergone unusual disturbance, the strata dip at angles between 10° and 20°. The prevailing directions of dip are west, northwest, and southwest, but in the northeastern part of the field, where the trend of structural lines leads toward the Book Cliffs, along the south rim of the Uinta Basin, the dip is northeast. These are broad, general features. When the structure is examined in detail, many local irregularities are found.

Those details of the structure which were determined in the present work are shown on Plates 31 and 32 by means of structure contours and by cross sections, which illustrate the attitude of the strata along selected lines across the field. The structure contours were drawn wherever possible on the basis of altitudes determined by the topographer on the key beds described for each geologic formation in the foregoing section of this report. In parts of the field where key beds are either lacking or uncertain the contours have been projected, on the basis of strikes and dips and stratigraphic data, from the areas where they are founded on the elevations of reliable key beds. The different patterns used in drawing the contours to show relative certainty suggest, in general, the nature of the data on which they are based. As a rule, those contours nearest the plateau front are the most reliable, and those in the faulted regions, where key beds are difficult to find, are most uncertain. In some parts of the field where available lines of evidence conflict or where the drawing of contours would otherwise rest on conjecture, areas are left blank. Other conditions that affect the accuracy of detailed parts of the maps are set forth in the local descriptions, which should be consulted by the reader who desires to use the maps as a source of detailed structural information.

## FAULTS

### GENERAL NATURE

The most interesting structural features of the field and the most important to the mine operator are the numerous faults, or dislocations of the strata, which occur within it. The only large parts of the field practically free of faults are the part between East Mountain and South Horn Mountain, on the eastern front of the plateau, and the part west of the Joes Valley fault zone in the Ferron, Muddy Canyon, and Convulsion Canyon areas. (See pp. 57–58.) In no other known parts of the field are the unbroken stretches between faults more than 3 miles wide. The faults are all of the normal type—that is, they involve the simple dropping of the beds on one side of a break in the strata, and the fault planes that have been observed are all vertical or very nearly so.

## FAULT ZONES

The faults of the plateau are grouped into definite zones, and between the fault zones lie relatively broader areas in which the rocks are undisturbed. The general location of the fault zones in the plateau is shown in Figure 4, and their names and general relations are shown in the following table, beginning with the easternmost:

*Fault zones in eastern part of Wasatch Plateau*

| Name | Known length in plateau | Average width | Average distance from nearest zone on west | Greatest displacement |
|---|---|---|---|---|
| | *Miles* | *Miles* | *Miles* | *Feet* |
| North Gordon | 22 | 4 | 6 | 800 |
| Pleasant Valley | 35 | 4 | 5 | 1,500 |
| Joes Valley | 75 | 2 | 12 | 2,500+ |

West of the Joes Valley fault zone the rocks of the plateau are practically unbroken for about 12 miles at the south end of the plateau and about 5 miles at the north end. In the southern part of the plateau two more fault zones intervene between the Joes Valley zone and the monocline at the western border of the plateau,[46] but at the north end no definite zones have been distinguished west of that of the Joes Valley.

Each of these fault zones consists of a dropped prism of the earth's crust in which considerable minor fracturing has occurred. In some places the minor fracturing is very intense, and some of the subsidiary faults approach in dimensions the major faults bounding the zones. The minor faults are normally more or less parallel to the major faults, but in the northern part of the field many faults of diverse trend have been found, and because of this diversity the faulting of Pleasant Valley and of the North Gordon Creek district is very complex.

The locations of the known faults of these zones are shown on Plates 31 and 32, and the displacements of many of them may be ascertained from the maps at places where definite formation boundaries are offset within a short space. It is not practicable, however, to show on the maps all the known displacements, and for that reason many of them are given in the detailed descriptions of the different areas of the field. At some places, such as Ferron Canyon, where the faulted rocks are well exposed, the faults shown on the map probably represent all that are present, but at many other

[46] Spieker, E. M., Geology and coal resources of the Salina Canyon district, Sevier County, Utah: U. S. Geol. Survey Bull. 796, pp. 145–149, 1927.

places the minor faults are undoubtedly more numerous than those shown on the map. In Pleasant Valley, for example, mines have crossed intricate zones of faults that are not clearly evident at the surface, and in parts of the Joes Valley fault zone the shattered rocks are so poorly exposed that it is impossible to recognize individual faults.

#### NORTH GORDON FAULT ZONE

The North Gordon fault zone, the easternmost in the field, differs from the others on the west in two particulars—it is not a simple graben, or down-dropped prism, and the faults within it are much more diverse in trend than those in the other zones except the faults in the adjacent parts of the Pleasant Valley district, which have a similar origin. The faults bounding the North Gordon zone on the east and west are not the largest in the zone, and the block outlined between them has not dropped, as a unit, with reference to the adjacent rocks. Several dropped blocks exist within the zone, however, and an exposure of one of these is shown in Plate 8, *B*.

The northernmost known fault of the North Gordon zone crosses Price River at the mouth of Fish Creek, where it was noted by Campbell.[47] From this place south to North Fork of Gordon Creek the faults of the zone appear to be regular in trend and are not numerous. Within and south of the drainage basin of North Fork of Gordon Creek the zone widens out, and the faults become diverse in trend. In the Bob Wright embayment the principal faults trend nearly north and die out southward, the zone ending in the northern part of Gentry Mountain, near Star Point.

The diversity in trend of the faults in this zone and the northern part of the Pleasant Valley zone stands in marked contrast to the regular trend of the faults elsewhere in the field, and it is probably due to the bend in the major structural lines between the Wasatch Plateau, where the prevalent dip of the rocks is westward, and the western Book Cliffs, where the prevalent dips are northward and northeastward. The change in direction of dip is coincident with the development of the diverse fault pattern of North Fork of Gordon Creek and Pleasant Valley, as is shown on Plates 31 and 32.

#### PLEASANT VALLEY FAULT ZONE

The Pleasant Valley fault zone extends from the north end of Pleasant Valley southward to Cottonwood Creek. The exact northern limit of the zone is not known, but it probably dies out not far north of Fish Creek. The southern limit of the zone lies in the area of

[47] Campbell, M. R., Guidebook of the western United States, part E: U. S. Geol. Survey Bull. 707, p. 218, 1922.

Mancos shale in the valley of Cottonwood Creek, west of Orangeville, the faults dying out short distances beyond the cliffs of the plateau front.

In Pleasant Valley the zone is 3 to 5 miles wide, and the faults in it are complex and, because of poor exposures, are difficult to detect. The coal mines in and near Pleasant Valley have done much to reveal the intricate nature of the faulting at places in the zone, and at many places where the outcrops afford no precise evidence of the structure the rocks at the surface are shattered and split in a manner clearly indicative of faulting.

At the north end of Pleasant Valley the fault zone clearly consists of a graben, or down-dropped block. It terminates south of Scofield, where the eastern faults undoubtedly unite with the western (Pleasant Valley) fault, which continues southward from Clear Creek to the lower part of Huntington Canyon. This fault has been recognized and located in all the canyons which it crosses, but in the high ridges its position is inferred by alinement of the places where it is known.

South of Scofield the Pleasant Valley fault zone consists essentially of the single large fault, accompanied by several smaller faults on which there has been sympathetic movement. East of the major fault at Clear Creek there are faults which bound a graben and are well displayed in the Clear Creek mines. They are traceable southward in Woodward and Tie Fork Canyons to Trail Canyon and beyond.

Southwest of Pleasant Valley, in the upper part of Huntington Canyon, the westernmost part of the zone contains a few small faults and one large fault, called the Valentine fault because of its prominence in Valentines Gulch. This fault diverges from the Pleasant Valley zone and extends southwestward, merging with the Joes Valley zone near the head of the gorge on the left fork of Huntington Creek. The belt of rocks between the two fault zones is broken by no other important faults.

The faults of the Pleasant Valley zone are nearly parallel in the southern part of Huntington Canyon, and the general trend of the zone is about N. 7° E. In this part of the field the excellent exposures of the massive sandstone beds in the Mesaverde group (pl. 9, *B*) afford good opportunity to study the faults, and at many places the displacement may be measured almost exactly. In Huntington Canyon south of Trail Canyon the faults of the Pleasant Valley zone are numerous, but most of them die out southward before reaching the cliffs north of Cottonwood Creek, and the whole zone dies out between the cliffs and the creek.

### JOES VALLEY FAULT ZONE

The Joes Valley fault zone is the most extensive of the three fault zones of the Wasatch Plateau coal field. Throughout its length of 75 miles in the plateau it is a graben in which the rocks have dropped 1,500 to 2,500 feet, and the dropped block is everywhere much shattered. In the northern part of the zone the evidence of this subsidiary faulting is qualitative rather than quantitative, but south of The Dragon faults are well displayed in the sandstones of the Mesaverde group, and the fracturing within the major dropped block is determinable with considerable exactness. The complexity of the internal faults of the zone is excellently shown on Ferron Creek; and a similar profusion of faults presumably exists in Joes Valley and in parts of the zone farther north, where softer rocks form the surface and the exact nature of the faulting is not determinable.

The north end of the Joes Valley fault zone lies somewhere not far north of Cleveland Reservoir. The easternmost fault of the zone, which was called by Taff [48] the Joes Valley fault, has caused a steep escarpment that is continuous from the north end of Candland Mountain (see pls. 4, *A*, and 10) to Ferron Canyon. Not far north of Ferron Canyon the displacement on the east side of the zone is taken up by a fault that branches from the Joes Valley fault and connects southward with the Paradise fault of southern Castle Valley. The westernmost fault of the zone is continuous from Miller Flat to the divide south of Ferron Canyon, and there the displacement is taken up by an overlapping fault, analogous and opposite to the branching Paradise fault, that continues southward as far as Quitchupah Creek. The whole fault zone is thus offset eastward about 1 mile, as shown on the map.

In Joes Valley the symmetrical character of the graben is well displayed by the opposing escarpments of the limiting faults, in which the similarity of the rock succession is readily visible. Between Joes Valley and Muddy Creek the fault zone is clearly displayed, physiographically as well as geologically, behind the easternmost tier of mountains forming the plateau front. In the drainage basin of Muddy Creek the fault zone emerges from the mass of the plateau west of Nelson Mountain and parallels its eastern edge as far south as Emery, where it passes on into the Mancos shale of Castle Valley.

The Paradise fault, the easternmost fault of the zone, borders Nelson Mountain on the west. Along this fault the Flagstaff limestone member of the Wasatch formation abuts against Mancos shale, and the throw of the fault is thus equal at least to the combined thickness of the Mesaverde group plus the lower member of the Wasatch formation, which in this part of the field is over 2,500 feet.

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[48] Taff, J. A., op. cit. (Bull. 316), p. 345.

At the north end of The Hole, on the timber road to Ferron Mountain, this fault is strikingly exposed, as shown in Plate 24, *B*. The limestone beds on the west curve sharply up to the break, showing with diagrammatic clearness the effect of drag, and on the east the massive beds of the Star Point sandstone lie almost flat, ending abruptly at the fault plane with only the slightest downward bend in response to the drag of the down-dropped beds.

South of Nelson Mountain the fault continues in the Mancos shale, and its trace may be followed fairly well because of exposures of the Emery sandstone member. The throw of the fault is about 2,000 feet at the crossing of Muddy Creek, causing the Emery sandstone to abut against the upper part of the Blackhawk formation, and the trace of the fault is followed by the low scarp formed by the Emery sandstone in the gulches north and south of Muddy Creek and is marked by the east base of the sugarloaf hill west of Emery.

South of Emery the faults of the Joes Valley zone, visible in the outcrop of the Emery sandstone, gradually become less numerous. Near Saleratus Creek they begin to swing southwestward and continue past the Oak Spring ranch toward Paradise Valley, where the easternmost fault of the zone joins with the Paradise fault as mapped by Lupton,[49] who believed this fault was probably continuous with the Thousand Lake fault. If this is true, the Joes Valley fault zone extends uninterruptedly as far south as T. 31 S. and is about 105 miles long.

The writer's interpretation of the structure south of Saleratus Creek differs from that of Lupton[50] in some respects, as may be noted by comparing the maps. Nearly all of this difference is due to the identification of the sandstone in the western part of Castle Valley south of Emery as the Emery sandstone member of the Mancos shale, instead of the Mesaverde formation, as it was regarded by Lupton. This sandstone, instead of being faulted down to its present position east of the cliffs, passes beneath the cliffs in normal succession, and the Paradise fault of Paradise Valley, instead of swinging northward along the base of the cliffs, continues northeastward and joins the easternmost fault of the Joes Valley zone, which is accordingly named in this report the Paradise fault. In a similar manner the Emery sandstone dips northward south of Ivie Creek, and the normal succession of rocks in the Mancos shale occupies the valley between Deer Peak and the cliffs of the Mesaverde group; the east-west fault mapped by Lupton in the southwestern part of T. 24 S., R. 5 E., doubtless does not exist.

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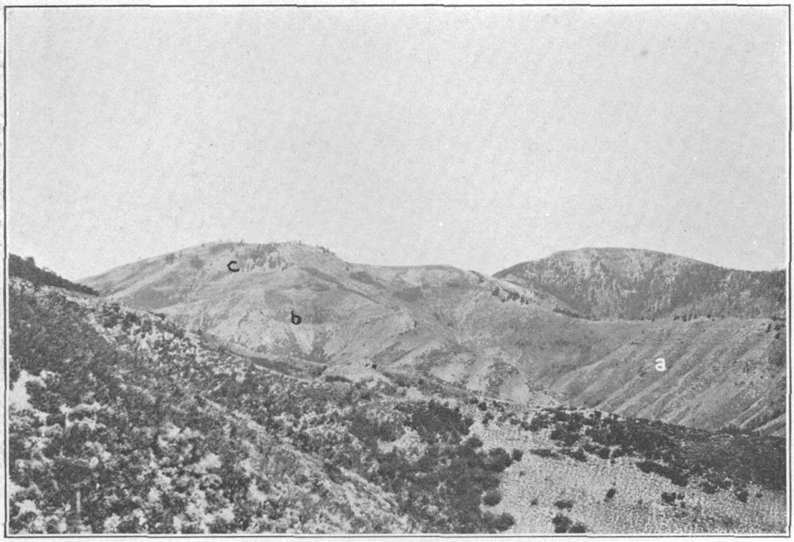
[49] Lupton, C. T., Geology and coal resources of Castle Valley in Carbon, Emery, and Sevier Counties, Utah: U. S. Geol. Survey Bull. 628, p. 41, 1916.

[50] Idem, pl. 12, p. 86; pl. 10, p. 74.

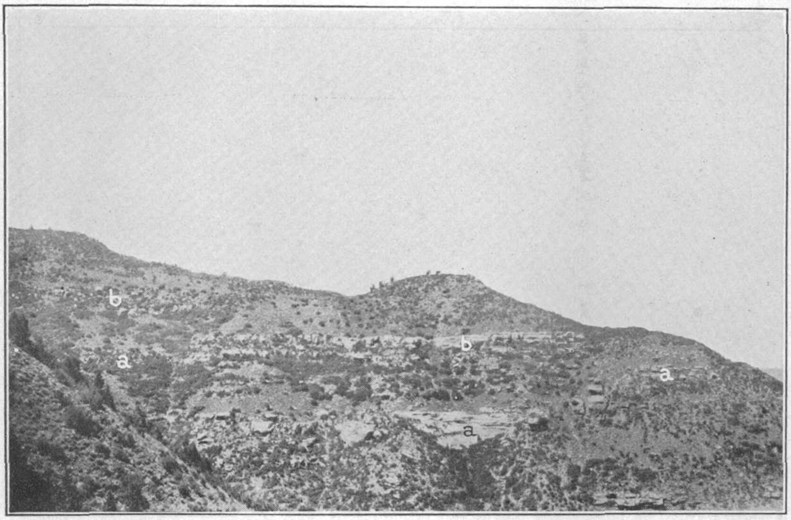



*A.* HEAD OF SPRING CANYON, LOOKING NORTH

a, Blackhawk formation; b, Price River formation, with Castlegate sandstone member at base; c, Wasatch formation.

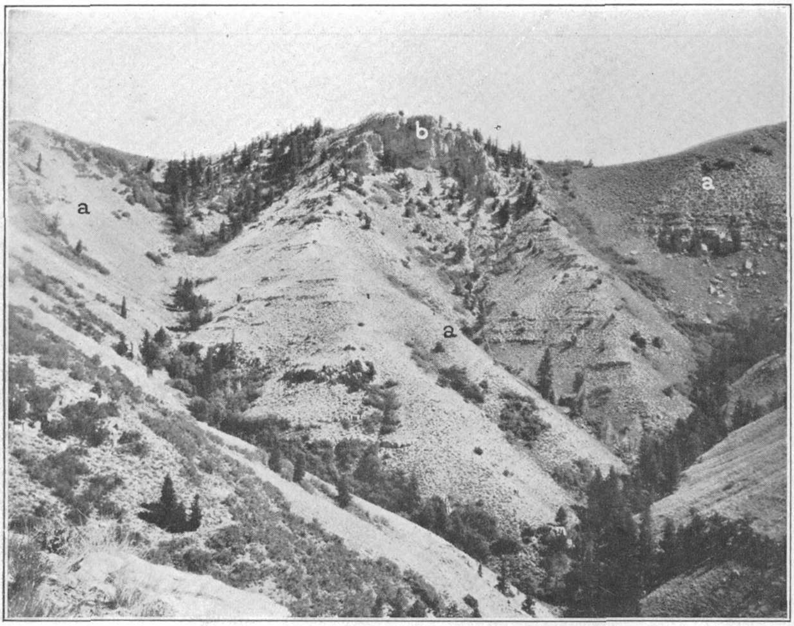
*B.* PRICE RIVER SANDSTONE AND CONGLOMERATE EXPOSED IN NORTH END OF PLEASANT VALLEY

Showing irregularity of bedding and weathering habit of the sandstone.



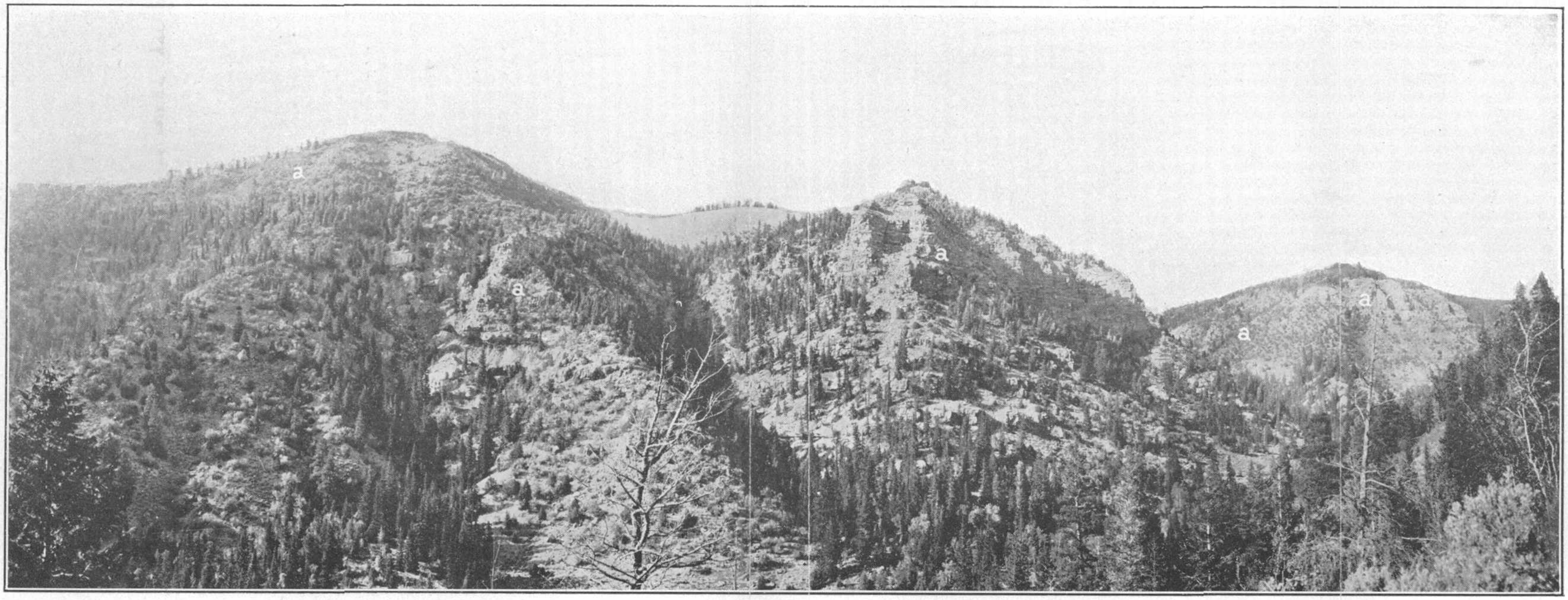

*A*. FAULT BLOCK IN STAR POINT AND BLACKHAWK FORMATIONS IN SEC. 5, T. 15 S., R. 8 E.

a, Top of Star Point sandstone; b, white sandstone in Blackhawk formation 170 feet above its base.



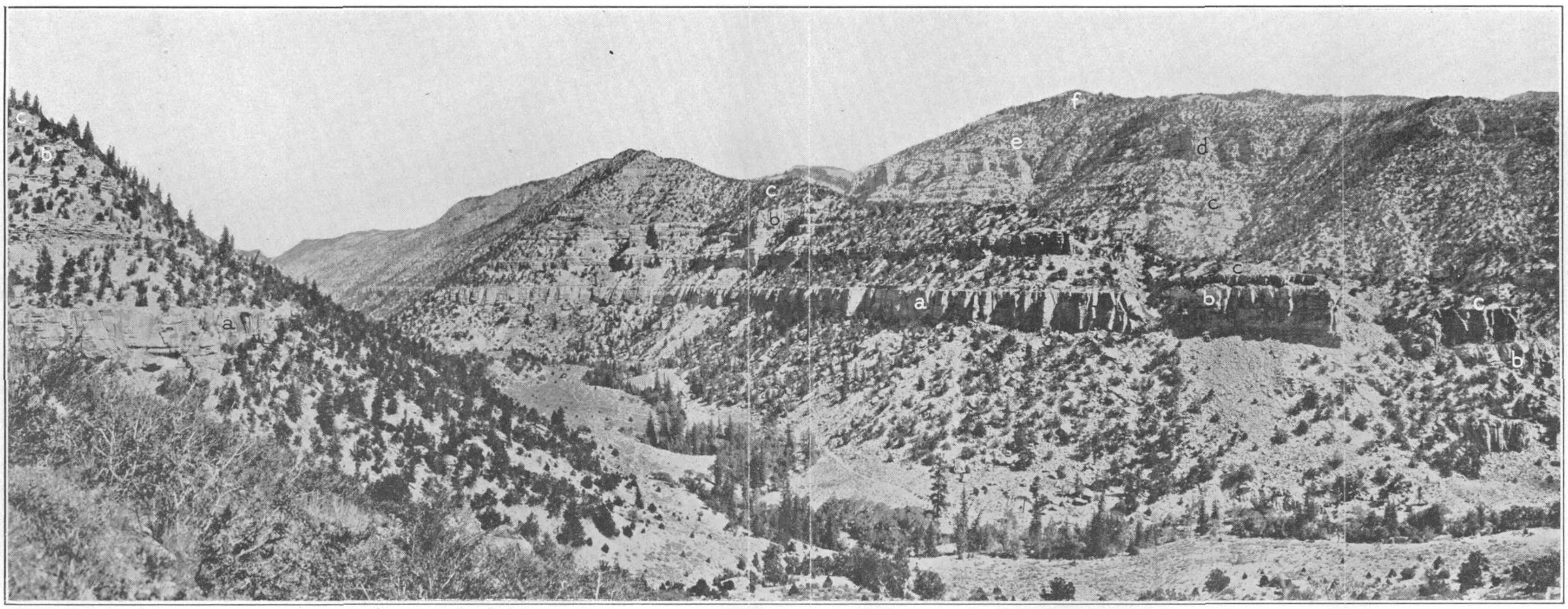

*B*. FAULT BLOCK IN CANYON NORTH OF CEDAR MESA RANCH, SEC. 15, T. 13 S., R. 8 E.

a, Blackhawk formation; b, Castlegate sandstone member of Price River formation.



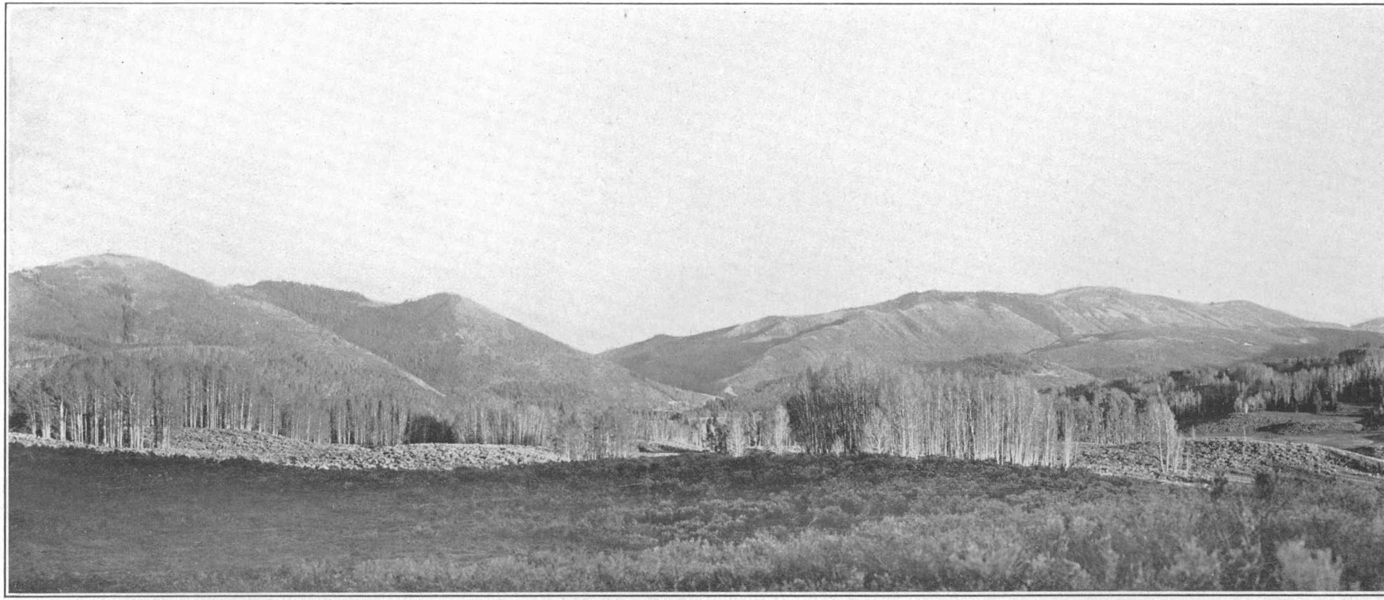

*A.* NORTH WALL OF TIE FORK CANYON, SHOWING FAULTS OF PLEASANT VALLEY ZONE

The displacements are visible in the Castlegate sandstone, marked "a" in each of the fault blocks.



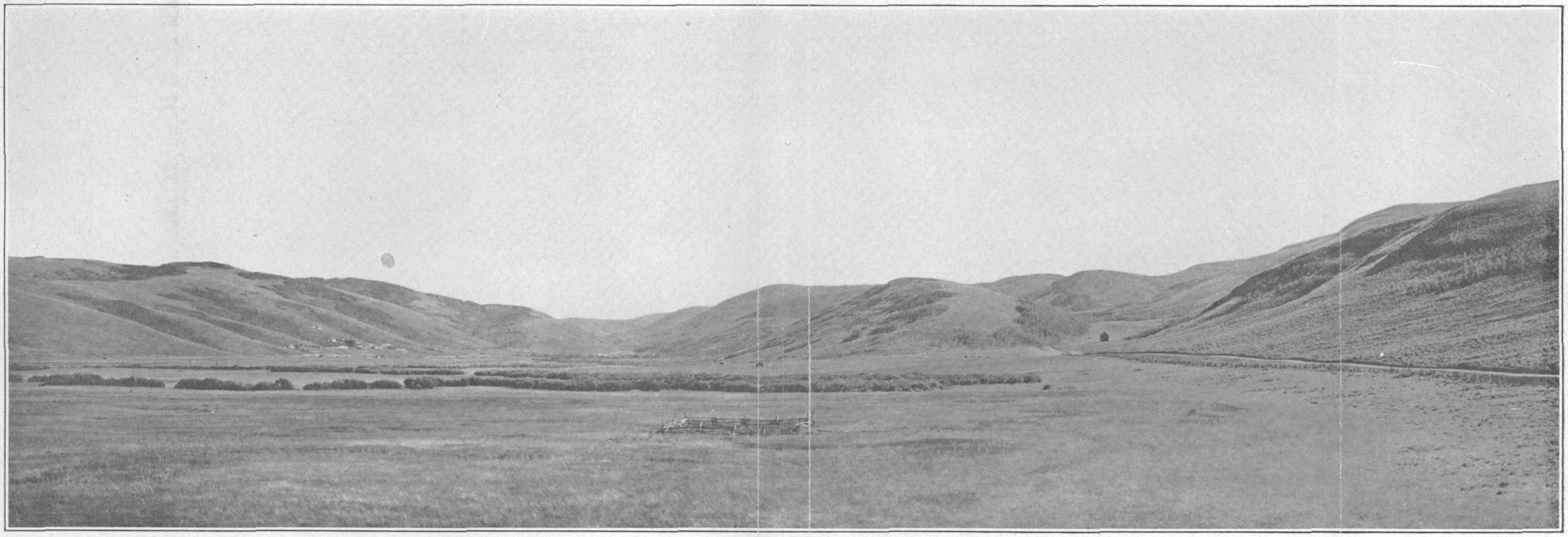

*B.* HUNTINGTON CANYON ABOVE MOUTH OF TRAIL CANYON

Showing sandstones of Mesaverde group and western faults of Pleasant Valley zone. The general direction of view is northeast. Trail Canyon on right, across ridge. The Pleasant Valley fault and a closely associated fault appear in the point of the ridge, at the right. a, Basal sandstone; b, upper, white-capped sandstone of the Star Point; c, Blackhawk formation; d, Castlegate sandstone; e, upper member of Price River formation; f, Wasatch formation.



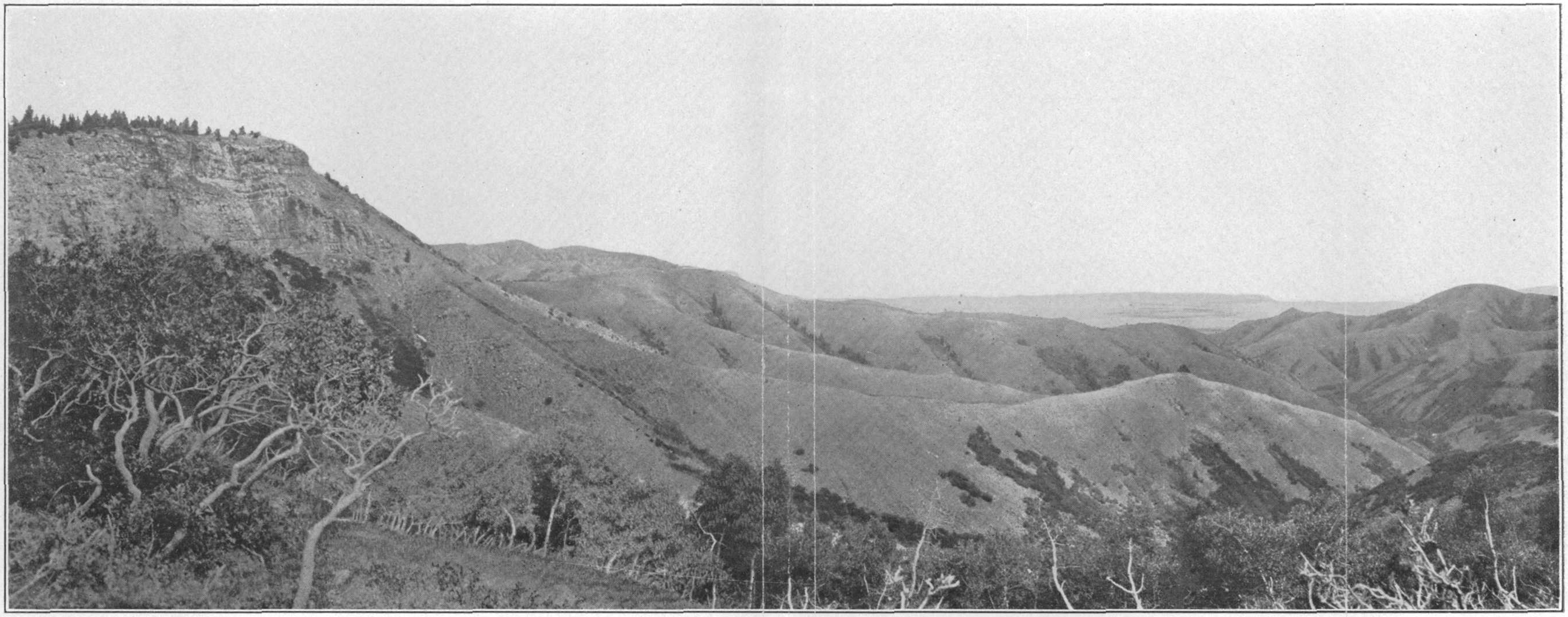
CANDLAND AND SEELEY MOUNTAINS, FROM HILLS WEST OF CLEVELAND RESERVOIR

The scarp of the Joes Valley fault, near its north end. Candland Mountain on left, Seeley Mountain on right, gorge of the Left Fork of Huntington Creek between them. North end of East Mountain on extreme right; Bald Mountain in right middle ground.



*A*. PLEASANT VALLEY FROM A POINT ON THE WEST SIDE OPPOSITE MILLER CREEK

Scofield to left of center. This view shows the broad, flat valley formed by the V-shaped graben, the southward-converging scarps of the limiting faults, and the type of hills underlain in this part of the plateau by the Blackhawk and Price River formations.



*B*. HILLS BORDERING NORTH FORK OF GORDON CREEK, FROM BEAVER CREEK DIVIDE

A characteristic view of the northeastern part of the plateau. North Fork of Gordon Creek on right; Castle Valley in distance. Cliff of Castlegate sandstone on left; hills of Blackhawk formation and Star Point sandstone in center and on right.

#### EFFECT OF FAULTS ON SURFACE FEATURES

Many of the faults have had pronounced effects upon the surface features of the plateau. Larger faults such as the Pleasant Valley and Joes Valley faults have produced imposing scarps; the sunken blocks of some fault zones have produced prominent valleys; the structurally higher blocks have in places produced well-defined mesas; and the courses of streams have in places been guided by faults. Some stream courses, principally those of minor streams, have been considerably altered by the faulting, whereas others, principally those of major streams, have retained their original position in spite of obstacles placed in their paths by faults. Examples of these phenomena are profuse in the faulted zones of the plateau, and many are referred to in the areal descriptions of structure farther on in this report; only a few need be mentioned here to illustrate the more striking relations that exist between structure and surface features.

Pleasant Valley, for example, represents the block dropped by the Pleasant Valley fault zone (see pl. 11, *A*), and many of the canyons east of Pleasant Valley have been eroded along zones of weakness formed by the shattering of the rocks during the faulting. The trace of the Pleasant Valley fault south of Clear Creek is partly marked by canyons thus localized.

The most striking surface features resulting from faults are Joes Valley and the line of valleys south of it, which owe their location and nature largely to the faults of the Joes Valley zone. (See pl. 4, *A*.) Joes Valley is walled in by cliffs of Cretaceous rocks which are the scarps of the limiting faults of the zone, and the floor of the valley is composed of softer Tertiary rocks capping the dropped prism. Farther south in this zone, near Ferron Canyon, the rocks in the prism rise gently southward, and many of the mesas and other surface features of this part of the plateau are due to the harder Cretaceous rocks which emerge from beneath the soft shale and sandstone of the Wasatch formation. Still farther south, near Emery, the dropped prism is expressed on the surface by parallel ridges and valleys, bounded by faults.

Not all the stream courses of the plateau, however, have responded to the conditions imposed by the faulting by following fault lines. Fish Creek, in the Pleasant Valley area; Seeley Creek, in the Joes Valley-Straight Canyon region; and Ferron Creek, to mention the most prominent examples, have kept their courses directly across the faulted zones and have cut deep gorges in solid masses of sandstone which were thrown across their paths by the faulting, whereas their normal response to such conditions would have been to adjust their courses so as to follow lines of least resistance—either the shattered zones adjacent to faults or the belts of soft rocks introduced by the faulting—and thus to follow the fault zones instead of crossing them. This phenomenon is fairly common in the Colorado Plateaus and was early explained by Powell and Dutton[51] as due to the fact that the structural features, such as folds and faults developed so slowly that the major streams were able to cut through hard masses of rock placed in their paths as fast as the masses arose and thus to continue the courses they established for themselves at an earlier stage in the history of the region, when they were flowing over a more or less even surface.

Another good example of the relation between the faults and surface features, which incidentally throws some light on the relative recency of movement on some of the faults, is afforded by the valley of the Acord Lakes, whose probable origin is discussed on page 190.

## COAL

The coals of the Wasatch Plateau field are of bituminous rank and in general are notable for their low content of impurities and their excellent physical character. They contain, as a rule, less than 7 per cent of ash, 0.5 to 0.7 per cent of sulphur, and notable amounts of resin. Most of the coal is massive, resistant to weathering and shattering, and hence an excellent shipping and stocking fuel. These characteristics, together with the occurrence of the coal in thick beds under conditions generally favorable to mining, make the coal reserves of the Wasatch Plateau an important factor in the present and more particularly the future fuel markets of the western United States.

Perhaps the outstanding feature of the Wasatch Plateau coal field is the unusual thickness of many of the coal beds. Beds of clear coal 6 to 10 feet thick are common almost throughout the field, and in Gentry Mountain and East Mountain, on Quitchupah Creek, and in Pleasant Valley beds 15 to 30 feet thick are present. It is estimated[52] that in 1917 83.7 per cent of Utah's total output of coal was mined from beds ranging between 8 and 17 feet in thickness, whereas only 12.6 per cent of the output of the country as a whole was mined from such beds. In 1917 34.1 per cent of the coal mined in Utah came from beds 16 to 17 feet thick, as compared with only 0.4 per cent of the total bituminous output of the country from beds of that thickness. In considering these figures it should be noted that the Wasatch Plateau and Book Cliffs fields combined produce normally about 96 per cent of the coal mined in Utah.

[51] Dutton, C. E., Geology of the High Plateaus of Utah, p. 163, U. S. Geog. and Geol. Survey Rocky Mtn. Region, 1880.

[52] U. S. Geol. Survey Mineral Resources, 1921, pt. 2, p. 647, 1923.

## VERTICAL DISTRIBUTION

The principal coal beds of the field occur in the lower 250 to 350 feet of the Blackhawk formation. Thinner beds occur in the upper part of the Blackhawk and in the Ferron sandstone, which underlies the field at considerable depths, and the thin coals exposed near Sterling, on the west side of the plateau, may belong to the Price River formation, though probably no coal occurs within that formation in the area covered by this report.

The stratigraphic relations of the coal beds are shown graphically by three groups of sections as follows:

1. A group of columnar sections which show the coal-bearing part of the Blackhawk formation. These sections, shown on Plates 14–16, 18, 19, and 21–23, are nearly all correlated at the base on the top of the massive Star Point sandstone, and wherever the basal line joining them is solid there is little or no doubt of the correlation.

2. A group of shorter columnar sections (figs. 7, 9–11; pls. 25, 28–30) which show in greater detail the variations in the basal part of the Blackhawk formation for local drainage areas. These sections represent areas in the southern half of the field where exposures are good enough to permit very detailed examination and correlation of the coal and surrounding beds.

3. A group of individual sections which show the coal beds of the field that are 30 inches or more thick, also thinner beds that are believed to be continuous with beds that are elsewhere at least 30 inches thick. These sections are given on a scale that permits the portrayal of still greater detail of the coal beds themselves and appear on the plates of columnar sections.

The difficulty of correlating coal beds by comparing their stratigraphic positions in columnar sections, even where the sections are accurate and based on a well-defined plane of correlation, is clearly seen in places where adjacent sections based on the Star Point sandstone show, for example, the Castlegate "A" bed, which is traceable, exactly opposite a coal bed that is known to be beneath or above the Castlegate "A" bed. Variations in thickness of sedimentary rocks such as these are in places so great that the attempt to correlate coal beds by comparison of sections alone is liable to gross error, and it is because of this difficulty that the correlation lines on the plates of columnar sections, except those on the Hiawatha and Castlegate "A" beds and others that are mentioned in the detailed descriptions, should be regarded as suggestive only.

Difficulty in correlating entire columnar sections for lack of any well-defined connecting horizon has been experienced only in Pleasant Valley and upper Huntington Canyon. In Pleasant Valley the great complexity of structure and the scarcity of rock outcrops prevent the precision of correlation that is possible elsewhere in the field, and in the northern part of Huntington Canyon the scarcity of rock outcrops is alone sufficient to make difficult the detailed correlation of the coal beds. Elsewhere in the field the top of the Star Point sandstone may be traced with sufficient regularity to insure at least one connecting line between the columnar sections measured from place to place along the cliffs.

## NAMES OF COAL BEDS

At the time this investigation was begun none of the coal beds in the field were recognized by generally accepted names, and the only bed which has been definitely ascertained to be continuous with a named bed in adjacent areas is the Castlegate "A" bed, originally named in the Book Cliffs field, at Castlegate. The writer has applied names to all coal beds of more than local extent, and the beds are designated by these names in the following descriptions by areas.

The naming of certain coal beds which are not known to be continuous but which appear, at different places, at approximately the same stratigraphic position with reference to the Star Point sandstone has been a vexatious problem. It is not desirable to use the same name for coal beds which, even though they are at the same horizon, are probably not continuous; on the other hand, it is equally undesirable to introduce a long and complex list of names. Obviously a middle course should be taken, and the writer has attempted to solve the problem by giving the same names to those important coal beds that appear at approximately the same horizons in connected parts of the field, and different names to beds at the same horizons but in different parts of the field separated by areas in which the continuity of the beds is greatly to be doubted. The best examples of the application of this plan are afforded on the one hand by the Blind Canyon bed, and on the other by the Bear Canyon, Wattis, and Gordon beds. The name Blind Canyon is applied to the coal bed 40 to 60 feet above the Star Point sandstone in the lower part of Huntington Canyon and the plateau front as far south as Rock Canyon. At the outcrop several places are known where this bed is absent, but it appears with fair regularity at approximately the same position in a part of the field where it may be continuous underground. The names Bear Canyon, Wattis, and Gordon, on the other hand, are applied to coal beds in different areas that occur at about the same horizon, or from 90 to 120 feet above the Star Point sandstone, but in different parts of the field between which, all available evidence seems to indicate, they are probably not continuous.

## IRREGULARITY OF THE COAL BEDS

The coal beds of the Wasatch Plateau field, though irregular as to thickness and purity, are as a whole no more irregular than those of other fields of similar size, and at least one bed, the Hiawatha bed, is remarkably persistent. However, the persistence of the Hiawatha bed is known for the length of the plateau only, and very little is known of its presence west of the plateau front. It does not extend far northeastward into the Book Cliffs coal field. The higher coal beds of the field are much more irregular.

The common variations and irregularities of thickness of coal beds, such as rolls, "horsebacks," "wants," splitting and pinching of the beds are present at many places in the field. They are best shown in the mines, but at many places they are also evident on the outcrop.

One type of "want" that occurs at several places in the field has aroused considerable discussion among engineers as to its origin and is of sufficient general interest to justify description. Perhaps the best known example is well displayed in the Mohrland mine of the United States Fuel Co. In an entry where this "want" is exposed in cross section the contact between the coal and the overlying sandstone pitches down at an angle of about 20°, cutting down the thickness of the coal from 24 feet to a few inches. The sandstone replaces the coal for about 200 feet in the entry, and at the other side of the "want" the contact rises again at a similar angle, and the coal regains its thickness of 24 feet. The sandstone that replaces the coal is fine grained and very homogeneous, like the roof sandstone of the coal in the area bordering the "want."

The opinion has been expressed by some engineers who have seen these "wants" that the coal has been forced out by differential pressure. If that were the case evidence of pressure in the coal adjacent to the "want" ought to be present in the form of contorted bedding planes, slickensided surfaces, and other signs of squeezing and flowage of the coal, but these phenomena are absent. The coal at the contacts of all the "wants" observed by the writer shows no evidence of pressure greater than that imposed by the load of overlying rocks.

The "wants" of this type are probably old drainage channels in the original swamp into which fine sand was washed after depression had caused the submergence of the swamp. Less probably they represent channels cut by rivers shifting their courses during times of flood. In the King No. 2 mine the workings have blocked out enough of the "wants" to indicate roughly the position of the drainage channel.

"Wants" similar to that of the King No. 2 mine have been found at several places on the outcrop of the Hiawatha bed. In the northern part of the field, where exposures are poor, none have been observed, but in the southern part, where exposures are excellent, the replacement of the coal by massive sandstone is plainly noticeable in Rock Canyon, on Nelson Mountain, and on the plateau front south of Muddy Canyon. The "wants" at these places are described in the detailed accounts of the coal in the Rock Canyon and Muddy areas.

## NUMBERING OF COAL SECTIONS AND COLUMNAR SECTIONS

The sections showing individual coal beds and the coal-bearing part of the Blackhawk formation are numbered in order from north to south across the field. The numbering begins in Pleasant Valley and crosses to North Gordon Creek, whence it continues on the east front of the plateau to the mouth of Huntington Canyon, at location 170. Location 171 is at the head of Huntington Canyon, from which the numbering proceeds in order southward to the end of the field. Sections for each location number are shown graphically on the plates accompanying the areal descriptions.

In the columnar sections, which for the northern part of the field are more numerous than the individual coal sections taken at places where columnar sections were not measured, the different coal beds bear the number of the location at which the columnar section was measured, but they are designated by the letters a, b, c, etc., beginning in each section with the lowest important or identifiable bed and proceeding upward without regard to the correlation of the beds so lettered. Thus a bed designated 109 c may not be the same as a bed designated 110 c; the letter c merely means that the bed is the third important or recognizable bed from the base of the columnar section in which it was noted. On the maps the lettered beds of columnar sections are not located, except in places where the columnar sections were measured over considerable horizontal stretches of ground. The locations of columnar sections shown on the maps ordinarily indicate only the base of the section, and it is to be assumed that the sections were measured vertically upward from the numbered point. This method is adopted to avoid the crowding of numerals on the map that would be necessary to show all the coal beds in sections that were measured on very steep slopes and cliffs, where the contours and consequently the coal beds are very close together.

## PHYSICAL PROPERTIES

Coal of various physical attributes exists in the Wasatch Plateau field, but the predominant and characteristic type is hard, massive, and nearly structureless and breaks into large lumps, which shatter but little under handling. As a further consequence of this hardness but little fine coal is produced, and solid lumps of coal weighing several tons are commonly blasted down during mining.

In addition to the massive coal, other types occur at many places, both in separate beds and in layers between benches of massive coal. Coal showing bedding structure is common and seems to be more jointed than other kinds, with the result that it breaks off in cubical or rectangular blocks of all sizes rather than in lumps. Some of the bedded coal is very finely laminated. In the central part of the field, in a "rider" bed above the Hiawatha bed, occurs a third type of coal, which is very homogeneous, fine in texture, brilliant in luster, and usually characterized by the small circular flat parting surfaces of "birdseye coal." Further description of this coal will be found on pages 166–167, in the section on the Rock Canyon area.

The blocky nature of some of the distinctly bedded coal seems to be due, in part at least, to the same causes which produced the jointing and faulting of the adjacent rocks, but in places the jointing of the coal appears to bear little relation to the regional structure. In highly faulted areas, such as Pleasant Valley, blocky coal predominates near the faults, and the jointed structure is doubtless related to the faulting. Some of this coal is so highly jointed that it is very difficult to mine it in lump sizes. In other parts of the field, where the rocks are not much jointed, blocky, friable coal occurs in layers beneath typical massive coal, and at such places it causes difficulty in mines because it splinters and crushes in faces and ribs under the load of considerable cover.

At the outcrop most of the coal has been reduced, by the long-continued attack of weathering agencies, to a friable state, which usually renders the distinction of different physical kinds impossible. All but the phenomenally resistant coal eventually yields to these processes, and even the massive coal of this field weathers away at most places on the outcrop. Where it is weathered the massive coal normally shows either granular or semiblocky structure, and it commonly contains nodules, in shape not unlike the concretions found in marine shale. The coal that is blocky when fresh seems not to form these nodules. At a few places in the field, notably Bear Creek Canyon, in T. 16 S., R. 7 E., and Clear Creek, in T. 24 S., R. 4 E., the massive coal has resisted the weather and appears in cliff-like outcrops resembling that of massive sandstone; elsewhere, as at the entrance to the manway of the King No. 2 mine, the depth of weathering is only a few feet.

One of the most valuable physical attributes of the Wasatch Plateau coal is its stocking quality, or its ability to withstand the weather during such periods of time as coal is ordinarily held in storage. Most of the coal of the field appears to be an excellent stocking fuel, although at least one sample (see p. 168) showed the effect of weather after exposure for one year.

The specific gravity of several coals from the field is shown by the following table:

*Specific gravity of samples of coal from the Wasatch Plateau coal field* [a]

| Laboratory No. | Source | Location | | | | Coal bed | Specific gravity | Ash content (per cent) |
|---|---|---|---|---|---|---|---|---|
| | | Quarter | Sec. | T. S. | R. E. | | | |
| 83555 | Huntington mine | SE. | 11 | 14 | 6 | Castlegate "A" | 1.31 | |
| 83559 | do | SE. | 11 | 14 | 6 | do | 1.30 | 4.90 |
| 83748 | Natural exposure in Tie Fork | SE. | 34 | 15 | 7 | Upper (not named) | 1.300 | 5.33 |
| 86407 | Anderson mine | SW. | 26 | 17 | 7 | Hiawatha | 1.339 | |
| 86428 | Johnson mine | NE. | 25 | 17 | 6 | do | 1.328 | |
| 82235 | Prospect on Ivie Creek | SW. | 34 | 23 | 4 | Ivie | 1.346 | 7.30 |
| 82236 | Prospect on Clear Creek | NW. | 10 | 24 | 4 | do | 1.374 | 5.98 |

Average specific gravity, 1.328.

[a] Determined in Pittsburgh laboratory of Bureau of Mines; A. C. Fieldner, chemist in charge.

## CHEMICAL PROPERTIES

The coals of the Wasatch Plateau field are uniformly of medium bituminous rank, low in sulphur, low in ash, and high in content of resinous material, much of which occurs in visible masses and flakes. Coal samples for analysis have been collected from most of the mines and prospects within the field, and after excluding such of the samples as might have suffered deterioration by weathering the analyses given on pages 69–71 were selected as indicating the general character and heating value of the Wasatch Plateau coals. Many more analyses are published in Bureau of Mines Technical Paper 345, which contains analyses of Utah coals and gives much information regarding their mining and use.

The proximate analysis separates the coal into the general constituents that determine its properties as a fuel, and it is the form of analysis generally used for comparing coals as to their commercial value. The ultimate analysis is principally of scientific importance, though having special technical uses, and reports the percentages of the several chemical elements composing the coal. It does not, however, show the way in which these elements are chemically combined within the coal. The proximate analysis, because of its cheapness and present value for comparing coals, is more commonly made than the ultimate analysis.

Both proximate and ultimate analyses are reported in three forms, which are designated in the table by the letters A, C, and D. Form A represents the coal as it comes from the mine, Form C is a computed analysis, representing the coal after all moisture has been eliminated, and Form D is also computed, representing the coal after all moisture and ash have been theoretically removed. Neither of the two conditions last mentioned exists in nature, but Form C is used by mechanical engineers, and Form D is valuable for comparing the quality of the pure coal substance and the effect on its heating value of the impurities present, and it is also used by petroleum geologists as an index of the degree of regional metamorphism at the point of sampling.

The value for all purposes of chemical analyses of coal depends largely on uniformity of practice, both in the collection and analyses of samples. Analyses given in this report represent samples taken and analyzed under the standard conditions of Geological Survey practice. The parts of coal beds sampled are shown in the graphic sections.

Different methods of coal analysis have been found to show different results for the same coal, and this is notably true of the determination of volatile matter. When heated over the Bunsen burner, as is the practice in many commercial laboratories, the sample will not yield uniform results in successive analyses. The electric furnace affords a means of avoiding this difficulty, and it is now used by the United States Bureau of Mines. The determination of heating value is another part of the analysis in which standard practice is necessary to produce accordant results. In the analyses made by the United States Bureau of Mines the heating value is determined by the use of the Mahler bomb calorimeter, under great precaution to secure uniformity of result. The analyses here presented are comparable with other analyses made by the Bureau of Mines and as such are of importance in determining the value of the coal relative to other coals of the United States.

The sample taken under the standard conditions will represent the coal as it would be produced by careful mining and picking, but it may not represent the coal as it is delivered to the consumer if the miner is careless in the picking of the coal or if the mine has a friable roof, pieces of which may be included with the coal. Analyses of delivered coal from the King No. 1, Hiawatha, King No. 2, and Winter Quarters mines have been published and described by N. H. Snyder.[53] The samples for these analyses were taken, systematically, from large shipments of coal ranging between 300 and 3,510 tons, and they thus represent fairly the coal as the consumer receives it. A comparison of the analyses of delivered coal with those of samples from the mines that furnished the coal shows for the most part very slight differences in fixed carbon and volatile content, and almost invariably less moisture and ash and higher heating value in the

[53] Analyses of Utah coals: Bur. Mines Tech. Paper 345, pp. 74–77. 1925.

delivered coal than in the mine samples. This favorable condition is doubtless due in part to efficient mining and in part to the fact that the large mines of the field are now working chiefly in thick beds of clear coal, which are comparatively easy to mine without the inclusion of much impurity.

Measured by the standards proposed by Campbell [54] and generally adopted for the classification of coal, the coal of the Wasatch Plateau is all of bituminous rank. In all characteristics the fresh coal varies little from one end of the field to the other, and within certain parts of the field the variation between samples from different places is negligible. In considering this classification of coal the difference between rank and grade should be kept clearly in mind. The rank of the coal depends on the proportions it contains of the vital constituents, fixed carbon, volatile matter, and moisture. The grade is dependent upon the proportion of ashy impurities present, and a high-grade coal is one relatively free from such impurities. It is possible, therefore, to have a high-rank, low-grade coal or a low-rank, high-grade coal, or any possible combination of the two different features. The Wasatch Plateau coal should be designated, in these terms, as a high-grade, medium-rank bituminous coal. A summary of the analyses shows that the outstanding chemical characteristic of the coal is its low content of sulphur, moisture, and ash, which are the chief impurities commonly found in coal.

[54] Campbell, M. R., The coal fields of the United States: U. S. Geol. Survey Prof. Paper 100–A, pp. 3–9, 1922.

*Analyses of coal samples from the Wasatch Plateau coal field*

[Made at the Pittsburgh laboratory of the Bureau of Mines; A. C. Fieldner, chief chemist]

| Laboratory No. | Mine or prospect | Location | | | | No. on Plates 31 and 32 | Air-drying loss | Form of analysis | Proximate | | | | Ultimate | | | | | Heating value | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Quarter | Sec. | T. S. | R. E. | | | | Moisture | Volatile matter | Fixed carbon | Ash | Sulphur | Hydrogen | Carbon | Nitrogen | Oxygen | Calories | British thermal units |
| 79844 | Winter Quarters No. 1 | NE. | 1 | 12 | 6 | 10 | 2.2 | A | 6.94 | 43.1 | 44.8 | 5.2 | 0.72 | 6.0 | 69.1 | 1.3 | 17.7 | 6,930 | 12,470 |
| | | | | | | | | C | | 46.3 | 48.1 | 5.6 | .77 | 5.6 | 74.2 | 1.4 | 12.4 | 7,445 | 13,400 |
| | | | | | | | | D | | 49.0 | 51.0 | | .82 | 5.9 | 78.6 | 1.5 | 13.1 | 7,885 | 14,190 |
| 79839 | Kinney | NW. | 4 | 12 | 7 | 7 | 3.2 | A | 8.1 | 41.3 | 45.0 | 5.6 | .92 | 5.8 | 67.6 | 1.4 | 18.7 | 6,790 | 12,220 |
| | | | | | | | | C | | 45.0 | 48.9 | 6.1 | 1.00 | 5.4 | 73.6 | 1.5 | 12.5 | 7,390 | 13,300 |
| | | | | | | | | D | | 47.9 | 52.1 | | 1.06 | 5.7 | 78.3 | 1.6 | 13.3 | 7,865 | 14,160 |
| 79931 | Clear Creek No. 3 | SW. | 34 | 13 | 7 | 104 | 1.2 | A | 5.9 | 42.4 | 46.4 | 5.3 | .54 | 5.7 | 69.4 | 1.4 | 17.6 | 6,940 | 12,490 |
| | | | | | | | | C | | 45.0 | 49.3 | 5.7 | .57 | 5.3 | 73.8 | 1.5 | 13.1 | 7,375 | 13,280 |
| | | | | | | | | D | | 47.8 | 52.2 | | .60 | 5.6 | 78.2 | 1.6 | 14.0 | 7,820 | 14,080 |
| 80861 | do | SW. | 34 | 13 | 7 | 104 | 6.4 | A | 8.1 | 42.0 | 44.9 | 5.0 | .53 | | | | | 7,275 | 13,100 |
| | | | | | | | | C | | 45.7 | 48.9 | 5.4 | .58 | | | | | 7,920 | 14,260 |
| | | | | | | | | D | | 48.3 | 51.7 | | .61 | | | | | 8,375 | 15,080 |
| 79935 | Clear Creek No. 4 | SW. | 34 | 13 | 7 | 104 | 2.2 | A | 6.5 | 45.6 | 44.4 | 3.4 | .50 | 6.1 | 71.1 | 1.4 | 17.4 | 7,100 | 12,780 |
| | | | | | | | | C | | 48.8 | 47.5 | 3.7 | .53 | 5.8 | 76.1 | 1.5 | 12.4 | 7,595 | 13,670 |
| | | | | | | | | D | | 50.6 | 49.4 | | .55 | 6.0 | 79.0 | 1.6 | 12.9 | 7,890 | 14,200 |
| 80860 | do | SW. | 34 | 13 | 7 | 104 | .9 | A | 2.8 | 46.0 | 46.9 | 4.3 | .45 | | | | | 7,260 | 13,070 |
| | | | | | | | | C | | 47.3 | 48.2 | 4.4 | .46 | | | | | 7,470 | 13,450 |
| | | | | | | | | D | | 49.5 | 50.5 | | .48 | | | | | 7,815 | 14,070 |
| 82668 | Wattis mine prospect pit | NW. | 16 | 15 | 8 | 131-a | 3.0 | A | 7.3 | 39.7 | 46.7 | 6.3 | .59 | | | | | 6,800 | 12,240 |
| | | | | | | | | C | | 42.8 | 50.4 | 6.8 | .64 | | | | | 7,340 | 13,210 |
| | | | | | | | | D | | 45.9 | 54.1 | | .69 | | | | | 7,875 | 14,180 |
| 82666 | Wattis | NE. | 16 | 15 | 8 | 131-c | 2.6 | A | 7.9 | 40.2 | 48.9 | 2.9 | .70 | | | | | 6,960 | 12,830 |
| | | | | | | | | C | | 43.6 | 53.1 | 3.2 | .76 | | | | | 7,560 | 13,610 |
| | | | | | | | | D | | 45.1 | 54.9 | | .79 | | | | | 7,810 | 14,060 |
| 83263 | do | NE. | 17 | 15 | 8 | 131-c | 4.1 | A | 6.8 | 41.4 | 47.3 | 4.5 | .84 | 5.9 | 70.1 | 1.4 | 17.2 | 6,995 | 12,390 |
| | | | | | | | | C | | 44.4 | 50.8 | 4.9 | .90 | 5.5 | 75.3 | 1.5 | 12.0 | 7,510 | 13,520 |
| | | | | | | | | D | | 46.7 | 53.3 | | .95 | 5.8 | 79.1 | 1.6 | 12.6 | 7,890 | 14,200 |

*Analyses of coal samples from the Wasatch Plateau coal field*—Continued

| Laboratory No. | Mine or prospect | Location: Quarter | Location: Sec. | Location: T. S. | Location: R. E. | No. on Plates 31 and 32 | Air-drying loss | Form of analysis | Proximate: Moisture | Proximate: Volatile matter | Proximate: Fixed carbon | Proximate: Ash | Ultimate: Sulphur | Ultimate: Hydrogen | Ultimate: Carbon | Ultimate: Nitrogen | Ultimate: Oxygen | Heating value: Calories | Heating value: British thermal units |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 80815 | Hiawatha No. 1 | NW. | 29 | 15 | 8 | 143 | 2.4 | A | 6.3 | 41.4 | 44.8 | 7.4 | .74 | 5.9 | 69.4 | 1.4 | 15.0 | 6,895 | 12,410 |
| | | | | | | | | C | ------ | 44.2 | 47.8 | 8.0 | .79 | 5.6 | 74.1 | 1.5 | 10.0 | 7,365 | 12,250 |
| | | | | | | | | D | ------ | 48.1 | 51.9 | ------ | .86 | 6.0 | 80.5 | 1.6 | 10.9 | 8,000 | 14,400 |
| 80893 | Hiawatha No. 2 | NW. | 29 | 15 | 8 | 141 | 3.4 | A | 5.8 | 41.6 | 45.3 | 7.3 | .66 | 5.8 | 69.0 | 1.4 | 15.8 | 6,890 | 12,400 |
| | | | | | | | | C | ------ | 44.2 | 48.1 | 7.7 | .70 | 5.5 | 73.3 | 1.5 | 11.2 | 7,310 | 13,160 |
| | | | | | | | | D | ------ | 47.9 | 52.1 | ------ | .76 | 6.0 | 79.4 | 1.7 | 12.2 | 7,925 | 14,260 |
| 80716 | Blackhawk (King No. 1) | NW. | 3 | 16 | 8 | 148 | 1.9 | A | 5.9 | 41.9 | 45.5 | 6.7 | .87 | 6.1 | 70.0 | 1.3 | 15.0 | 6,985 | 12,570 |
| | | | | | | | | C | ------ | 44.5 | 48.4 | 7.1 | .92 | 5.7 | 74.4 | 1.4 | 10.4 | 7,420 | 13,360 |
| | | | | | | | | D | ------ | 47.9 | 52.1 | ------ | .99 | 6.2 | 80.1 | 1.5 | 11.1 | 7,990 | 14,380 |
| 81013 | Mohrland (King No. 2) | SE. | 8 | 16 | 8 | 159 | 4.9 | A | 6.3 | 41.6 | 45.7 | 6.4 | .66 | 6.2 | 69.7 | 1.4 | 15.5 | 6,995 | 12,590 |
| | | | | | | | | C | ------ | 44.4 | 48.8 | 6.8 | .70 | 5.9 | 74.4 | 1.5 | 10.6 | 7,465 | 13,430 |
| | | | | | | | | D | ------ | 47.6 | 52.3 | ------ | .75 | 6.3 | 79.8 | 1.7 | 11.4 | 8,010 | 14,420 |
| 83560 | New York or Huntington | SE. | 11 | 14 | 6 | 173 | 4.1 | A | 6.9 | 40.1 | 47.8 | 5.2 | 1.10 | 5.7 | 69.9 | 1.3 | 16.8 | 6,915 | 12,440 |
| | | | | | | | | C | ------ | 43.1 | 51.3 | 5.5 | 1.18 | 5.3 | 75.1 | 1.4 | 11.5 | 7,430 | 13,370 |
| | | | | | | | | D | ------ | 45.6 | 54.3 | ------ | 1.25 | 5.6 | 79.5 | 1.5 | 12.1 | 7,865 | 14,160 |
| 81865 | Larsen | SW. | 2 | 15 | 6 | 205 | 4.7 | A | 9.8 | 38.3 | 47.4 | 4.5 | .60 | 5.8 | 67.4 | 1.3 | 20.3 | 6,640 | 11,960 |
| | | | | | | | | C | ------ | 42.5 | 52.6 | 4.9 | .67 | 5.3 | 74.9 | 1.4 | 12.9 | 7,365 | 13,260 |
| | | | | | | | | D | ------ | 44.7 | 55.3 | ------ | .70 | 5.5 | 78.8 | 1.5 | 13.5 | 7,750 | 13,950 |
| 83748 | Natural outcrop in Tie Fork | SE. | 34 | 15 | 7 | 218 | 1.9 | A | 3.8 | 40.7 | 50.1 | 5.3 | .79 | ------ | ------ | ------ | ------ | 7,225 | 13,000 |
| | | | | | | | | C | ------ | 42.3 | 52.1 | 5.5 | .82 | ------ | ------ | ------ | ------ | 7,510 | 13,520 |
| | | | | | | | | D | ------ | 44.8 | 55.2 | ------ | .87 | ------ | ------ | ------ | ------ | 7,950 | 14,310 |
| 82349 | Prospect in Bear Canyon | SE. | 24 | 16 | 7 | 253–b | 4.4 | A | 5.6 | 44.1 | 45.8 | 4.5 | .55 | ------ | ------ | ------ | ------ | 7,305 | 13,150 |
| | | | | | | | | C | ------ | 46.7 | 48.5 | 4.8 | .58 | ------ | ------ | ------ | ------ | 7,740 | 13,930 |
| | | | | | | | | D | ------ | 49.1 | 50.9 | ------ | .61 | ------ | ------ | ------ | ------ | 8,125 | 14,630 |
| 82353 | do | SE. | 24 | 16 | 7 | 255 | 5.2 | A | 7.6 | 42.6 | 44.7 | 5.1 | .48 | ------ | ------ | ------ | ------ | 7,165 | 12,900 |
| | | | | | | | | C | ------ | 46.2 | 48.4 | 5.5 | .55 | ------ | ------ | ------ | ------ | 7,760 | 13,970 |
| | | | | | | | | D | ------ | 48.8 | 51.2 | ------ | .57 | ------ | ------ | ------ | ------ | 8,210 | 14,780 |
| 82351 | do | SE. | 24 | 16 | 7 | 253–c | 3.1 | A | 6.3 | 41.7 | 48.2 | 3.8 | .56 | ------ | ------ | ------ | ------ | 7,180 | 12,920 |
| | | | | | | | | C | ------ | 44.5 | 51.5 | 4.0 | .60 | ------ | ------ | ------ | ------ | 7,665 | 13,800 |
| | | | | | | | | D | ------ | 46.4 | 53.6 | ------ | .63 | ------ | ------ | ------ | ------ | 7,985 | 14,380 |

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 83749 | Deer Creek | NW. | 11 | 17 | 7 | 269 | 2.6 | A | 4.6 | 45.2 | 45.1 | 5.1 | .64 | | | | | 7,385 | 13,290 |
| | | | | | | | | C | | 47.4 | 47.3 | 5.3 | .67 | | | | | 7,740 | 13,940 |
| | | | | | | | | D | | 50.1 | 49.9 | | .71 | | | | | 8,175 | 14,720 |
| 86246 | Anderson | SW. | 26 | 17 | 7 | 286–a | 2.0 | A | 4.5 | 39.9 | 46.7 | 8.9 | .6 | | | | | 6,880 | 12,380 |
| | | | | | | | | C | | 41.8 | 48.9 | 9.3 | .6 | | | | | 7,205 | 12,970 |
| | | | | | | | | D | | 46.1 | 53.9 | | .7 | | | | | 7,940 | 14,290 |
| 86245 | Mine in upper Grimes Wash | SE. | 22 | 17 | 7 | 288–a | 1.9 | A | 4.4 | 40.6 | 46.9 | 8.1 | .6 | | | | | 6,910 | 12,440 |
| | | | | | | | | C | | 42.5 | 49.0 | 8.5 | .6 | | | | | 7,235 | 13,020 |
| | | | | | | | | D | | 46.5 | 53.5 | | .7 | | | | | 7,905 | 14,230 |
| 86247 | Johnson | NE. | 25 | 17 | 6 | 308–a | 1.9 | A | 4.1 | 39.7 | 47.6 | 8.6 | .7 | | | | | 6,930 | 12,470 |
| | | | | | | | | C | | 41.5 | 49.5 | 9.0 | .7 | | | | | 7,220 | 13,000 |
| | | | | | | | | D | | 45.5 | 54.5 | | .8 | | | | | 7,940 | 14,290 |
| 82352 | Oliphant | NE. | 11 | 18 | 6 | 318 | 1.9 | A | 4.6 | 40.4 | 46.2 | 8.8 | .56 | | | | | 6,955 | 12,520 |
| | | | | | | | | C | | 42.3 | 48.4 | 9.2 | .59 | | | | | 7,290 | 13,120 |
| | | | | | | | | D | | 46.6 | 53.4 | | .65 | | | | | 8,030 | 14,460 |
| 86404 | Lower Rock Canyon | NE. | 7 | 19 | 7 | 350 | 1.4 | A | 6.4 | 41.0 | 46.3 | 6.3 | .8 | | | | | 6,815 | 12,270 |
| | | | | | | | | C | | 43.8 | 49.5 | 6.7 | .8 | | | | | 7,285 | 13,110 |
| | | | | | | | | D | | 46.9 | 53.1 | | .9 | | | | | 7,805 | 14,050 |
| 86403 | Upper Rock Canyon | NW. | 5 | 19 | 7 | 345 | 2.2 | A | 6.8 | 41.0 | 47.0 | 5.2 | .6 | | | | | 6,930 | 12,490 |
| | | | | | | | | C | | 44.0 | 50.4 | 5.6 | .7 | | | | | 7,445 | 13,400 |
| | | | | | | | | D | | 46.6 | 53.4 | | .7 | | | | | 7,890 | 14,200 |
| 87022 | do | NW. | 5 | 19 | 7 | 345 | 3.2 | A | 9.8 | 34.4 | 54.4 | 1.4 | .9 | | | | | 6,890 | 12,400 |
| | | | | | | | | C | | 38.1 | 60.4 | 1.5 | 1.0 | | | | | 7,635 | 13,740 |
| | | | | | | | | D | | 38.7 | 61.3 | | 1.0 | | | | | 7,755 | 13,960 |
| 82689 | Hiawatha | NW. | 29 | 15 | 8 | | 0.0 | A | .30 | | | 11.13 | .4 | 8.6 | 69.2 | .3 | 10.4 | 8,166 | 14,699 |
| | | | | | | | | C | | | | 11.16 | .4 | 8.6 | 69.4 | .3 | 10.2 | 8,191 | 14,743 |
| | | | | | | | | D | | | | | .45 | 9.7 | 78.1 | .3 | 11.4 | 9,220 | 16,595 |

79844. Castlegate "A" bed; composite of four samples taken at different places in mine in 1921 by W. H. Carrick.

79839. Castlegate "A" bed; composite of two samples taken at different places in mine in 1921 by W. H. Carrick.

79931. Castlegate "A" bed; composite of two samples taken at different places in mine in 1921 by A. D. Pierson.

80861. Castlegate "A" bed; coal fresh; sampled in 1921 by H. I. Smith.

79935. Bob Wright bed; composite of two samples taken at different places in mine in 1921 by A. D. Pierson.

80860. Bob Wright bed; sampled in 1921 by H. I. Smith.

82668. Hiawatha bed; 70 feet from outcrop in prospect tunnel; coal appeared fairly fresh; sampled in 1921 by H. I. Smith and E. M. Spieker.

82666. Wattis bed; about 200 feet from opening of mine; coal appeared weathered or affected by heat; sampled in 1921 by H. I. Smith and E. M. Spieker.

83263. Wattis bed; composite of five samples taken in mine in 1921 by W. H. Carrick.

80815. Hiawatha bed; composite of four samples taken in mine in 1921 by W. H. Carrick.

80893. Hiawatha bed; composite of four samples taken in mine in 1921 by W. H. Carrick.

80716. Hiawatha bed; composite of four samples taken in mine in 1921 by W. H. Carrick.

81013. Hiawatha bed; composite of four samples taken in mine in 1921 by W. H. Carrick.

83560. Castlegate "A" bed; composite of two samples taken in mine in 1921 by H. I. Smith and F. W. Downey.

81865. Castlegate "A" bed; composite of two samples taken in mine (abandoned); coal fresh; sampled in 1921 by H. I. Smith.

83748. Upper bed, not named; sample taken at outcrop in stream channel; bed forms ledge and appears totally unaffected by weather; sampled in 1921 by H. I. Smith and E. M. Spieker.

82349. Bear Canyon bed; about 30 feet from opening of prospect tunnel; coal appeared somewhat weathered; sampled in 1921 by E. M. Spieker.

82353. Bear Canyon bed; about 50 feet from opening of prospect tunnel; coal had been exposed to weather for many years but was solid and appeared fresh; sampled in 1921 by E. M. Spieker.

82351. Upper Bear Canyon bed; face of drift 40 feet from mouth; coal somewhat weathered; sampled in 1921 by E. M. Spieker.

83749. Blind Canyon bed; face of entry about 600 feet from mouth; coal long exposed to weather but appeared fresh; sampled in 1921 by E. M. Spieker.

86246. Hiawatha bed; 200 feet from mine mouth; mine operating, coal fresh; sampled in 1922 by J. B. Eby.

86245. Hiawatha bed; 50 feet from mouth of abandoned mine; coal apparently not affected by weather; sampled in 1922 by J. B. Eby.

86247. Hiawatha bed; 250 feet from mouth of abandoned mine; coal apparently not affected by weather; sampled in 1922 by J. B. Eby.

82352. Hiawatha bed; 300 feet from mouth of operating mine; sampled in 1922 by E. M. Spieker and H. I. Smith.

86404. Hiawatha bed; 150 feet from mouth of recently abandoned mine; coal apparently fresh; sampled in 1922 by E. M. Spieker.

86403. Hiawatha bed; 175 feet from mouth of abandoned mine; coal appeared fresh; sampled in 1922 by E. M. Spieker.

87022. Upper bench of Hiawatha bed, 1 foot 6 inches thick and about 2 feet above main bed; coal fresh; very bright, "birdseye" coal; sampled in 1922 by E. M. Spieker.

82689. Resin from Hiawatha bed; sampled in 1921 by H. I. Smith.

The coal contains much resin, at least half of which is red to yellow, and specimens from some of the mines show the lighter-colored resins very prominently. The analysis of an extremely resinous specimen from a mine in the Salina Canyon district, at the south end of the field, shows about 15 per cent of resin, about half of which is red and half black. The resin alone gives a heating value of more than 14,500 British thermal units, and its presence in coal enhances rather than lessens the heat value, although it increases the smokiness of the coal. The analysis of a sample of resin from the Hiawatha mine is given on page 71 (No. 82689).

The average coal of the Wasatch Plateau field is compared graphically in Figure 3 with average coal from other fields in the western United States which may compete with it in Pacific coast markets and with representative eastern coals. All the features shown in Figure 3 represent analyses of the coal as it was received in the laboratory, and each column is intended to represent the general average of the coal of the field or district named. The coals compared are bituminous, except No. 8, from Gallup, which is subbituminous; No. 10, from Washington, which represents subbituminous in part; Nos. 12 and 13, from the Bering River field, Alaska, and No. 16, from the Pocahontas and New River fields of Virginia and West Virginia, which are semibituminous. Nos. 2 to 4 represent coals from Wyoming and Utah that compete actively with Wasatch Plateau coal at the present time; Nos. 5 to 9 coals from Rocky Mountain fields that may possibly compete in the future; Nos. 10 to 13 Pacific coast coals; and Nos. 14 to 16 eastern coals, of which only No. 16 may be expected to compete on the Pacific coast with Wasatch Plateau coal, but data for which are given to afford a comparison with well-known coals of the Appalachian region.

This comparison is limited to those features which are readily available from chemical analysis, and it does not take into account other features, such as physical character and general behavior on burning, which are of great importance in determining the relative values of the fuels for special purposes. Perhaps the most significant elements shown by the diagram are the percentages of fixed carbon and ash and the heating value. The diagram is intended to show the average coal from the several fields, and each field produces some coal of higher and some of lower quality than that shown. Furthermore, in some fields the range between extremes is great, whereas in others it is small. In the Wasatch Plateau and in fields Nos. 2, 3, 4, 9, 11, 14, 15, and 16 the range is not great. The analyses from which Nos. 5, 6, and 8 were averaged represent a moderate range in quality, and those from which Nos. 7, 10, 12, and 13 were obtained show considerable variety. The coal from the Bering River field varies considerably in quality, principally because of great variation in the amount of ash, and to show coal representative of the kinds that are likely to be shipped from that field, two analyses are given. Some of the coal of the Bering River field falls below the quality represented by No. 12, but No. 13 may be taken to represent on the average the best coal of the field.

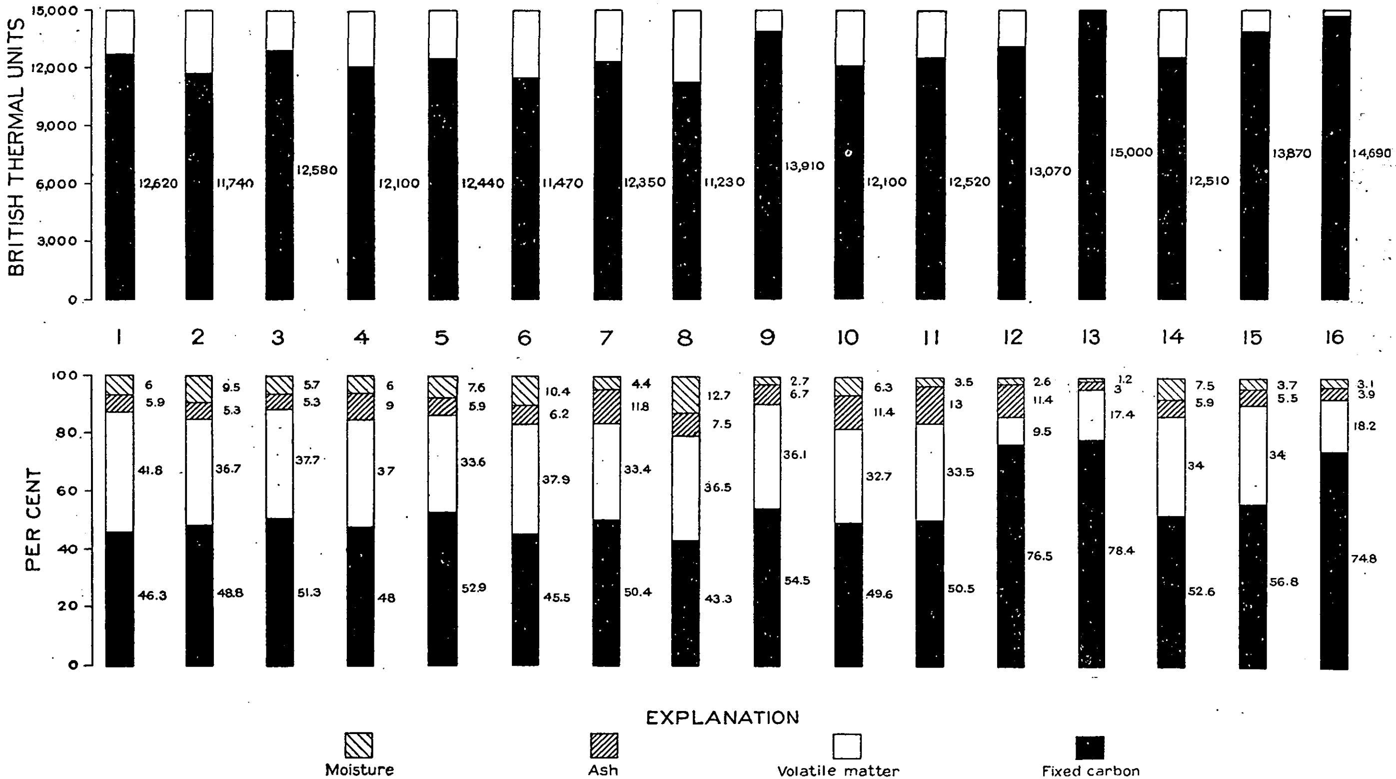



FIGURE 3.—Diagram comparing Wasatch Plateau coal with coal from other fields. 1, Wasatch Plateau, Utah; 2, Rock Springs, Wyo.; 3, Kemmerer, Wyo.; 4, Sego, Utah; 5, Grand Junction, Colo.; 6, Moffat County, Colo.; 7, Trinidad, Colo.; 8, Gallup, N. Mex.; 9, Durango, Colo.; 10, Puget Sound, Wash.; 11, Vancouver Island, B. C.; 12, St. Marys Creek, Bering River field, Alaska; 13, Trout Creek, Bering River field, Alaska: 14, Hocking Valley, Ohio; 15, Pittsburgh, Pa.; 16, Pocahontas, W. Va.

## COKING QUALITIES

Coking tests have been made from time to time in beehive ovens on nearly all the coal now being mined in the Wasatch Plateau field, but thus far no tests are known to have been thoroughly successful. Coke was made at Connelsville (now called Huntington mine), in sec. 11, T. 14 S., R. 6 E., and at Scofield between 1875 and 1885; and at Castlegate, in the adjacent Book Cliffs field, coke ovens were active until about 1900, when the coke ovens at Sunnyside were built. The undeveloped coal of the plateau has been little tested, and it is possible that an area of coking coal similar to that at Sunnyside may exist in this field. It has been announced that recent experiments on low-temperature coking processes [55] have worked successfully with the coal from this field, but the commercial applicability of the processes is not yet known. Future experimentation may develop a means of making good metallurgical coke from the coal.

## BURNING OF COAL AT THE OUTCROP

In practically every part of the field, except Pleasant Valley, some burning of the coal beds has taken place along the outcrops, and the reddened rocks resulting from such burning are particularly evident wherever the sandstone near the coal forms cliffs. As a rule the coal is burned on projecting spurs of the plateau and is not burned at the heads of the gulches, where it is usually protected by soil and slumped rock.

The burning of the coal has apparently taken place within geologically recent time, but the writer observed no place at which beds are now on fire. Many different causes have been suggested to account for the ignition of the coal, the commonest being lightning, human activity, and spontaneous combustion. The propensity of finely divided high-volatile coal to ignite spontaneously, owing to oxidation of the volatile matter, with liberation of heat which accelerates the chemical reaction and builds up an automatic chain of increases in heat until the ignition point of the coal is reached, seems the most likely cause. Rapid erosion of the coal beds and the consequent accumulation of piles of fine coal at the outcrop, together with long periods of dry weather and the heat of the summer sun, favor this process.

Once ignited, a coal bed will smolder slowly until the sagging of the overlying rock, due to reduction of the coal to ash, opens fissures that afford free access of oxygen and an outlet for the burning

[55] Parr, S. W., and Layng, T. E., The coking of Utah coals: Bur. Mines Repts. Inv. 02278, 1921. See also Analyses of Utah coals: Bur. Mines Tech. Paper 345, pp. 78–85, 1925.

gases, and the natural draft thus produced intensifies the fire. Under favorable circumstances the heat becomes sufficiently intense to melt the overlying rock. This process continues inward from the outcrop until the cover becomes too impervious to permit access of the necessary oxygen, and the fire is smothered.

A few places have been noticed in the field where the heated gases from the burning coal, on rising through fissures, have reduced the iron compounds instead of oxidizing them, and at such places the rocks instead of being reddened have been converted to a slag tinted either in delicate shades of green, yellow, and salmon-pink or in very dark colors. In some such places the reducing action has been sufficient to change the iron to magnetite (lodestone) or even to metallic iron, and at a number of places on burned outcrops the compass needle is strongly affected by such masses of magnetic iron. The phenomena associated with the burning of coal beds, and particularly the types of slag and clinker formed, have been concisely discussed by Rogers,[56] who draws largely for his evidence from Montana coal fields. His conclusions, however, have general application.

Observations made in mines show that only rarely has the burning of coal beds in this field penetrated farther than 500 feet from the outcrop, and as a rule no farther than 200 to 300 feet.

At many places in burned areas there are masses of black powder, similar to lampblack, beneath the soil at the horizons of coal beds. The writer dug out beds of such powder as thick as 40 to 50 inches in the burned cliffs and slopes north of the Cedar Mesa ranch, on North Fork of Gordon Creek, and found several other occurrences where burning has been extensive. The powder has probably resulted from the condensation, under cover, of carbon from volatile matter incompletely consumed when the coal was burning.

There is no sure way of determining the thickness of a coal bed from the amount of ash remaining or from the extent to which the heat has altered the surrounding rocks, but where as much as 20 to 50 feet or more of beds have been reddened and partly baked it seems safe to assume the former presence of a thick coal bed.

## NATURAL GEOGRAPHIC SUBDIVISIONS OF COAL FIELD

For the purpose of describing the coal and the possibility of mining, the writer has divided the field into areas, each of which conforms closely to a local drainage basin. This form of subdivision is adopted instead of describing the coal by townships, because many townships of the field contain parts of two or more naturally defined areas that for purposes of development bear no intimate relation to

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[56] Rogers, G. S., Baked shale and slag formed by the burning of coal beds: U. S. Geol. Survey Prof. Paper 108, pp. 1–10, 1918; Rogers, G. S., and Lee, Wallace, Geology of the Tullock Creek coal field, Mont.: U. S. Geol. Survey Bull. 749, pp. 81–85, 1923.

one another, and to take the township as an arbitrary unit would necessitate much repetition and cross reference in the text, in order to keep clear the natural relations of different parts of the field. The boundaries of the areas have been drawn on those land lines which best approximate the natural limits of the drainage basins constituting the natural units. (See fig. 4.)

*Areas of the Wasatch Plateau coal field described in this report*

| Name | Approximate area (square miles) | T. S. | R. E. | Parts of township contained in area |
|---|---|---|---|---|
| Price River | 22 | 11 | 9 | Secs. 31, 32, 33; part of 29. |
| | | 12 | 9 | Secs. 4-9, 16-18, 19-30 north of 30° 45′. |
| Beaver | 38 | 11 | 8 | Sec. 36. |
| | | 12 | 8 | Secs. 26-35 west of 111°; secs. 1, 2, 11-14, 23-26 north of 39° 45′; secs. 15, 16, 21, 22. |
| | | 12 | 7 | Secs. 25, 36. |
| | | 13 | 8 | Secs. 1-12. |
| | | 13 | 7 | Secs. 1, 2, 11-14. |
| Pleasant Valley | 75 | 12 | 7 | Secs. 9-24; 26-35. |
| | | 12 | 6 | Secs. 26-28; 34-36. |
| | | 13 | 7 | Secs. 2; 3-10, 15-22, 27-34. |
| | | 13 | 6 | Secs. 1-3, 10-14, 24, 25. |
| | | 14 | 7 | Secs. 4-6, 8, 9, 16, 17, 21. |
| North Gordon | 20 | 13 | 8 | Secs. 14-23, 26-35. |
| | | 13 | 7 | Secs. 23-26. |
| Bob Wright | 36 | 13 | 7 | Secs. 35, 36. |
| | | 14 | 7 | Secs. 1, 2, 11-14, 23-26, 35, 36. |
| | | 14 | 8 | Secs. 3-10, 15-22, 27-34. |
| Hiawatha | 27 | 15 | 7 | Secs. 1, 2, 12. |
| | | 15 | 8 | Secs. 3-10, 15-22, 27-34. |
| Mohrland | 36 | 16 | 8 | All. |
| | | 13 | 6 | Secs. 15, 22, 23, 26, 27, 34-36. |
| Upper Huntington | 93 | 14 | 6 | All east of 111° 15′. |
| | | 14 | 7 | Secs. 3, 7, 10, 15, 18-20, 22, 27-34. |
| | | 15 | 7 | All except secs. 1, 2, 12. |
| | | 15 | 6 | All east of 111° 15′. |
| | | 16 | 6 | Secs. 1, 2, 11-13, 24, 25, 36. |
| Lower Huntington | 62 | 16 | 7 | All. |
| | | 17 | 7 | Secs. 1-6, 8-17. |
| | | 17 | 8 | All west of 111°. |
| Cottonwood | 136 | 16 | 6 | All east of 111° 15′ except secs. 2, 11, 13. |
| | | 17 | 6 | All except secs. 6, 7. |
| | | 17 | 7 | Secs. 7, 18, 19-36. |
| | | 18 | 6 | All. |
| | | 18 | 7 | All. |
| | | 18 | 8 | All west of 111°. |
| Rock Canyon | 48 | 19 | 7 | All. |
| | | 19 | 6 | Secs. 1, 2, 11-14, 23-26, 35, 36. |
| Ferron | 78 | 19 | 5 | All. |
| | | 19 | 6 | Secs. 3-10, 15-22, 27-34. |
| | | 20 | 6 | Secs. 1-18. |
| Muddy Canyon | 104 | 20 | 5 | All. |
| | | 20 | 6 | Secs. 19-36. |
| | | 21 | 5 | Secs. 1-12, 13, 24. |
| | | 21 | 6 | All. |
| | | 21 | 5 | Secs. 14-23, 25-36. |
| Convulsion Canyon | 82 | 22 | 4 | Secs. 1-4, 9-16, 21-28, 33-35. |
| | | 22 | 5 | All except secs. 31-33. |
| Saleratus | 66 | 22 | 4 | Sec. 36. |
| | | 22 | 5 | Secs. 31-33. |
| | | 23 | 4 | Secs. 1-30. |
| | | 23 | 5 | All. |
| Ivie | 78 | 23 | 4 | Secs. 31-36. |
| | | 24 | 4 | All. |
| | | 25 | 4 | All. |

If it is desired to find the description of the coal in any particular land subdivision, the name of the area in which the land is contained may be ascertained by reference either to the three columns on the right of the table or to Figure 4.

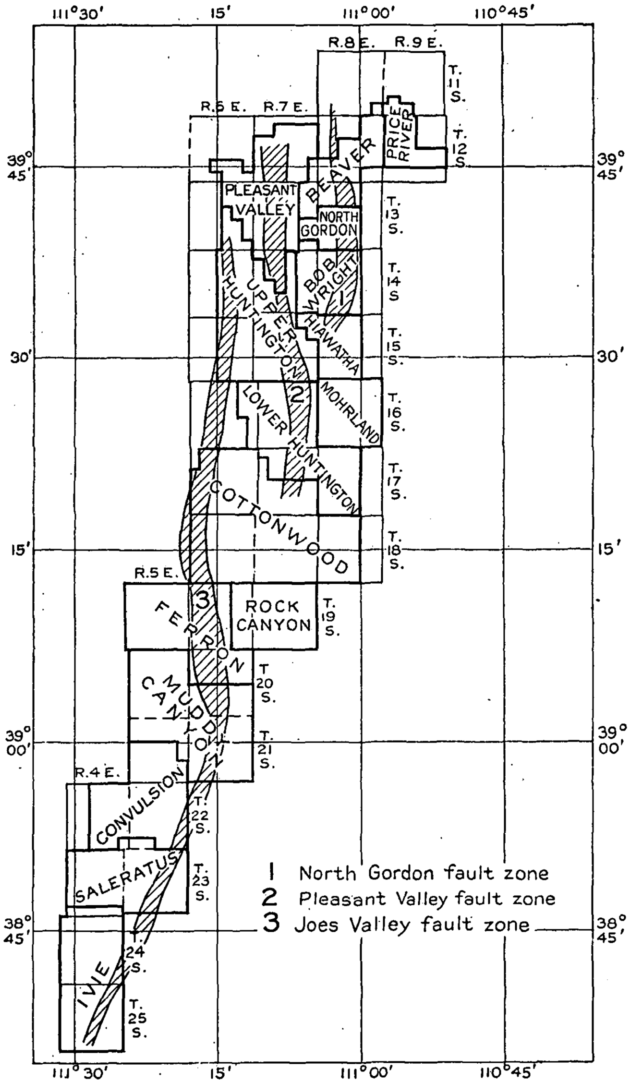


FIGURE 4.—Index map of Wasatch Plateau coal field showing subdivisions of the field and fault zones

## DETAILED DESCRIPTIONS

### PRICE RIVER AREA

The Price River area lies east of the one hundred eleventh meridian and is entirely in the Book Cliffs coal field, according to the coal field boundaries accepted in this report. It is described here, however, because the opportunity to map it topographically came in the course of the present work after the completion of Clark's work in the Book Cliffs,[57] which did not extend north or west of the Castlegate quadrangle.

[57] Clark, F. R., op. cit.

The Castlegate sandstone is the lowest stratigraphic unit exposed in the Price River area, and no coal appears at the surface, but the area is important as a probable source of coal because the coal-bearing part of the Blackhawk formation may be near enough to the surface to be mined by shaft in the deeper canyons as far north as Nolan, a siding on the Denver & Rio Grande Western Railroad, or even farther north if economic conditions ever justify very deep mining. The Blackhawk formation is known to be rich in coal in the Castlegate district, which touches the Price River area on the southeast, and in the Spring Canyon district, in which the nearest known coal is only 1 mile south of the southwest corner of the Price River area. The presence of valuable coal beneath the surface in this area is therefore highly probable.

The coal beds that crop out in the Castlegate and Spring Canyon districts, and the stratigraphic intervals between them, are shown in the following skeleton sections, which are generalized from the report by Clark.[58]

*Section showing coal beds in western parts of Castlegate and Spring Canyon districts*

| | | Range in thickness (feet) | |
|---|---|---|---|
| | | Spring Canyon | Castlegate |
| Kenilworth (=Castlegate "D") coal bed | | 1-4 | 0-2 |
| Interval | | 70 | 35-55 |
| Castlegate "C" coal bed | | 1-5 | 1-6 |
| Interval | | | 45-60 |
| Royal Blue coal bed | | | ½-2½ |
| Interval | | 90-100 | 25 |
| Castlegate "B" coal bed | | | 1-2 |
| Interval | | | 40 |
| Castlegate "A" coal bed | | 2-14 | 4-10 |
| Interval | | 90-125 | 210 |
| Gordon coal bed | Spring Canyon coal group | 1-6 | |
| Interval | Spring Canyon coal group | 100 | |
| Hiawatha coal bed: Upper split | Spring Canyon coal group | 2-6 | |
| Hiawatha coal bed: Lower split | Spring Canyon coal group | 1-7 | ⅓-2 |
| Star Point sandstone. | | | |

At least one and probably more of these beds may be expected to persist northward into the Price River area, and the probability of disclosing workable coal there by prospecting with the diamond drill is great. Comparison of the stratigraphic sections in surrounding districts indicates that the Castlegate "A" bed is probably present and over 30 inches thick, and the Castlegate "D" or Kenilworth bed is probably present in the southern part of the area. The Hiawatha bed and other beds of the Spring Canyon group should be present according to the evidence in Spring Canyon, but the absence of the Hiawatha bed in the Pleasant Valley district suggests that it may

[58] Clark, F. R., op. cit., pp. 122–130, pl. 5.

habitually disappear westward, and its meager showing in the Castlegate district suggests that the Price River area may be near its northern limit. The Castlegate "A" bed is the most likely of the group to be present, with the Castlegate " D " and the Hiawatha beds second and third respectively.

The depth of these beds beneath the surface increases northwestward from the southern part of the area, owing both to the dip of the rocks and to the rise of the surface. The surface rocks are well exposed in the Price River Canyon, and the dips can be measured with accuracy that would allow satisfactory prediction of the depths to the coal beds at selected places, if it were certain that the intervals from the recognizable strata of the Price River and the Wasatch formations were fairly constant. Unfortunately for such prediction, it is known that these intervals increase considerably westward. In Pleasant Valley the interval between the base of the Castlegate sandstone and the Castlegate "A" coal bed is at least 1,400 feet, as compared with only 700 feet for the Castlegate district, and at the northwest corner of the Scofield quadrangle it is probably 1,700 feet. If this thickening were uniform it might be prorated, but evidence in the North Gordon area suggests that it is irregular. Without further information the best that can be done toward an estimate of the depth of the coal beds in the area is a rough guess based on intervals between the Castlegate sandstone and the coal beds somewhat larger than those at Castlegate and in Spring Canyon. This type of estimate, for four places in Price River Canyon, gives the following results:

*Probable depths beneath the surface of Castlegate "A" coal bed in upper Price River Canyon*

| | Feet |
|---|---|
| Southern boundary of area | 800 |
| Mouth of Crandall Canyon | 1, 400–1, 500 |
| Nolan siding | 2, 100–2, 200 |
| Mouth of Horse Creek | 3, 300–3, 400 |

In Crandall Canyon the dip of the Castlegate sandstone is greater than the gradient of the creek bed, and for some distance up the canyon the depth to the Castlegate "A" coal is no more and in places as much as 100 feet less than its depth at the mouth of the canyon. At Nolan the rocks overlying the Castlegate "A" coal bed include probably 900 to 1,000 feet of the Blackhawk formation, all of the Price River formation, and about 180 feet of the Wasatch formation, or 2,100 to 2,200 feet in all. At the mouth of Horse Creek the thickness of Wasatch rocks beneath the surface is about 1,250 feet, and the Blackhawk formation is probably somewhat thicker than at Nolan.

### BEAVER AREA

The Beaver area is similar geologically to the Price River area in that most of the coal is underground and the rocks at the surface are chiefly those of the Price River and Wasatch formations. In most of the Beaver area, however, the coal is nearer the surface, as the upper part of the Blackhawk formation is exposed near the head of Beaver Creek and the lower part of the Price River formation is exposed in many adjacent valleys. The prediction of the depth at which coal will be found in this area is equally as difficult as for the Price River area, because the geologic section of the Pleasant Valley area, the next on the west, shows that the Blackhawk formation thickens westward and that the coal beds change in distribution through the lower part of the formation. In the Beaver area stratigraphic distances must be reckoned from the Castlegate sandstone, which is known to be much farther above the coal in those parts of Pleasant Valley where it is present than it is in North Fork of Gordon Creek and Spring Canyon. The valley of Beaver Creek, however, is not far from known exposures of the Blackhawk formation in North Fork of Gordon Creek and Spring Canyon, and it is possible to estimate the depth of the coal there with reasonable assurance.

#### COAL BEDS

The coal beds in the western part of the Spring Canyon district, which adjoins the Beaver area on the east, are tabulated in the description of the Price River area (p. 79). The coal beds of the North Gordon area, just south of the Beaver area, are as follows:

*Coal beds in North Gordon area*

| | Feet |
|---|---|
| Castlegate "A" coal bed | 2–8 |
| Interval | 60–120 |
| Gordon coal bed | 0–6 |
| Interval | 90–120 |
| Hiawatha coal bed | 3–10 |
| Top of Star Point sandstone. | |

The coal beds above the Castlegate "A" bed are not important in the adjoining part of the North Gordon area, and little may be expected of them in the Beaver area. The Castlegate "A" and Hiawatha beds are likely to be workable beneath Beaver Creek, but the Hiawatha bed may thin westward. The uncertainty of the correlation of the coal beds in Pleasant Valley makes it difficult to use the evidence there, which might otherwise throw considerable light on this matter. The Gordon bed may be present beneath Beaver

Creek, and it is likely that other beds of the Spring Canyon coal group as defined by Clark[59] are present and possibly more than 30 inches thick. At the heads of Spring and Wildcat Canyons the Castlegate "A" coal bed is commercially worthless, and it may be so under Beaver Creek in secs. 3, 4, and 5, T. 13 S., R. 8 E., and secs. 32 and 33, T. 12 S., R. 8 E. At the heads of both branches of North Fork of Gordon Creek and probably under the part of Beaver Creek above Sand Gulch, the Castlegate "A" coal bed is more than 40 inches thick. It is unsafe to make any predictions concerning the Castlegate "A" coal bed north of secs. 32 and 33, T. 12 S., R. 8 E., but this bed is known to be present at the nearest exposures in the Price River Canyon and on the plateau front, and the chance of finding it, as well as the lower coal beds, is good enough to warrant prospecting in those parts of Beaver Creek where the coal is not too deep for present-day mining.

The depth to the coal-bearing zone at places in this area where it is desirable to prospect by drilling may be ascertained within 50 feet by reckoning downward from the base of the Castlegate sandstone. (See pl. 31.) The Castlegate "A" coal bed is about 850 feet beneath the Castlegate sandstone at the nearest place where both are well exposed, and this interval is probably not much greater in the part of Beaver Creek north of sec. 12, T. 13 S., R. 7 E. Farther west the interval may be greater than 850 feet, and it is impossible to say how much greater, because no well-defined exposures of the Castlegate sandstone have been found in near-by parts of Pleasant Valley where the Castlegate "A" coal bed is clearly recognized. In the ridge east of Clear Creek, southwest of the Beaver area, the interval seems to be about 875 feet, and in the southwestern part of the Beaver area it is undoubtedly greater than 850 feet.

In the valley of Beaver Creek at the mouth of Johnston Creek the Castlegate "A" coal bed is probably over 1,100 feet beneath the surface, and at the mouth of Jump Creek probably over 1,000 feet. West of the straight stretch of Beaver Creek south of the Richards ranch the rocks rise at an average angle of about 3°, and the depth of the coal beneath the canyons of Jump and Johnston Creeks probably remains the same for some distance west of Beaver Creek.

On the part of Beaver Creek above Sand Gulch the rocks rise gently upstream, so that more and more of the Blackhawk formation is exposed in the canyon, and in secs. 11, 12, and 14, T. 13 S., R. 7 E., several thin coal beds come to the surface. One of these coal beds is about 3 feet thick where it crosses Beaver Creek, about 500 feet S. 18° E. of the north quarter corner of section 14, and this is the only coal approaching commercial value that is known to appear at the surface in the drainage basin of Beaver Creek.

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[59] Clark, F. R., op. cit., pp. 125–127.

East of the part of Beaver Creek between Sand Gulch and the Richards ranch the rocks dip northwestward, and the coal beds accordingly rise away from Beaver Creek. A broad, shallow syncline crosses Beaver Creek at the mouth of Jump Creek. Between Johnston Creek and the Richards ranch the rocks dip downstream, and north of the ranch they dip almost due north about 9°. The coal thus becomes deeper and deeper beneath the surface in the lower part of Beaver Creek; the Castlegate "A" coal bed is estimated to be at least 2,000 feet deep at a point about 800 feet north and 250 feet east from the west quarter corner of sec. 22, T. 12 S., R. 8 E., and over 4,000 feet deep at the mouth of Beaver Creek.

The drainage basins of Spring and Wildcat Canyons extend into the southeast corner of the Beaver area, and the outcrop of the Castlegate "A" coal is present in secs. 10, 11, and 14, T. 13 S., R. 8 E. In all these sections the Castlegate "A" coal bed and the beds above it are thin and of no present economic importance.

### FAULTS

The rocks of the Beaver area are not greatly disturbed by faulting, and mines established there will probably encounter little difficulty on account of structural irregularity. The faults of the North Gordon fault zone cross the eastern part of the area from north to south, but in this area the faults are not numerous, and they are in places where they will probably not seriously interfere with the laying out of mining units.

The easternmost known fault in the area crosses Beaver Creek near the bend northeast of the Richards ranch. The displacement of this fault is difficult to measure, because of the varied character of the Wasatch rocks in which it is displayed, but the evidence suggests that the rocks have dropped about 55 feet on the west side. West of this fault and near the ranch buildings is a zone of jointed and sheared rocks in which some displacement has doubtless occurred, but none of the faults are believed to be of large dimension.

Mines on Beaver Creek near Johnston and Jump Creeks will probably encounter no large faults within a mile or more of the shafts, but the faults of the North Gordon zone parallel the ridge dividing Beaver Creek from Spring Canyon, and these faults are not all clearly recognizable on the surface. The easternmost fault, the throw of which is about 60 feet down on the west, is well displayed in the rocks of the Price River formation at the head of Burnt Tree Fork of Spring Canyon, and the rocks on the ridge west of this fault show plainly considerable disturbance that is doubtless due to more faulting, the exact nature of which is not known. The easternmost fault at the head of Burnt Tree Fork is the eastern fault of the graben displayed in the canyon north of the Cedar Mesa ranch, and it is likely that the western fault of this graben, together with the zone of sheared rocks in the graben, is present on the ridge at the head of Burnt Tree Fork. West of this ridge the rocks are on the whole too poorly exposed to show the details of the geologic structure, and it is possible that some faults, not shown on the map, exist between the graben and Beaver Creek in sec. 33, T. 12 S., R. 8 E., and secs. 3 and 4, T. 13 S., R. 8 E. South of this tract, however, in sections 8 and 9, no faults are known.

The hill west of Jump Creek in secs. 25 and 26, T. 12 S., R. 7 E., is crossed by two faults shown on Plate 31, between which a block has dropped, bringing limestone of Wasatch age opposite sandstone of the Price River formation. The displacements of these faults are not exactly known, but the minima are 200 feet for the northern fault and 450 feet for the southern one. Both of these faults appear to die out at Jump Creek, and if so, the block between them must be bounded on the southeast by a cross fault, as suggested on the map. (See p. 92.)

A fault is shown on the map in sec. 1, T. 13 S., R. 7 E., connecting the fault of the Pleasant Valley zone in sec. 27, T. 12 S., R. 7 E., with the fault of the North Gordon zone in sec. 17, T. 13 S., R. 8 E. The evidence for this fault in the intervening territory is largely indirect, consisting of the alinement of topographic features and the general relations of the rocks to the north and south, but the fault is believed to exist approximately as shown on the map. The dip of the rocks in the area may be ascertained by reference to Plate 31.

### PLEASANT VALLEY AREA

The first large coal mines of Utah were opened in the Pleasant Valley district, and to-day it is farther advanced in development than any other part of the Wasatch Plateau field. The oldest mines of the district, which have been operating for more than 40 years, have exhausted large areas of coal, and later mines have made considerable inroads on the accessible coal remaining, but even after this long period of mining there remains in the district a reserve of coal much greater than the amount thus far extracted. Much of the remaining coal, however, is less readily accessible than that now being mined.

Early development in Pleasant Valley came as a result of its accessibility from the populated centers of Salt Lake Valley rather than because of especially favorable conditions for prospecting and mining the coal. The coal-bearing rocks in Pleasant Valley are on the whole very poorly exposed, and they are cut by a complex system of faults that has greatly increased the cost of extraction in most of the producing mines of the district. The district was opened up, however, before the main line of railroad had crossed the Wasatch Plateau, and the advantage of an early start, together with the favorable railroad haul to Salt Lake City, has fostered its development. High-grade coal is plentiful in the district, and some of the beds mined are very thick.

### COAL BEDS

*Correlation.*—The correlation of the coal beds of this district, both between places within the area and with the well-known coal beds of adjacent areas on the east, is made difficult by complicated structure and lack of rock exposures. (See pl. 11, *A*.) Much of the evidence for the present attempt at correlation of the coal beds has been afforded by the underground development of the district, and without the information available from this source the correlation of some beds would be impossible. The Clear Creek mines of the Utah Fuel Co. extend through the mountain from Clear Creek into Bob Wright Canyon and afford a connecting link between this area and the eastern front of the plateau, although this link is not perfect for purposes of correlation because the mine passes through a zone of pronounced faulting. The identification of the coal beds of Pleasant Valley with those on the plateau front consequently depends entirely on the determination that the coal bed of the Clear Creek Nos. 1 and 2 mines is the same as the bed of the No. 3 mine (in Bob Wright Canyon), which is identified on the basis of the present work as the Castlegate "A" coal bed. The No. 3 mine is separated from mines Nos. 1 and 2 by the fault zone mentioned above, across which the coal beds have been correlated with probable accuracy by a comparison of columnar sections.

The coal beds are not continuously traceable in any direction from Clear Creek, and the identification of the beds in other parts of the area depends upon the projection of known horizons across concealed areas and a comparison of columnar sections—processes both of which are so fallible that the result should perhaps be characterized as a well-regulated guess, and certainly as opinion rather than fact. The Pleasant Valley fault, which passes through the town of Clear Creek, separates the east from the west side of the canyon throughout its length and prevents the direct projection of the horizons of the coal beds westward from the Clear Creek mines. The stratigraphic succession at the nearest exposures west of the fault is sufficiently different from that east of the fault to raise doubt in the correlation of the coal beds. The succession of sandstones beneath the Blackhawk formation, which might otherwise be used as an aid to the recognition of the lowest coal bed, is much thicker in

Pleasant Valley than it is in the Bob Wright area, and no individual bed in it is certainly recognizable. The lower thick coal bed west of the fault is here correlated with the lower bed in the Clear Creek mines and is therefore called the Castlegate "A" bed, chiefly because it is underlain by a white sandstone and is about 200 feet beneath a coal bed, not underlain by white sandstone, which is probably the same as the bed about 200 feet above the Castlegate " A " bed at Clear Creek and which may be an upper bed of the Bob Wright coal group. The lower bed on the west side of Pleasant Valley above Clear Creek seems to be the same bed as that mined at Winter Quarters, which has been positively identified by mining operations as far south as Eccles Canyon. South of Eccles Canyon the bed is not traceable, however, and the northwest dip of the strata is so variable and in places so steep (10° in Eccles Canyon) that the projection of the coal bed across forested areas is subject to error.

The identification of the thick bed in the canyons west and southwest of Clear Creek as the Castlegate " A " bed affects somewhat the correlation of the coal beds in the Upper Huntington area, because the bed at the Huntington mine, in sec. 11, T. 14 S., R. 6 E., is probably the same as this bed, and to call the bed of Huntington Canyon the Castlegate " A " bed necessitates the correlation of it through Candland Mountain to the Left Fork of Huntington Creek, where the Castlegate " A " bed appears in the normal stratigraphic succession. In Candland Mountain the correlation of the coal beds is possible only through recognition of characteristic rock succession, and it is impossible to verify the identification of the coal beds of Pleasant Valley by carrying the correlations through from the lower part of Huntington Canyon. The comparison of sections measured on Candland Mountain, however, seems to support the present identification of the Castlegate " A " coal bed.

At Scofield, in the central part of the Pleasant Valley area, three coal beds are known to be present, but they are separated by intervals different from those separating the principal coal beds at Clear Creek, North Fork of Gordon Creek, and Winter Quarters. If the beds at Scofield were identified by comparison with those of the North Gordon area alone, the natural assumption would be that they belong in the lower group (Spring Canyon coal group of Clark[60]), with the Hiawatha bed at the base and the Gordon bed at the top. (See North Gordon area, p. 99.) If the bed at the Winter Quarters mine is correctly identified as the Castlegate "A," however, the part of the section in which the Hiawatha and Gordon beds should appear contains little or no coal at Winter Quarters, and it is hardly likely that the bed in the Winter Quarters mine is not represented

[60] Clark, F. R., op. cit., p. 125.

by one of the thick beds at Scofield. On the east side of Pleasant Valley the sandstone beneath the Castlegate "A" bed can be traced as far as the Utah mine, but farther north it apparently dips beneath the surface and between Utah Mine and Scofield several faults disturb the beds to an extent that makes correlation on this evidence also uncertain. The bed in the Gibson mine, in the NE. $1/4$ sec. 8, T. 13 S., R. 7 E., is probably the same as that in the Utah mine and the same as the upper bed mined at the Union Pacific property and the Kinney and Blue Seal mines, east of Scofield. The thick bed worked at the Union Pacific No. 1 mine is probably local in extent, and it is not recognized either at Winter Quarters or at Clear Creek. It is known to split north and east of Scofield into three beds, none of which is more than 3 feet 6 inches thick 1 mile north of Scofield.

The writer's correlation of the coal beds in the Pleasant Valley district may be summarized as follows: The Castlegate "A" bed is the one mined at the Clear Creek Nos. 1 and 2, Utah, Gibson, upper Union Pacific, Winter Quarters, Kinney, and Blue Seal mines. The thick bed mined at the Union Pacific No. 1 mine is probably at the horizon of the Gordon bed of the North Gordon area. The Hiawatha bed is not known to be economically important anywhere in Pleasant Valley. The beds 150 to 200 feet above the Castlegate "A" bed at Winter Quarters and Clear Creek and in the intervening territory probably belong to the Bob Wright coal group. Sections showing the thicknesses of coal beds in this area, measured at the locations shown on Plate 31, are given in Plate 14.

*U. P. bed.*—The U. P. coal bed, one of the thickest beds of high-grade bituminous coal in the western United States, crops out in a relatively short stretch along the east side of Pleasant Valley near Scofield. For many years it has been worked at the Union Pacific mine, east of Scofield, and in parts of that mine it consists of 30 feet of clear coal. This unusual thickness, however, seems to be local, as the entire bed disappears west of Scofield, and north of the Union Pacific mine it thins materially and becomes split by partings of sandstone and shale. Its extent east of Pleasant Valley is not known, but it may be the same as the Gordon bed of the North Gordon area, and it may underlie part of the land between Pleasant Valley and North Fork of Gordon Creek. South of Scofield little is known of the bed; it may be present underground at Utah Mine, but it seems definitely absent near Clear Creek. In Green and Eccles Canyons the U. P. bed may be represented by a coal bed which has been found, at places, from 70 to 80 feet beneath the Castlegate "A" bed, but elsewhere south of Scofield it is not known to be present.

The only exposure of the U. P. bed near the Union Pacific mine is north of the mine, where part of it crops out in a short cut bank at the base of the hill. Elsewhere its outcrop is covered by a heavy mantle of soil and alluvial waste, which is at least 40 feet thick at a pit in the middle of the gulch south of the Union Pacific mine.

*Bed between U. P. and Castlegate "A" beds.*—Near the Union Pacific mine the rocks between the U. P. and Castlegate "A" coal beds contain a third coal bed that is said to range in thickness between 1 and 5 feet. This bed has not been recognized elsewhere in the area, and it is of doubtful extent. It is apparently not represented in any part of the North Gordon area, and it has not been found south and west of Scofield.

*Castlegate "A" bed.*—The Castlegate "A" coal bed, according to the correlation here proposed, is the most valuable and most extensive coal bed in the Pleasant Valley area. The only parts of the area in which its continuity is doubtful are between Clear Creek and Broad Hollow, on the east side of Pleasant Valley, and north of Woods Canyon, on the west side. Elsewhere it seems to be continuous and from 6 to 19 feet thick.

In this area, as elsewhere in the northern part of the field, the Castlegate "A" bed is underlain by a gray to white sandstone that is in places massive and pronounced. In the severely faulted parts of Pleasant Valley this sandstone is so shattered and jointed that it has weathered away at the outcrop and is not prominent, but near Clear Creek and Winter Quarters it stands out in bold ledges. Near Utah Mine it is recognizable but not prominent, and between Eccles Canyon and Clear Creek it appears in places, despite the generally forested nature of the country, in alinement sufficiently clear to allow correlation. At Scofield this sandstone is generally not exposed, but it appears in the large caved pit at location 12, directly beneath the Castlegate "A" bed.

The Castlegate "A" bed has been mined at practically every easily accessible place in the area except in the stretch between Clear Creek and Utah Mine, and in the part of the area northeast of the Blue Seal mine. In both of these localities the rocks are intricately faulted, and between Clear Creek and Utah Mine the bed is probably thin, as suggested by the sections at locations 23 and 24. West of the Pleasant Valley fault and south of Eccles Canyon the bed contains a large amount of coal and is probably unbroken by faults, but it is very high above the valley bottom.

The thickness of the Castlegate "A" bed at those places where it could be measured in the present work is shown on Plate 14.

*Bob Wright coal group.*—The Bob Wright group of coal beds is known in the part of the Pleasant Valley area south and west of Scofield, but north of Scofield it is almost certainly absent. At Clear Creek only one bed of the group is known, and that bed is probably equivalent to the uppermost bed of the group as developed in Bob Wright Canyon. In the canyons indenting the west side of Pleasant Valley between Clear Creek and Winter Quarters are scattered exposures of several coal beds that probably belong in the Bob Wright group, but none of these can be traced, and their identification is based entirely on their position with reference to the Castlegate "A" bed.

The general lack of rock exposures in the part of the area where the Bob Wright coal bed is present makes futile any attempt to give a connected account of the group from surface observations, and perhaps the best statement of the results of the present work is that given by the graphic sections in Plate 14. These sections, which represent considerable detailed study of the ground they cover, may be taken to show clearly the advisability of careful search on the part of the prospector for the coal beds of the Bob Wright group in the part of the area south of Winter Quarters. The places where the coal beds may be expected to lie are determinable, on the topographic map, by reference to the position for any given locality of the Castlegate "A" coal bed, above which, at intervals ranging ordinarily between 100 and 200 feet, the Bob Wright beds may be present.

Near Clear Creek the bed representing this group ranges in thickness between 5 and 8 feet, and it is probably of similar thickness in large parts of the area accessible from the canyons at the head of Mud Creek. Between Finn Canyon, where one bed of the group is known to be 6 to 8 feet thick, and Eccles Canyon no bed certainly belonging to the group has been found, but in Eccles Canyon and at Winter Quarters beds 5 to 7 feet thick have been found 90 and 150 feet above the Castlegate "A" bed. It is not known whether these beds are continuous between the places mentioned.

*Haley bed*.—The name Haley bed is here applied to the coal that crops out in Fish Creek Canyon between the extreme northwestern part of sec. 13, T. 12 S., R. 7 E., and the head of the canyon, as shown on Plate 31. This bed has been mined at the Haley mine, but the quality of the coal is apparently not high enough to make mining profitable. As shown by sections 1 to 5 on Plate 14, the Haley bed is 4 to 6 feet thick at its easternmost outcrops, but west of the Haley mine it becomes thinner and poorer in quality.

The stratigraphic relation of the Haley bed to the identifiable coal beds of the Blackhawk formation in near-by areas is not definitely known. The Castlegate sandstone member of the Price River formation lies about 900 feet stratigraphically above the Haley coal bed, and if the rocks in that interval were at all constant between the east side of the plateau and Fish Creek Canyon the Haley bed would not be far from the position of the Hiawatha coal bed. Farther south and west in Pleasant Valley, however, the Castlegate sandstone is much farther above the known coal beds than it is on the east side of the plateau, and it is likely that a similar condition prevails in Fish Creek Canyon; if so, the Haley bed is much higher stratigraphically than the Hiawatha and Castlegate "A" beds.

The Haley coal bed has not been recognized outside of Fish Creek Canyon. Projected southward from its outcrop in secs. 14 and 15, T. 12 S., R. 7 E., at the angle of dip observed on Fish Creek, it would come to the surface in the lower part of the north side of Miller Creek Canyon, but it has not been noted there, and it may thin out southward. No important coal bed at the horizon here assigned to the Haley bed has been noted anywhere south of Fish Creek in the Pleasant Valley area. A bed which may be the same as the Haley bed has been mined on Pondtown Creek, a branch of Fish Creek, in the northeastern part of T. 12 S., R. 6 E., west of the area covered by the present map.

## FAULTS

The Pleasant Valley area contains the most complex and intricate faults of the Wasatch Plateau field and affords a good illustration of the effects of faults on mining, because all the mines of the area except one have passed through faulted zones, and most of the mining problems introduced by faults have been met and solved. Most of the faults crossed by the Pleasant Valley mines are of small displacement, and the only difficulty they impose is that of grading entries between displaced blocks. Some of the mines, however, have encountered faults whose displacements are large enough to necessitate either making separate mining units of the faulted blocks, or crossing them, by means of rock tunnels and slopes, to the coal beyond.

The only large part of the Pleasant Valley area that is relatively free of faults is the part west of the Pleasant Valley fault and south of Eccles Canyon, and in this tract mining has thus far been discouraged by the great height of the coal above the valley bottom. Elsewhere in the area no tract large enough to accommodate a large mine is sufficiently free of faults to permit unhampered mining, and in some places the faults are so numerous and intricate that extraction of the coal would be very expensive. The faults observed in the present work are shown on Plate 31, where the structure contours show the approximate displacements.

The central down-dropped block of the fault zone, which constitutes the flat valley north of Scofield, is of doubtful value for mining, both because the coal is very deep beneath the surface and because the rocks in this graben are broken by minor faults, which would alone make mining very difficult. The graben is bounded on the east and west, however, by land in which the coal crops out or is near enough to the surface to be minable despite the large number of faults.

In Fish Creek Canyon faults are apparently not numerous. At the entrance to the canyon, in sec. 10, T. 12 S., R. 7 E., are two large faults which border the graben of Pleasant Valley on the east. The combined displacement of these faults is at least 1,100 feet and may be 1,300 feet. The western fault is undoubtedly the greater; the eastern fault has a displacement of 500 feet on Miller Creek, about 2 miles farther south, and it appears to diminish northward, because the rocks west of the fault on Fish Creek are a part of the Blackhawk formation probably not much higher stratigraphically than the rocks east of the fault. On the north side of the canyon east of the entrance the rocks are well exposed and are not broken by any large faults. A small fault, whose displacement (down on the west) is about 10 feet, is visible at the prospect at location 5. In the southeastern part of sec. 12, T. 12 S., R. 7 E., two faults are present whose combined displacement (down on the east) is probably between 25 and 100 feet.

The part of the area to which Miller Creek gives access is cut into blocks by two systems of faults, one trending about north and the other northwest. Miller Creek itself follows the trace of a fault on which the rocks have dropped, on the south side, at least 600 feet, and this fault continues eastward into the Beaver area. Near the mouth of Miller Creek Canyon, on the north side, are two faults that bound a small graben; the eastern fault has a displacement of about 50 feet, and the western fault about 30 feet. About 1,500 feet farther up the creek, in the first prominent gulch on the north side, is a large fault on which the rocks have dropped about 500 feet on the west. This fault crosses the fault on Miller Creek, continuing southward, but on the south side of the creek its displacement has diminished to about 350 feet. This fault is probably continuous, as suggested on Plate 31, with the zone exposed in the Clear Creek mines.

The ridge north of Miller Creek is apparently cut in sections 23 and 24 by three or more faults, between the extremes of which a block has dropped, bringing rocks of the Wasatch formation into contact with those of the Price River and Blackhawk formations. The displacements of these faults are not known, but the block may not have dropped more than 500 feet. Within the block, on the top of the ridge, the beds of limestone and shale of the Wasatch formation are much disturbed, standing vertical in places and dipping 45° E.

in others. These faults die out northward, before reaching Fish Creek, and on the south they probably abut against the fault in Miller Creek.

The broad divide between Miller and Jump Creeks, largely in section 25, is formed by a dropped block, capped by the Wasatch formation, between the fault of Miller Creek and a parallel fault on the south which extends westward at least as far as section 27. East of this divide, in the valley of Jump Creek, evidence of these faults is difficult to find, and at least the southern fault appears to stop at Jump Creek, east of which at this place the rocks seem to be continuous. If so, the displacement of the fault must be taken up by a fault in Jump Creek Canyon, and such a fault is shown on the map, solely on the basis of this evidence.

The long ridge between the South Fork of Miller Creek and Pleasant Valley is bounded on both sides by large faults, as indicated in Plate 31. The eastern fault has not been traced farther south than section 27, but it is in line with the easternmost fault in the Clear Creek mines, and the long, straight canyon of the Right Fork of Miller Creek, which lies on the projected line, probably owes its origin to the presence of the fault. Other faults may exist parallel to this one, but the rock exposures in this canyon are very poor, and no fault has been definitely recognized. The western fault bounding the ridge is the eastern fault of the Pleasant Valley graben. The valley west of this fault contains no rock exposures as far south as sec. 5, T. 13 S., R. 7 E., and the displacement is not known. The rocks in the ridge between the two faults are doubtless cut throughout its length by many more faults than those shown on the map. Evidence of this condition is present in the mines which have penetrated part of the ridge and on the surface, where scattered exposures of disturbed rocks plainly indicate faulting but do not show the exact nature of the displacements.

Between Ingalls Canyon, in secs. 26 and 33, T. 12 S., R. 7 E., and the Union Pacific mine the part of this ridge fronting Pleasant Valley is but slightly broken by faults, and in this tract three mines have been established. A fault, whose displacement is to the west, probably not more than 400 feet, branches from the eastern fault of the central graben north of the Union Pacific mine and extends up the gulch in which the mine is located, and the rocks in the V-shaped segment between this fault and Pleasant Valley are probably cut by minor faults, the exact nature of which can not be determined from surface observations.

The rocks in the hills west of the part of Pleasant Valley north of Scofield are broken by several faults whose presence is reasonably certain but whose exact location and trend are in places difficult to determine. The fault bounding the valley on the west is the Pleasant Valley fault of Taff[61] and is the principal fault of the Pleasant Valley fault zone as defined in this report. West of this fault lies a low range of hills, separated from the higher part of the plateau beyond by a line of gulches which follow the trace of a second major fault, approximately parallel to the Pleasant Valley fault. The rocks in this range of hills have dropped, possibly as much as 1,000 feet, with reference to the rocks on the west, and they are broken northwest of Scofield by minor faults, two of which, shown on the map, were recognized by the displacement of rocks in the Price River formation but not precisely located.

A third fault approximately parallel to the Pleasant Valley fault crosses Woods Canyon in sec. 31, T. 12 S., R. 7 E., and Winter Quarters Canyon in sec. 6, T. 13 S., R. 7 E. This fault is observable both in the rock outcrops of the two canyons and in the Winter Quarters mine; its greatest known displacement is 55 feet, and its extent is probably not greater than that shown on the map.

Immediately south of Winter Quarters Canyon the rocks are crossed by many faults, of diverse trend and for the most part of small displacement. All these faults, except the one last described, have been recognized in the Winter Quarters mine only. The first east-west fault south of the mine entrance has a displacement of 45 feet down on the south and the next one 90 feet down on the north. The other faults have displacements ranging between 3 and 12 feet.

South and west of the Winter Quarters mine the rocks appear to be practically undisturbed by faults, but the rock exposures are for the most part poor, and faults of moderate displacement might easily escape detection. The fault in the south fork of Eccles Canyon suggested on the map has not been observed, but it is believed to exist because of the sharp drop in the Castlegate "A" coal bed in this canyon. This drop may be due to a very sharp monocline, but no evidence of such a feature has been noted; it might also be merely apparent, due to misidentification of geologic horizons, but that, too, seems unlikely.

At Clear Creek the effect of the Pleasant Valley fault zone is clearly seen in the displacement of the Castlegate "A" coal bed, which on the east side, lies near the canyon bottom, and on the west side crops out near the heads of Long, Finn, and Boardinghouse Canyons, 1,000 to 1,250 feet higher. The displacement at the Pleasant Valley fault probably exceeds 1,500 feet. West of this fault and those closely associated with it the rocks appear to be unbroken.

[61] Taff, J. A., The Pleasant Valley coal district: U. S. Geol. Survey Bull. 316, p. 343, 1907.

The continuation northward of the Valentine fault, of the Upper Huntington area (see p. 130), may possibly pass through sections 24 and 25, T. 13 S., R. 6 E., but the only evidence of displacement in this part of the area is the sharp drop of the Castlegate "A" coal bed in the south fork of Eccles Canyon, in section 24. The rocks on the top of the ridge south of section 24 show no positive evidence of a fault, and a careful search of the hills northwest of Monument Peak failed to reveal the presence of the Valentine fault. It is entirely possible that the displacement of the rocks due to this fault is represented west of Finn Canyon by a monocline, and that the difference in altitude between the coal beds in Finn Canyon and Huntington Canyon is due simply to the west dip of the strata.

East of Clear Creek, in the ridge between Pleasant Valley and Bob Wright Canyon, are many faults, some of which doubtless are the continuation of the faults of Miller Creek and all of which are crossed by the Clear Creek mines. Near the mouth of mine No. 1 is a small group of faults, approximately parallel to the Pleasant Valley fault, which extend southward at least as far as sections 8 and 9, T. 14 S., R. 7 E., and probably farther. Clear Creek mine No. 2 is within this group and is separated from mine No. 1 by the easternmost fault, which has a displacement ranging between 6 and 40 feet, down on the west. On the westernmost fault the rocks are also downthrown on the west an unknown distance, and this fault bounds the mines on the west. The other faults of this group are of displacement not exceeding 12 feet as a rule.

In sec. 33, T. 13 S., R. 7 E., and sec. 4, T. 14 S., R. 7 E., Clear Creek mines Nos. 1 and 2, on the west, are separated from mines Nos. 3 and 4, on the east, by a graben in which the coal beds have dropped about 400 feet. The dropped block is intricately fractured by minor faults, which were revealed in detail when the rock tunnels connecting the mines were driven in 1915. The faults bounding this block doubtless continue for some distance beyond the mines, although they are for the most part not observable in detail at the surface, and the easternmost fault may continue from Miller Creek in sec. 27, T. 12 S., R. 7 E., to connect with the Trail Canyon fault in the lower part of Huntington Canyon, in sec. 34, T. 16 S., R. 7 E.

South of Clear Creek the chief displacement is that of the Pleasant Valley fault and associated fractures, on which the coal beds have dropped from their higher positions on Monument Peak to positions beneath the surface in Mud Creek and Snider Canyons. The exact locations of these faults south of Clear Creek is unknown, because of poor rock exposures, but they have been located approximately by alinement with places to the north and south where the faults have been observed.

MINING

*Mines and prospects in Fish Creek Canyon.*—A mine and several prospect pits have been opened in Fish Creek Canyon, east of Pleasant Valley, on the Haley coal bed. The mine, which is known as the Haley mine, was opened many years ago, and for a time it produced a moderate amount of coal, but it has been abandoned, and the tipple and other outside works have fallen into decay. The mouth of this mine was caved shut in 1923, and the extent of the workings could not be determined.

*Kimball mine.*—On the west side of Pleasant Valley, near the center of sec. 30, T. 12 S., R. 7 E., is the Kimball mine, a wagon mine that has yielded considerable coal but was abandoned many years ago. Three openings have been made at the site of this mine, in two of which track was laid. The mine is accessible by a steep and poorly graded road. The coal bed is probably the Castlegate "A."

*Smith mine.*—In Woods Canyon, east of the air opening of the Winter Quarters No. 2 mine, is an old mine, known as the Smith mine, that has been abandoned for many years. The mouth and dump of this mine give evidence of considerable past activity, but in 1923 the entrance was caved shut and the outside equipment was badly decayed. The mine is accessible by a poor wagon road.

*Winter Quarters mine.*—The Winter Quarters mine, in Winter Quarters Canyon about 1½ miles west of the town of Scofield, is one of the oldest and largest mines in the Pleasant Valley district. This mine, which is operated by the Utah Fuel Co., is on a coal bed considered to be the same as the Castlegate "A" bed, and it extends on both sides of Winter Quarters Canyon through to the canyons on the north and south. The tipple is in the middle of Winter Quarters Canyon, and the coal coming from the mine is carried by a conveyor to screens. Opening No. 1 is on the south side of the canyon and extends through the ridge west of Pleasant Valley to Eccles Canyon, a distance of 2.3 miles. No. 2 is on the north side of Winter Quarters Canyon and extends through to Woods Canyon, a distance of about 1 mile. This part of the mine was not operated in 1923. No. 3 is in a down-faulted block, beneath the northern part of No. 1, and No. 4 is on the south side of the canyon, east of No. 1 and separated from it by a fault which has dropped the coal bed 45 feet on the west. No. 5 extends west from a point on the north side of the canyon, opposite No. 1, under Winter Quarters Creek.

The Winter Quarters mine has crossed many faults and dikes, some of which are well displayed in the entries and rooms. (See pl. 12.) One zone of dikes, 1.35 miles in an air line south of the mouth of the mine, is in places over 100 feet wide and is the largest zone of dikes known in the Pleasant Valley district. The faults disclosed in this mine trend in diverse directions and afford a detailed example of the complex type of fracturing that is common in all parts of the district bordering directly on Pleasant Valley. At the surface few of these faults can be recognized.

*Union Pacific mines.*—The Union Pacific mines, formerly operated by the Union Pacific Coal Co. but now leased by the Scofield Coal Co., are on the east side of Pleasant Valley, in the small canyons east of the south end of the town of Scofield. The lower mine, which is on the 30-foot U. P. coal bed, is situated at tipple height above the railroad. The main entry of this mine dips eastward, and the loaded cars are hauled by cable to the mouth of the mine. Faults have caused considerable trouble in this mine, and development is not nearly so far advanced as the age of the mine might suggest. The upper mine is directly above the lower one, and the coal is discharged from it through a chute to the same tipple as the lower mine. This mine is on a coal bed about 90 feet above the thick bed and has been opened in recent years.

*Kinney mine.*—The Kinney mine, operated by the Kinney Coal Co., is north of the Union Pacific mines, on the upper of the two coal beds above mentioned. This mine is a drift mine and is similar in general respects to the other mines of the district except that no faults had been encountered in the workings up to the summer of 1923. The mine mouth is at tipple height above railroad grade, and the loaded mine cars are discharged over the usual screens directly into railroad cars.

*Blue Seal mine.*—The Blue Seal mine is north of the Kinney mine, on the face of the hill east of Pleasant Valley, and is similar in most respects to the other mines of the district but is small and was not operated in 1923.

*Utah mine.*—The Utah mine of the Utah Fuel Co. is the oldest mine in the district. This mine, which was formerly called the Mud Creek mine, is on the east side of Pleasant Valley about 3 miles south of Scofield and is opened on the Castlegate "A" coal bed. The mouth of the mine is at tipple height above the railroad, and in 1923 the coal, which was then being mined for railroad use, was dumped from the mine cars without screening into railroad cars. This mine was idle for many years after it was opened, and the workings are less extensive than those of the other old mines of the district. The mine crosses an intricate network of faults, most of which are of relatively small displacement. The mine also exposes a number of dikes, among which is the large dike of the Winter Quarters mine.

*Gibson mine.*—The Gibson mine is on the east side of Pleasant Valley about 1.3 miles south of Scofield. It is a slope mine, and the coal bed is about 145 feet beneath the mine opening. The mine was opened in 1922, and when examined it had not advanced beyond the preliminary stage of development.

*Clear Creek mines.*—The mines at Clear Creek, which are the southernmost productive mines of the district, are mainly drift mines on the east side of the valley, east of the main fault, and practically at the end of feasible railroad grade in the valley. The mouth of the mines is at tipple height above the railroad. Nos. 1 and 2 mines are on the Castlegate "A" coal bed and are separated by a fault. No. 2 extends south of the main opening, and No. 1, the south end of which is east of No. 2, extends both north and south of the main opening. The mouth of No. 1 and the tipple are shown in Plate 13, *A*.

Mine No. 1 is limited on the east by a fault zone through which a rock tunnel has been driven to the coal on the east side of the ridge, and east of the fault zone two mines have been established, one on the Castlegate "A" coal bed and the other on the main bed of the Bob Wright group. The mine on the Castlegate "A" bed, which is called No. 3, has been driven through to Bob Wright Canyon and is connected at its mouth there by means of a short gravity plane with mine No. 4, which is on the Bob Wright coal, about 140 feet higher. The coal from both No. 3 and No. 4 is brought through a rock tunnel to the main haulage way of No. 1 and is discharged over the tipple at Clear Creek.

The Clear Creek mines have operated fairly continuously since they were opened in 1899, and the western mines are in an advanced stage of development. The mines east of the fault zone are newer, and when they were examined in 1923 most of the coal being produced came from development work.

*Prospects.*—All the coal beds of the district have been opened by prospectors, and in some parts of the district the prospecting has been intensive. Most of the work was done many years ago, however, and by 1923 many of the pits were almost completely destroyed. The coal bed in Fish Creek has been prospected at many places, and the beds on both sides of Pleasant Valley near Scofield have been opened in pits, which for the most part cluster about the mines. South of Scofield prospecting has been more active on the west side of the valley than on the east, largely because the natural showings of coal are most prominent in the long canyons west of the valley. South of Clear Creek the Bob Wright bed has been opened in two prospects, and in Mud Creek Canyon an inclined shaft, known as the Fireside prospect, has been sunk in an unsuccessful search for the coal beds that are exposed farther north near Clear Creek. Many pits have been dug on the Castlegate "A" bed in the canyons west of the Pleasant Valley fault, but most of these pits were so badly caved in 1923 that they no longer showed the thickness of the coal bed.

*Conditions affecting mining.*—In the part of Pleasant Valley area now opened by mines the principal difficulties in the way of mining are those imposed by faults. A description of the faults of the area will be found on pages 90–94. The largest undeveloped parts of the area are the northeastern and southwestern parts. The northeastern part, which includes the hills east of Pleasant Valley between Fish Creek and Scofield, contains many faults, and any plan to mine in this part of the area should be made in full recognition not only of the faults shown on the map (pl. 31) but also of the probability that many more exist whose presence may not be observable at the surface.

The southwestern part of the area consists of the mountainous country south of Scofield and west of Clear Creek. This part of the area, appears to be largely unfaulted, but the coal beds there lie 1,000 to 1,500 feet above the railroad grade in Clear Creek, and the canyons tributary to Clear Creek Canyon are narrow and steep. This part of the area contains considerable coal (see pl. 14) and will support several mines. The canyons between Finn and Eccles Canyons are nearly straight and would afford favorable sites for tramways or gravity planes.

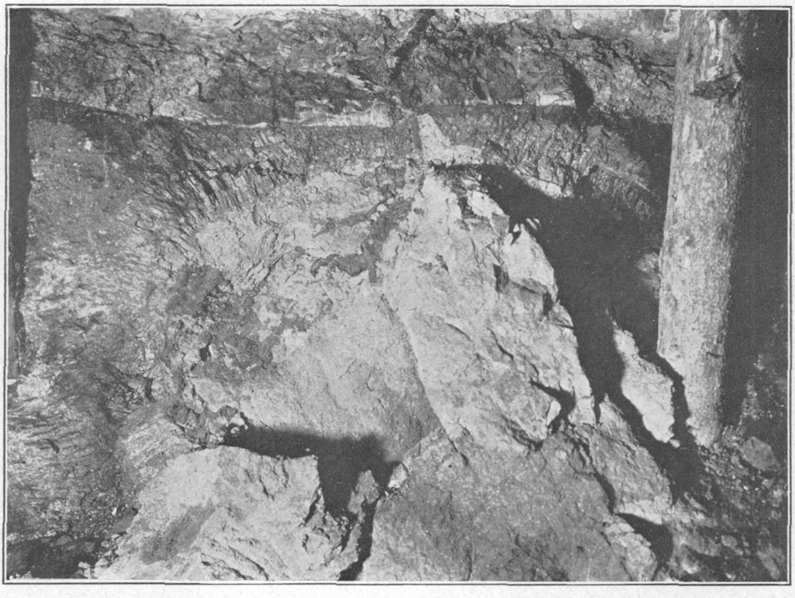
South of Clear Creek the coal is in general more difficult to reach. In addition to the problems introduced by the faults of the Pleasant Valley zone (see pl. 31), the increasing gradients of the canyon bottoms and the ruggedness of the country impose difficulties that will make mining there more expensive than it has been in developed parts of the area. West of the Pleasant Valley fault in this part of the area the coal beds are high in the mountain, and the acreage of coal under Monument Peak, for example, is not large. East of the Pleasant Valley fault considerable coal is present under conditions similar to those in the Clear Creek mines, with the exception that the Bob Wright bed is the lowest one at the surface. This bed crops out near the mouth of Snider and Long Canyons. The coal beds dip southward in this part of the area, and mines established there will probably have an upgrade haul to the mine mouth. The faults will probably make it necessary to mine long, narrow strips of coal by single operations.

The streams draining the west side of Pleasant Valley and those south of Clear Creek contain a supply of water probably ample for all ordinary future mining in the area. In most of Pleasant Valley, however, the pollution of these streams by human agency has become so great that a good domestic water supply can be obtained only by piping the water from springs near the sources of the streams or by proper sanitary precautions.

Large amounts of timber are present on the top of the plateau near Pleasant Valley, but the requirements of mines in the district are so heavy that it is unsafe to say whether this timber will prove

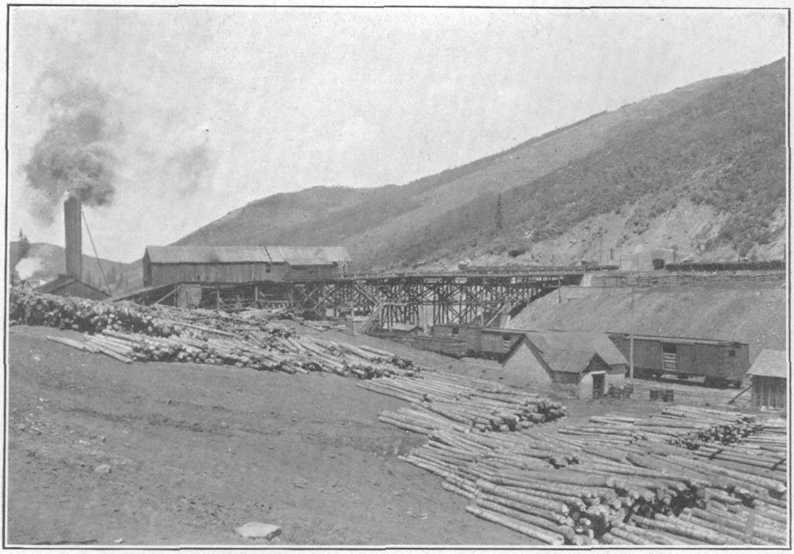
*A*. IGNEOUS DIKE IN WINTER QUARTERS MINE

The dike is 3 to 4 feet thick. Shows the thin layer of coke, and, particularly on the left, the proximity of apparently unaffected coal.



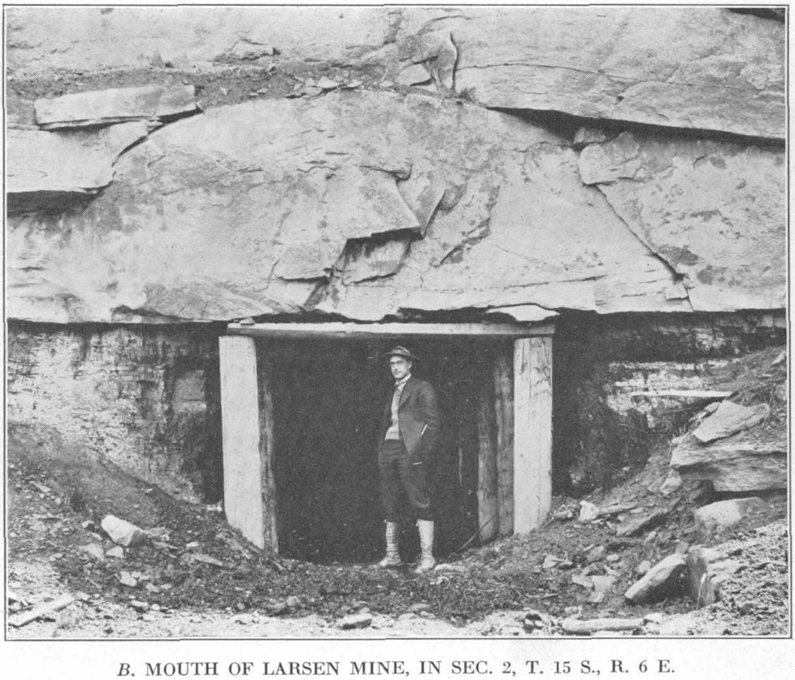
*B*. IGNEOUS DIKE INTRUDED INTO COAL BED OF WINTER QUARTERS MINE

Shows how the dike has swelled in penetrating the coal; also the aureole of coke produced by the heat of intrusion.



*A*. CLEAR CREEK MINE AND TIPPLE

The mouth of mine No. 1 is visible at the end of the tipple; the mine cars at the extreme right are on the motor road to mine No. 2. Piles of mine timber in the foreground.



*B*. MOUTH OF LARSEN MINE, IN SEC. 2, T. 15 S., R. 6 E.

Showing massive sandstone overlying Castlegate "A" coal bed.

sufficient, even under careful reforestation, for future mining. A suggestion of the amount of timber needed is given by the piles of mine props in the foreground of Plate 13, *A*. The supply for the present mines is brought down from the top of the plateau on steep wagon roads and drag trails.

## NORTH GORDON AREA

### COAL BEDS

Two coal beds more than 5 feet thick are present almost throughout the North Gordon area, and a third exists in part of it. The lowermost bed, the Hiawatha bed, ranges between 3 and 10 feet in thickness and normally rests upon the white sandstone at the top of the Star Point sandstone. This sandstone is traceable throughout the area, and the identity of the coal above it is everywhere practically certain. Faults add to the difficulty of tracing strata in this area, but fortunately exposures of the sandstone beds are good enough for the correlation of stratigraphic sections across the faults. The Castlegate "A" bed is also above a prominent white sandstone and on that account is stratigraphically located throughout the area. In the eastern part of the area this bed is thin, as shown in the sections on Plate 15, but west of Coal Canyon it is 5 to 8 feet thick in considerable tracts. In this area it is 160 to 200 feet above the Hiawatha bed. The third bed, called the Gordon bed, lies between the other two, usually about 100 feet above the base of the Hiawatha bed. The floor and roof of this bed are of shale at two of the three places at which good sections of it have been obtained, and on that account its outcrop is usually covered by soil. Wherever shale underlies a coal bed in this field slumping at the outcrop is common, and places at which sections may be measured are few.

Sections showing the thicknesses of coal beds in this area, measured at the locations shown in Plate 31, are given in Plate 15.

*Hiawatha bed.*—The Hiawatha bed is thin in the northeast corner of sec. 22, T. 13 S., R. 8 E., and is only 3 feet 4 inches thick in the W. ½ sec. 15. In Coal Canyon, in the SE. ¼ sec. 16, it is 6 feet 7 inches thick, and west of Coal Canyon it ranges from 6 to 10 feet in thickness. It is more than 6 feet thick in practically all of the coal-bearing part of this area west of Coal Canyon. Detailed sections of the Hiawatha bed in this area are shown on Plate 15.

The Hiawatha bed normally rests upon firm white sandstone. The coal is overlain by shale at most of the places where it has been seen, and the roof formed by the shale is by no means so good as the sandstone roof characteristic of most beds farther south in the field. A parting of tough smoke-gray shale about 1 inch thick, 1 to 2 feet below the top of the Hiawatha bed, is present at many places in the part of the area west of Coal Canyon, as shown by the sections in Plate 15.

*Gordon bed.*—The coal bed that lies from 90 to 120 feet above the top of the Hiawatha bed is at about the same position as a bed in Spring Canyon which is included by Clark in the Spring Canyon group of coal beds. This bed, which is here called the Gordon bed, occupies the same stratigraphic position as the Bear Canyon bed of Huntington Canyon and the Wattis bed of the Star Point region, but it is probably not continuous with either, because it does not appear at many places in the intervening area. It may be continuous with the U. P. bed of the Pleasant Valley area, but it is not known to extend beyond this area. It has been observed by the writer at but four places in this area, but sections measured in Wildcat and Spring Canyons[62] in the eastern part of T. 13 S., R. 8 E., show it to be consistently present there and to have a thickness of 4½ to 7 feet. In Coal Canyon the bed is about 6 feet thick, but it is split by partings, as shown in the section at location 64 b. (See pl. 15.) Farther southwest, in sec. 30, T. 13 S., R. 8 E., it is 7½ feet thick and is not broken by partings. In most of the western part of the area the covering of soil on the shale slopes is so thick that the presence or absence of the bed could not be ascertained.

*Castlegate "A" bed.*—The Castlegate "A" coal bed is so named because it was first mined at Castlegate, in the adjoining part of the Book Cliffs coal field. In the North Gordon area this bed is from 160 to 210 feet above the Hiawatha bed and immediately overlies a prominent white sandstone, similar to the top of the Star Point sandstone, by means of which it may be identified throughout the northeastern part of this field and the western part of the Book Cliffs field. This sandstone is the Aberdeen sandstone member described by Clark.[63] The coal bed here called Castlegate "A" is equivalent to the Castlegate "A" bed of the Castlegate district, where a group of four or more coal beds, designated by letters, exists above the Aberdeen sandstone. The Castlegate "B," "C," and "D" beds, which were identified by Clark[64] in Spring Canyon, are not of sufficient importance in the North Gordon area to justify the attempt to identify them. The Bob Wright (?) bed may possibly be continuous with the Kenilworth or Castlegate "D" bed, but the irregularity of the rocks at the horizon of this bed suggests that it is not continuous, even if it is at the same stratigraphic position.

The Castlegate "A" coal bed is less uniformly developed than the Hiawatha bed but contains considerable coal in this area and will undoubtedly invite mining at a number of places. At the eastern

[62] Clark, F. R., op. cit., pl. 18.
[63] Idem, p. 117.
[64] Idem, pp. 133–134.

edge of the area it is thin, only a few inches being recorded in the sections measured in sec. 15 and the eastern part of sec. 16, T. 13 S., R. 8 E. (See pl. 15.) In the area west of the Coal Canyon fault, however, it is normally about 5 feet thick, and, although it is missing in some of the measured sections on account of either burning or slumping, it is probably 5 feet thick in sections 16 to 20, 29, and 30, and also in the northwest corner of the township, where it is possibly available by shaft on Beaver Creek. In this area the Castlegate "A" bed is apparently thickest in section 29, where 8 feet was measured in an old prospect pit on the west side of Trail Canyon, at location 95. On the east side of Trail Canyon it is split by partings, but elsewhere all known exposures show it to consist of clear coal. The floor is almost everywhere sandstone, but the roof is shale at a number of places.

*Bob Wright (?) and Castlegate "C" (?) beds.*—In this area two coal beds worthy of mention are present above the Castlegate "A" bed. The lower lies 90 to 130 feet above the Castlegate "A" bed and may possibly be the Castlegate "C" bed of the Castlegate district, but its identity has not been proved by tracing. In the part of the area east of Coal Canyon this bed is not more than a foot thick, and on North Fork of Gordon Creek it has not been definitely recognized. In Trail Canyon the bed is from 4 to 6 feet thick in a small tract near location 90. Elsewhere in the area it is not known to be so thick.

The upper bed, about 150 feet above the base of the Castlegate "A" bed, has been noted in secs. 20 and 30, T. 13 S., R. 8 E. If the vertical distance above the Castlegate "A" bed is a trustworthy criterion, this bed is the Bob Wright bed, which is commercially important in the Bob Wright and Pleasant Valley areas.

At location 86, near the head of the North Fork of Gordon Creek, a coal bed was uncovered in the soil-covered banks of the stream. The bed has apparently slumped at this place, and its thickness is consequently in doubt. Apparently it is at least 10 feet thick and possibly as much as 15 feet. The coal rests on solid sandstone, enough of which was uncovered to show the dip of the slumped rocks. At location 84b, in a small tributary creek not more than 700 feet from location 86, the coal bed is split by a parting of shale about 2 feet thick. The stratigraphic relations are much obscured at these places, and no definite evidence of the identity and extent of this coal bed could be found. In the writer's opinion, however, it is probably the Bob Wright (?) bed, which is known to be present not far to the south.

Present knowledge thus indicates that the rocks immediately above the Castlegate "A" bed, which are richly coal-bearing in the Price

River Canyon, contain little coal of value in the eastern part of the North Gordon area. Farther south and west one or in places two beds more than 30 inches thick are present in this general part of the stratigraphic column, but nowhere in the known part of the

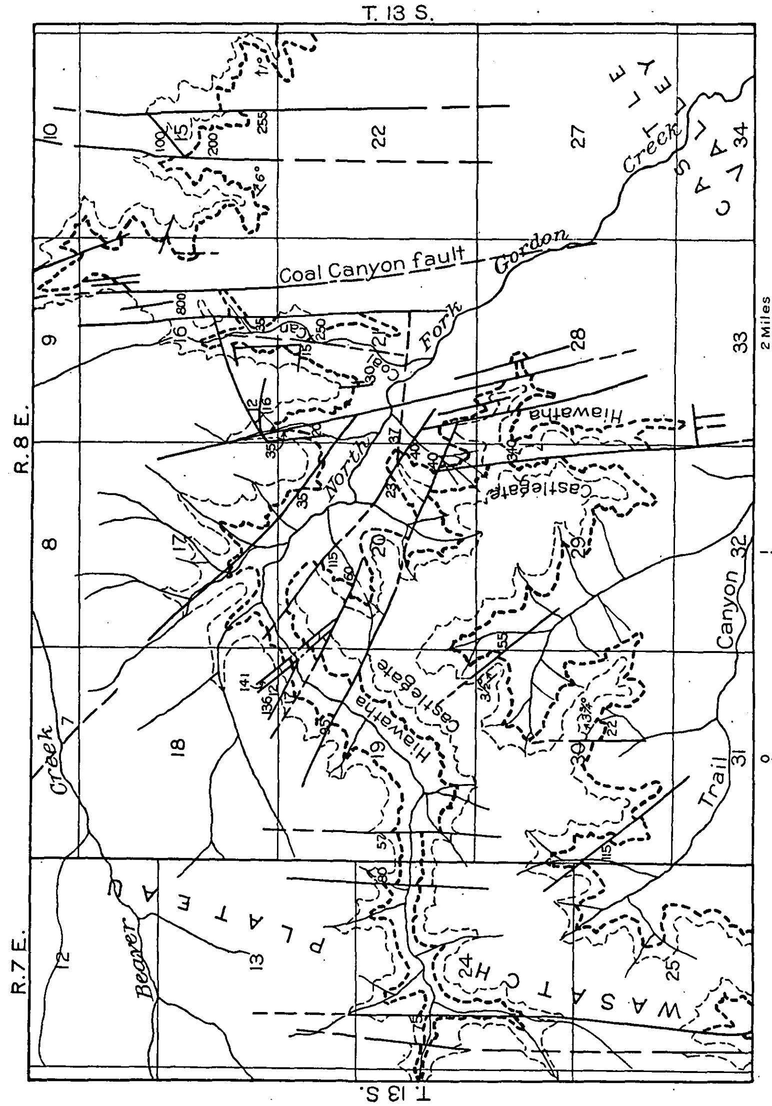



FIGURE 5.—Map of North Gordon area showing displacement of faults, in feet (small figures)

Wasatch Plateau coal field is commercially valuable coal as plentiful above the Castlegate "A" bed as in the Price River Canyon.

## FAULTS

In the North Gordon area the coal-bearing rocks are broken by the network of faults that constitute the North Gordon fault zone. This fault zone is most complex and extensive in the valley of North

Fork of Gordon Creek, where it is about 5 miles broad. Between the eastern border of the area and the head of North Fork of Gordon Creek there are at least 33 faults, 10 of which have displacements greater than 100 feet. Most of the larger faults trend nearly north, but many others extend in diverse directions, forming an irregular network within which the positions of the coal beds are somewhat complicated.

The displacements of these faults at representative places where they were measured are shown on Figure 5. This small map and Plate 31 show all the faults that were observed in the present work, and it is believed that these represent all the notable faults in the area. Many more small faults may exist near the larger ones, particularly in the part of the area north of North Fork of Gordon Creek, but if so they would be difficult and perhaps impossible to locate from the surface.

In the canyon north of the Cedar Mesa ranch, in secs. 15 and 22, T. 13 S., R. 8 E., a graben is exposed in which the rocks have dropped 200 feet and more. This graben is very clearly displayed at the head of the canyon, where the Castlegate sandstone abuts on both sides against the Blackhawk formation, as shown in Plate 8, *B*.

The largest fault in the area is the Coal Canyon fault, on which the coal-bearing rocks have dropped from high positions in the cliffs east of Coal Canyon to positions near creek level on the west. Associated with this fault are several smaller ones, shown on Figure 5. The Coal Canyon fault decreases in throw northward, owing to the strong northeastward dip of the strata east of the fault. The faults west of the Coal Canyon fault and the manner in which they have displaced the coal beds are shown on Figure 5.

## MINING

At the time the field work for this report was done no active mines existed in the North Gordon area, but in 1925 operations had been started by the Sweet Coal Co. in sec. 17, T. 13 S., R. 8 E., and a railroad grade had been constructed as far as section 21. Prospect pits and adits have been dug on all the principal coal beds at many places in the area, but many of these openings have caved so thoroughly that they no longer afford opportunity to examine the coal beds.

The outstanding feature affecting future mining in the North Gordon area is the faulted condition of the rocks. The details obtained in the present work show clearly that few tracts in the area are sufficiently free of faults to be mined according to plans that do not take the geologic structure into account.

North Fork of Gordon Creek contains a flow of good water that is probably sufficient for the mining towns that may be established in the northern part of the area, and this flow has been augmented in recent years, for purposes of irrigation, by the diversion of water from Beaver Creek on a spillway near the northern boundary of sec. 18, T. 13 S., R. 8 E. Beaver Creek, however, will doubtless be drawn upon to supply mining operations in Beaver Creek Canyon and possibly also for the many mining towns in Spring Canyon. The southern part of the North Gordon area contains no plentiful supply of water, and mines established in Trail Canyon might find it necessary to pipe water from springs on the plateau.

A small amount of serviceable mine timber might be cut near the coal outcrop, but for most of the supply recourse must be had to the forested area near the heads of North Fork of Gordon Creek and Beaver Creek, and the amount available there will possibly not suffice if mines in the area require large amounts of timber.

## BOB WRIGHT AREA

### COAL BEDS

In the Bob Wright area the Blackhawk formation contains coal throughout from base to top, but the valuable beds are concentrated in a zone 250 feet thick above the base of the Castlegate "A" coal bed. In this area the coal beds crop out in long, steep-sided promontories of the plateau, 1,000 to 1,700 feet above the adjacent lowland, and are not easily accessible. The coal beds recognized in this area and the average intervals between them are as follows:

*Coal beds in Bob Wright area*

| | | Feet |
|---|---|---|
| Blackhawk formation: | | |
| Upper bed (not named) | | 0–4 |
| Interval | | 40–65 |
| Bob Wright coal group; two to three beds | Coal | 0–4 |
| | Interval | 5–25 |
| | Coal (main Bob Wright bed) | 3–10 |
| | Interval | 3–20 |
| | Coal | 2–8 |
| Interval | | 25–35 |
| Royal Blue (?) bed | | 0–6 |
| Interval | | 50–70 |
| Castlegate "A" bed | | 6–15 |
| Interval | | 160–200 |
| Hiawatha bed | | 0–3 |
| Star Point sandstone. | | |

The sections of coal beds measured in this area are shown on Plate 16.

*Correlations.*—The correlation of these coal beds across the area is difficult because of stratigraphic irregularity in the lower part of the Blackhawk formation and the absence of traceable rocks above the Castlegate "A" coal bed. The correlation of the separate beds in the Bob Wright group has been made purely by comparison of the columnar sections shown in Plate 16 and is therefore subject to the chance of error always present in that method of correlation, even when the datum on which the sections are correlated is certain. None of the beds of this group can be traced far in the soil-covered and wooded slopes of the area. The Castlegate "A" and Hiawatha beds can be traced, although not without difficulty, because of the similarity of the white sandstone beds underlying them, and both of these beds have been carefully identified throughout the area. The best exposures of the white sandstone beds in the area are shown in Plate 5, *A*.

In the Bob Wright area the Hiawatha coal bed is presumably thin and unimportant, and the rocks between it and the Castlegate "A" coal bed contain little or no coal. At a few places one or two thin coal beds have been noted in this stratigraphic interval, but for the most part no valuable coal is known to exist in the area beneath the Castlegate "A" bed. This absence of coal seems extraordinary when the columnar sections of the area (pl. 16) are compared with those of the adjoining Hiawatha area (pl. 14), where in the interval of 200 feet above the Hiawatha coal bed there are several thick and persistent coal beds, and suggests at once the possibility that the sections have been wrongly correlated—that the Hiawatha bed of the Hiawatha area may be the same as the Castlegate "A" bed of the Bob Wright area. This possibility was carefully considered in the field, and there seems to be no escape from the conclusion that the white sandstone at the top of the Star Point, normally underlying the Hiawatha coal bed, is persistent and identifiable throughout the Bob Wright embayment. The only chance for confusion in tracing this sandstone arises because of its similarity to the sandstone beneath the Castlegate "A" coal bed, and in places, such as Corner Canyon, where one of the two is not clearly exposed for considerable distances, it is difficult to decide which sandstone is present. The Hiawatha coal bed has been traced, by the underlying white sandstone, from the Castlegate district, where it first appears, to the north branch of Corner Canyon, and from Seeley Canyon, east of Corner Canyon, to Hiawatha, the type locality, and thence southward to the end of the field, east of Mount Hilgard. A visual comparison of the rocks in the Star Point sandstone, beneath the Hiawatha coal bed, between the promontories north of Corner Canyon and those east of it yields the conclusion that the Hiawatha bed as correlated and mapped in this report is the same throughout. It is therefore necessary to believe that the coal beds immediately above the Hiawatha bed thin out north of Corner Canyon and that the beds above the Castlegate "A" coal bed become relatively thin east of Corner Canyon; but the part of the Blackhawk formation above the horizon of the Castlegate "A" coal bed contains some good coal beds in Gentry Mountain between Wattis and the mouth of Huntington Canyon, and the general aspect of the columnar sections (pl. 18) for that part of the field is not greatly disproportionate when compared with those of the Bob Wright area. Whatever the identity of the coal beds in Corner Canyon, it seems certain that the Hiawatha bed of Hiawatha is the same as the Hiawatha bed of North Fork of Gordon Creek, or the lowest bed of Clark's Spring Canyon coal group, and is not the same as the Castlegate "A" bed.

As a whole, the Bob Wright area is one of the richest in coal of the whole field, though the value of the coal is reduced by the proximity to the outcrop of the easternmost faults of the Pleasant Valley fault zone and by the inaccessibility of the coal outcrop from the east. In time these disadvantages will be outweighed by the amount and high quality of the coal.

*Hiawatha bed.*—The Hiawatha coal bed is of slight value in the Bob Wright area, and south of location 104, near the mine of the Utah Fuel Co., it appears to be absent. In the northeastern part of the area the outcrop of the bed seems everywhere to be either heavily covered by slumped rock or burned, and no reliable measurements of the coal were obtained in the present work. It is possible that the bed is 30 inches or more thick in parts of secs. 35 and 36, T. 13 S., R. 7 E., but its character can be ascertained only by extensive prospecting. In the middle of Bob Wright Canyon the bed is definitely known to be thin, and nowhere in the area south of Bob Wright Canyon is there any sign of coal near the white sandstone that normally lies beneath the bed.

*Castlegate "A" bed.*—The Castlegate "A" coal bed is consistently present throughout the Bob Wright area and is believed to be everywhere at least 4 feet thick. In the extreme northeastern part of the area the coal of this bed has been extensively burned at the outcrop, and the search for exposures gave no information as to its thickness. This condition is shown in columnar sections 98 and 99, Plate 16. The succeeding sections all show coal at the horizon of the Castlegate "A" bed, and it is practically certain that the bed is at least 6 feet thick almost everywhere in the area south of location 100. The maximum thickness recorded is 15 feet, at location 113, in unsurveyed land, and a thickness of 10 feet was noted at locations 101 and 115.

The Clear Creek mine No. 3 of the Utah Fuel Co., at the head of Bob Wright Canyon (location 104), is in the Castlegate "A" bed. The analysis of a sample taken near the mouth of No. 3 mine (No. 80861, p. 69) shows an unusually high heating value for coal from Utah, and the appearance of the coal in the bed at places on the outcrop where it is accessible by moderate digging is very good.

At the south end of the area another coal bed appears, 15 to 20 feet above the Castlegate "A" bed. This bed may be either a split of the main bed or a separate lens. It has not been recognized north of location 118. At location 108 a thin bed was found at the horizon of this bed, and it may be present between locations 108 and 118.

*Bed at Royal Blue horizon.*—At a few places in the area a coal bed has been noted at the same general distance (50 to 70 feet) above the Castlegate "A" bed as that of the Royal Blue coal bed of the Castlegate and Kenilworth districts. In the section at location 108 this bed may possibly represent the downward transgression of the lowest bed of the Bob Wright coal group, but the identification of the bed here is of slight importance, because location 108 is at the end of a large promontory of the plateau. The only other places at which this bed is known are locations 116 and 117, but it may be present in a larger area than that indicated by these sections.

*Bob Wright coal group.*—The Bob Wright group of coal beds, as here defined, consists normally of three beds, contained in a stratigraphic interval of about 45 feet. A typical section of the group is shown in the columnar section measured at location 102. It is impossible to trace any of the beds in this group for more than short distances, and the individual identity of one or two of the beds in sections where part of the group was not observed is not known. The correlation lines shown in Plate 16 are probably correct for individual beds between locations 99 and 106, but elsewhere they merely suggest that the beds connected belong in the same group.

At the Clear Creek No. 4 mine, in Bob Wright Canyon, the middle bed of the Bob Wright group is being mined, and both the upper and the lower beds are of workable thickness. The lower bed of the group here contains very hard, massive coal, and the middle bed a highly resinous coal. North of the mine the beds of this group are not well defined at the outcrop, and it is probable that only one persists as far as the eastern border of the area; which one, however, the writer can not say. The thick bed in sec. 23, T. 13 S., R. 7 E., near the headwaters of the left branch of North Fork of Gordon Creek, may belong in the Bob Wright group, and it suggests the persistence northward of workable coal in the group.

South of the mine coal beds have been recognized near the interval occupied by the Bob Wright group as shown on columnar sections 106 to 116, Plate 16, but the evidence there presented suggests that toward the south the group loses its compact nature, and that only one of the beds in it persists far south of Bob Wright Canyon. In the territory bordering on Corner Canyon the group appears to be absent.

*Upper bed.*—At locations 99, 106, 110, 116, 117, 118, and 121 a coal bed 6 inches to 4 feet thick, appears at an average distance of 220 feet above the Castlegate "A" coal, or about 400 feet above the base of the Blackhawk formation. The continuity of this bed in parts of the area is decidedly to be questioned, and the bed is therefore not named.

### FAULTS

The faults of the Bob Wright area belong to the North Gordon fault zone. Those in the eastern part of the zone cross the broad area of Mancos shale in the Bob Wright embayment and are of no importance in a consideration of mining, because they occupy the part of the area from which the coal-bearing rocks have been eroded. The western faults of the zone, however, cut the coal-bearing rocks at many places in the spurs extending out into the embayment and will be of importance in the mining of the coal contained in these spurs.

In secs. 35 and 36, T. 13 S., R. 7 E., are four parallel faults that have cut the coal into three long, narrow blocks, the relative displacements between which range between 50 and 150 feet. The two extreme faults of this set are traceable across the spurs at the head of the Bob Wright embayment as far south as Corner Canyon. Farther south the faults die out, but how far they extend is not known because they do not show at the surface on the smooth plateau top. The eastern fault, which occupies the center of the canyon in sec. 36, T. 13 S., R. 7 E., is apparently continuous between the upper canyon of North Fork of Gordon Creek and Corner Canyon. The downthrow of this fault is to the west, and the displacement is 75 feet in North Fork of Gordon Creek, 125 feet in the NE. ¼ sec. 12, T. 14 S., R. 7 E., and 77 feet near the southwest corner of section 12; near the north line of section 16 it is 53 feet, and in section 35 it is about 45 feet. The displacement thus decreases southward. The western fault is traceable as far south as First Water Canyon, and its displacement also decreases southward; it is 112 feet in section 11 and 10 feet in sec. 23, T. 14 S., R. 7 E.

These faults cross the coal-bearing rocks in three of the large spurs extending into the Bob Wright embayment, and in each spur they delimit a block in which the coal is lower than in the remainder of the spur. The amount of minable coal in these spurs is not great, but at some future time it will doubtless be recovered.

### MINES AND PROSPECTS

The only mines operating in the Bob Wright area are those of the Utah Fuel Co. at the head of Bob Wright Canyon, near the south quarter corner of sec. 34, T. 13 S., R. 7 E. These mines have their outlet through the rock tunnel that connects with the main haulage way of the Clear Creek mine No. 1, and their product is discharged over the Clear Creek tipple. The approach from the east in Bob Wright Canyon is so difficult that it was decidedly cheaper to reach the coal from the Clear Creek mine, and in 1915 a tunnel was driven from that mine through a fault block to the coal in Bob Wright Canyon.

Two mines are operated by the company—mine No. 3, on the Castlegate "A" bed, which is probably the equivalent of the lowest bed at Clear Creek, and mine No. 4, on the Bob Wright bed, stratigraphically 138 feet higher. The coal from mine No. 4 is brought to daylight in Bob Wright Canyon, lowered on a short tramway to the level of mine No. 3, and taken through mine No. 3, the rock tunnel, and mine No. 1, to the tipple at Clear Creek.

Prospecting for coal in this area has lacked the stimulus of a favorable outlet and has accordingly not been so widespread as in other parts of the field. Pits have been dug at a few places in the Bob Wright embayment, but no systematic attempt has been made to discover the number and thickness of beds present.

The outcrops of the coal beds in the Bob Wright area are set back from the normal line of the plateau front by the great embayment in the cliffs drained by Bob Wright Creek and neighboring streams, and this embayment contains sharply dissected country which offers some obstacles to railroad construction. A line might be projected from the Utah Railway in sec. 36, T. 14 S., R. 8 E., by way of Wiregrass Bench to tipple sites in the southern part of the area, but the grade necessary to gain the top of the bench and the irregular nature of the country west of the bench would make difficult the selection of a feasible route. A branch of the proposed line on North Fork of Gordon Creek might be projected southwestward across the country of lesser relief west of Horse and Telephone benches, and such a line, though rather long and devious, would probably afford the best approach to the area.

The outcrops of the coal beds are 1,000 feet and more above the highest feasible tipple sites at the base of the plateau, and tramways or other types of conveyor would probably be necessary to transport the coal down the steep slopes from the mine mouths to the tipples. The Utah Fuel Co. has avoided this difficulty for part of the area by driving a tunnel from its Clear Creek mine through the mountain to Bob Wright Canyon, but aside from the possible extension of the mine it will probably not be feasible to reach much of the remaining territory in the area by similar means. Some of the coal in the southwestern part of the area might be reached through a rock tunnel from Woodward Canyon, but such an operation would depend on a railroad in Huntington Canyon and might in the end be less desirable than mining from the east.

Another feature that should be considered in planning the development of this area is the faulted zone which any mine on the east side will probably encounter at distances ranging between 1 and 2 miles from the mine mouth. This zone, the southward continuation of the one in the Clear Creek mine, will interfere with mining from the east in the northern half of the area and may do so throughout. In the Clear Creek mine a block about half a mile wide has dropped about 400 feet (see p. 94), and the coal within it is doubtfully recoverable, on account of the profusion of minor faults within the main block. The fault on the west side of this block may die out in the southern half of the area, but the eastern fault seems to continue southward.

Little or no water is available near the coal outcrop in most of the canyons of the Bob Wright area, but many springs are present in the upper valley of Woodward Creek, and sufficient water for the needs of mining camps that are established in the Bob Wright embayment can probably be brought in by pipe line if it is not already available in the streams. The streams in the lower part of the Bob Wright embayment and particularly those draining the northern slope of Gentry Mountain, in the adjacent part of the Hiawatha area, normally contain a good supply of water.

Timber is fairly plentiful on the top of the plateau. For many years the supply for the Clear Creek mines has been cut at the head of Snider Canyon, which abuts against the head of Woodward Canyon behind the ridge fronting the Bob Wright embayment. Whether the timber available, however, will be sufficient for all mining that may be carried on in this area is not certain.

### HIAWATHA AREA

So far as the present commercial value of the coal is concerned, the Hiawatha area presents the most attractive set of conditions to be found in the field. It contains the largest number of thick beds, and in addition it is very favorably situated for mining and shipping. The height of the coal beds above the lowland is the chief drawback to mining in this area, but the difficulty has been overcome by the construction of tramways (gravity planes) from the mines in the cliffs to the tipple sites in the flat land at the base of the cliffs.

The quality of the coal in the several beds differs in detail from place to place but in general is as high as in any other part of the field. The coal ranges in habit between blocky and massive and as a rule withstands weathering and transportation well. It is normally hard and lustrous, but in places coal that is perfectly good as fuel is dull in appearance.

The chemical quality of the coal is indicated in analyses given on pages 69–70 which represent four beds. The samples obtained in mines indicate good coal, but those from prospect pits show much lower values, probably on account of weathering. The Hiawatha and Wattis beds, the only ones yet mined, differ only slightly in chemical quality and heating value.

### COAL BEDS

Five valuable coal beds have been distinguished in this area, and two more may be present. Columnar sections 122 to 147, Plate 18, indicate the position of these beds with reference to the top of the Star Point sandstone and show suggested correlations. The amount of coal is apparently greatest in the region west of Star Point.

The correlation of the coal beds of this area with those of the Bob Wright area, which has been the subject of some doubt, is discussed on pages 104–106. The identity of the lowest coal bed in Corner Canyon may perhaps be questioned, but the correlation of the Hiawatha bed of Star Point with the lowest coal bed of the region north of Corner Canyon is practically certain.

*Hiawatha bed.*—The lowest coal bed, here called the Hiawatha bed, on account of its typical occurrence at Hiawatha, lies above the white upper member of the Star Point sandstone, which is traceable throughout the area, and its identity is practically certain everywhere except possibly in Corner Canyon. This bed is very thick in the southern part of the area, where the United States Fuel Co. has exploited it over large areas, and it is believed to be at least 5 feet thick everywhere. The Hiawatha mines disclose thicknesses ranging from 7 to 20 feet of good coal, with good roof and floor, and generally well situated for mining. North of Hiawatha prospect tunnels show the bed to be from 5 to 10 feet thick, usually with partings, and in the Star Point region 5 feet is the common thickness of the bed. The coal normally lies directly on the white sandstone, but in the southern part of the area a broad lens of shale and buff sandstone intervenes, and the base of the coal attains a height of 17 feet above the sandstone in the NE. ¼ NW. ¼ sec. 32, T. 15 S., R. 8 E. Partings in the main body of the coal appear in the northern part of the Miller Creek basin. Between West Hiawatha and Mud Water Canyon, in section 5, the bed also contains partings, and some columnar sections show a second bed, 6 to 12 feet above it, which may be either a split from the lower bed or a separate lens. Individual sections of the Hiawatha bed in this area are shown in Plate 18.

*Intermediate beds.*—The lower beds above the Hiawatha in the part of the area between Wattis and Corner Canyon are so close together that extended correlation is impossible, and most of them will have to be mined through before their relative identity from place to place is known. It is practically impossible to trace with certainty any but the Hiawatha bed, and the identification of that bed would be uncertain at many places were not the sandstone beneath it characteristic and prominent. Forested and otherwise concealed areas prevent the continuous tracing of any bed.

The Wattis bed is the next extensive coal bed above the Hiawatha bed, but the interval between the two locally contains beds over 30 inches thick, particularly in the cliffs west of Star Point. Correlation of these beds is merely suggested, and no great reliance should be placed on it. Perhaps the principal value of the columnar sections, where beds are so close together as some of these, is that they indicate the presence at given localities of a certain number of beds, the more prominent of which are probably continuous between the localities.

In the northern part of the area the next bed above the Hiawatha is probably present throughout, but it is 5 feet or more thick only between Mud Water and Wattis Canyons. A short drift on it beneath the Wattis mine shows 6 feet 9 inches of clear coal, and in Mud Water Canyon 5 feet or more of coal is present. Columnar section 123, which is complete, indicates that in Corner Canyon this bed is present, if at all, merely as a stringer.

Above this bed lies a third, 9 feet thick in Corner Canyon and certainly absent at Wattis, where its horizon is occupied by massive sandstone. It appears to be of fair thickness as far east as Mud Water Canyon, where it is normally about 7 feet thick, but east of Mud Water Canyon it is absent. A fresh sample was not obtained from this bed, and the exact character of the coal is not known. It has, however, the general appearance characteristic of all coal in this field.

South of Wattis the lower 100 feet of the Blackhawk formation contains one coal bed above the Hiawatha bed. The sections measured there probably do not indicate the entire extent of this bed, as it is believed to be present though concealed in many sections which do not actually show it. This inference is drawn from its thickness in section 138 c, which probably continues for some distance at least. The bed at location 137 b may be the same, and so may that at 145 b, though direct evidence of continuity is wanting.

*Wattis bed.*—The Wattis bed, so called because it is mined at Wattis, is probably workable between Corner Canyon and the center of the Miller Creek drainage basin. In Corner Canyon it is 9 feet thick, and it is recognizable in all the columnar sections which are at all complete as far as the Wattis mine, where it ranges in thickness between 8 and 12 feet. South of Wattis the horizon at which it should exist gives evidence of much burning, and, although no good measurements are available, it is probably present and may be represented by the bed at locations 137 c and 138 d. South of locality 140 there is no definite evidence of the bed. The Wattis bed at the mouth of the Wattis mine is shown in Plate 20, *A*.

It is not known whether the bed at location 129 b or that at 129 c is the Wattis bed. The one at 129 b has been indicated as the probable correlative, chiefly on account of its nearness in the section to the horizon of the Wattis bed. Bed 129 d may continue to Wattis Canyon, but if so it is effectively concealed. The identity of the bed at 128 d is not certain; it may be either the Wattis bed or the correlative of the bed at 129 c.

The Wattis bed occupies the same position in the stratigraphic column as the Gordon bed of the North Gordon area and the Bear Canyon bed of Huntington Canyon. Its continuity with the Gordon bed can not be shown, and its relation to the Bear Canyon bed could be discovered only by mining through, under Gentry Mountain, to Huntington Canyon or perhaps by extensive drilling. These beds are all named separately, despite the fact that their stratigraphic position appears to be identical, to avoid the implication that they are known to be the same. The exposure of the Wattis bed at the entry of the Wattis No. 1 mine, shown in Plate 20, *A*, demonstrates the pinching of coal beds at the outcrop.

*Tank bed.*—In Wattis Canyon, 196 feet above the Wattis bed, is a bed about 6 feet thick, which has been called the Tank bed. It is recognizable at this one locality only, and nothing may be said of its persistence southward except that the bed at location 135 b and less probably that at 137 d may be the same. That at location 133 b is almost certainly not the same. It is barely possible that the Tank bed is the same as the uppermost bed in Bear Creek Canyon (location 253 d), but neither bed could be traced far, and the distance between locations 137 and 253 is too great to bridge with a purely suggestive correlation.

### FAULTS

The faults of the North Gordon zone extend a short distance into the northern part of the Hiawatha area, but by far the greater part of the area is undisturbed by faults, and structural conditions are favorable for mining.

Three faults, whose trend is nearly north, cross the large spur in secs. 5 and 6, T. 15 S., R. 8 E., and extend a short distance southward into the mass of Gentry Mountain, but they affect little valuable coal land. The eastern two of these faults bound a small graben, the appearance of which at the outcrop is shown in Plate 8, *A*. The displacement of the coal beds on the eastern fault is about 60 feet at the end of the spur in sec. 32, T. 14 S., R. 8 E., and 80 feet near locality 126. (See pl. 31.) This fault dies out near the head of the canyon of the Right Fork of Miller Creek, south of Star Point. The displacement of the western fault of the graben is 170 feet northwest of location 125 and 40 to 50 feet in the next spur on the south. This fault dies out rapidly southward. The third fault is somewhat smaller, having a displacement between 50 and 75 feet in the northern part of sec. 6, T. 15 S., R. 8 E., and apparently dying out rapidly southward. West of this group of faults, in sec. 1, T. 15 S., R. 7 E., is a short east-west fault on which the rocks have dropped about 20 feet to the north. Other smaller faults may be present in the forested parts of these canyons, where the rocks are not exposed.

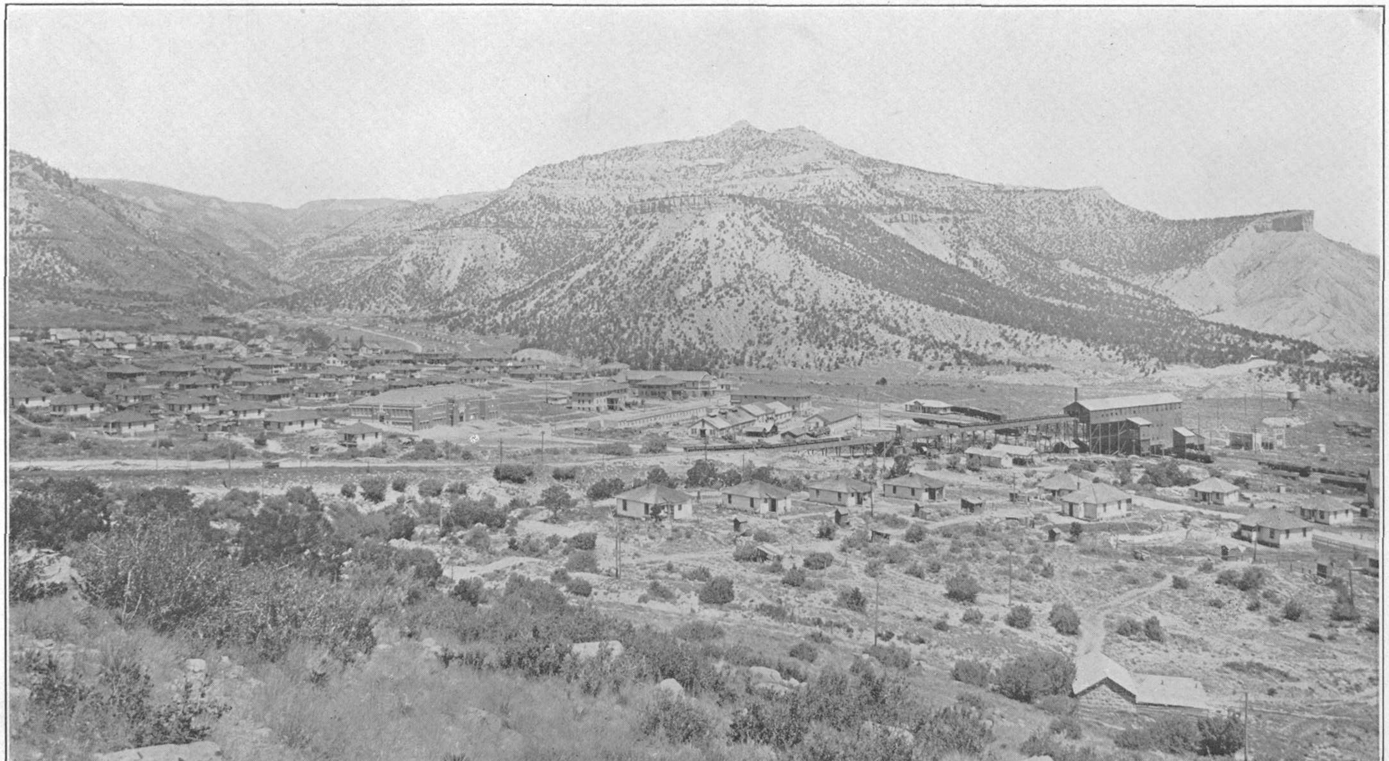
### MINES AND PROSPECTS

Four large mines are active in this area. The United States Fuel Co. has two at West Hiawatha and one at Hiawatha and the Lion Coal Co. one at Wattis. The King No. 1 mine of the United States Fuel Co. is in the Mohrland area, but its tipple and nearly all its surface works are in the Hiawatha area and it is therefore described here.

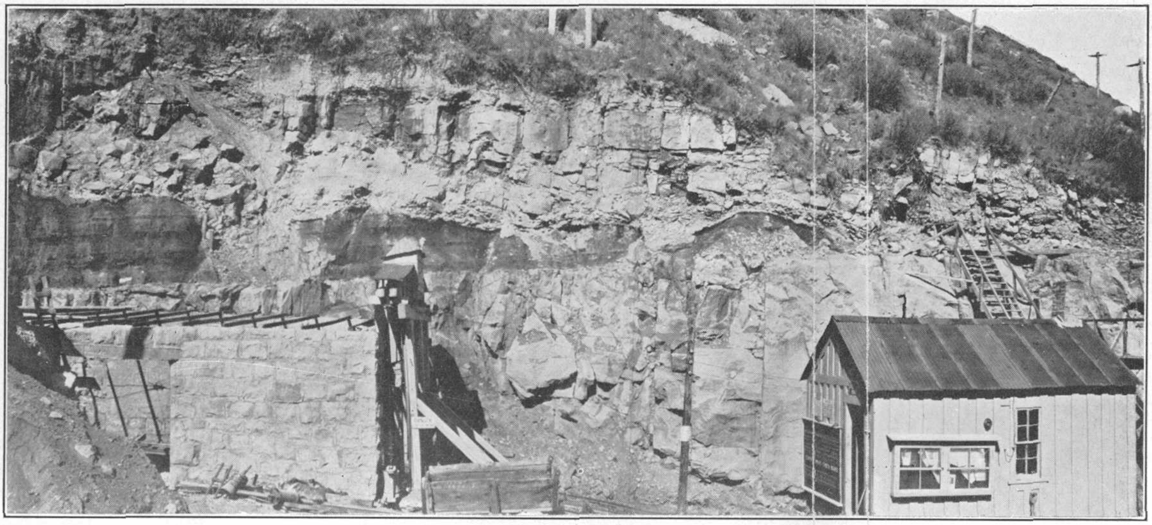
The Hiawatha mines are situated in the canyon of the middle fork of Miller Creek. The two mines are drift mines, on opposite sides of the canyon, at an altitude of about 8,100 feet, or about 700 feet above the tipple. The loaded cars are brought to the mine mouths by electric locomotives and are lowered by cable over a tramway about 1¾ miles long to the tipple.

The King No. 1 mine is on the promontory of the plateau between Miller Creek and Cedar Creek, at an altitude of about 7,975 feet, or about 750 feet above the tipple. This mine has well-graded haulage lines, with heavy rails, leading from the farthest points of the mine to the mouth, and modern hoisting equipment operates a well-graded tramway from the mine mouth to the tipple. Eighteen-car trips are lowered to the tipple, which has a daily capacity of 3,000 tons. The King No. 1 tipple and the eastern part of the town of Hiawatha are shown in Plate 17.

The mine at Wattis, in Wattis Canyon, is on the third coal bed above the base of the Blackhawk formation, and the mouth of the

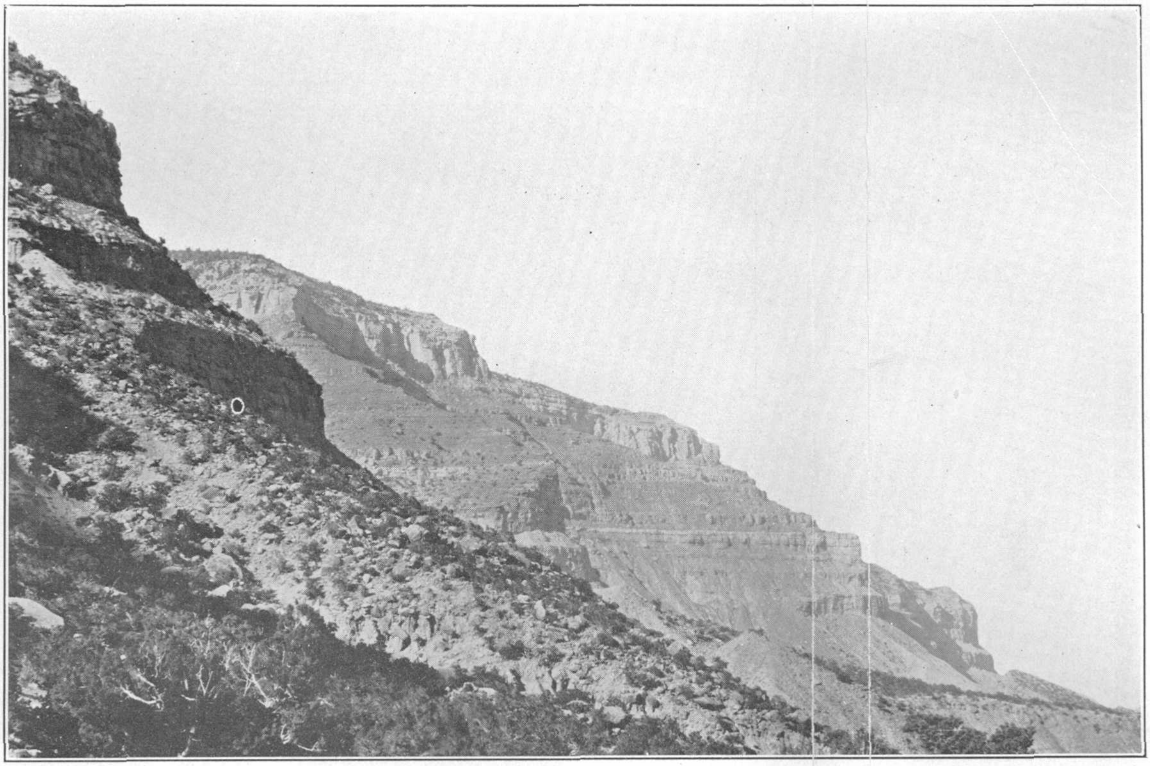


EASTERN PART OF HIAWATHA



*A*. WATTIS COAL BED AT MOUTH OF WATTIS No. 1 MINE

Shows the pinching of the coal bed toward the outcrop. The exposure is the result of excavation in opening the mine. The coal bed is 10 feet thick in the mine.



*B*. CLIFFS OF PLATEAU FRONT EAST OF COTTONWOOD CANYON AND NORTH OF COTTONWOOD CREEK

The profile in the center of the view is characteristic of the central and southern parts of the plateau; the upper cliff is the Castlegate sandstone, the broken slopes beneath are the Blackhawk formation, and the lower cliff is the Star Point sandstone, underlain by the slope of Mancos shale. Note the gray-white sandstone at the top of the Star Point.

mine is at an altitude of 8,560 feet, or about 1,060 feet above the tipple. It is a drift mine, and the dip of the coal bed is slight, about 1° or 90 feet to the mile, in an average direction of S. 20° W. The mine was established in 1917. The coal is hauled by electric motor to the mine mouth and by tramway to the tipple. The tramway is about 1¼ miles long, has a maximum grade of 36 per cent, and is double-tracked from the mine mouth to the halfway point. The hoist can handle a loaded trip of 10 cars, and the capacity of the tipple is 1,500 tons a day. A view from the Wattis mine, showing the tramway and the distant town, is given in Plate 1, *B*.

Prospecting of the coal has been intensive near the mines of this area, but in the northern part of the area little evidence of prospecting was found.

The northern part of this area, which includes the stretch of plateau front in the southern part of the Bob Wright embayment between Star Point and Corner Canyon, is the only part in which future development is not either outlined or made possible by the work of companies now operating. It contains a large amount of coal but presents the same problems of access as the adjoining parts of the Bob Wright area.

The long, fingerlike spurs extending out from Star Point formerly contained, in the aggregate, considerable coal, but much of this coal has burned at the outcrop, and it is likely that little coal remains unaffected in the narrowest parts of these spurs. In the Wattis mine the coal has been found to be affected by burning to distances of 600 feet from the outcrop, and a similar amount of burning in the narrow spurs on the north would have rendered valueless all of the coal they contained. The evidence of burning is so strong at the outcrop of practically all beds of this part of the area that slight hope may be held of finding much salable coal in any of the spurs, except perhaps the broad promontory west of Mud Water Canyon.

Mine sites may be found in any of the canyons west of Star Point, but all of them are so high above the lowland of the Bob Wright embayment that steep tramways will be necessary to carry the coal from the mines to the tipples. The dip of the coal beds, to the south and southwest, is unfavorable for mines located in these canyons, and the sites there available are possibly not so good for the mining of the coal in the northern part of Gentry Mountain as the available sites in the canyon of the Right Fork of Miller Creek, where advantage can be taken of the dip of the beds. The difficulties of fairly steep haulage grades for loaded cars and of pumping ordinary amounts of water should be thoroughly taken into account if the development of this part of the area is planned by mines entering on the north side. The dip of the coal bed at the outcrop in Corner Canyon and the canyons east of it ranges between 4° and 9°, and those angles represent gradients, for entries driven down the dip, of 7 to 15 per cent. These dips doubtless decrease southward, and in large parts of mines located in these canyons the gradients of haulage ways may not be high. It seems certain, however, that for a short distance from the outcrop they will in places be too high for ordinary motor haulage.

Water is fairly plentiful on the top of the plateau, and the mining towns of this area now draw their supply from the springs on Gentry Mountain. Corner Canyon and Mud Water Canyon, on the north slope of Gentry Mountain, contain streams large enough to supply small towns, and some of the other drainage channels contain small amounts of water.

Timber for mining is also available on the top of the plateau, and the supply needed for existing mines is brought down on steep roads. The northern face of Gentry Mountain is possibly too steep for inexpensive road building, but if mining is established there the necessary timber can be brought down by drag trails, as it is in many other parts of the field.

## MOHRLAND AREA

### COAL BEDS

*Hiawatha bed.*—The Hiawatha bed is by far the most valuable coal bed in the Mohrland area, in the northern part of which it attains its greatest known thickness. The King No. 1 and King No. 2 mines of the United States Fuel Co. are on the bed in this part of the area, and the workings thus far extended have proved the coal for most of secs. 4, 8, and 9, T. 16 S., R. 8 E. In the King No. 1 mine the bed is from 6 to 16 feet thick, and in the King No. 2 mine the maximum thickness is about 28 feet. The bed is somewhat irregular in this part of the area but is more than 10 feet thick in most of the tract being mined.

Locally in the King No. 1 and King No. 2 mines the coal bed is replaced by either sandstone or bone. The miners call these replacement deposits "wants." Three different types of "want" are distinguishable. One type consists of simple "islands" of bone and dirty coal, formed at muddy places in the original swamp. A second type is caused by local flexures in the rocks, as a result of which the coal is thinner in the synclines and thicker in the anticlines; "wants" of this type were probably caused by slight local compression, and none are known to cut out the coal completely. The third type, which involves the replacement of part or all of the coal by sandstone, is described on page 63.

At many places in these mines the coal is massive and extremely resistant. At the entrance to the manway in the King No. 2 mine, for example, the coal a few feet from the outcrop is hard, massive, and completely unchanged by weathering.

Sections 150 to 170, Plate 19, show the thickness of the bed in the vicinity of Mohrland. South of the Cedar Creek drainage basin the bed thins, and in the steep cliffs north of Chris Otteson Hollow it is probably not more than 3 feet thick. In Chris Otteson Hollow it is 4½ feet thick, and in Fish Creek Canyon it is from 2 to 5½ feet thick.

Analyses of the coal in this bed, made on samples taken in the King Nos. 1 and 2 mines, are shown in the table on page 70, as Nos. 80716 and 81013.

*Bear Canyon bed.*—The Bear Canyon bed, so named on account of its typical occurrence in Bear Creek Canyon,[65] in sec. 24, T. 16 S., R. 7 E., is present in Fish Creek Canyon but was not observed in this area. In Fish Creek Canyon it is from 4 to 6 feet thick, according to measurements represented in sections 167 to 170, and it may thus be workable in the southern part of the projecting point of the plateau between Chris Otteson Hollow and Huntington Creek Canyon.

*Upper beds.*—Most of the sections measured in the Mohrland area show a number of relatively thin coal beds from 150 to 400 feet above the Hiawatha bed, but these beds appear to be irregular. Correlations of the thicker of these beds are suggested in Plate 19, but these correlations are based only on the insecure evidence of stratigraphic position. Certain of these beds, such as those at locations 153 d, 165 e, and 168 c, may be much more extensive than is suggested by the columnar sections, and in general the evidence obtained in the present work suggests the desirability of prospecting in this part of the Blackhawk formation. In Cedar Creek Canyon the rocks above the Hiawatha coal bed are on the whole poorly exposed, and the sections there presented may fall considerably short of indicating the true amount of coal present.

### MINES

The King No. 1 and King No. 2 mines of the United States Fuel Co., the largest mines in the Wasatch Plateau coal field, are in this area. The outside equipment of the King No. 1 mine is in the adjoining part of the Hiawatha area, and the mine is described on page 114.

*King No. 2 mine.*—The King No. 2 mine is on Cedar Creek west of the town of Mohrland, and the mouth of the mine is about 530 feet higher than the tipple, with which it is connected by a tram-

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[65] Not to be confused with Bear Canyon in T. 14 S., R. 6 E., in the Upper Huntington area.

way, or gravity plane, about 1¼ miles long. The mine was established at the site of an old wagon mine, in which the workings were irregularly laid out. The mine extends principally west and north of the opening and is separated on the north from the King No. 1 mine by a barrier pillar about 100 feet wide. It provides for the mining of practically all the coal in the Hiawatha bed accessible in the drainage basin of Cedar Creek. The mine is well equipped with modern appliances, and 90 to 96 per cent of the coal is extracted. The Hiawatha coal bed in this mine is on the whole very thick, but it is cut out at a number of places by "wants," which cause considerable trouble in mining.

*Conditions affecting mining.*—The coal in the northern half of this area is within the reach of the existing operations of the United States Fuel Co., and that available in new enterprises lies in the southern part of the area, in the drainage basins of Fish Creek and Chris Otteson Hollow. The information available at the outcrop seems to show that the southern half of the area contains considerably less coal than the northern half, and at many places in Fish Creek Canyon and Chris Otteson Hollow only thin beds were found. These canyons are exceedingly rough and precipitous, and the establishment of mines there will be difficult.

Mining in the southern part of the area will probably await the building of a railroad in Huntington Canyon, and even then it will presumably be delayed until the more favorable mine sites in that canyon have been occupied. The extension of the Utah Railway south of Mohrland would be a difficult and expensive undertaking, because the shale benches at the base of the cliffs, on which this line is built north of Mohrland, are deeply dissected between Mohrland and the mouth of Huntington Canyon.

Both water and timber are scarce in the southern part of the area. Fish Creek contains a moderate flow of water, but Chris Otteson Hollow is nearly always dry. Timber is available on the top of the plateau, but the construction of roads on which to bring it down to mines in these canyons will be difficult.

## UPPER HUNTINGTON AREA

### COAL BEDS

Three valuable coal beds are present in considerable parts of the Upper Huntington area, and coal more than 30 inches thick has been recognized at nine or ten horizons in the Blackhawk formation. The rocks in this area are on the whole poorly exposed, and the coal beds can not be traced with the same degree of precision as that possible farther south. The walls of Huntington Canyon north of the canyon of the Left Fork are heavily timbered and soil covered, and the only places at which the coal beds crop out in the timbered areas are in the channels of a few streams that have scoured away the alluvium and exposed the underlying rocks. The type of country in this area is shown in Plate 10.

*Correlation.*—For the correlation of the coal beds of this area with the well-known beds of adjoining areas two ways of approach are available—one from the south, through Huntington Canyon, and the other from the northeast, through Pleasant Valley. In Huntington Canyon the top of the Star Point sandstone has been traced with reasonable certainty as far north as the mouth of the Left Fork of Huntington Creek, but north of that place rock exposures are so rare in the timbered and soil-covered walls of the canyon that detailed tracing of any bed is impossible. On the east side of the canyon the rocks may be traced in places, and the top of the Star Point sandstone has been tentatively identified there, but the details of the lower part of the Blackhawk formation are consistently different from those on the west side of the canyon, and to place the important coal beds found on the west side of the canyon in the section established on the east side is an uncertain task.

The approach in correlation from Pleasant Valley is also difficult, chiefly because the two areas are separated at the critical place by the Valentine fault, and the exact projection of known horizons from Finn Canyon into Huntington Canyon is impossible. It seems likely that the lowest valuable coal bed is the same in both canyons, and that decision is corroborated in the projection, according to all known data concerning the structure, of the horizon of the bed from Finn Canyon into Coal Canyon, where the lowest valuable coal bed is well exposed near the Huntington mine, in sec. 11, T. 14 S., R. 6 E. The lower coal bed in Coal Canyon is therefore identified as the Castlegate "A" bed. The data that apply to the identification of the bed in Finn Canyon are presented on page 86.

The Castlegate "A" bed is traceable from the Huntington mine, on the east side of Huntington Canyon, as far as the Valentine fault. On the west side of the canyon it is traceable as far as the bend in Huntington Creek opposite location 176 (pl. 31), and between this point and the mouth of the little canyon north of Bear Canyon it probably dips beneath creek level and lies very close to the surface under the alluvium in the bottom of the canyon. At the mouth of Bear Canyon the rocks are for the most part concealed, and those which appear at the surface give evidence of structural irregularity, possibly incident to faulting. South of Bear Canyon the Castlegate "A" bed appears above creek level on the west side of Huntington Canyon at locations 180 and 181, and it appears to be cut off on the west by a fault, as suggested on the map. The coal bed exposed in the prospect pit at location 177 is probably the bed above the Castlegate "A" bed that is here called the Candland bed (p. 126). South of location 181 the identity of the Castlegate "A" bed is established, probably correctly, in all the sections on the west side of Huntington Canyon, and it is certainly the same bed as the lowest bed in Valentines Gulch, at locations 182 and 183.

If this bed were the Hiawatha the rocks beneath it should be, according to all observed evidence, barren sandstone of the type characteristic of the Star Point sandstone, but if it were the Castlegate "A" bed the underlying rocks should be of the coal-bearing type of the Blackhawk formation. Near the mouth of Bear Canyon the rocks beneath the coal bed in question are of the type normal to the Blackhawk formation, as shown by the following section:

*Section of lower part of Blackhawk formation at locality 179*

| | Ft. | in. |
|---|---|---|
| Sandstone, blocky to massive | 15 | |
| Shale, gray | 1 | |
| Sandstone, blocky | 4 | |
| Shale, gray | | 8 |
| Coal | 2+ | |
| Shale, gray | 1 | 6 |
| Sandstone, buff, blocky, fine grained | 1 | 2 |
| Shale, gray | 1 | |
| Sandstone, brown, irregular | 1 | |
| Shale, gray | 1 | |
| Sandstone, buff, fine grained | | 8 |
| Shale, gray | 1 | |
| Coal (incompletely exposed) | 2 | |
| Shale, smoke-gray | 1 | |
| Concealed | 4 | |
| Shale, gray, carbonaceous at top | 3 | |
| Sandstone, blocky, buff; weathers gray | 2 | |
| Shale, gray | 1 | |
| Sandstone, platy, irregular | 4 | |
| Shale, gray | 3 | |
| Sandstone, platy, buff | 1 | |
| Shale, gray clay, lenticular | 1 | |
| Sandstone, platy, buff | 1 | 6 |
| Shale, gray clay | | 8 |
| Sandstone, brown to buff, fine grained, blocky | 2 | |
| Sandstone, buff, fine grained | 5 | |
| Shale, black to gray clay | | 4 |
| Shale, green-gray clay (base unexposed). | | |
| | 61 | 6 |

This section is not accurately located in the formation, but it undoubtedly belongs stratigraphically below the coal bed (Castlegate "A.") at locations 180 and 181. Another section measured near the center of sec. 14, T. 14 S., R. 6 E., not far from location 179, shows rocks of similar character, and these facts tend to substantiate the conclusion that the coal bed is the Castlegate "A." In Valentines Gulch, however, and in the gulches on the west side of Huntington Canyon as far south as Flood Canyon, the rocks beneath this coal bed are of the Star Point type and contain absolutely no coal. It seems likely that the barren zone in the lower 200 feet of the Blackhawk formation noted in the southern part of the Bob Wright embayment extends westward as far as this part of Huntington Canyon.

The fact should be remembered, however, in reviewing this evidence, that east of the Wasatch Plateau the sandstones of the Star Point type rather regularly change westward to coal-bearing sandstone and shale of the Blackhawk type, and that sandstone of the Star Point type develops below, by intertonguing with the Mancos shale. (See pp. 24–25.) In Pleasant Valley the Star Point sandstone shows abundant evidence of such downward thickening (p. 24), and south of Hughes Canyon, in the Upper Huntington area, similar conditions appear to exist. The coal-bearing rocks beneath the bed here called Castlegate "A" in upper Huntington Canyon may represent a further downward encroachment of the two lithologic types, and the coal bed may be the Hiawatha. If so, the bed here named the Candland bed may really be continuous with the Blind Canyon bed (pp. 141–142), because it occupies a stratigraphic position above the Castlegate "A" bed similar to that of the Blind Canyon bed above the Hiawatha. To sum up, the conclusion that the bed of the Huntington mine is the Castlegate "A" bed rests principally on its identification with the bed in Finn Canyon, which is almost certainly the same as the Castlegate "A" bed in the Clear Creek mines; but this conclusion is rendered uncertain by the evidence given above and the difficulty of tracing geologic horizons in Huntington Canyon above the Left Fork.

According to this conclusion the Hiawatha bed is probably absent or poorly developed in the northern part of this area. The sections measured at locations 186, 187, 188, 189, and 196, on the east side of Huntington Canyon, are thought to be based on the Hiawatha coal bed, and the lowest coal at location 187 is at the altitude at which the Hiawatha bed should appear if it is continuous under Monument Peak from location 53 a, where the Castlegate "A" bed is recognized. The Hiawatha bed has been identified in Woodward Canyon and farther south in Huntington Canyon.

The coal bed identified as the Castlegate "A" between location 180 and the Larsen mine (205) is probably the same throughout Candland Mountain. The beds found on the west side of Candland Mountain, at locations 192, 193, and 194, are not definitely located in the Blackhawk formation because they appear in isolated outcrops in a region of poor exposures. The bed at location 194 may possibly be the same as the Castlegate "A" bed, but it is probably higher. The bed at location 193 may be the same as the bed at 194, but if so the strata dip southward at a rate greater than the exposures indicate. The bed at location 192 is undoubtedly the highest bed, stratigraphically, in the area, and it is not known at any other place. Suggested correlations of other beds in the area are briefly mentioned in the descriptions of the beds.

*Hiawatha bed.*—The Hiawatha bed, so far as known, is of little value in the Upper Huntington area. It is apparently thickest in the southern part of the area, and there it is not known to be more than 4½ feet thick. It is apparently absent in much of the area north of Flood Canyon and is not certainly recognizable at those places where coal exists near the horizon at which it is presumed to belong.

On the east side of Huntington Canyon south of Valentines Gulch the Hiawatha is the lowest coal bed, and it is apparently thin as far south as Woodward Canyon. In Woodward Canyon, where it is exposed west of the Pleasant Valley fault, it is 3 feet thick, and it may be equally thick in a large part of the area south of Woodward Canyon, but so far as known it is not much more than 3 feet thick anywhere on the east side of Huntington Canyon north of T. 16 S.

In the canyon of the Left Fork of Huntington Creek the Hiawatha bed is irregular and probably not valuable anywhere. At location 204, at the head of the canyon, it is represented by a thin band of coal overlain by 12 feet of carbonaceous shale intermixed with dirty coal, but not far east of this location the coal is 4 feet 6 inches thick, overlain by sandstone, and the carbonaceous shale is absent. The Hiawatha bed seems to be irregular, after this fashion, throughout the area. In Horse Canyon and Blind Canyon it is either absent or very thin. The thickness of the bed at those places in the area where it was found is shown in Plate 21.

*Blind Canyon bed.*—The Blind Canyon bed, which is 40 to 55 feet higher than the Hiawatha bed, is not known in this area north of location 199. It is most valuable in Blind Canyon, whence it derives its name, and is probably 6 feet or more thick in most of the part of the area south of Horse Canyon.

In Pole Canyon and the canyon of the Left Fork of Huntington Creek a thin bed appears at the horizon of the Blind Canyon bed, but farther north the bed is probably absent. In and near Blind

Canyon the bed has been found at locations 209 to 213, and it is probably present, but burned, at 214 and 215. Some of the sections at these places probably do not show the complete thickness of the bed. The coal of this bed contains much resin, and its physical appearance is that of good coal. No coal fresh enough to yield a reliable analysis was found in the area. The measurements of this bed are shown in Plate 21.

*Third bed.*—In Blind Canyon and in the canyon on the opposite side of Huntington Canyon is a bed about 25 feet above the Blind Canyon bed which does not certainly appear in any other section in this area. It may be present in concealed intervals represented in the sections at locations 207, 208, and 213, but positive evidence regarding it is confined to locations 209 and 211, where it is about 6 feet thick. It is apparently limited in extent to a small area bordering on Blind Canyon.

*Fourth bed.*—A fourth bed, about 85 feet above the base of the Blind Canyon bed and 55 feet above the third bed, was found at locations 209 and 211 but was not observed elsewhere in the area. It is 6 feet or more thick in Blind Canyon, but on the opposite side of Huntington Canyon, at location 209 c, only 3 feet 8 inches of coal is present. This bed is certainly not correlatable with any other bed known in this general part of the field, and unless it is uniformly concealed elsewhere it is probably workable in a small area only, similar to that in which the third bed is known. East of the Pleasant Valley fault in Woodward Canyon a coal bed is present at about the same distance beneath the Castlegate "A" bed (as there determined) as the fourth bed in Blind Canyon, and it may be the same bed. The bed in Woodward Canyon ranges between 2 and 3 feet in thickness and is probably of minor value. Sections of this bed measured in Woodward Canyon are as follows:

*Sections of coal bed 60 feet beneath Castlegate "A" bed in Woodward Canyon*

**Near location 197 a**

| | Ft. | in. |
|---|---|---|
| Sandstone, massive. | | |
| Shale, carbonaceous | | 3 |
| Coal | 2 | 3 |
| Shale, very sandy, brown-yellow, containing lenses of coal. | | |
| | 2 | 6 |
| Total coal | 2 | 3 |

**At location 197 b**

| | Ft. | in. |
|---|---|---|
| Shale, gray | 3 | |
| Coal | 2 | 1 |
| Shale, gray | 2 | |
| Sandstone | 1 | 6 |
| Coal | | 2 |
| Shale, gray. | | |
| | 8 | 9 |
| Total coal | 2 | 3 |

The stratigraphic section in Blind Canyon shows more coal than any other in this part of the field, and it might be suspected that this large showing of coal is due to unusually favorable conditions for observation, but that is not true; the covering of soil is as smooth and complete here as at all other places. The coal of every bed was located only after considerable prospecting with pick and shovel.

*Castlegate "A" bed.*—The Castlegate "A" bed, as recognized in this work, is the most valuable bed of the area. It has been found at a sufficient number of places to justify the conclusion that it is at least 4 feet thick in most of the area. On the east side of Huntington Canyon between Hughes Canyon and Woodward Canyon it appears to be thinner and irregular, and near Horse Canyon it may be absent. The identity of this bed is not certain, and the questions concerning it are discussed on pages 119–122.

The northernmost exposure of the bed in the area is at the Huntington mine, in sec. 11, T. 14 S., R. 6 E., where it is 11 feet thick, and the coal is of high quality. Analysis 83560 represents a sample taken at this mine. The Castlegate "A" bed probably extends a considerable distance northward from this mine, to judge by its extent at the outcrop in the Pleasant Valley area, and it may be present throughout the part of the area north of the mine. If present, it is probably not more than 800 feet beneath the surface at Burnout Canyon, and 1,100 to 1,500 feet between Swens Canyon and The Kitchen. These figures are based on the projection of dip from Pleasant Valley into this area, and they are not certain because the trend of the rocks may be disturbed by concealed faults in the ridge between the areas.

South of the Huntington mine the Castlegate "A" bed is probably 3 to 11 feet thick throughout Candland Mountain and on the east side of Huntington Canyon as far as Valentines Gulch. On the east side of Monument Peak, in the Pleasant Valley area, the bed is thick, but on the west side, south of the Valentine fault, it appears to be much thinner, and its value is much decreased by its inaccessible position, high in the canyon walls. In Flood Canyon, on the west side of Huntington Canyon, the Castlegate "A" is tentatively identified as the lower of two prominent coal beds, but it may possibly be the upper bed. The stratigraphic relations of the coal-bearing rocks exposed in Flood Canyon are obscured by faults and scanty exposures.

In Woodward Canyon, east of the Pleasant Valley fault, the coal bed at locations 197 a and 197 b is identified as the Castlegate "A" bed because it overlies a pronounced white sandstone, beneath which are coal-bearing rocks of the Blackhawk formation. Near the fault this bed is 5½ feet thick, but at locations 197 a and 197 b it is considerably thinner. A section of the bed measured near the fault, about 1,500 feet west of location 197 a, is as follows:

*Section of Castlegate "A" (?) coal bed near Pleasant Valley fault in Woodward Canyon*

| | Ft. | in. |
|---|---|---|
| Shale. | | |
| Coke | 1 | 6 |
| Coal | 5 | 6 |
| Clay. | | |
| | 7 | |

The coke in this section may have been produced by igneous intrusion, but no igneous rock was noted on the exposure, and the position of the coke, above the coal, suggests rather that it was formed by the incomplete burning of the bed under cover. The exposure lies in the zone of shattered rocks adjacent to the Pleasant Valley fault, and the coal bed is therefore not accurately identified. West of the Pleasant Valley fault in Woodward Canyon the horizon of the Castlegate "A" bed is entirely covered by soil and vegetation.

In the canyon of the Left Fork of Huntington Creek the Castlegate "A" bed has been recognized at several places, and it is probably present in nearly all of the area adjacent to the canyon. It was not found at location 201, and it may be absent in part of the canyon between locations 201 and 202, but the coal beds are so thoroughly burned and concealed in this stretch that any conclusion concerning their presence is subject to doubt. The south wall of the canyon is so heavily forested that no information on the coal is obtainable there, and even the steep stream channels show no rock exposures in the Blackhawk formation. At the head of the canyon, however, the rocks are fairly well exposed, and the columnar section measured at location 204 shows all the coal beds as far up as the bed above the Castlegate "A" bed. Above the horizon of this bed the rocks are not so well exposed, and the higher coal beds noted farther north on Candland Mountain are not in evidence. At the Larsen mine (location 205) the Castlegate "A" bed has in past years been actively mined to supply the domestic market of Sanpete Valley, and throughout this mine the coal is good and the roof and floor are massive sandstone. The exposure of the Castlegate "A" bed at the mouth of the mine is shown in Plate 13, *B*. The analysis of a sample taken at the Larsen mine is given on page 70 as No. 81865.

In the lower part of Horse Canyon the Castlegate "A" bed was not found because of poor exposures, but at location 207, near the place where the bed crosses the canyon, it is considerably thinner than it is in the canyon of the Left Fork of Huntington Creek, and it is probably either very thin or absent in most of Horse Canyon. On the east side of Huntington Canyon opposite Horse Canyon it appears to be absent. In Blind Canyon it appears to be thickening southward, and in the gulch south of Blind Canyon it is over 8 feet thick. In this gulch, however, the stratigraphic relations are somewhat confused by a fault, on neither side of which are the rocks well exposed, and the identification of the thick coal bed at locations 212 and 213 as the Castlegate "A" bed is not certain.

On both sides of Huntington Canyon south of Blind Canyon the coal beds are extensively burned, and the character of the Castlegate "A" bed at locations 214 and 215 is not known.

*Candland bed.*—In Candland Mountain a coal bed 4 to 14 feet thick occurs fairly persistently 40 to 75 feet above the Castlegate "A" coal bed. This bed is important enough to require a name, and it is here called the Candland bed because of its consistent presence in Candland Mountain. In order to avoid the confusion of names that might arise if the correlations of this bed and the Castlegate "A" bed prove on extensive prospecting and mining to be erroneous, location 185 is designated as the type locality for this bed. The question of correlation is reviewed on pages 119–122.

The Candland bed has not been definitely recognized in Huntington Canyon north of location 180, and in Coal and Cox Canyons it is probably thin if present. The coal bed bared in a prospect pit at location 177 is tentatively identified as the Candland bed, but the structure in this part of Huntington Canyon is apparently irregular, and the rock exposures are not clear enough to permit definite correlation. At location 180 the bed is certainly recognizable, and it appears to be present in most of Candland Mountain and in part of Monument Peak.

In Valentines Gulch the Candland bed is clearly present and over 7 feet thick, but it has not been recognized in Hughes Canyon and the other canyons in the area on the east side of Huntington Canyon. The steep gulches on the west side of Huntington Canyon between location 185 and Flood Canyon were searched in detail, but no certain exposures of the coal were found. In Flood Canyon the rocks are well exposed in the stream bed, but the stratigraphic relations of the rocks in the Star Point sandstone and the lower part of the Blackhawk formation are obscured by faults, and the thin strip of rock exposures available is not sufficient to show the amount and direction of displacement on these faults. The sides of Flood Canyon are heavily timbered, and no rocks are exposed outside of the stream channel. The coal beds found there are correlated with the Castlegate "A" and Candland beds chiefly because of their stratigraphic relation to one another, which is similar to that of the beds at the Larsen mine, at the mouth of the Left Fork, and in the canyons near Valentines Gulch. The Candland bed is thick enough in Flood Canyon to be valuable, but the canyon is precipitous, and the coal outcrop is difficult of access.

South of Flood Canyon the west side of Huntington Canyon is heavily timbered, and no information on the coal is available as far as the mouth of the Left Fork. In the canyon of the Left Fork the Candland bed seems to be consistently 4 to 4½ feet thick, and above the Larsen mine, where it is largely covered by slumped soil and shale, it may be thicker. South of the Left Fork the Candland bed has not been recognized.

The Candland bed is probably 6 feet or more thick in most of Candland Mountain north of Flood Canyon and is best accessible in the canyons south of Bear Canyon between locations 180 and 185.

*Bob Wright (?) coal group.*—The coal beds found at locations 186 a, 186 b, 187 c, 187 d, 188 c, 188 d, and 189 e (see pl. 21) may possibly belong to the Bob Wright group, but no evidence of their identity, other than that of stratigraphic position, is available, and the possibility that they represent the Bob Wright group is suggested chiefly because the locations are not far from Pleasant Valley, where the Bob Wright group is recognized at several places. These beds in Huntington Canyon are of little commercial value, both because they are relatively thin and because they are inaccessible. They have not been recognized at any places in the area other than those named above.

*Upper beds.*—In the columnar section measured at location 184 is a bed, designated 184 c, about 270 feet above the Castlegate "A" coal. This bed is exposed in an old digging high in the little canyon in the NW. ¼ sec. 24, T. 14 S., R. 6 E., at the site of an old sawmill. It is not correlatable with any other bed known in the area, save perhaps one of the higher beds found on the west side of Candland Mountain. It was thought at first that this bed might be displaced by a fault and might properly belong somewhere in the lower part of the Blackhawk formation, but the rocks are bared in the stream channel where the section was measured, and a close examination yielded the conclusion that no fault is present.

The presence of this coal bed can not be established for more than a small area near location 184 c, but inasmuch as the other columnar sections on the west side of Huntington Canyon are not long enough to include it, if it were present, the evidence is not complete. The strata are covered by soil above the places at which the measurements stop in the other columnar sections. It is possible that the bed at location 193 is the same as this bed, but the evidence is inconclusive because the key beds in the lower part of the section are entirely concealed.

At location 192, on the top of Candland Mountain, a coal bed was found at a stratigraphic position apparently much higher than that of any other bed known in the area. The extent of this bed is not known. The bed at location 188 e, which is the only other bed of any value known in the upper half of the Blackhawk formation, seems to be much lower than this bed. The columnar section measured at location 193, however, shows practically no coal in the upper part of the Blackhawk formation, and a critical examination of the whole formation at the south end of Candland Mountain showed that there, too, the upper part contains no notable coal. It is possible that the bed at location 192 is lower in the formation than is suggested by its altitude, and that the beds drop eastward in this part of Candland Mountain, either through faulting or through an abnormal dip. In the canyon including location 185 the strata dip eastward in the short stretch where they are exposed, and this dip may continue westward to the crest of the mountain.

Many thin coal beds, shown in columnar sections 187 and 188, occur east of Huntington Canyon in the part of the Blackhawk formation above the horizon of the Bob Wright group, but none of these beds appear to be worthy of development. Elsewhere in the area this part of the formation appears to be almost entirely barren of coal.

### STRUCTURE

The features of the geologic structure, particularly the faults that affect the disposition and accessibility of the coal beds, are shown on Plate 31.

The Upper Huntington area is divided by faults into four parts, the outlines of which are shown graphically in Figure 4. The easternmost division consists of a small tract in the southeastern part of the area, east of the Pleasant Valley fault zone. The rocks in this tract are unbroken by faults, so far as known.

The next division is the Pleasant Valley fault zone, in which the rocks have been broken by faults of fairly large dimensions into long, narrow blocks. The fault zone enters this area from the north in the high land west of Trough Springs Ridge. This part of the area is probably considerably fractured by minor faults near the Pleasant Valley fault, but the rock exposures in the hills east of Trough Springs Ridge are too poor to allow detailed study of the structure, and the only evidence bearing on the matter is to be found in Woodward Canyon, where the rocks are obviously much shattered in the strip about a quarter of a mile wide east of the Pleasant Valley fault. North of the head of Pole Canyon the Pleasant Valley fault zone is probably intricately fractured, but south of Pole Canyon the movement of the rocks in the zone seems to have separated out into a group of clear-cut faults, which divide the zone into narrow blocks. These blocks are best visible in Tie Fork Canyon, where five faults are present; the westernmost is the Pleasant Valley fault, and the others probably represent the southern continuation of the part of the zone exposed in the Clear Creek mines. The displacement of the Pleasant Valley fault is about 580 feet and is distributed through a shear zone in which five main steps are visible. The next fault is about 600 feet east of the Pleasant Valley fault in Tie Fork Canyon, and its downthrow is about 100 feet to the west. The next to the east crosses Tie Fork Creek about 600 feet northeast of the first large tributary and is visible both in the cliff north of the creek and in the creek bed at location 218 (see fig. 6), where the beds are well exposed and the fault plane is clearly visible. The downthrow of this fault is to the west, and the displacement is 150 feet. About 250 feet farther east is another fault, which has a displacement of about 300 feet, also downthrown to the west. This fault is probably the southward continuation of the easternmost of the group in the Clear

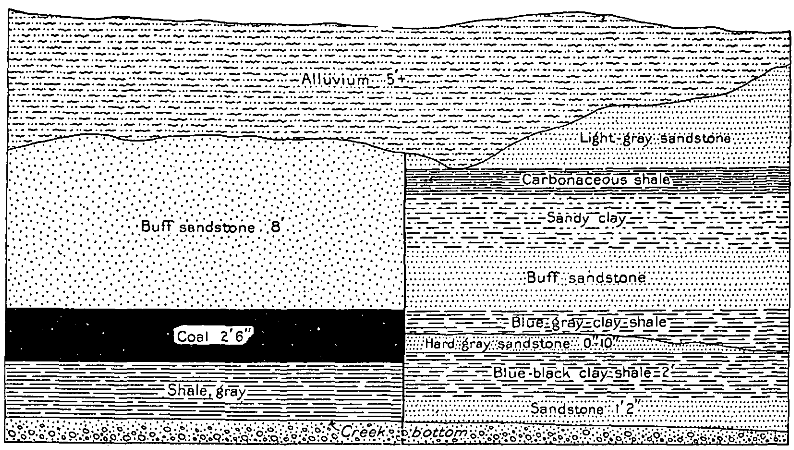


FIGURE 6.—Diagrammatic sketch of fault exposed on Tie Fork at location 218

Creek mine, and the northward continuation of the Trail Canyon fault, which is so named on account of its prominence in Trail Canyon. The easternmost fault noted in Tie Fork Canyon is about 1,250 feet east of the Trail Canyon fault. It has a displacement in Tie Fork Canyon of about 100 feet, the downthrow to the east. All these faults are plainly visible in Tie Fork Canyon on account of the prominent cliff of the Castlegate sandstone, the displacements of which are easily discernible. (See pl. 9, *A*.) It is not everywhere possible, however, to measure the throws exactly, because of the difficulty of finding individual strata that are recognizable on both sides of the faults. The rocks between the faults appear to be unbroken by minor fractures east of the Trail Canyon fault, but on the west they appear to be somewhat sheared and broken in the exposures on the south side of Tie Fork Canyon.

The third division is the relatively broad strip of land between the Pleasant Valley and Joes Valley fault zones. In this strip the rocks are broken by only one large fault and a few smaller faults; and the Valentine fault, the large one, brings down the coal to altitudes north of Valentines Gulch at which it is much more easily accessible than in the canyons to the south. The Valentine fault extends diagonally across the belt between the two large fault zones, forming a connecting link between them. In Valentines Gulch, where the fault is best displayed, the displacement is about 800 feet, but it decreases southwestward, and on the Left Fork of Huntington Creek, where it is next visible, it is the easternmost of a group of faults, and its displacement is about 100 feet. The other faults of this group belong in a certain sense, to the Joes Valley zone, because they join the Joes Valley fault not far south of the Left Fork of Huntington Creek, and they represent there a movement sympathetic and allied with that of the Joes Valley fault. The displacement of the first fault east of the Joes Valley fault is about 55 feet, with the downthrow to the east. Near this fault and parallel to it is a smaller one whose displacement, also down on the east, is 10 feet. The next fault, 400 to 500 feet farther downstream, has a displacement of 110 feet down on the west; the next, 120 feet down on the east; and the next, 120 feet down on the west. The Valentine fault, the easternmost of the group, has a displacement of 102 feet on the north side of the canyon.

In Flood Canyon, in the southeastern part of sec. 25, T. 14 S., R. 16 E., the rocks exposed in the creek bottom show unmistakable evidence of faulting, but the exposures are too narrow and the rocks exposed not sufficiently characteristic to determine the exact nature of the displacement. This evidence suggests that the area occupied by Candland Mountain, where the rocks are effectively concealed almost throughout by a dense cover of forest, may be broken by faults to an extent greater than that shown by the excellent exposures on the south face of the mountain, in the gorge of the Left Fork of Huntington Creek.

In the small canyon south of Blind Canyon in sec. 32, T. 15 S., R. 7 E., a fault occurs in the area between the Pleasant Valley and Joes Valley zones. The trend of this fault is apparently S. 35° E. at the only place where it was seen, and the displacement 77 feet, down on the west side. The measurement is not entirely reliable, because no bed could be recognized positively, but it is based on a comparison of sections measured on both sides of the fault and is certainly not too small.

The fourth division lies in the Joes Valley fault zone, where the rocks have dropped on the west, carrying the coal beds beneath the present surface of the valleys west of Candland Mountain. The Joes

Valley fault zone apparently dies out north of Cleveland Reservoir (see pl. 31), and in the northern part of Huntington Canyon, where the zone would project if continuous northward, no notable faults were observed north of James Canyon. In James Canyon a fault, shown in Plate 31, is discernible in a number of broken outcrops of sandstone, but the amount and direction of the displacement are not readily determinable on the surface, because no characteristic sandstone is exposed on either side of the fault. South of Coal Canyon, in sec. 14, T. 14 S., R. 6 E., at least one fault extends across the nose south of Bear Canyon but apparently dies out before reaching the east side of Huntington Canyon south of the Huntington mine. On this fault the rocks have dropped to the west, and the lowest coal beds are beneath the surface in Bear Canyon. The throw of this fault is not exactly known, but if the coal bed at location 177 is the Candland bed, the rocks have probably dropped not more than 25 to 50 feet. This fault may connect southwestward with the Joes Valley fault.

In the group of valleys west of Candland and Seeley Mountains rocks belonging to the Price River and Wasatch formations lie at surface altitudes from 1,000 to 2,000 feet lower than the base of the Price River formation in the two mountains. With the exception of the part of the Wasatch formation in Bald Mountain, these rocks present puzzling relations as to lithology, identity, and distribution, and to determine the depth of the coal beds from surface evidence in this part of the area is an uncertain and perhaps an impossible undertaking. Detailed observations were made, however, at many critical places, and a brief summation of these, with tentative conclusions, is given in the following paragraphs:

The principal fault, the Joes Valley fault, follows the base of Candland and Seeley Mountains, whose steep western fronts form the northern part of the great scarp of this fault. (See pl. 10.) The northernmost evidence of the fault is in the valley in the SW. ¼ sec. 15, T. 14 S., R. 6 E., between Bear Canyon and the northeast arm of Cleveland Reservoir. The conical hills east of this valley contain rocks characteristic of the Blackhawk formation, whereas the large hill on the southwest, in section 22, contains a bed of coarse conglomeratic sandstone 600 feet thick, which is of Price River type. The fault thus appears to pass through the valley and doubtless guided the erosion that caused it. The displacement of the fault here is roughly estimated to be not less than 500 feet. North of the valley, in Bear Canyon, no positive evidence of the fault was found. West of the fault in section 22 the Castlegate "A" coal bed is probably at least 1,100 feet beneath the level of Cleveland Reservoir and possibly deeper. If the highest coal beds in Candland Mountain are present here, they are possibly within 300 to 600 feet of the surface, but these beds are very irregular, and their presence can not safely be assumed. (See pp. 127–128.)

South of the locality described above, on the low divide in the western part of sec. 23, T. 14 S., R. 6 E., soil characteristic of that produced by the Wasatch formation appears, and in the southwest corner of section 23 scattered outcrops of limestone indicate the presence of the Wasatch formation. Hog Flat, a basinlike park in the western part of section 26, is underlain by the Wasatch formation, and in the western part of section 27 typical Wasatch rocks are abundant. This area of Wasatch rocks is separated from the area of Price River rocks on the north by a fault, the exact trend and displacement of which are not known. This fault adds to the displacement of the Joes Valley fault, making it at least 1,500 feet east of Hog Flat. The hill in the NW. ¼ sec. 35, T. 14 S., R. 6 E., is made up of Price River sandstone, and the fault clearly follows the gulch east of this hill; the displacement here is at least 1,300 feet. Farther south, as far as the Larsen mine, it is impossible to give even rough estimates of the displacement, but no evidence has been found to show that it decreases. In Scad Valley and the head of Upper Joes Valley it is probably at least 1,500 feet. All these estimates are uncertain, because the exact thickness in this area of the Price River formation is not known and because no distinctive beds have been recognized in the Wasatch formation. The estimates are based on the observed partial thickness of these formations, and if the true thicknesses are much greater, the displacements of the Joes Valley fault are greater than those given above.

The rocks west of the Joes Valley fault dip steeply westward between Hog Flat and the southern boundary of sec. 35, T. 14 S., R. 6 E., and they may be broken by minor faults. Near the main fault shattering and step faulting are doubtless present throughout its length, as is suggested by an exposure of sheared rocks near the fault in the NE. ¼ NW. ¼ sec. 11, T. 15 S., R. 6 E., on the south side of the gateway to the gorge of the Left Fork of Huntington Creek. A shear zone is plainly evident in the rocks exposed in Staker Canyon, and other evidence of minor disturbance is noticeable in the scattered exposures of sandstone in neighboring stream channels. In the SW. ¼ SW. ¼ sec. 1, T. 15 S., R. 6 E., a massive sandstone 40 feet thick is cut off abruptly at the mouth of a little gorge in a manner which strongly suggests a fault, the amount and direction of which are not determinable. The rocks in this part of the valley, between Miller Flat Creek and Rolfson Canyon, either lie flat or dip westward at gentle angles.

The valley northwest of Cleveland Reservoir is crossed by a fault, shown in Plate 31, the evidence for which is clear but the exact trend and location of which are difficult to determine. The hill in the northeastern part of sec. 22, T. 14 S., R. 6 E., contains rocks of the Price River formation, as described above, and the hill on the west side of the valley contains rocks that appear to belong to the Blackhawk formation. The location shown for the fault separating these hills is based on surface features and the alinement of a group of small springs in the southwestern part of section 22. The downthrow of the fault is probably on the east side, but the amount is not known beyond the inference that it must be at least 700 feet. If the trend of this fault is correctly ascertained, the fault must meet the Joes Valley fault somewhere near Bear Canyon, and, by virtue of its opposite and approximately equal displacement, it must counteract the throw of the Joes Valley fault, ending the fault zone. In other words, this fault and the Joes Valley fault appear to delimit on the north a wedge-shaped block which has sunk 500 to 700 feet with reference to the rocks on the northeast and northwest.

The rocks in the little gorge of the Left Fork of Huntington Creek between the mouth of Staker Canyon and the center of sec. 27, T. 14 S., R. 6 E., are shown on the map as belonging to the Price River formation, despite the fact that they contain much sandstone and carbonaceous shale of the kind common in the Blackhawk formation. The carbonaceous shale has led to frequent reports that coal is present in this gorge. The Price River formation contains zones of fine-grained carbonaceous shale and even coal-bearing rocks on the west side of the plateau. Farther south, in the hills bordering on Joes Valley, it contains similar carbonaceous rocks but no known coal. If these rocks in the little gorge were of the Blackhawk formation, a fault of considerable magnitude would exist between them and the hills directly to the east, but all available evidence suggests that they belong to the Price River formation and probably to the upper part of the formation. The Castlegate "A" coal bed is thus probably at least 1,500 to 1,700 feet beneath the surface. The alinement of the Left Fork above the mouth of Miller Flat Creek and Scad Valley suggests a fault, but none has been observed except the one on the Left Fork, described above, in the SW. ¼ SW. ¼ sec. 1, T. 15 S., R. 6 E.

The evidence reviewed above is given to provide such answer as is possible to the query which is likely to arise in the reader's mind concerning the depth of the coal west of the Joes Valley fault. The presentation, though summary, is more detailed than that necessary for other faulted parts of the field because the writer feels that in a place such as this, where evidence is difficult of interpretation, it is better to present major facts than arbitrary conclusions. It should be remembered, in addition to the facts presented above, that this part of the Joes Valley fault zone is probably similar to the parts farther south, where many minor faults exist which are not discernible at the surface.

### MINES AND PROSPECTS

*Huntington mine.*—The first coal mine operated in this field was opened in 1875, in the small canyon east of Huntington Canyon in sec. 11, T. 14 S., R. 6 E. It has thus had a long history but has produced comparatively little coal, because it has been idle during much of the time, and when active it has produced merely a small amount for the use of farmers from Sanpete Valley. It was the only mine operating in the area in 1921. This mine, which is now called the Huntington mine but which in past years has been called the Connelsville mine and the New York mine, is a drift mine and is laid out on the room and pillar system. In 1921 the main entry was about 500 feet long, and the pillars are as a rule about 25 feet wide. At that time about four miners were employed. The coal is shot from the solid and is hauled in small horse-drawn cars to a rude tipple in the canyon below the mine, where it is dumped over a bar screen into wagons below. Domestic lump is the only size sold. The annual production, concentrated into a working time of less than six months, is from 2,000 to 3,000 tons. In 1921 the price of the coal at the tipple was $3 a ton.

Mining conditions are excellent. The coal bed is 11 feet thick, and the roof is solid sandstone. The bed dips 5° to 7° SW., and some trouble is experienced with water in the rooms driven down the dip. The entire thickness of the bed is mined without difficulty; but the method of mining produces much slack coal, an unsalable product.

*Larsen mine.*—The Larsen mine, in the SW. ¼ sec. 2, T. 15 S., R. 6 E., near the head of the canyon of the Left Fork of Huntington Creek, is the only other mine in this area, and it was not operated at the time of this work. It is a good example of the better class of wagon mines, and is well equipped to produce coal on a small scale. It is situated on the west face of Candland Mountain, 250 feet above the valley floor and about a quarter of a mile north of the Left Fork. The beds are very nearly flat; the main entry extends eastward into the mountain for about 350 feet, and rooms have been driven at intervals of about 50 feet, the plan being fairly regular. Steel rails have been laid, and small horse-drawn cars, with a capacity of about a ton each, have been used to take the coal out to the tipple. The usual outside equipment of tipple, bins, blacksmith shop, and scales is present, and most of it was in fair condition in 1921. The tonnage produced by the mine is not known, but when operating it has been an important source of domestic fuel for the town of Mount Pleasant, from which the mine is accessible by a fair mountain road.

Prospecting for coal has not been as thorough here as in parts of Huntington Canyon farther south, chiefly because the coal is generally so high in the mountains that possibilities of development in the near future are slight. At some places, however, where the coal is near creek level or is otherwise in a position to attract attention, prospect pits have been dug. Many of these are old and have caved in long ago, but a few still show part of the thickness of the coal beds.

Near the Huntington mine prospecting has been active in past years. In Huntington Canyon above Coal Canyon are two prospects on coal beds above the Castlegate "A" bed, at locations 171 and 174, Plate 31. In and near Coal Canyon and in several canyons south of Bear Canyon, the Castlegate "A" bed has been operated at a number of places. Between Valentines Gulch and Woodward Canyon practically no prospecting has been done in Huntington Canyon.

High in the canyon in the NE. ¼ sec. 23, T. 14 S., R. 6 E., is a pit which was dug long ago on one of the upper beds to supply coal for a sawmill, the remains of whose foundations are still standing near the prospect. On the west side of Candland Mountain some prospecting has been done recently north of the Larsen mine, but with one exception the holes dug show only thin beds of coal. In Woodward Canyon, near the Pleasant Valley fault, several prospect pits have been dug on a bed estimated to be the Castlegate "A." This coal is not far from the valley bottom and has attracted prospectors on that account. A few prospect pits, old and badly caved, are to be found on the west side of Huntington Canyon south of the Left Fork of Huntington Creek.

### FUTURE MINING

The Upper Huntington area presents considerable variation in the main factors governing the planning and establishment of mines, and most of the difficulties imposed by natural conditions characteristic of the field are present in the area at one place or another. The details of such important conditions as presence of coal, mine sites, accessibility of the coal outcrops, and geologic structure may be ascertained by the reader, so far as they were observed in the present work, by reference to the preceding description and to Plates 21 and 31. The following paragraphs are intended to point out, in general, those additional features which should be given prominence in the formulation of plans to mine in the area.

The first requisite to be satisfied before large-scale mining can begin in the area is access by railroad. A railroad might approach this area from existing lines in either of two ways; it might leave the Sanpete branch of the Denver & Rio Grande Western Railroad at Fairview and enter the area from the northwest, or it might come from the south, connecting with the main railroad at Price. Either line would be thoroughly feasible, with grades no heavier than those of existing lines in the field, and the northern route would have the advantage, in shipping to Salt Lake City, of being shorter and of having a smaller climb for loaded trains. The chief difficulty to be expected lies in the great danger of washouts in Huntington Canyon. The canyon of the Left Fork of Huntington Creek is narrow, but a railroad might be built there. It should be noted that much of the bottom of this canyon is in the Mancos shale, the soft nature of which and consequent tendency to slide will present difficulties in railroad maintenance. The grade between the mouth of the canyon and the Larsen mine is the most difficult; in the valley west of Candland Mountain there is more room, and any climbing that is necessary can be taken at lower grades.

In much of the area the coal outcrops are high on the canyon walls, and the difficulty, common in the field, of lowering the coal from mine mouth to tipple is a vital factor. However, in three parts of the area—the upper part of Huntington Canyon, the west side of Candland Mountain, and Woodward Canyon east of the Pleasant Valley fault—the coal is relatively near feasible tipple sites.

The best locations for mines on the west side of Huntington Canyon in T. 14 S., R. 6 E., are between sections 11 and 24. Southeast of section 24 the coal is higher and the canyons are narrow and steep. In section 24 mines might be opened in the small canyons on the west side, with very short tramways, but there is little room in the canyons for the buildings necessary at a mine. In section 14 conditions are better in almost every way, but the dip of the coal is considerable in the north half of the section, and mines there will necessarily be slope mines.

In the part of Huntington Canyon in T. 15 S., R. 7 E., north of the Left Fork of Huntington Creek, the coal is far above the canyon bottom. Furthermore, prospecting will be necessary to determine the presence of coal in the west side of the canyon, where a dense mantle of soil and vegetation conceals all the rocks. A search on the west side of the canyon revealed no exposures between Flood Canyon, in T. 14 S., R. 7 E., and the mouth of the Left Fork. It is probable, however, that minable coal is present, and the search for it will probably be worth while.

On the west face of Candland Mountain mines may be established, but it will probably be necessary to sink shafts or drive rock slopes to reach the lower coal. The lower coal beds are probably not more than 200 feet beneath the surface at the base of Candland Mountain, and the territory north of the mine should be prospected by drilling, chiefly for the purpose of determining the location of the Hiawatha and Castlegate "A" beds in this territory, where the lay of the coal beds is not certain. Care should be exercised in locating drill holes in search of coal in the mountain, to see that they are well east of the Joes Valley fault. These beds may be above the base of the mountain near the bend in the road about 1¼ miles north of the Larsen mine, but if so they are completely covered by soil and vegetation. There is room for several large operations in the valley west of Candland Mountain, and the facilities for mining are better, in general, than at any other part of the area. Water, timber, and town sites are plentiful, and a railroad could be built with little trouble to almost any mine site at the base of Candland Mountain.

In the part of this area east of the Pleasant Valley fault the coal is easily accessible only in Woodward Canyon, and there the unbroken stretches between faults are not wide. Sufficient coal for profitable mining may be present, however, in the Castlegate "A" bed, and it may be worth while to prospect the Hiawatha bed by drilling. All the coal beds appear to be variable in Woodward Canyon, and an attempt at mining should be preceded by thorough prospecting.

The canyon of the Left Fork of Huntington Creek is exceedingly rugged, and good mine sites are lacking. This part of the area is perhaps the least favorable for mining, but the difficulties are not insurmountable. The faults near the head of the canyon, all of which are well exposed and clearly discernible, will govern development there, and elsewhere in the canyon prospecting to determine the amount of coal present is the chief prerequisite to mining. Steep tramways will be necessary at all the mine sites in the canyon. Because of the general south dip of the rocks, the sites on the north side of the canyon are the best.

In Huntington Canyon south of the Left Fork of Huntington Creek mining will not be difficult, as a rule. The body of coal between the outcrop on the east wall and the Pleasant Valley fault can be brought down by steep tramways or conveyors to railroad grade in the main canyon. Tipple sites are not plentiful. On the west side the canyons are longer and tramways can be more cheaply built and operated. Horse Canyon, for example, will probably accommodate a straight tramway of moderate gradient.

The general dip in the Huntington Canyon region is southward, and mines will probably be best located on the north sides of tributary canyons, where they will have the advantage of natural drainage and downhill haul for loaded trips. This principle may be applied for any locality by study of Plate 31. On the west side of Candland Mountain the dip is probably westward with a slight southward component, near the Joes Valley fault, and mines located there will thus have the advantage of driving up grade on the coal.

West of the Joes Valley fault the faulted condition of the rocks, explained on pages 132–134, greatly affects the possibility of mining. In this part of the area, where such coal as may be present lies beneath the surface, a deep drill hole will determine the amount and position of the coal for any given place, but no operation should be planned on the basis of a single drilling.

Water is plentiful throughout the area. The creeks all carry sufficient for the use of such mining industry as may be established, and many springs will provide a good supply of water for domestic use.

Timber is also plentiful. The west wall of Huntington Canyon is nearly everywhere well forested with spruce and poplar, most of which is amply large for mine timber and some of which will afford saw logs sufficiently good to make medium-grade lumber for construction work. In past years timber has been sawed at several places in the area.

## LOWER HUNTINGTON AREA

### COAL BEDS

The Lower Huntington area, which centers about the lower part of Huntington Canyon, is one of the most promising of the undeveloped parts of the field. In this area the lower part of the Blackhawk formation contains five coal beds over 4 feet thick, at least three of which are present in sufficiently large parts of the area to be of major importance when mining is undertaken. These five beds are all contained in the lower 350 feet of the Blackhawk formation, and the more valuable coal, as far as known, occurs in the lower 150 feet of the formation. The relative stratigraphic position of these beds is shown on Plate 22.

*Correlation.*—The Hiawatha bed is the only bed that has been positively identified throughout the area by tracing, and the others have been correlated from place to place by the comparison of columnar sections based on the Star Point sandstone. The only serious question in the correlation of the beds of this area concerns the identification of the Blind Canyon and Bear Canyon beds on the west side of Huntington Canyon south of Rilda Canyon. It is possible that in this part of the area the Bear Canyon bed descends in the stratigraphic column to the approximate horizon occupied farther north by the Blind Canyon bed, and that the thick bed in Deer Creek Canyon is the Bear Canyon instead of the Blind Canyon, as it is named in this report. The evidence for this suggested behavior of the Bear Canyon bed, however, is not strong enough to be convincing, and because the thick bed in Deer Creek Canyon may be alined in the row of columnar sections with the Blind Canyon bed it is thus correlated. The correlation of the coal beds in this area, even by the comparison of well-alined columnar sections, is difficult because the rocks are poorly exposed in about half of the area, and in the part of the area where the rocks are well exposed the coal beds have been burned almost completely along the outcrop.

*Hiawatha bed.*—The Hiawatha bed has been identified throughout this area by means of the white sandstone underlying it, which is traceable continuously south of the Left Fork of Huntington Creek except in a few forested parts of the canyon wall. The coal of this bed has been burned so extensively in the Lower Huntington area that exact measurements of it are obtainable at few places. Many of the measured sections represented in Plate 22 do not show the complete thickness of the bed; they show the greatest thickness of unburned coal that could be found, and there is no sure way to estimate the amount of coal that has been burned. It is probable, however, that the bed is 5 feet or more thick nearly everywhere in the area.

On the west side of Huntington Canyon, in Crandall Canyon, the Hiawatha bed is probably at least 6 feet thick, and sections 219 and 220 are probably representative of the entire area covered by the canyon. South of Crandall Canyon the thickness is probably greater than the 6 feet 2 inches recorded at location 221. In section 225 a, which is incomplete, the coal beneath the shale parting has been burned, and a large part of the represented thickness of 2½ feet is ash and soot. Between location 225 and Mill Fork Canyon the best measurements show more than 6 feet of coal; all others represent partly burned coal. The bed is probably at least 6 feet thick in this part of the area.

In Mill Fork Canyon no place was found at which a complete section of the bed could be obtained without extensive prospecting, but the presence of some coal above the white sandstone is everywhere fairly certain, and the effects of burning are so prominent that it seems safe to assume the existence, in the intervals between measured sections, of coal under cover as thick as that shown by the best sections. At location 233 the bed is burned, and a true measurement is not obtainable, but at location 232, 1,500 feet farther east, it is at least 5½ feet thick. The thickness of 6 feet 9 inches measured at location 234 may represent the entire bed, but at location 235 it is burned, and only 3 feet of coal remains.

South of Mill Fork Canyon the bed thickens, and it is at least 10 feet thick on the west side of Huntington Canyon between Rilda Canyon and the southern border of T. 16 S. At location 244, in the small canyon opposite Trail Canyon, it is at least 8 feet thick, and an unknown amount is burned. In Rilda Canyon three measurements, at locations 245, 246, and 248, show thicknesses all greater than 10 feet. In most of North Fork of Meetinghouse Canyon the average thickness seems to be 10 feet or more, as shown by the sections at locations 260 and 261; at 263 a the coal is partly burned.

In Meetinghouse Canyon a prospect pit at location 264 shows the bed to be 6 feet thick. The white sandstone on which the bed rests is plainly exposed on both sides of the canyon, and the pronounced blooms of coal that show up on this sandstone between burned areas suggest strongly that the bed is 5 feet or more thick throughout Meetinghouse Canyon. In Deer Creek Canyon the bed is probably thinner, and at location 270 it may be entirely absent, but the evidence here presented on the Hiawatha bed in this canyon should not be accepted as final, because reliable sections are not obtainable without thorough prospecting.

In Maple Gulch the Hiawatha bed is largely burned, but at location 274 it is about 11 feet thick. At location 272 is a prospect pit which does not reach the unburned coal, and it is possible that the sections at locations 272 and 273 do not represent the full thickness of the bed. In the long point east of location 274 the coal is burned, and the rocks above the horizon of the Hiawatha bed are extensively reddened and baked. In the cliffs above Stump Flat the bed seems to have a fairly constant thickness of 7½ feet as far south as location 275, but natural exposures in the cliff at locations 276 to 278 show clearly a pronounced thickening toward the southeast. Between locations 276 and 278 the bed increases steadily from 7 feet 7 inches to 12 feet 6 inches in thickness.

On the east side of Huntington Canyon burning of the Hiawatha bed has been even more extensive than on the west side. In Tie Fork Canyon no good measurement of the bed was obtained, but coal at least 5 feet thick is believed to be present. Farther south, in the long stretch of cliff between Tie Fork and Trail Canyons, the only good measurements obtainable indicate from 5 to 9 feet of coal and probably at least 6 feet almost throughout. (See sections 223, 224, 228, 236, pl. 22.) In Trail Canyon the bed is probably not less than 5 feet thick anywhere, and it is known to be thicker at locations 243 and 237. These sections, considered together with those on the west side of Huntington Canyon and the apparent intensity of burning, lead to the belief that the Hiawatha bed is present and probably continuous in most of the northern part of the area.

In the upper part of Bear Creek Canyon, however, there is unmistakable evidence of a local thinning of the bed. This is the only place in the area at which the bed is positively known to be less than 5 feet thick; at all others where less than 5 feet of coal is measurable it is possible that the sections are not complete. At location 254, in a shallow prospect pit, it seems certain that the complete bed is exposed, and there it is 4 feet 8 inches thick. At location 252 it is probably not much more than 3 feet 9 inches thick, and at 251 it is almost entirely replaced by clay, shale, and sandstone. At location 250 it is about 4 feet thick. The local basin or channel in which the bed is thin seems to center about location 254 and does not extend far west, because at location 249 the bed is known to be 7 feet 9 inches thick. Neither does it extend far south, because the bed is known to thicken toward location 259, where 10 feet 2 inches of coal was found. Its extent toward the north and east is not known but may be assumed to be at least a mile from location 254.

*Blind Canyon bed.*—South of Blind Canyon, the type locality, the Blind Canyon bed is not traceable anywhere, and individual coal sections are correlatable with it only by stratigraphic reference to the top of the Star Point sandstone. In the present area, therefore, the bed has not been absolutely identified, but the name Blind Canyon is applied to a coal bed that appears rather persistently at the horizon, normally 40 to 60 feet above the top of the Star Point sandstone, which is occupied by the Blind Canyon bed at its type locality. Stratigraphic sections measured just south of Blind Canyon show a number of relatively thin beds in the general part of the column where the Blind Canyon bed should appear. The Blind Canyon bed may be represented by one of these thin beds that pinches out southward, and the bed bearing the name in this area may not be continuous with the bed in Blind Canyon.

The Blind Canyon bed is not known to be present in Crandall Canyon. The effects of burning suggest the presence of coal somewhere near its probable position, but no positive evidence of coal more than a foot thick was found in this work. South of Crandall Canyon, however, between locations 225 and 234, the bed may be 4 feet or more thick almost throughout, and it appears to be best on the west side of Huntington Canyon between locations 225 and 229, where it is probably more than 5 feet thick. On the east side of the canyon, opposite this locality, it is not known to be so thick, but it is badly burnt. In Tie Fork Canyon the only good measurements, at locations 216 and 217, show a thickness in excess of 5½ feet.

South of Mill Fork Canyon the bed is thin and of little value as far as Meetinghouse Canyon. It has been recognized at a number of places in this part of Huntington Canyon, but at none of them is it more than 3 feet 7 inches thick. It is apparently absent near the mouth of Trail Canyon, and in Bear Creek Canyon it appears in thin lentils only. In the east fork of Bear Creek Canyon its horizon is clearly occupied by massive sandstone.

In the North Fork of Meetinghouse Canyon the Blind Canyon bed is apparently of little or no value as far west as location 262, but at 263 it contains 11 feet 6 inches of good coal, and it may be present in similar thickness for some distance west of the outcrop. However, in Meetinghouse Canyon the section measured at location 264 shows only 2 feet of bony coal at the horizon where it should appear. The sandstone and shale above the Hiawatha bed are so extensively burned and slumped on the north side of Meetinghouse Canyon that it is impossible to say whether or not the bed is present, but on the south side of the canyon it is probably at least 6 feet thick throughout, and the evidence afforded by the section at location 265 is regarded as representative for that part of the canyon.

In Deer Creek Canyon the bed is well developed. It attains its greatest known thickness in the wagon mine at location 269, where it is 15 feet 4 inches thick at the mine mouth and ranges between 12 and 15 feet in thickness inside the mine. The analysis of a sample taken in the Deer Creek mine is shown on page 71 (No. 83749). The coal in this mine is hard and lustrous and contains few bony layers. Elsewhere in Deer Creek Canyon the bed is represented at the outcrop by ashes and sooty coal. At location 266 the overlying shale, 30 feet thick, has been baked, and only 2 feet 2 inches of coal remains.

At location 271 the coal is likewise burned, and its true thickness is not known. The extent of the burned shale and sandstone between locations 271 and 274 suggests the presence of a thick bed; and at location 274 there is 5 feet 4 inches of coal intact, with the overlying beds so reddened as to imply that the full thickness of the coal is much greater. At location 275 the bed seems to be absent.

In the easternmost cliffs of the Cottonwood area, which are not far from the southernmost locations in the Lower Huntington area, the rocks above and below the coal beds are well exposed, and the true relations of the beds may be seen. There the Blind Canyon bed may be seen definitely to appear and disappear in irregular fashion, and the irregularity of the bed as portrayed by the sections in this area need not in itself cast doubt on the correlations suggested.

*Bear Canyon bed.*—The Bear Canyon bed is so named because it is typically developed in Bear Creek Canyon. It lies normally about 100 feet above the Hiawatha bed, and at many places it is underlain by a bed of massive sandstone that is traceable for moderate distances. At location 255, the type locality of the bed, this massive sandstone extends vertically downward to the Hiawatha bed, but at many other places it is split near the middle by the Blind Canyon coal bed, and in the Lower Huntington area generally it normally contains several other thin coal beds. In the Cottonwood area this sandstone is prominent and easily recognizable in the barren cliffs of the plateau front.

Sections measured north of Mill Fork Canyon, with the possible exception of those at locations 224 and 226, do not show the Bear Canyon bed, and it is probably not present in Crandall Canyon. It appears, 16 feet thick, at location 233, but there is no sign of its presence farther north except the rather ambiguous evidence afforded by the extensively burned sandstone and shale in the lower 150 feet of the Blackhawk formation and the thin beds in sections 164 and 166. At location 225 the outcrop burning appears to have been especially intense at the horizon of the Bear Canyon bed. The bed is probably more than 15 feet thick throughout Mill Fork and Trail Canyons, and it may be equally thick in Rilda Canyon, where the rocks at its probable position show the effects of intense burning. In Meetinghouse Canyon it is burned almost everywhere on its outcrop, but one measurement, at location 264, shows it to be at least 5 feet thick.

The bed is seen to best advantage in Bear Creek Canyon, where the coal is unusually resistant and is well exposed. At location 255 a prospect tunnel on the bed, about 240 feet long, shows hard, lustrous coal throughout its length. At the mouth of the tunnel the coal crops out in a sheer wall, and it shows very little deterioration, even after exposure to the weather for many years. A sample of coal from the wall of this tunnel about 35 feet from the mouth and one taken from another tunnel at location 253 b proved on analysis to be of high grade. The analyses are shown on page 70 (Nos. 82349 and 82353).

The continuity of the Bear Canyon bed underground east and southeast of Bear Creek Canyon is suggested by the appearance of the bed in sections measured south of Chris Otteson Hollow, in the plateau front in the Mohrland area. Northeast of Bear Creek Canyon the bed probably pinches out, because it has not been found in Cedar Creek. North of location 143, in Miller Creek Canyon, the bed locally called the Wattis bed appears at the same horizon, and it may be continuous underground north of Bear Creek Canyon, but the available evidence is not sufficient to warrant the use of the same name for both beds.

In Deer Creek Canyon and in Maple Gulch the Bear Canyon bed has not been found, but the rocks near its normal position show the effects of intense burning, and it may therefore be present. It is probably represented at location 275 by the partly burned bed designated 275 b. It is known to exist in the adjoining part of the Cottonwood area, and it may be continuous throughout the point of East Mountain between Cottonwood and Huntington Canyons.

*Upper Bear Canyon bed.*—Above the Bear Canyon bed, at an interval ranging between 11 and 34 feet, lies a bed which is about 8 feet thick in Bear Creek Canyon but has not been recognized elsewhere in the area. This bed may be either a lenticular "rider" or a split from the Bear Canyon bed, and because of its close relation to that bed it is called Upper Bear Canyon. A bed, in places 5 feet or more thick, appears at the same horizon in the eastern part of the Cottonwood area, and it is impossible to say, because of outcrop burning on the west side of Huntington Canyon, whether this bed is present there or absent owing to irregularity of deposition. The analysis of a sample from a prospect tunnel at location 253 c is shown on page 70 (No. 82351).

*Upper beds.*—The evidence of coal more than 2 feet thick in this area above the two Bear Canyon beds is very meager. In Bear Creek Canyon, at location 253 d, a bed over 6 feet thick was found 335 feet above the base of the Blackhawk formation, but elsewhere in the area the rocks near this horizon appear at the outcrop to contain no similar coal beds. The extent of the uppermost bed in Bear Creek Canyon is not known, but evidence at the outcrop indicates that it is not persistent westward. This bed may be continuous northward with one of the upper beds noted in the Hiawatha area and eastward with similar beds in the Mohrland area. It lies at the same horizon, with reference to the top of the Star Point sandstone, as the Bob Wright bed of the Pleasant Valley and Bob Wright areas, but it is not likely to be continuous with the Bob Wright bed, and the application of that name seems hardly justifiable. Thin beds, some of which are burned at the outcrop and thus may be thicker than is apparent, have been noted in this part of the section in Meetinghouse and Deer Creek Canyons. The extent of the bed in Bear Creek Canyon can be determined only by extensive prospecting, and the evidence at the outcrop on both sides of Gentry Mountain seems to justify such prospecting before development is undertaken.

### FAULTS AND THEIR EFFECT ON MINING

The faults of the Pleasant Valley zone cross the eastern part of the Lower Huntington area from north to south, as shown in Figure 4. In Tie Fork Canyon, the south side of which falls in the Lower Huntington area, the zone comprises five well-defined faults, but between Trail and Deer Creek Canyons, where the zone crosses Huntington Canyon, it includes 12 major faults, many of which are accompanied by shear zones containing numerous smaller faults. These faults have obviously disturbed the strata bordering Huntington Canyon in the southeastern part of T. 16 S., R. 8 E., to an extent that will greatly hamper mining, but in the northeastern parts of both T. 16 S. and T. 17 S., R. 7 E., the larger faults seem to be spaced widely enough to allow considerable mining in the intervening blocks.

On the south side of Tie Fork Canyon the rocks are not well exposed, but most of the faults, which are plainly visible on the north side of the canyon, may be discerned in the offset outcrop of the Castlegate sandstone, and the nature of the structure is undoubtedly similar to that on the north side of the canyon. (See pp. 128–129.) In the westernmost block of the zone the Hiawatha coal bed is 300 to 350 feet beneath the bottom of Tie Fork Canyon, and the other coal beds are nearer to the surface by the intervals indicated in the columnar sections on Plate 22. In the next block on the east the Hiawatha coal bed is about 250 feet beneath the canyon bottom at the west end and about 450 feet at the east end. In the narrow block bordering Wild Cattle Hollow the coal is 75 to 100 feet higher, and in the next block on the east the Hiawatha bed is only 150 feet beneath the canyon bottom at the west end and nearly 250 feet at the east end. East of this block it is about 100 feet lower near the fault.

The next place south of Tie Fork Canyon at which the faults of the Pleasant Valley zone are visible is in Trail Canyon, at the mouth of which the Pleasant Valley fault, still the westernmost of the group, appears in the narrow point of rocks that separates Trail Canyon from Huntington Canyon. The exposures of the fault at this locality are shown in Plate 9, *B*. Here, as at most other places where it is exposed, the Pleasant Valley fault is not a simple fracture but is closely accompanied by subsidiary faults. Some of the smaller subsidiary faults are too close to the larger ones to be mapped separately, but at Trail Canyon one is sufficiently large and distinct to be shown. The main fault here has a displacement of about 450 feet, and the subsidiary fault about 100 feet. The Trail Canyon fault, which extends northward probably as far as the Pleasant Valley area (see p. 129), occupies the center of Trail Canyon and causes a displacement of the Hiawatha coal bed of 150 feet, down on the west. On the south side of Huntington Canyon the displacement has decreased to 100 feet, and the fault is almost certainly not present in Meetinghouse Canyon.

In Huntington Canyon southeast of the Trail Canyon fault six faults exist within a distance of three-quarters of a mile. Only two of these faults penetrate the Blackhawk formation on the northeast side of the canyon, but on the opposite side all six have caused displacements of the coal beds ranging between 35 and 75 feet. The displacement of the first fault east of the Trail Canyon fault is 35 feet on the south side of Huntington Canyon, with downthrow to the west; that of the next fault on the east is 45 feet on the north side of the canyon and 70 feet on the south side, with downthrow to the east. The next fault, which appears to be less than a mile long, has a displacement of 80 to 90 feet, down on the west. The next fault crossing Huntington Creek is the first one of the group to cut the coal beds on the north side of the canyon, where its displacement, down on the west, is about 50 feet. This fault increases southward, and in Meetinghouse Canyon its displacement is 70 feet on the north side and about 100 feet on the south side. Another fault branches from it on the south side of Huntington Canyon and increases southward in displacement from about 50 feet to 102 feet on the north side of North Fork of Meetinghouse Canyon. In Meetinghouse Canyon the displacement of this fault is about 100 feet. The easternmost fault of this group has a displacement of 77 feet on the north side of Huntington Canyon, down on the west, and 160 feet on the north side of Meetinghouse Canyon. This fault doubtless merges with the next fault on the west before reaching the south side of Meetinghouse Canyon.

In Meetinghouse Canyon the coal-bearing strata are broken by three large faults, two of which are mentioned in the foregoing paragraph and the westernmost of which is the Pleasant Valley fault. The displacement of this fault in the western part of sec. 3, T. 17 S., R. 7 E., is about 200 feet. South of this canyon the Pleasant Valley fault has not been observed, and it dies out before reaching the cliffs north of Cottonwood Creek, in the Cottonwood area. In the small gulch between the two openings at the Huntington community mine is a small fault whose downthrow is about 25 feet to the east.

The easternmost fault visible on the north side of Huntington Canyon is the Bear Canyon fault, which has been noted on both sides of Bear Creek Canyon, Huntington Canyon, and Deer Creek Canyon. In the west wall of Bear Creek Canyon the displacement is 250 feet, and in the south wall it is 160 feet. In the north wall of Huntington Canyon northeast of the Bear Creek ranger station it is 182 feet (see pl. 4, *B*), and in Deer Creek Canyon it is 275 feet. The downthrow of the Bear Canyon fault is to the west.

In Deer Creek Canyon there is a second fault just west of the Deer Creek mine. It is best visible on the north side of the canyon, where the displacement is 160 feet, down on the east. A smaller fault, the easternmost noted in the Pleasant Valley zone, is visible in Maple Gulch, where the displacement ranges between 40 and 70 feet and the rocks have dropped on the east.

### MINES AND PROSPECTS

*Community mine in Meetinghouse Canyon.*—A mine was opened late in 1921 by citizens of the town of Huntington in Meetinghouse Canyon, opposite location 264, on the Hiawatha coal bed. This mine is operated on a cooperative basis by the citizens to produce coal for their own domestic use. The mine is accessible by a recently graded wagon road. The Hiawatha bed is about 6 feet thick at this mine, and the coal is reported to be an excellent domestic fuel.

*Deer Creek mine.*—At location 269, on the south side of Deer Creek, a mine has been opened on the Blind Canyon bed. This mine has been active in past years and is probably further developed than any other country mine in the field. Since 1921 the people of Huntington, who were the chief purchasers of coal from the mine, have obtained their coal from the community mine in Meetinghouse Canyon, and the Deer Creek mine has been inactive.

The thick coal bed and the excellent roof and floor of this mine afford good mining conditions, and the entries and rooms are all spacious. The coal was hauled to the mine mouth in small cars and was dumped down a chute to a loading bin about 50 feet below. The mine is accessible by a fair road in Deer Creek Canyon, and its nearness to Huntington made it available to a rather large number of people. The quality of the coal is high, as shown by the analysis on page 71.

*Prospects.*—Prospect pits have been dug, for the most part many years ago, on the coal beds in practically all the canyons of this area. The prospecting has been confined in general to the lower beds, of which the Hiawatha bed has received most attention, and the upper beds have apparently not been sought out at all. In Bear Creek Canyon, where the prospecting has been most intensive, all the known beds have been opened, but elsewhere nearly all of the prospecting has been done on the Hiawatha and Blind Canyon beds.

*Conditions affecting mining.*—The Lower Huntington area contains some of the best ground for future development to be found in the whole field. The area contains ample coal, to which Huntington Canyon and many of its deep tributary canyons afford easy access, and the natural conditions for the location of mines and towns are probably as favorable here as at any other undeveloped part of the field.

Good mine sites may be found in most of the canyons tributary to Huntington Canyon in this area, and instead of mere accessibility the chief factors governing the location of mines in the area are the lay of the coal beds and the location of faults. Some of the canyons, however, such as Bear Creek Canyon and the gulches south of Deer Creek, are exceedingly rugged and afford few favorable places for the location of mines.

Between the northern boundary of the area and Meetinghouse Canyon the general dip of the rocks is southward, and in this part of the area the best locations for mines are on the north sides of the east-west canyons, where the advantage of gravity may be had for both haulage of loaded cars and drainage of the mines. The larger canyons, such as Crandall, Tie Fork, Mill Fork, Rilda, Meetinghouse, and Deer Creek Canyons, all contain ample room on the north side for establishment of mines.

The faults of the Pleasant Valley zone cross this area from north to south and define a belt between Tie Fork Canyon on the north and Maple Gulch on the south, in which the location of mines should be made only after careful consideration of the faults. Many of the faults have a displacement sufficient to limit individual mining operations, and others break the rocks into small blocks. The locations of all faults recognized in the present work are shown on Plate 31, and the faults are described on pages 144–146. These faults affect the possibility of mining most in Tie Fork, Trail, and Bear Creek Canyons.

Crandall Canyon is more spacious than any of the canyons farther north tributary to Huntington Canyon and contains room for several mines and one or two towns. The lower part of the canyon is somewhat narrow, and a town built there would be stretched over considerable length, but at the second fork of the canyon, near the center of sec. 1, T. 16 S., R. 6 E., is a broad open space which would make a good town site for mines operating on any of the upper beds. The gradient of Crandall Canyon is too great for ordinary railroad construction, but a good tramway, or gravity plane, might be built from a mine site near location 220 (pl. 31) to a tipple site near the mouth of the canyon. A railroad spur in the canyon to a tipple site near location 220 might be feasible; the total gradient of this stretch is about 7 per cent. The gradient of a well-planned tramway would be about 10 per cent.

In Tie Fork Canyon east of the Pleasant Valley fault the coal is underground and could be reached by shaft or slope, but west of the fault a fairly large block of coal is available for drift mines extending both north and south of the canyon. West of the Pleasant Valley fault the depth to the several coal beds may be ascertained by reference to the position on Plate 31 of the base of the Castlegate sandstone, which lies at the following approximate distances above the principal coal beds:

| | Feet |
|---|---|
| Castlegate "A" bed | 650–700 |
| Blind Canyon bed | 770–810 |
| Hiawatha bed | 850 |

The faults of the Pleasant Valley zone delimit three blocks each of which probably contains enough coal for a single operation and two smaller blocks.

Little Bear Canyon is short and steep, but a tramway might be built there at an average gradient of about 16 per cent, and the coal in the northern parts of secs. 7, 8, and 9, T. 16 S., R. 7 E., and the sections adjoining on the west, might be reached by a mine near location 226. (See pl. 31.)

Mill Fork Canyon is much like Crandall Canyon, and the Hiawatha, Blind Canyon, and Bear Canyon coal beds may be mined there under conditions similar to those described for other canyons in the area west of Huntington Canyon. As usual, the most favorable tipple sites are on the north side of the canyon. Rilda Canyon is also similar to Crandall Canyon. The average gradient of the lower part of Mill Fork Canyon is about 7 per cent, and that of Rilda Canyon is about 5.7 per cent.

Both Meetinghouse Canyon and the North Fork are rugged, and the North Fork is exceedingly precipitous. The gradient of the bottom of the main canyon from the mouth of the canyon to the community mine is about 7.5 per cent, and that of the North Fork is about 13.5 per cent. The faults of the Pleasant Valley zone cross Meetinghouse Canyon, and the major faults define blocks that will probably be mined as units.

Deer Creek Canyon is the southernmost of the canyons on the west side of Huntington Canyon in which mining conditions are favorable. Maple Gulch and the gulches south of it are short, steep, and rough, and the approach to the coal beds is very difficult. The coal accessible in Deer Creek Canyon is cut by faults into three blocks, each of which will probably make a mining unit. The coal in the easternmost block is least accessible of all, but it can probably be brought down by means of a short, steep conveyor to a tipple site near the mouth of the canyon. The coal in the other two blocks may be reached by the usual form of tramway.

In Trail Canyon the faults of the Pleasant Valley zone have cut the rocks into long, narrow blocks. The block bordering Huntington Canyon might perhaps best be mined from Tie Fork Canyon, but a mine could be established in Huntington Canyon near the mouth of Trail Canyon. The coal in the next block on the west is considerably lower in altitude, and might be taken out by a long, narrow mine near the mouth of Trail Canyon. East of this block the coal is higher again, but it might be reached by tramway in Trail Canyon. The canyon is rough and rocky, and any attempt at mining in it will be difficult. Both the Hiawatha and the Bear Canyon beds are workable in Trail Canyon.

Exposures in Bear Creek Canyon reveal several thick coal beds, but the canyon is precipitous, and access to the coal is difficult. Four beds are workable in large parts of the area bordering the canyon, and all but the highest bed could be reached by steep tramways. A fault that passes through the center of the left fork of Bear Creek Canyon divides the ground there into two mining units. South of Bear Creek the cliffs are so rugged that the coal is probably best accessible by mines either in Bear Creek Canyon or in Fish Creek Canyon, in the adjoining part of the Mohrland area.

In all the canyons of this area, particularly in Bear Creek, Meetinghouse, and Deer Creek canyons, the danger to mining equipment from severe floods is great, and any operations planned in these canyons should be safeguarded against floods in every way possible. Every heavy rainstorm sends down these canyons torrents of water that damage or completely destroy any works of man in their paths, and in canyons such as Bear Creek Canyon it will be difficult to find places for railroad, tramway, or buildings entirely safe from floods.

In most of this area the coal-bearing rocks seem to contain considerable water. Nearly all the prospect openings that enter the coal from the south contain water, but those that enter from the north are dry. Mines entering from the north would be dry for a short distance, but when they reach the zone of saturation it will be necessary to pump the water to the surface. Mines entering from the south—that is, on the north sides of the east-west canyons—would probably be wet from the start but would enjoy the advantage of natural drainage for all water encountered above stream level. The slight west component of dip present in most of the canyons on the west side of Huntington Canyon will make pumping necessary for all water encountered west of the places in the canyons where the coal beds dip beneath creek level.

The mining of the coal in this area depends largely on the construction of a railroad in Huntington Canyon. Such a line has been planned to connect with the main line of the Denver & Rio Grande Western Railroad near Price, and when it is built mines may be established at the places suggested in the foregoing discussion. Huntington Canyon contains ample space in this area for towns, yards, and the general appurtenances of a railroad, and the gradient of the canyon bottom is not much greater than that of the Price River Canyon, through which the main line of the railroad ascends the eastern slope of the plateau.

All the larger canyons of the area drain the flanks of the higher parts of the plateau and contain streams of good water, fed by springs in the Wasatch formation. With proper precaution against the pollution of these streams by towns established in the canyons, a good supply of water for domestic use is available for any mining that may be carried on. Timber is available on the tops of East and Gentry Mountains, and in many canyons roads have been built to reach sawmills which for years have been producing small quantities of lumber from the forests of the plateau.

## COTTONWOOD AREA

### COAL BEDS

Five beds of coal more than 3 feet thick are present in the Cottonwood area, and three of these are valuable in considerable parts of the area. The coal is most abundant in the eastern part, in the cliffs east of Cottonwood Canyon, and it decreases in amount southward until in the eastern face of North Horn Mountain many tracts have been found in which no coal exists. On the whole, however, the Cottonwood area compares favorably in amount of coal with the areas in Huntington Canyon.

In the western part of the area the coal is all underground, and the exposures nearest to this part of the area suggest a progressive westward diminution in the amount present. The presence of valuable coal in the western half of Trail Mountain is rendered doubtful because of this evidence. However, coal may exist at depth in Trail Mountain, and drilling on the west scarp of the mountain will probably be advisable at some future time because of the excellent town sites to be had in Joes Valley and the comparative accessibility of the region. In Cottonwood Canyon from one to five beds over 3 feet thick are present. Only the lowest, the Hiawatha bed, is continuously valuable; and the others are not only thinner but more irregular.

The part of the area included in North Horn Mountain appears to contain less coal than almost any comparable tract of the entire field. Actual measurements of the coal in this tract would make it the poorest, in coal content, except that inferences drawn from showings in Rock Canyon, just south of it, point toward the existence of a small area of good coal in the southwestern part of T. 18 S., R. 7 E.

*Hiawatha bed.*—In Grimes Wash and the neighboring drainage channels the Hiawatha bed is present throughout, and in the gulch west of Grimes Wash, at location 294, it was found to be thicker than at any other place in the field except the King No. 2 mine of the United States Fuel Co. The sections shown in Plate 23 indicate a bed approximately 10 to 20 feet thick, and it seems safe to conclude for the stretches not covered by measurements that the bed is present and of similar thickness. The bed is worked at the Anderson mine, at location 286, and has been worked in past years at the Otterson mine, location 284, and at old mines in Grimes Wash at locations 288 and 290. The analysis of a sample from the Anderson mine is given on page 71 (No. 86246).

The coal in the mine at location 288, which had long stood in the rib, exposed to the weather and the dampness of percolating waters in the mine, yielded an analysis (No. 86245) which shows that long exposure has no appreciable effect on the quality of the coal. In Cottonwood Canyon the minimum complete section of the Hiawatha bed shows 6 feet of coal, and thicknesses between 8 and 9 feet predominate. On the east side of Cottonwood Canyon exposures of the bed are fairly plentiful but hard to reach. Near the mouth of the canyon the outcrop of the bed has been extensively burned, and it is doubtful if good sections could be obtained even if the cliffs were scalable. In the gulch in sec. 31, T. 17 S., R. 7 E., the exposure of the Hiawatha bed is almost continuous; on the north side of the gulch the coal lies between massive sandstone beds, and every detail is presented to view, but it is inaccessible. The writer estimated the thickness, by careful leveling across the gulch, at about 11 feet. On the south side of the canyon only one exposure of the bed was noted, and there it is 6 feet thick with a parting of bone 1 to 3 inches thick 18 inches from the top. In the gulch north of the national forest boundary, on the east side of Cottonwood Canyon, exposures are few, but those found seem to indicate an average thickness of about 10 feet.

The data given on Plate 23 afford a close control on the thickness of the bed near the Johnson mine. South of the mine, on the west side of the canyon, outcrop burning has been fairly extensive, but the complete sections found show coal 8 to 9 feet thick. For purposes of rough computation the Hiawatha bed may be taken to be 9 feet thick in the part of the area immediately east of Cottonwood Canyon and south of Roans Canyon, and it is probably 8½ feet thick west of Cottonwood Canyon for a distance of a mile beyond the outcrop.

The quality of the coal in the Hiawatha bed is indicated in the analysis of a sample collected at the Johnson mine, which is given on page 71 (No. 86247).

At many places in this area a band of bright coal 1 to 2 feet thick occurs above the main body of the Hiawatha bed and is separated from it by about 18 inches of fine-grained sandstone. This coal is present also in the Rock Canyon area and is described on pages 171–172.

On the north side of Straight Canyon the data obtained on the Hiawatha bed show it to be at least 5 feet thick as far west as the Oliphant mine (location 318). It is probably of similar thickness in the southern part of Cottonwood Canyon as well, but there it is largely burnt at the outcrop. West of the Oliphant mine a single exposure, in a pit by the roadside, at location 319, shows it to be badly split. The bed exposed in this pit is assumed to be the Hiawatha bed, on the basis of its general position, but the canyon sides between the Oliphant mine and the pit are strewn to a confusing extent with boulders and landslides, and the identity of the bed has not been proved by tracing. The bed is either the Cottonwood or, more probably, the Hiawatha. The following is a section measured in this pit:

*Section of Hiawatha coal bed in prospect pit in Straight Canyon*

| | Ft. | in. |
|---|---|---|
| Sandstone, fine grained, steel-gray, thin bedded. | | |
| Bone and laminated sandstone | | 3 |
| Coal, very resinous | | 8 |
| Coal, dull, with bright streaks | | 4 |
| Coal; weathers to irregular shapes and contains egg-shaped nodules | 1 | 9 |
| Mudstone, gray, calcareous | | 3 |
| Sandstone, very fine grained, calcareous | 1 | 5 |
| Coal | | 5 |
| Coal, bright and dull laminated | | 3 |
| Coal, massive | 1 | 4 |
| Coal and bone laminated, with some shale laminae | | 4 |
| Coal, very massive and hard | | 6 |
| Shale, smoke-gray, tough | 1 | 6 |
| Sandstone. | | |
| Total coal | 5 | 7 |
| Total partings within bed | 1 | 8 |

The coal in this pit is too badly weathered to yield a satisfactory analysis, and whether or not it contains a high percentage of ash is uncertain. Not far east of the pit, in the Oliphant mine, the Hiawatha bed is solid and massive from roof to floor and is 5 feet thick. The chemical character of the coal in the Oliphant mine is shown by analysis 82352, page 71.

On the south side of Straight Canyon the Hiawatha bed seems to be good for a short distance opposite the two mines, but east and west of this locality it is poor. At the mouth of the canyon it is very poor, and in the NW. ¼ sec. 21, T. 18 S., R. 7 E., it disappears entirely for a short distance, to appear again with a maximum thickness of about 1 foot. Somewhere between this general part of the outcrop and the southern border of the Cottonwood area the bed probably thickens again, but exactly where is not known.

The small area south of Cottonwood Canyon in which the Hiawatha bed is known to be 5 feet or more thick includes, roughly, section 1, the eastern parts of sections 2 and 11, and part of sec. 12, T. 18 S., R. 6 E. It is probably of similar thickness in secs. 31

and 32, T. 18 S., R. 7 E., and possibly also in sections 29 and 30. A statement as to its thickness elsewhere could hardly be better than a guess.

*Upper Hiawatha bed.*—At many places in the Cottonwood and Rock Canyon areas the zone of rocks 12 to 20 feet thick above the Hiawatha may represent the Upper Hiawatha bed, but elsewhere in feet thick. None of these beds appear to be more than locally continuous, and to correlate them in detail is at present impossible. Their general distribution is shown in part by the columnar sections in Plate 23. For purposes of description and reference the bed or group of thin beds in this zone is designated Upper Hiawatha, but the application of the name to beds at different locations is not meant to imply continuity, either within this area or with the Upper Hiawatha bed of areas farther south, except where expressly stated. The Upper Hiawatha bed is best developed in Straight Canyon, between the Black Diamond and Oliphant mines (see pl. 31), where it is from 2 to 6 feet thick, as shown by the sections at locations 315 to 317, Plate 23. The bed at location 324, on the opposite side of Straight Canyon, is probably the same, and that at location 331 b may also be the same, but in stratigraphic position these beds are near the Cottonwood bed, and their identity is therefore somewhat in doubt. At the Johnson mine, in Cottonwood Canyon, a bed 16 inches thick and about 15 feet above the Hiawatha may represent the Upper Hiawatha bed, but elsewhere in Cottonwood Canyon this bed has not been noted. The Upper Hiawatha bed may therefore be continuous in an irregular area between the Johnson mine, the Oliphant mine, and the large gulch in secs. 17 and 18, T. 18 S., R. 7 E.

In the gulch west of Grimes Wash a bed 2 feet 8 inches thick, shown on Plate 23, location 292 b, is present about 12 feet above the Hiawatha bed and is here referred to the Upper Hiawatha, although it seems certainly not to be present anywhere farther east and is probably not present in the next gulch west. It may be continuous with the bed at the Johnson mine, but it is not present at location 300, unless, of course, it really is continuous with the Cottonwood bed, as suggested below.

*Cottonwood bed.*—In Cottonwood Canyon, in the S. ½ sec. 30, T. 17 S., R. 7 E., a lenticular bed, here called the Cottonwood bed, appears about 30 feet above the Hiawatha bed. This bed is consistently present in the gulch north of the national-forest boundary, where it ranges between 3½ and 5 feet in thickness, but nowhere else in the area does it seem to be present. However, this bed may be continuous with the Upper Hiawatha bed, and it is here separately identified largely because of its consistent and apparently restricted appearance in Cottonwood Canyon.

*Blind Canyon bed.*—A bed that appears at the approximate horizon of the Blind Canyon bed of the Huntington Canyon region is here referred to by that name on account of its stratigraphic position. It is not known to be continuous with the Blind Canyon bed of Huntington Canyon, but it appears consistently at the same horizon and is given the same name to avoid the encumbrance of many names for coal beds in closely related parts of the field. In the cliffs east of Cottonwood Canyon this bed is extremely variable, and it is not more than 4 feet thick anywhere north of Cottonwood Creek. In the southern part of the area it is thicker in a lens which probably extends under the eastern edge of North Horn Mountain to Rock Canyon.

In Grimes Wash the bed lies between two massive sandstones, which in many places are continuous downward and upward to the Hiawatha and Bear Canyon coal beds, respectively. Laterally these sandstones are fairly continuous throughout the general region. They are not horizontally constant in characteristics, but they are traceable, and at many places they coalesce into one solid sandstone 100 feet thick, cutting out the Blind Canyon coal bed. At some places, notably near the head of Grimes Wash, the two sandstones are separated by more friable, extremely cross-bedded sandstone, but no coal is present.

In Cottonwood Canyon the Blind Canyon bed is lenticular and is not known to be thicker than 3 feet. The massive sandstone beds between which it lies are prominently displayed at a number of places, and there is small doubt of its correlation with the Blind Canyon bed in the Lower Huntington area; but it is, of course, not certainly continuous with the Blind Canyon bed in Blind Canyon. In the perfect exposures in parts of Cottonwood Canyon the bed pinches visibly from 2 feet to nothing and reappears and disappears irregularly. It is of little or no commercial value in this part of the area.

In the big gulch south of the mouth of Straight Canyon in secs. 17 and 18, T. 18 S., R. 7 E., the Blind Canyon bed is about 7 feet thick, but elsewhere south of Cottonwood Canyon it is either thin or absent. A bed above the Hiawatha bed, exposed at the roadside in Straight Canyon, is roughly estimated to be the Blind Canyon bed, but this bed is thin, impure, and commercially valueless.

The exposure in the gulch east of Straight Canyon is of importance because it may be correlated rather definitely with the exposures of the bed in Rock Canyon, and it suggests the possibility that the Blind Canyon bed is represented by a body of coal 7 feet or more thick in the strip of intervening territory. Even if allowance is made for the possibilities of variation in thickness, it seems likely that the bed will be found to be valuable in large parts of this strip. It is the only important bed immediately south of Straight Canyon.

*Bear Canyon bed.*—In the Cottonwood area the Bear Canyon bed is not known east of Grimes Wash, but the effects of outcrop burning suggest that it is present. On the east side of Grimes Wash it is 4 to 6 feet thick for a considerable distance, and on the west side it is partly burned at the next exposures found and completely burned at most of the outcrop. On the east side of Cottonwood Canyon the maximum known thickness of the bed is 4 feet. On the west side of the canyon measured sections do not show the bed, and evidence in surrounding areas suggests that it thins westward. It is of little consequence in this part of the area, but it is probably continuous between Cottonwood Canyon and Grimes Wash. In Cottonwood Canyon the coal in this bed appears to be of excellent quality.

South of Cottonwood Creek the Bear Canyon bed appears to be generally unimportant, but prospecting for the bed throughout this part of the area will probably pay. The identity of the sandstone beneath it is usually clear enough to provide a guide to prospectors.

*Upper Bear Canyon bed.*—Above the Bear Canyon bed in Grimes Wash a bed appears at the same approximate position as that of the similar bed in Bear Creek Canyon. This bed is not known elsewhere in the area, but the obscurity introduced by burned outcrops leaves its extent in doubt. It is probably present throughout Grimes Wash and possibly in neighboring canyons. East of Grimes Wash, at locations 284 and 285, it is probably not much more than 3 feet thick, if present at all. There it is difficult to distinguish the Bear Canyon and Upper Bear Canyon beds in the number of thin beds present above the massive sandstone, but at location 285 the Upper Bear Canyon bed is probably 2 feet 8 inches thick.

On the east side of Cottonwood Canyon a bed appears at approximately the horizon of the Upper Bear Canyon bed. This bed is not known to be more than 3 feet 6 inches thick, but, like the Bear Canyon bed, it contains good, bright, hard coal.

*Upper bed of Grimes Wash.*—In Grimes Wash a bed, 3 feet thick at its best, appears intermittently about 190 feet above the Star Point sandstone. (See location 286 d, pl. 23.) This bed appears also in Cottonwood Canyon, on the east side, where it is 3 feet thick; on the west side it is apparently absent. A bed 3 feet or more thick is present at this horizon at the mouth of Straight Canyon, but elsewhere in the area it is apparently absent.

The coal in all the beds above the Hiawatha appears on the weathered outcrop to be good, and the physical characteristics suggest that it is high-grade fuel.

*Bed in Joes Valley.*—In Dry Canyon, just west of Joes Valley and about a quarter of a mile west of the Joes Valley fault zone, a thin coal bed appears about 300 feet beneath the base of the Castlegate sandstone. This location is west of the boundary of the accompanying map. The following is a section measured in Dry Canyon:

*Section in Dry Canyon, west of Joes Valley*

| | Ft. | in. |
|---|---|---|
| Castlegate sandstone | 250 | |
| Sandstone, buff (two benches) | 100 | |
| Concealed | 30 | |
| Sandstone, very massive | 30 | |
| Concealed (largely shale) | 75 | |
| Sandstone | 8 | |
| Shale | 40 | |
| Sandstone, massive | 10 | |
| Shale | 3 | |
| Shale, containing laminae of coal | 4 | |
| Coal | | 7 |
| Clay, with streaks of coal | | 4 |
| Coal | 1 | 9 |
| Shale | | 7 |
| Sandstone. | | |
| | 553 | 3 |
| Total coal | 2 | 4 |

FAULTS

The faults of the Pleasant Valley zone, much lessened in number and prominence, appear in the cliffs north of Cottonwood Creek in the southeastern part of T. 17 S., R. 7 E., and the fault zone dies out not far south of the cliffs. The easternmost fault passes through the center of the gulch east of Grimes Wash in section 25, and the throw of this fault is about 150 feet down on the west. On the west side of this gulch is a sheared zone, near locations 280 to 283, in which numerous faults, too close together to be shown individually on the map, are distinguishable. The total displacement in this zone is about 40 feet, and the three largest faults have downthrows of 15, 8, and 15 feet to the west. In the small gulch west of this one a small fault, the throw of which is about 5 feet, cuts the Blackhawk formation west of location 284. The displacement of this fault has taken place in a zone about 15 feet wide.

In Grimes Wash, northwest of the Anderson mine, two faults, very close together, cut the rocks near location 287. The throws of these faults are 40 and 70 feet, down to the west. The dragged block between the faults probably wedges out north of the outcrop. These faults separate, for mining purposes, the land in sections 23 and 26 from that in sections 22 and 27.

No large faults have been noted between Grimes Wash and Joes Valley. A small fault cuts the Star Point sandstone south of the Johnson mine, in Cottonwood Canyon, but this fault affects none of the coal.

The Joes Valley fault zone occupies a strip between 1 and 2 miles wide at the western border of the Cottonwood area, and in this strip the coal beds have dropped from 1,500 to 2,000 feet. The adjoining part of the Joes Valley fault zone on the north, in the Upper Huntington area, is described on pages 130–132. Conditions in this area are somewhat similar, but only the Wasatch formation crops out at the surface in the dropped block, and this formation gives rise to rounded hills and flat valleys in which the rocks are not well exposed. Discrimination of the minor faults within the zone is therefore difficult.

The Joes Valley fault follows the western bases of Trail and North Horn Mountains. At the north end of the area the displacement is probably at least 1,500 feet, and at the head of Straight Canyon it is possibly more than 2,000 feet. Middle Mountain and the analogous ridge in the North Dragon are doubtless bounded by faults, and the intervening blocks are probably further fractured, but to what degree it is impossible to say.

### MINES AND PROSPECTS

A number of wagon mines have been opened in the Cottonwood area, but no railroad touches the area, and the production of coal, both past and present, is small. The Hiawatha bed and in a few places some of the upper beds contain a large amount of coal in this area, and the prospect for future development is good. The area contains all the natural requisites for mining on a large scale, and the development of mines for more than local use awaits merely a demand for coal sufficient to warrant the projection of a railroad to Cottonwood Creek.

*Anderson mine.*—High in the cliff on the east side of Grimes Wash (location 286) is the Anderson mine, the location of which is a tribute to the ability of country miners to overcome natural obstacles in their effort to produce coal. The mouth of the mine is about 700 feet above the creek bottom just southwest of it and 1,600 feet above the flat on Cottonwood Creek where the road to it branches from the main road. The road to the mine follows the benches south of the cliffs, at a fairly good grade, for about 3 miles north of the main road, but on reaching the cliffs it becomes very steep, rising about 400 feet in 0.4 mile.

The mine has been driven on the lower bench of the Hiawatha bed, which is here about 9 feet thick and is separated from the upper bench by a parting of bone and hard shale about 1 inch thick. This parting makes a good roof, and the upper coal, which is 5 feet 4 inches thick at the mine mouth, is not taken. About a foot above the upper coal is the bed of bright coal, here 1 foot 7 inches thick, that has been noted elsewhere in this area. The coal is hauled to the mine mouth in cars of about 1-ton capacity and is dumped down a rock chute about 175 feet to the loading station. The coal at the Anderson mine is hard and massive and stands rough handling with remarkably small reduction to slack.

The mine was active in 1922, but only a small tonnage was produced. The competition of the mines in Straight Canyon, which because of better roads are easier to reach despite their greater distance from Orangeville and Castle Dale, the towns supplied, reduces considerably the market for coal from the Anderson mine.

*Otterson mine.*—In the gulch east of Grimes Wash, on the east side of the gulch near the head, is the Otterson mine, one of the oldest country mines in the general region. When this mine was visited in 1922 the entrance was nearly caved shut, but the interior of the mine appeared to be in good condition. The mine is on the Hiawatha bed, which is somewhat broken by partings, as shown by the following section:

*Section of Hiawatha coal bed at Otterson mine (location 224)*

| | Ft. | in. |
|---|---|---|
| Sandstone. | | |
| Shale | | 10 |
| Coal | 1 | 4 |
| Shale | | 10 |
| Coal | 1 | |
| Shale, bony | | 3 |
| Coal | 5 | 10 |
| Shale | | 2 |
| Coal | 1 | 10 |
| Bone | | 2 |
| Coal | 3 | 6 |
| Shale | 1 | |
| Sandstone, shaly. | | |
| | 16 | 9 |
| Total coal | 13 | 6 |

Only the lower 6 feet of the coal has been mined. The road to the mine follows the broad bench just north of Orangeville and is not abnormally steep anywhere. Wagons formerly went directly to the mine mouth.

*Entry at location 223.*—In the next gulch east of the Otterson mine, at location 223, is an old caved entry which may connect with the Otterson mine. When this mine was visited in 1922 the entrance was nearly caved shut, and the interior of the mine was in bad condition because of the shattered rocks in the fault zone that is crossed by the entry. The mine appears to have been active many years ago. The road to the old loading station is exceedingly steep and the mine is difficult of access. Only traces of the loading station and the road now remain.

*Mines in upper Grimes Wash.*—In each of the forks of Grimes Wash is an abandoned mine (locations 288 and 289). The one at location 289 is the Reed mine, referred to by Taff.[66] Both are very old mines.

The mine at location 288 is largely caved, but the coal appears unaffected by weather, and a sample was taken for analysis. (See analysis 86245, p. 71.) Little coal has been taken from the mine and the entry is only about 75 feet long. A few short rooms have been turned off.

The mine at location 289 is more extensive, but it could not be explored in 1922 because of water. It is a true wagon mine; the road leads directly to the mine mouth and wagons were driven into the mine, loaded at the face, and driven out again through a second entry near the first. An older entry south of these two, now caved shut, probably served to ventilate the mine.

At both of these mines the coal is about 13 feet thick and is of the hard, massive type characteristic of the field. The road to the mines was in bad condition in 1922, but it is of even gradient, and when well kept it affords a good route for heavy wagons.

*Johnson mine.*—The Johnson mine, in Cottonwood Canyon, in the SW. ¼ NE. ¼ sec. 25, T. 17 S., R. 6 E., has produced in past years a small amount of coal for domestic use in the near-by portion of Castle Valley, but it has lain idle for a number of years. The mine is on the Hiawatha bed, on the west side of the canyon not far south of the point at which the coal bed passes beneath creek level, and the mine mouth is only about 30 feet above creek level. Two entries, a main haulage way, and an air course have been driven westward about 300 feet. When the writer visited the mine the mouth of the air course was closed by caving ground. Water apparently gave trouble to the miners in the main entry, and in order to avoid it many of the rooms were not dug to the base of the coal. The west dip of the coal bed made it impossible to keep the water down except by pumping, and water trouble may have caused the abandonment of the mine. The mine is one of the few "wagon mines" that give evidence of fairly careful mining. The small slack pile at the mouth of the mine, as well as evidence noted in some of the rooms, shows that the coal was probably undercut, and the regularity of room and pillar arrangement indicates careful planning.

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[66] Taff, J. A., The Book Cliffs coal field: U. S. Geol. Survey Bull. 285, p. 300, 1906.

The section of coal in the mine, measured at a place in the back entry where a cave-in of the roof has exposed the beds above the coal and where the base of the bed is attainable, is as follows:

*Section of coal in back entry of Johnson mine*

| | Ft. | in. |
|---|---|---|
| Sandstone, fine grained, gray. | | |
| Clay, with lenses of sandstone | 1 | 2 |
| Bone and coal, laminated | | 6 |
| Coal, "birdseye," black, lustrous, very good, low ash | | 8 |
| Clay parting | | 2 |
| Coal similar to above | | 5 |
| Sandstone, very fine grained | 1 | 3 |
| Clay parting | | 2 |
| Coal, massive, hard | 8 | 6 |
| Sandstone, white, massive. | | |
| Total coal | 9 | 7 |

*Straight Canyon mines.*—The Black Diamond and Oliphant mines, in Straight Canyon, are the most active mines in this area. These mines are on the main road between Ephraim and Orangeville, and they draw patronage from both Sanpete and Castle Valleys.

*Oliphant mine.*—The Oliphant mine, the western one of the two mines in Straight Canyon, has been operated for many years. This mine, which is on the Hiawatha bed, is about 190 feet above the road in Straight Canyon. The coal is brought to the mine mouth in hand-pushed cars of about 1-ton capacity, is dumped into a crude chute, the lower part of which serves as a combined screen and storage bin, and is loaded directly into wagons from the lower end of the chute.

The main entry of the mine has been driven very nearly along the strike of the coal bed, and rooms have been turned off on both sides. The advantage of gravity is taken on the haulage road. The coal is about 5 feet thick, and the roof of the mine is solid sandstone; no timber is necessary. The mine is dry. The coal is shot from the solid, and a large percentage of slack is produced. The slack is screened off in the lower part of the chute, and a huge pile of it has collected both above and below the road.

*Black Diamond (Fox) mine.*—The Black Diamond or Fox mine, about 1,000 feet east of the Oliphant, is considerably higher on the canyon wall, owing to the west dip of the strata. The mouth of this mine is about 380 feet above the main road, and it has been necessary to construct a steep roadway up to the loading bin, which is 275 feet or more above the main road. The upper part of the Star Point sandstone forms a massive cliff at this mine site, and the approach to the mine mouth is very difficult.

The miners ascend the cliff by way of a channel blasted out of the solid rock, in which a cable is hung. The coal is sent down from the mine mouth to the loading bin through a chute tunneled in the upper part of the Star Point sandstone. Where the coal emerges from the tunnel the cliff is overhanging, and there is room for a bin and a loading station. The coal passes over a screen before entering the bin, and the slack, which is plentiful, is carried through a galvanized-iron chute to the slope below the loading station, where it has already accumulated into a huge fan.

The main entry of the mine extends N. 10° E. 550 feet or more. The strike of the coal bed here is N. 15° W., and the trend of the entry thus permits gravity haulage of the loaded cars in both the main entry and the rooms on the east. The dip is 5½° W. The coal mined is hard and massive and is 6 feet 6 inches thick; the roof is massive, hard sandstone.

#### FUTURE MINING

The large amount of coal available in the Cottonwood area insures its future as a mining district. Much of the coal is difficult of access, but most of it can be reached by methods now used on the cliffs in other parts of the field, and the deeper canyons of the area afford mine sites better than the average available in the field.

In the eastern part of the area the coal is so high in the cliffs that tramways of some sort will probably be necessary to carry the coal from mine mouth to tipple. The gulches indenting the cliffs afford the best mine sites, and of these the coal is best accessible in Grimes Wash. The gulches east of Grimes Wash are steep, and mining there will be difficult, even by tramway.

The gradient of Grimes Wash is 3.5 to 5 per cent between Cottonwood Creek and the west quarter corner of sec. 35, T. 17 S., R. 7 E., but above this point it is probably too steep and the canyon bottom too rough for the construction of a railroad spur, and mines located there will probably be connected by tramway with tipples on the bench at the mouth of the canyon. Grimes Wash affords the best points of entry for a large area of coal east of Cottonwood Canyon. The coal east of Grimes Wash can probably be most efficiently mined from the east fork of the wash, but the faults west of the Anderson mine will probably make some rock tunneling necessary. The coal available west of Grimes Wash can probably also best be taken out through mines in Grimes Wash and possibly in Cottonwood Canyon.

In Cottonwood Canyon a railroad could be constructed to the site of the Johnson mine, where the Hiawatha coal bed is at tipple height above the canyon bottom, but the gradient of most of the line would be greater than 5 per cent unless the line followed the higher parts of the benches below the cliffs east of Cottonwood Canyon and entered the canyon some distance above the stream. Mines can be established near the Johnson mine to tap large areas of coal both east and west of Cottonwood Canyon, but the mine on the west side will have the disadvantage, due to the west dip of the rocks, of an upgrade haul for loaded cars and will probably strike considerable water. However, the site of the Johnson mine is the best point of entry for a large area of coal in Trail Mountain. The coal east of the canyon is more favorably disposed for mining. South of the Johnson mine the coal is high in the canyon walls, the gulches are rocky and precipitous, and no good mine sites are available. (See pl. 20, *B*.) The coal is high in the cliffs at the mouth of Straight Canyon, and the first half mile or more of outcrop contains no good mine sites, but near the Oliphant and Black Diamond mines the coal beds are more easily accessible.

In the big gulch south of the mouth of Straight Canyon the Bear Canyon bed may be worthy of development, but the transportation problem is difficult. A motor road might be built from a mine site in this gulch to the mouth of Straight Canyon, on the top of the Star Point sandstone, which forms a shelf not unfavorable for railroad building, and the coal might be lowered by tramway to the canyon floor. A tramway from the sandstone point to the floor would drop 1,225 feet in half a mile—an over-all gradient of about 46 per cent and a maximum gradient far in excess of that. It would probably be necessary to extend the tramway up Straight Canyon or to start it farther up the gulch. At all events it is a difficult piece of engineering to contemplate. The part of the area south of Straight Canyon contains, on the whole, insufficient coal to justify, for the present at least, the great expense of establishing mines on the cliffs.

The coal in the western part of Trail Mountain is probably best accessible by means of shaft mines in Joes Valley, at the base of the mountain. The amount of coal present in this part of the area can be determined by drilling only. The sites for test holes should be placed as far east of the Joes Valley fault as possible, in order to avoid the zone of crushed rocks adjacent to the fault, and the best places for such tests are in the gulches indenting the mountain. Drilling sites far enough east of the fault to be safe are all in poorly accessible places, but it will probably pay to go as far up the gulches as possible, at least far enough to drill abreast undisturbed outcrops of the Castlegate sandstone. A desirable site for a preliminary test of this part of the area is at the head of Straight Canyon, somewhere not far east of the gate formed by the Castlegate sandstone, but the results of such a test would have little bearing on the north end of Trail Mountain, and one or two holes farther north will be necessary before mining is contemplated there. These tests are fully as important to show the exact depth of the coal as to show its quantity, because the shafts will probably be sunk in the ground west of the fault, and the coal will be reached by entries driven through rock across the fault from the bottoms of the shafts. The greatest depth at which coal may be expected is ascertainable for any place on the west front of Trail Mountain by reckoning downward from the base of the Castlegate sandstone. The Hiawatha coal bed is about 750 feet beneath the Castlegate sandstone at the nearest exposures in Straight and Cottonwood Canyons.

Joes Valley affords ample room for surface works and towns, and mines may be situated at almost any place near Trail Mountain where surface conditions are satisfactory.

When a railroad reaches Joes Valley, the ground west of the Joes Valley fault zone will probably justify the cost of prospecting by the drill. This part of the plateau is more deeply indented by canyons than Trail Mountain, and satisfactory drilling sites are more easily found there. The depth to the coal-bearing zone of the Blackhawk formation in the canyons west of Joes Valley and north of Seeley Creek is similar to that east of Joes Valley, but in the canyon of Seeley Creek, due west of Straight Canyon, the coal beds are somewhat deeper, owing to the greater south dip of the rocks west of the fault zone. The area west of the Joes Valley fault zone is beyond the limit of the map made in the present work.

Any large-scale development of this area will undoubtedly await the completion of a railroad in Castle Valley at least as far south as Huntington, and that line will be built primarily for mining in Huntington Canyon. Mining in the Cottonwood area would therefore not normally begin until the demand for coal exceeds the supply easily available in Huntington Canyon.

The construction of a railroad from Castle Valley into this area, by way of Cottonwood Creek, will not be difficult as far as the lower entrance to Straight Canyon, but beyond that point the ruggedness of the canyon will impose obstacles requiring considerable expense to overcome. The gradient of Straight Canyon is amply low for ordinary railroad construction, and a route might be found there with an average gradient lower than 2 per cent. The canyon is narrow, however, and little choice of route is available. The most serious difficulty of a railroad in Straight Canyon will come in maintenance, because of the landslides that take place periodically in the spring, when the snow is melting.

From the head of Straight Canyon a railroad could be built to almost any desirable mine site in either Joes Valley or the North Dragon. A line built to reach the coal available in the northern part of Trail Mountain could penetrate as far as the forks of Indian Creek at the northern boundary of sec. 17, T. 17 S., R. 6 E., by following the base of the mountain and gaining as much altitude as necessary in the lower 2 miles of the route, with an average gradient of about $2\frac{1}{2}$ per cent. The rise in this stretch is about 660 feet, and the length of route about 5 miles.

Cottonwood and Seeley Creeks both contain a supply of water ample for mining needs, and the mines in the area north and west of the forks of these creeks will not be likely to suffer from lack of water, which is the besetting trouble of many mining towns in this general region. The cliffs near Grimes Wash, however, contain no continuous streams, and the stream in Grimes Wash is neither copious nor reliable as a source of water. South of Straight Canyon no water is available.

A supply of timber is available on the top of the plateau and can be reached by roads now existing in the area.

### ROCK CANYON AREA

The Rock Canyon area is divisible into two parts—a northern part in which coal over 4 feet thick is fairly plentiful, and a southern part in which such coal is practically absent—the dividing line following the middle of the canyon and extending northwestward to the area boundary.

Exposures of the coal on the cliffs in this area are probably better than anywhere else in the field, and wherever the coal-bearing rocks can be reached full information is obtainable on the lower beds. Continuous outcrops do not exist, but in most of the area natural exposures are sufficiently close together to permit reliable conclusions as to the amount of coal present. At a few places in Rock Canyon some of the coal is burned, and on the south side of the canyon the slopes of the coal-bearing member are grassy in places. On the whole, however, exposures in this area are excellent.

The value of the thin coal beds on the south side of Rock Canyon is seriously lessened by their high position in the steep cliffs, and even the thick coal beds on the north side of the canyon are for the most part in disadvantageous locations for mining. Two parts of the area, the northernmost and southernmost stretches of cliff, were not reached in the present work because of their inaccessibility.

#### COAL BEDS

*Hiawatha bed.*—The graphic sections of the Hiawatha bed shown in Plate 23 describe it better than words, largely because they are representative and abundant enough to give adequate control. The bed is an excellent body of coal on the north side of Rock Canyon as far west as the township line. Beyond location 371 it thins down to a mere stringer and in places vanishes entirely. On the south side it maintains a fairly constant thickness of about 3 feet, and an upper bed appears about 10 feet above it. The upper bed is very constant in Olsen Hollow and a little north of it. Near the end of the point at the mouth of Rock Canyon a rapid thickening of the Hiawatha bed is noted toward the area on the north side of the canyon where the bed is thick. A large area of thick coal has probably been eroded from the space now occupied by Rock Canyon.

Two country mines have been driven on the Hiawatha bed on the north side of Rock Canyon. The coal was sampled at both mines, and analyses are given on page 71 (Nos. 86404 and 86403). The coal at the southern mine, location 350, has poorer stocking qualities than that from the other, and it is possible that the greater amount of moisture remaining in the air-dried sample has some relation to the permanence of the coal. Both coals are about the same in heating value as that from the Straight Canyon mines, but in physical characteristics they are inferior. The analyses indicate, in connection with those from Straight Canyon, Cottonwood Canyon, and Grimes Wash, an even quality of coal in the Hiawatha bed throughout this part of the field. In carbon ratio the analyses from these mines, six in number, do not vary more than one unit. In heat value they range between 12,440 and 12,770 British thermal units, and all but the lowest are not far from 12,700 British thermal units. In ash the Rock Canyon samples are somewhat different, with 5 to 6 per cent; the others range between 8 and 9 per cent. In moisture, too, the coals of the two drainage areas differ, but here in favor of the Cottonwood Creek samples, which contain, air-dried, 2.2 to 2.8 per cent, as compared with 4.7 and 5.1 per cent in the Rock Canyon samples.

At the northern mine in Rock Canyon the layer of bright coal found above the Hiawatha bed, mentioned in the account of the Cottonwood area, was sampled, and the analysis is given on page 71 (No. 87022). This coal is totally different in appearance from the usual Wasatch Plateau coal. It is brilliant black and breaks along numerous parting planes, which are circular in area, giving it the appearance of birdseye coal. It is friable, and the bed containing it is only 1 foot to 18 inches thick. The analysis shows that it is also different in chemical composition from the usual coal of the field. Perhaps the most remarkable feature is the unusually low percentage of ash. The ratio of fixed carbon to volatile matter is greater than that of the usual Wasatch Plateau coal, and the coal is of higher rank. It contains more sulphur than most coal in the field, but that difference is not so striking. In heating value it is about the same as the coal in the underlying mass of the Hiawatha bed. Coal similar in appearance, and probably in these other characteristics as well, occurs in the same relationship to the Hiawatha bed in Cottonwood Canyon and in Grimes Wash. It would be interesting to determine whether or not this coal will coke, and also whether it is a good coal for blacksmith work.

*Blind Canyon bed.*—In the gulch containing the two mines of Rock Canyon the Blind Canyon bed is 10 to 13 feet thick. This thick lens may have a long north-south axis and may reach as far north as the gulch south of Cottonwood Canyon, where it is about 7½ feet thick. It is known to thin southward and westward, however, and the excellent exposures from place to place in Rock Canyon leave no doubt as to its presence on the south side of the canyon as a mere stringer in some places and its complete absence in others.

Only two good sections of the bed have been found, and at both places it had to be dug out. It is poorly exposed because it is underlain by shale and friable sandstone, and its presence is assured only for the small area about the head of the gulch. In the next gulch on the east it is probably absent.

*Bear Canyon bed.*—On both sides of Rock Canyon the Bear Canyon bed appears, but only in the mine gulch is it thick enough to be of present value. On the west side of that gulch it is consistently about 5½ feet thick for over half a mile, but on the east side of the gulch the best sections show only 2 feet 7 inches of coal, and in the next gulch west it is hardly thicker. On the south side of Rock Canyon the bed is nowhere more than 2½ feet thick, and nearly everywhere it is either absent or represented by a thin stringer.

*Other beds.*—In the gulch occupied by the two mines a coal bed 1 to 2¾ feet thick is present 25 to 40 feet beneath the Bear Canyon bed, as shown by the columnar sections at locations 343, 346, and 350, Plate 23. This bed has not been recognized elsewhere in the area. In the gulch east of the mine gulch, about 485 feet above the base of the Blackhawk formation, a coal bed 2 feet 4 inches thick is present (see section at location 337), but this bed has not been observed anywhere else in the area. The rock exposures are nearly perfect at many places in the area, and it seems fairly certain that the part of the Blackhawk formation above the Bear Canyon coal bed contains little or no coal of any value.

### MINES AND PROSPECTS

Two mines, which were not operated in 1922, have been opened on the Hiawatha bed in the long gulch that heads in the NW. ¼ sec. 5, T. 19 S., R. 7 E. They are accessible by a steep, narrow wagon road, and at times in the past they have supplied the residents of Ferron, Clawson, and Castle Dale with domestic fuel.

*Killpack mine.*—The Killpack mine (location 345) is near the head of the gulch, in a small side gulch near the place where the Hiawatha coal bed crosses the stream channel. The main entry of this mine has been driven about 250 feet N. 20° W., and at about 125 feet from the mouth a side entry has been driven S. 15° W. for about 100 feet. Another side entry has been driven due north about 100 feet, and two rooms had been turned off in 1922. The coal is brought by hand-pushed car to the mouth of the mine and is dumped down a rock chute to a crude bin from which wagons are filled. The production is small, even when the mine is operating at full capacity. The Hiawatha bed is about 6 feet thick in this mine, and the coal is good. (See analysis 86403, p. 71.)

*Axel Anderson mine.*—Near the mouth of the gulch, high on the cliff of the west wall (location 350), is the Axel Anderson mine. Here the Hiawatha coal is 10 to 12 feet thick, and the adjacent rocks are solid; mining conditions are thus excellent. In 1922 the mine had been driven 275 or 300 feet northwest from the mouth, and four large rooms had been turned from the main entry.

The coal is lowered from the mine mouth to the chute and loading station by a steep tramway, whose over-all gradient is about 73 per cent. The cars, of about 2-ton capacity, are moved to the mine mouth by hand and lowered over the tramway to the head of a chute down which the coal is dumped to the loading station. The road leading from the bottom of the canyon to the chute is very steep and narrow.

A carload of coal at the lower end of the tramway in July, 1922, showed that the coal of this mine probably does not stock as well as most of the Wasatch Plateau coal. The coal had stood there not more than a year, and it showed distinctly the effect of weather.

*Section of Hiawatha coal at Axel Anderson mine*

| | | |
|---|---|---|
| Sandstone, massive, hard. | | |
| Coal | 3 | 2 |
| Bone | | 1 |
| Coal | | 5 |
| Dirty coal | | 2 |
| Coal | | 5 |
| Bone | | 1 |
| Coal | 6 | |
| Shale, hard, granular, slate-gray | 1 | 8 |
| Sandstone, gray-white, massive | 100± | |
| Total coal and bone | 10 | 4 |

*Section in Axel Anderson mine about 200 feet from mouth*

| | Ft. | in. |
|---|---|---|
| Sandstone, massive. | | |
| Coal | 5 | 7 |
| Bone | | 1 |
| Coal, with a few streaks of bone | 1 | 1 |
| Bony coal | | 2 |
| Coal, good, bright | | 4 |
| Bone | | 2½ |
| Coal (base not reached) | 4 | 3+ |
| Total coal bed | 11 | 8½+ |

Farther northwest in the mine the coal is at least 12 feet 6 inches thick. The coal has weathered away considerably at the outcrop and has left a sort of gallery in the cliffs between the two massive sandstones.

*Prospects.*—Prospecting for coal in this area, except near the two mines described, has been discouraged by the roughness and inaccessibility of the country. Not many prospect pits exist, but where the outcrop of the bed has not been burned the exposures are generally good enough to show its presence without digging.

*Conditions affecting mining.*—The only conditions seriously disadvantageous to mining in the Rock Canyon area are the ruggedness of the cliffs in which the coal crops out and the great height of the coal above suitable tipple sites, and the difficulties imposed by these conditions are similar in general to those described for Grimes Wash on page 162, with the exception that the lowland at the base of the cliffs near Rock Canyon is much more intricately dissected, and approach by railroad is consequently more difficult, than in Grimes Wash. The lowest coal bed in Rock Canyon is 1,000 to 1,300 feet above the base of the cliffs, and in most places it is even higher above good tipple sites.

Structural conditions, as far as known, are favorable for mining. The dip of the coal beds is slight, and the rocks are not faulted. The attitude of the rocks in the area is shown in Plate 32, and the amount of coal present is shown in Plate 23 and in the descriptions on pages 165–167.

Water is scarce and alkaline in this area, and a supply for mining and camp use would have to be piped long distances from the plateau top, or pumped from the irrigation canals of Castle Valley. Timber is fairly plentiful on the top of the plateau, but none of value for mining is to be found below. The timber necessary for mining might be brought down from the plateau by a road in Rock Canyon. At the mouth of Rock Canyon there is room for town sites, but the canyon itself is too narrow and rocky.

## FERRON AREA

The fractured condition of the rocks in the Ferron area has left the tracts of coal land more or less irregularly scattered, and has introduced zones in which no coal is at the surface. East of the fault zone outcrop burning has been extensive, and the cliffs are practically inaccessible. It is fairly certain, by the interpolation of this stretch of cliffs between known places on the north and south, that little or no coal over 3 feet thick is to be found there. In the fault zone coal beds more than 3 feet thick appear to be rarely present. West of the fault zone coal beds as much as 8 feet in thickness have been found, but the exposures are not so good as those in Rock Canyon and Cottonwood Canyon.

A general survey of the coal in the area shows, so far as commercial values are concerned, that coal more than 4 feet thick is almost entirely restricted to the part of the area west of the Upper Ferron fault. A small area on Birch Creek may prove worthy of small-scale development, but elsewhere the prospect of commercial operation in the fault zone seems slight, owing about equally to the thinness of the coal beds and to the faulted character of the ground.

### COAL BEDS

Three coal beds, the Hiawatha, Upper Hiawatha, and Slide Hollow, are thick enough in places to deserve mention. The Upper Hiawatha

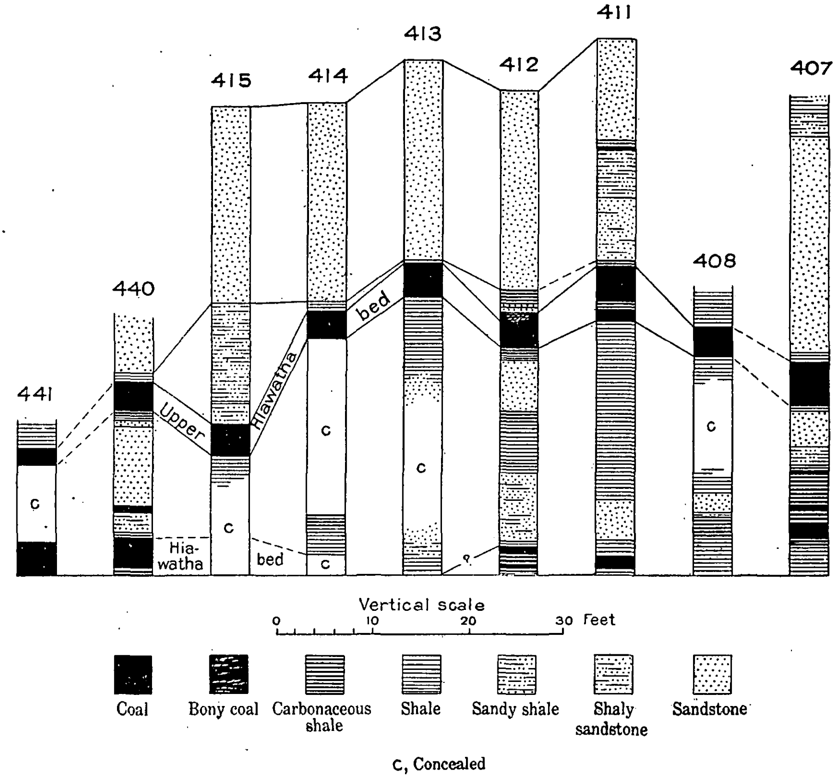
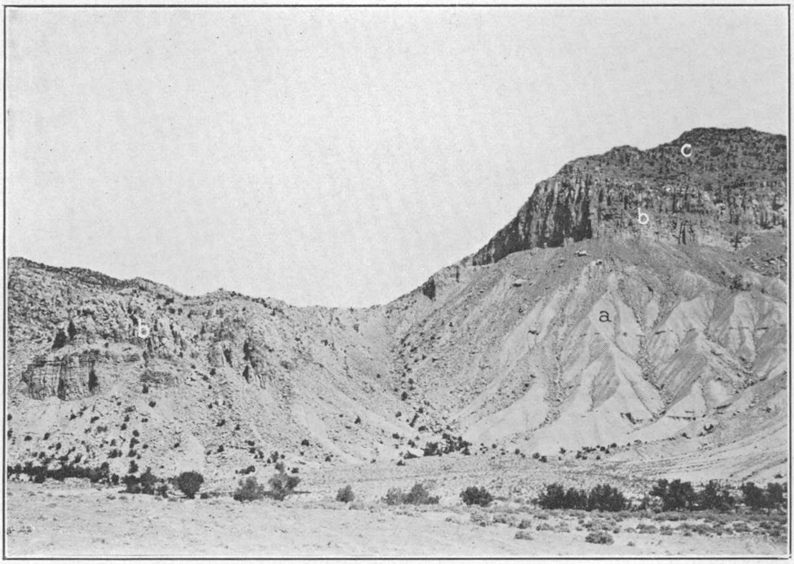


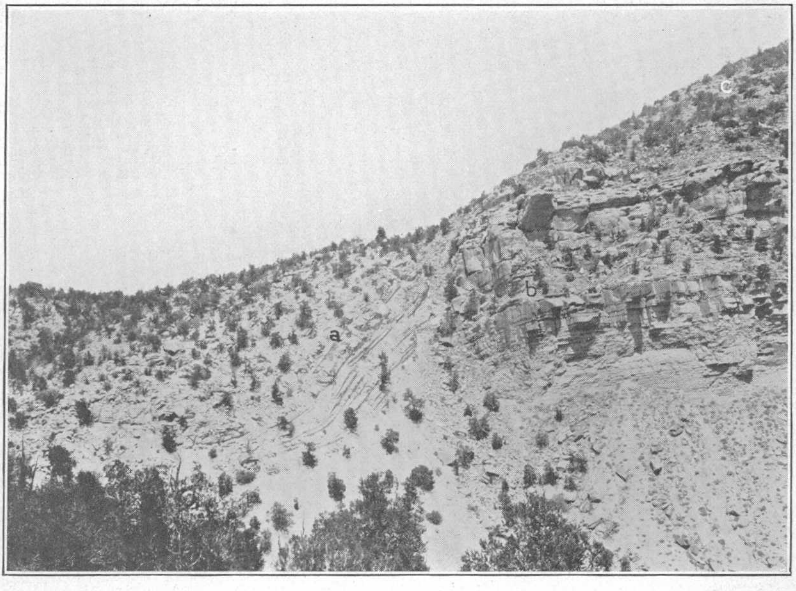

FIGURE 7.—Short columnar sections of lower part of Blackhawk formation in Ferron Canyon, showing correlation of coal beds

bed may not be the same as the bed of that name in Rock Canyon, but it is so named more to designate its nearness to the Hiawatha bed than to indicate precise correlation. The Slide Hollow bed occurs in a fault block in Slide Hollow, detached from the best key beds of the region, and its position in the Blackhawk formation is not absolutely certain. It is estimated chiefly on the basis of structural relations in and near Slide Hollow to be probably 200 feet above the Hiawatha bed. It has been recognized in Slide Hollow only.




*A.* PARADISE FAULT AND ADJACENT SHEAR ZONE EXPOSED ON NORTH WALL OF FERRON CANYON

The fault passes almost directly down the gulch in the center of the view. a, Upper member of Mancos shale; b, Star Point sandstone; c, Blackhawk formation.




*B.* PARADISE FAULT EXPOSED IN THE HOLE, NORTH OF MUDDY CREEK

a, Flagstaff limestone; b, Star Point sandstone; c, Blackhawk formation. The dragged edges of the dropped rocks are well shown at this locality.

The coal sections shown in Plate 25 and Figure 7 are in general complete, and where they are not qualified they probably represent the actual thickness of the beds. Nowhere in the area are exposures of the coal beds good, and practically every thickness represented was obtained by digging.

*Hiawatha bed.*—Just east of the Paradise fault two measurements, at locations 407 and 408, indicate that in general the Hiawatha bed is thinner than in the adjoining part of the Rock Canyon area, and west of the fault the bed is either effectively concealed throughout or is absent. No data are available for the bed in Ferron Canyon within the limits of the fault zone. The top of the Star Point sandstone is fairly well exposed in all the fault blocks as far west as the Joes Valley fault, and in places the beds of the superjacent Blackhawk formation are well enough exposed to show conclusively that the Hiawatha bed is absent or represented by thin beds of carbonaceous shale. Places where this condition exists are not located on the map.

West of the Joes Valley fault the horizon of the Hiawatha bed is about 800 feet beneath Ferron Creek. It is brought nearer to the surface again by the Muddy fault, but it does not appear anywhere in the main canyon between the Joes Valley and Upper Ferron faults.

In Slide Hollow the bed is present for a short space west of the Muddy fault, and sections taken at locations 419 to 422 show it to be 3 to 4 feet thick. This short stretch of outcrop affords the only information on the bed in the block west of the Muddy fault, and the constancy of thickness observed farther west, in Stevens Creek, suggests that it may be 4 feet thick, more or less, in all of this block.

West of the Upper Ferron fault the Hiawatha bed crops out in Stevens and Dairy Creeks and in a stretch nearly 1½ miles long in Upper Ferron Canyon. In practically all of the area controlled by these exposures it is from 4 to 8 feet thick, and its commercial value is diminished only by its relative inaccessibility.

*Upper Hiawatha bed.*—A bed which occurs, in this area, normally about 25 feet above the top of the Star Point sandstone is here called the Upper Hiawatha bed in the sense that it is the uppermost of a series of beds and benches of coal that might properly be called the Hiawatha coal group. This grouped condition of several coal beds within 20 to 30 feet of the Star Point sandstone is fairly constant throughout the field south of Rock Canyon, and inasmuch as the group is normally divisible into two units of coal that may be regarded as individual beds (that is, thickness of coal, bone, shale. and sandstone in which the coal is usually separated by rock not thicker than the benches of coal) the two units are called the Hiawatha and Upper Hiawatha beds. In the Rock Canyon area the bed called the Upper Hiawatha is probably equivalent to the upper bench of the Hiawatha bed in Ferron Canyon, if so exact an equivalency may be stated, and the name Upper Hiawatha has no exact correlative meaning. In Rock Canyon the name is applied to the upper bed because it is distinct and is farther from the main Hiawatha bed than the upper bench of Ferron Canyon and elsewhere. South of Ferron Canyon the name as applied in this work bears more consistent significance.

The Upper Hiawatha bed is variable in thickness east of the Paradise fault. In the zone of sheared rocks west of the fault, in Biddlecome Hollow, a bed exposed in two old mines and a prospect pit (locations 409 to 411), considered to be probably the Upper Hiawatha, is 5 feet or more thick, and were it not so unfavorably located, in a zone of sheared and broken rocks, it might claim commercial attention. The rocks near the coal are sheared to an extent that makes doubtful the correlation of the bed. On the south side of Ferron Canyon the bed is visible in two prospect openings and two rather poor exposures, where it is thinner on the whole than in Biddlecome Hollow. West of location 415 the conditions true of the Hiawatha bed apply also to the Upper Hiawatha. West of the Upper Ferron fault the bed is 2 to 4½ feet thick. It holds some commercial possibilities where it is thickest, but for the most part it is not of great value, and its development is something of a problem on account of the proximity of the Hiawatha bed, which has a better claim for attention. On the whole the Upper Hiawatha bed is not of great importance in this area.

*Blind Canyon (?) bed.*—In Upper Ferron Canyon, at location 430, a bed appears about 45 feet above the Star Point sandstone, so far above the normal position of the Upper Hiawatha bed that it hardly seems safe to consider it other than separate, with the reservation that it may be the Upper Hiawatha, higher than usual because of the thickening of the massive sandstone beneath it. It is at the horizon of the Blind Canyon bed and is referred to as the Blind Canyon (?) bed, with no suggestion that it has any actual connection with the Blind Canyon bed of Rock and Straight Canyons. At location 430 it is 5 feet thick. Elsewhere in the canyon no coal appears in the broken slopes at the horizons of this bed, but the exposures are for the most part so poor as to indicate nothing concerning its extent. It is certainly not present near the Upper Ferron fault.

*Slide Hollow bed.*—The bed here called the Slide Hollow bed is exposed in three prospect pits and an old mine in the lower part of Slide Hollow, on Birch Creek. There the bed is about 8 feet thick and would be valuable but for the unfavorable structural conditions affecting it. It is fairly accessible and may be thick enough to make a profitable mine if its extent between faults is large enough. The Slide Hollow bed has not been recognized elsewhere in the area.

### FAULTS

Perhaps the most striking geologic feature of the Ferron area is the profusion of faults exposed in the canyon of Ferron Creek. These faults, all of which belong to the Joes Valley fault zone, are

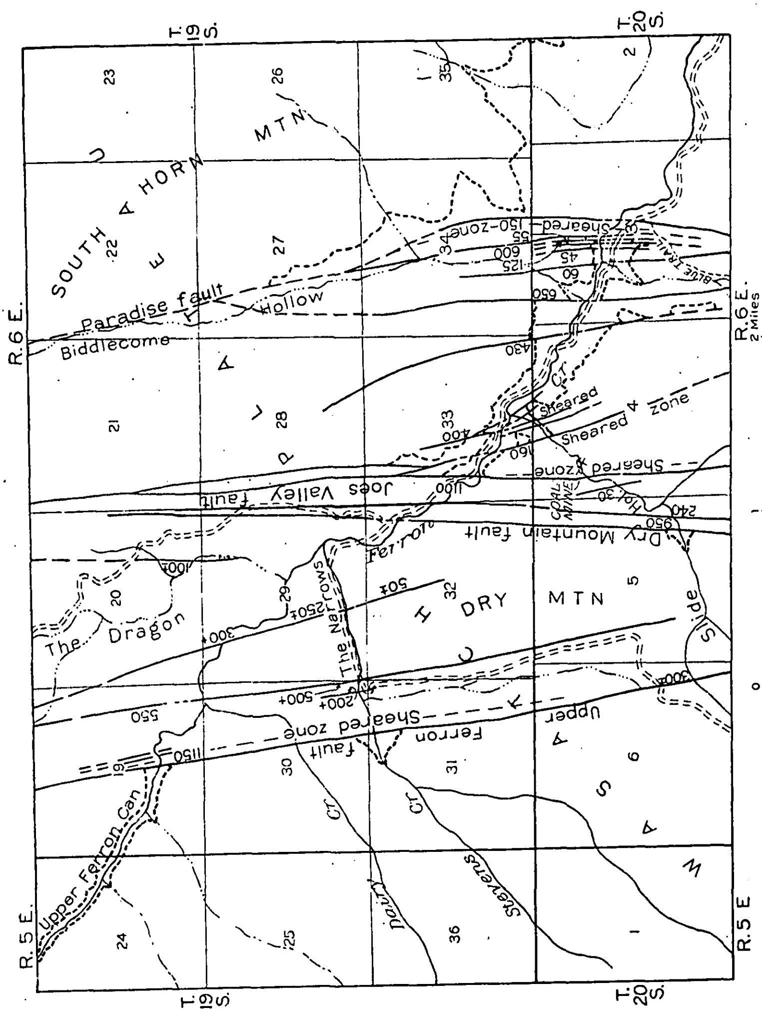



FIGURE 8.—Map of part of Ferron Canyon showing faults. Displacement in feet shown on downthrown side. Heavy dotted line indicates outcrop of Hiawatha coal bed

shown on Plate 31, and the known displacements are shown on Figure 8. The faults shown on Figure 8 are those which are visible in and near Ferron Canyon, where rock exposures permit fairly thorough observation of structural detail. Other minor faults, not shown on the map, may exist north and south of Ferron Canyon. Near many of the larger faults the rocks are much jointed, sheared, and dragged, and the principal places where this condition exists are designated on Figure 8.

The principal faults are the Paradise, Joes Valley, Dry Mountain, and Upper Ferron faults. The Paradise fault branches from the Joes Valley fault in sec. 32, T. 18 S., R. 6 E., and south of this place it is the easternmost of the zone as far as Ivie Creek. The wedge-shaped block between the Paradise and Joes Valley faults is considerably sheared by minor faults, as shown on Figure 8 and Plate 24.

Between the Joes Valley and Dry Mountain faults is a graben, which forms the valley east of Dry Mountain, which in turn represents a horst bounded by the Dry Mountain fault and the next fault west. The north-south valley west of The Narrows represents the westernmost graben of the zone, and the pronounced western wall of this valley is the scarp of the Upper Ferron fault.

## MINING

There are no operating mines in the Ferron area, but several old entries give evidence of past attempts at local development. A good country mine in this area, accessible to the residents of Castle Valley in and near the town of Ferron, would probably thrive.

*Biddlecome Hollow mines.*—In Biddlecome Hollow two mines have been driven on a bed, probably about 25 feet above the Star Point sandstone, in one of the narrow fault blocks west of the Paradise fault. These mines are about half a mile by road from Ferron Canyon and about 6½ miles from the town of Ferron. The road has been washed out by floods and was not passable in 1922. Both mines are about 50 feet above the bottom of Biddlecome Hollow.

The southern of the two mines consists merely of an entry which has been driven N. 50° W. about 50 feet to a fault that cuts the coal off completely. The presence of the fault probably was the chief deterrent to development, but the coal bed is not attractive, as may be seen in the following section, which was measured in the entry:

*Section of coal in southern entry in Biddlecome Hollow*

| | Ft. | in. |
|---|---|---|
| Sandstone, argillaceous, gray | 6 | 6 |
| Shale, containing coal laminae | | 8 |
| Coal, very resinous | 2 | 5 |
| Coal, bony | | 3 |
| Coal | | 2 |
| Coal, bony | | 4 |
| Coal | | 4 |
| Shale, containing few coal laminae | | 11 |
| Coal | 1 | 2 |
| Shale, gray | 18 | |
| Total coal | 4 | 8 |

The northern mine, the mouth of which is about 270 feet N. 15° E. of the southern one, has been driven N. 45° W. about 100 feet, and one room has been turned to the south. The entry ends against the same fault as that in the other mine. At this mine the coal bed is as follows:

*Section of coal bed in northern mine in Biddlecome Hollow*

| | Ft. | in. |
|---|---|---|
| Sandstone, massive. | | |
| Sandstone, gray, fine grained | 1 | |
| Shale, carbonaceous, black, very hard | | 6 |
| Coal, resinous | 3 | 6 |
| Bone, sandy | | 3 |
| Coal | 1 | 7 |
| Shale. | | |
| Total coal | 5 | 1 |

The bed is more pure at this place and might be worth development for local use. The operators may have been discouraged by the fault, but there is nothing apparent to prevent lateral extraction of coal from the block.

*Slide Hollow mine.*—In the little gorge of Birch Creek, part of the large depression known as Slide Hollow, is an old mine from which a moderate amount of coal has been taken but which has not been operated for a number of years. The mine is a little more than half a mile from the main road in Ferron Canyon and was formerly accessible by a mine road, but in 1922 only slight traces of this road remained and even saddle-horse travel in the canyon was difficult.

The main entry of the mine has been driven about 250 feet S. 20° E., and five rooms have been turned. In the mine the coal dips 9° W., and the strike is about N. 25° W. The entry has been driven approximately on the strike of the rocks. At the end of the entry the roof dips down suddenly, in manner similar to that common in "wants," and the coal thins abruptly from 8 feet to 3½ feet. The coal here is friable and powdery, and the upper part of the bed has the appearance of burned coal. Between the coal and the overlying sandstone is 1 to 2 inches of a powdery white material much like ash. It is thus possible that the coal has been burned here, although it is difficult to account for the origin of a fire 250 feet from the outcrop, with the intervening coal unburned.

The coal in this mine is not as fresh and hard as that normal to the field but has more the appearance of outcrop coal. The joint planes are covered with rusty-looking resin. The lower part of the bed is better than the upper part. Near the roof and floor the coal contains many inclusions of sand, called "spar" by miners in the field.

The roof of the mine is a homogeneous massive sandstone that is so friable that huge blocks of it have fallen into all the rooms, although it appears solid and massive. It crumbles readily in the hand. Timbers in the main entry show no sign of stress, yet the roof has caved completely in all the rooms save one. The condition of this sandstone and the coal shows how far from the outcrop the effect of weather may penetrate in faulted zones.

*Prospects.*—Near the mines described above are prospect pits which show thicknesses of coal similar to those in the mines. Prospecting has been limited in this area by the meager occurrence of coal at the outcrop. In Ferron Canyon, just above the gate entrance to the Manti National Forest, is a prospect pit on the Hiawatha bed, and about a quarter of a mile farther west is another showing about 3 feet of coal. On Stevens and Dairy Creeks some prospecting has been done, and sections on the coal there are given in Plate 25.

In the upper canyon of Ferron Creek prospecting has been encouraged by the greater thickness of the coal, and several pits have been dug. Near the point where the Hiawatha bed crosses Ferron Creek is an old opening in the vicinity of which are evidences of much past activity.

*Conditions affecting mining.*—The faults of the Joes Valley zone and the general lack of thick coal beds in the eastern part of the area are the chief obstacle to mining in this area. West of the fault zone the principal difficulty is access to the coal. A summary of these conditions shows that the Ferron area is less promising for large-scale operations than the adjacent areas of the field.

The coal west of the fault zone is best accessible in upper Ferron Canyon, and available mine sites there are at least 12 miles from a probable railroad grade in Castle Valley and about 40 miles or more from the proposed railroad to Huntington Canyon. In the 5 miles between the mouth of Ferron Canyon and the gateway to the upper canyon, in sec. 19, T. 19 S., R. 6 E., the canyon bottom rises 700 feet, an average gradient of about 2.65 per cent, and in the upper canyon the gradient is about 2.6 per cent, but the upper canyon is very narrow and rocky.

The apparent scarcity of coal over 30 inches thick within the fault zone may not be representative for those faulted blocks in which the coal beds are beneath the surface, and the larger blocks in the western part of the zone might, in particular, be worthy of testing with the drill. The block underlying Dry Mountain and its continuation north of The Narrows might be mined, if it is found to contain coal, by shaft or slope from fairly favorable mine sites in Ferron Canyon. In the blocks to the east and west of this one the coal is deeper and the likelihood of minor faults is greater.

The most promising coal bed known in the fault zone through outcrops is the Slide Hollow bed, and the old mine on this bed on Birch Creek might be developed into an operation of moderate size, but such an operation would be limited in extent by the faults shown in Plate 32 and Figure 8, and it might be hampered by the dip of the coal bed, which is 9° S. 65° W.

Coal for local domestic use, to supply the part of Castle Valley within 10 miles of the town of Ferron, might be mined on Stevens Creek west of the fault zone, in sec. 31, T. 19 S., R. 6 E. Transportation of the coal, the principal problem for such operation, might be provided for by an extension westward of the road in The Narrows.

All the creeks from the plateau contain a good supply of clear, pure water, and all possible mine sites would be well supplied. Timber is fairly plentiful on the plateau top and might easily be brought down by existing roads.

## MUDDY CANYON AREA

### COAL BEDS

In the Muddy Canyon area four beds of coal are intermittently thick enough to work. These beds, the Hiawatha, Upper Hiawatha, Muddy No. 1, and Muddy No. 2, together contain a fairly promising amount of coal, and they make almost certain the future development of Muddy Canyon as a mining district.

Exposures in Muddy Canyon are generally good, and the evidence presented by several of the measured sections is therefore closely indicative of the actual variation in the thickness of the several coal beds within the area. The section at location 470, for example (pl. 28), which shows the two Hiawatha beds to be totally absent, is conclusive. Other sections not far distant corroborate this evidence. Likewise the section at location 453, which shows only thin beds of coal above the Hiawatha bed, is final in its evidence.

Thick coal in the lower beds is almost restricted to the north side of Muddy Canyon between the Muddy Canyon fault and Last Water Canyon, and in the upper beds it is centered about the place where the Star Point sandstone crosses Muddy Canyon.

On Nelson Mountain exposures are not plentiful, but enough was seen of the coal measures in the present work to show that no important bed is present. The east face of the mountain and Youngs Point were not investigated in this work because of inaccessibility, lack of importance, and poor prospect of gaining valuable information.

At the north end of Nelson Mountain is exposed a " want " in the Upper Hiawatha bed similar to the " wants " in the King No. 1 and

King No. 2 mines, farther north. The sandstone overlying the coal bed thickens downward, cutting out all but 1 foot 2 inches of the coal, and within a short distance the sandstone thins again and the bed has its normal thickness of about 6 feet. Another "want" is exposed in the tilted block south of Muddy Creek in secs. 16 and 21, T. 21 S., R. 6 E. The center of this "want" at the outcrop is at location 487, where the rocks are clearly exposed and the cutting out of the coal bed by thickening of the overlying sandstone is unmistakable.

*Hiawatha bed.*—In Nelson Mountain the Hiawatha bed appears to be less than 2 feet thick as a rule. In much of the outcrop it is burned, but nowhere does the evidence suggest the presence of a valuable coal bed.

In the tilted block east of the Muddy Canyon fault the bed is generally absent. Its place is taken by carbonaceous shale, laterally grading in places to gray shale, and in many places the shale contains a stringer of coal 6 inches or so thick. At several places in Muddy Canyon the edges of the beds above the Star Point sandstone are clearly exposed in cliff-faced gullies, and there the absence of the bed is obvious. Elsewhere in the block the covering of alluvium above the top of the Star Point might suggest concealment of the coal, but it is not likely to be present anywhere. The evidence in Wileys Fork of Muddy Creek is similar, and the distant view of the largely inaccessible cliffs in Wash Rock Canyon, a tributary of Muddy Creek, suggests the absence of coal at the horizon of the Hiawatha bed.

In Muddy Canyon the bed is variable to an extent that is surprising to one who is familiar with it farther north. It is thin near the Muddy Canyon fault on both sides of the canyon. On the north side it thickens rapidly westward, and between locations 452 and 461 it is for the most part over 4 feet thick with a maximum observed thickness of 8 feet 7 inches at location 461. Between locations 461 and 462 it thins to about 2 feet, and as far west as Last Water Canyon it is no thicker. Still farther west it disappears entirely, and the evidence found on the south side of the canyon indicates that it is almost completely absent there. In the cliffs south of Wash Rock Canyon it is probably thin as far south as sec. 30, T. 21 S., R. 6 E., but as seen from the terraces below it appears to be a bed of coal 4 or 5 feet thick in the point east of Link Canyon, near the center of sec. 31. This thickness may be overestimated, and it is also possible that the bed contains much carbonaceous shale, which is not distinguishable from coal in distant view.

For the area as a whole the Hiawatha bed is worthy of commercial attention only in the stretch between locations 452 and 461. The position of location 461, at the very head of the gulch, suggests a thickening northward that will bear investigation, at least, and the fact that the trend of thick lenses of coal in this field is in many places nearly north-south lends strength to the prospect of finding a minable body of coal in this bed.

*Upper Hiawatha bed.*—For the most part the Upper Hiawatha bed is of less value in this area than the Hiawatha bed. At the north end of Nelson Mountain it is of workable thickness, and it may be equally thick in part of the east front of the mountain. At the south end of the mountain, however, the bed ranges from 1 to 3 feet in thickness and is accordingly of small present value. The thicknesses of this bed on Nelson Mountain are shown in the sections for the Hiawatha bed at locations 443 to 450, Plate 32, and columnar sections on Nelson Mountain are shown in Figure 9.

In the tilted block east of the Muddy fault the Upper Hiawatha bed is constantly about 3 feet thick, except in the short stretches where the "want" above mentioned cuts it out. South of Muddy Creek this thickness prevails as far as exposures are present; in the block west of Emery the bed is obviously irregular and probably not more than 3 feet thick at any place.

In Muddy Canyon west of the fault zone the bed is thickest in much the same area as that in which the Hiawatha is thickest, but even there it is not known to be more than 4 feet thick, and generally it is 3 to 3½ feet. It continues in about this thickness farther west than the thick lens of the Hiawatha bed but disappears between locations 469 and 470, where the beds are burned and no data are available. Near the point where the horizon crosses Muddy Canyon, however, between locations 471 and 472, a bed which is here called the Upper Hiawatha appears and reaches a thick-

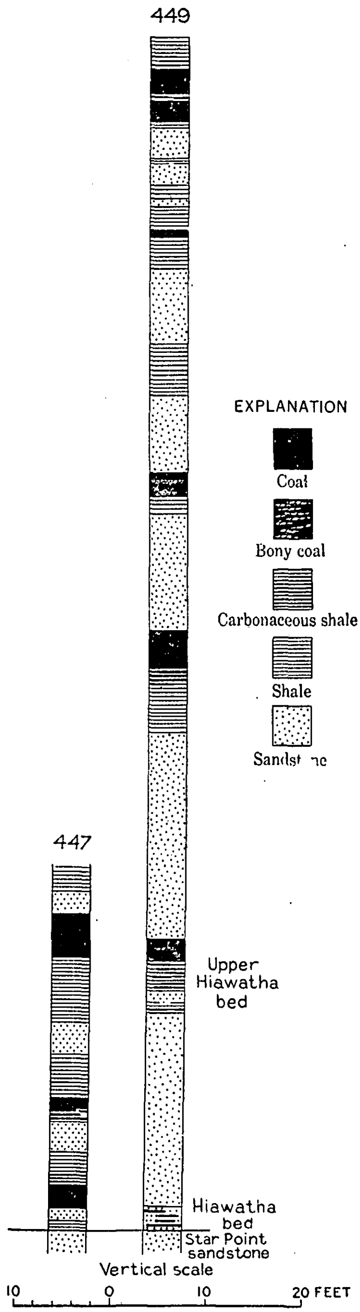



FIGURE 9.—Short columnar sections of lower part of Blackhawk formation on Nelson Mountain

ness of more than 5 feet. This bed is somewhat higher in the section than the Upper Hiawatha farther east and quite obviously is not connected with it by coal on the outcrop, but it may be called the Upper Hiawatha in the sense that it is the uppermost of what might be designated the Hiawatha coal group. It is barely possible that this bed represents the northwestern edge of the lens which shows so strikingly in Quitchupah Canyon and in which the coal attains thicknesses of 18 feet and more. Here again the possibility of a northward-trending lens makes the bed worth prospecting. On the south side of Muddy Canyon the Upper Hiawatha bed is either thin or absent in all exposures.

*Muddy No. 1 bed.*—The Muddy No. 1 bed is the lowermost valuable bed of a group which may here be called the Muddy coal group. On the whole this group of beds is too far from the beds of similar horizons farther north to justify using their names, and it is somewhat lower in the section than the normal position of the Ivie coal beds which bear the important coal south of Convulsion Canyon and may be represented here. The use of names such as Ivie, on the one hand, or Cottonwood and Blind Canyon, on the other, would introduce undesirable suggestions as to the continuity of the beds. If names were to be extended, with our present knowledge, Ivie would be preferable for the Muddy No. 2. The use of local names seems the best way out of the difficulty, with the reservation clearly made that mining through from Quitchupah and Convulsion Canyons may prove the equivalency of the Ivie and the Muddy No. 2 beds.

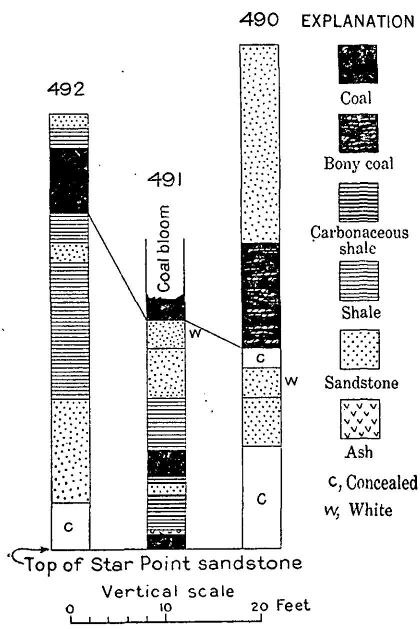



FIGURE 10.—Short columnar sections of lower part of Blackhawk formation on hill west of Emery

The Muddy No. 1 bed appears from place to place throughout Muddy Canyon, and it is certainly 4 to 6 feet thick for the most part between Last Water Canyon and location 471 in Muddy Canyon. Near the mouth of the main canyon it appears to be less than 2 feet thick, except in Wileys Fork, where it is 4 feet thick for a short distance near location 480.

The section measured at location 470 shows 6 feet 3 inches of coal, but the top of the bed is burned, and the scorched condition of the overlying rocks suggests that considerable coal has been destroyed. Where the bed crosses Muddy Canyon it is somewhat thinner, but on the south side are found thicknesses correlative with that of location 470, and the thick coal extends farther east. It is nearly 9 feet thick in the canyon east of Box Canyon, and it may continue eastward at such thickness into the burned and inaccessible stretch of cliffs between locations 478 and 479. In Wileys Fork Canyon it is variable and probably valuable only in spots.

In the hill northwest of Emery the bed appears in thicknesses of more than 6 feet for a stretch of possibly a mile. (See fig. 10.) At location 491, where it is well exposed, it is split in a manner that shows clearly a comparatively rapid change of conditions during the time when it was laid down. This section may be of interest in detail, because of the unusually fine lamination it shows. The bed lies here between massive sandstones, and the section is as follows:

*Section of Muddy No. 1 coal bed in prospect pit at location 491*

| | Ft. | in. |
|---|---|---|
| Sandstone, buff, massive. | | |
| Bony coal | | 1½ |
| Sandstone, gray, very fine grained | | 3 |
| Coal and bone, laminated | | 1 |
| Sandstone, fine grained, gray, coal laminae at top | 1 | |
| Bone, sandy, coal laminae | | 5 |
| Coal | | 2½ |
| Sandstone, fine grained, containing laminae of coal | | 6 |
| Coal | | 10 |
| Sandstone as above | | 3 |
| Sandstone, massive, light buff | 1 | 8 |
| Sandstone, finely laminated, gray | | 2 |
| Bone | | 1 |
| Coal, good at top, poor at base | 1 | 6 |
| Bone, light gray, porcelain-like, hard | | 2 |
| Bone with many laminae of coal, dark gray | | 4 |
| Bone, porcelain-like, gray, lenticular | | ¼ |
| Coal | | 5 |
| Bone as above | | ½ |
| Coal, bright and dull laminae | 1 | |
| Coal, dirty | | 7 |
| Bone | | 6 |
| Coal | | 6 |
| Concealed (may be coal) | 1 | |
| Sandstone, very fine grained, white, massive. | | |
| Total bed | 11 | 7¾ |
| Total good coal | 4 | 5½ |

The perfect detail shown in this exposure reveals a minute lamination that is not common in this field. The units given in the section may be followed in the cliff of coal at this outcrop for 200 feet, and they are as constant and perfect as the laminae of a marine formation. The coal is of little commercial value on account of the fine interlamination of bone.

Elsewhere in the general vicinity the bed appears to be purer, but the shearing and faulting in the hill decrease its value for mining. The fact that it is so much lower and hence more accessible than the coal west of the fault zone has encouraged prospecting, but the writer was informed by residents of Emery that the adits, now caved, discouraged the prospectors because they revealed faulting.

A summary of these observations shows at once that the Muddy No. 1 bed is the most valuable bed in the Muddy Canyon area. It is 4 feet or more thick in a longer stretch of outcrop than any other bed, and the possibility is strong that it continues southward into the Quitchupah area, where, if present, it is largely burned at its outcrop.

*Muddy No. 2 bed.*—Evidence on the Muddy No. 2 bed is not so complete as that on the Muddy No. 1, but there is reason to suspect its presence in places for which no conclusive data are available. Near the fault zone in Muddy Canyon the bed may safely be said to be not much over a foot in thickness. As far west as Last Water Canyon, at location 464, data are lacking. Beyond location 464 the bed may be workable as far as location 470, where it seems from the extent of burned rock to be possibly a thick bed.

Where the bed crosses Muddy Canyon (location 471 c) it is split into two members, each about 2 feet thick. In Box Canyon the upper split is burned at the outcrop, and it is not likely to be valuable. Somewhere between Box Canyon and the next canyon on the east the bed thickens to about 5 feet, but beyond that canyon and Wileys Fork it pinches out.

*Higher beds.*—Above the horizon of the Muddy No. 2 bed coal over 2 feet thick appears to be rare in this area, but at location 481, in Wileys Fork Canyon, a bed of clear coal 8 feet thick was found about 117 feet above the base of the Blackhawk formation. Owing to lack of space, this bed is not shown on Plate 28, but the section containing it is given here.

*Section at location 481, joining at base with graphic section shown on Plate 28*

| | Ft. | in. |
|---|---|---|
| Sandstone, with one thin shale parting near base | 25 | |
| Coal | | 5 |
| Sandstone, irregular | 6 | |
| Coal | | 8 |
| Sandstone, irregular | 1 | 6 |
| Shale, carbonaceous | 1 | |

| | Ft. | in. |
|---|---|---|
| Sandstone, massive, buff | 4 | |
| Coal | 8 | |
| Shale | 1 | |
| Sandstone, massive, buff | 14 | |
| Coal, good | 1 | 1 |
| Coal, impure | | 8 |
| Shale, sandy, gray | | 8 |
| Sandstone, massive, buff | 4 | 8 |
| Coal | | 10 |
| Sandstone, massive, buff | 2 | 10 |
| Coal | | 6 |
| Shale, gray | | 8 |
| Sandstone, gray | 3 | 8 |
| Shale, with carbonaceous streaks and sandstone partings (uppermost unit in graphic section for location 481, pl. 28) | 16 | |

The 8-foot coal bed in this section was not certainly recognized in Muddy Canyon west of Wileys Fork, but it may be represented by burned rocks at location 470 and by a bed at the same horizon 1 foot 6 inches thick at location 474, not shown on Plate 28 for lack of space. The bed may be present at numerous other places where the rocks are burned and at some places where the cliffs are unscalable. It seems probable, however, that the thicker stretches of this bed follow the general north-south trend common in thick lenses of coal in the field; it may be equivalent to the bed on Nelson Mountain near the top of the section at location 447 (fig. 9), which is there about 5 feet thick, with a parting in the middle, and to a bed at the same horizon in Biddlecome Hollow, location 407 (pl. 6), about 3 feet thick. At the nearest exposures southwest of Wileys Fork, in Link Canyon, the bed at location 497 c may be the same; this bed, as pointed out on page 193, may be equivalent to the Upper Ivie bed of Convulsion Canyon. Future prospecting for this bed in the Muddy Canyon area therefore promises most in the eastern part of Muddy Canyon.

### FAULTS

The Joes Valley fault zone crosses the eastern part of the Muddy Canyon area, separating Nelson Mountain from the main mass of the plateau and introducing a belt of irregular surface features in the lower part of Muddy Canyon. The zone is considerably simpler here than in the Ferron area, but the maximum displacement of the rocks is greater. Four major faults are present, and between the Paradise and the Muddy faults, the extremes, the dropped block normally constituting the zone is clearly defined. (See structure section H–I, pl. 32.) The limiting faults in this area are not the same as those north of the Ferron area but are about a mile farther east.

The greatest displacement in the zone is near the eastern edge instead of near the middle, as in the Ferron area, and on Muddy Creek the rocks rise westward in three steps, produced by the three western faults, in a total displacement of about 2,800 feet; but the cumulative effect of these faults is partly neutralized by westerly dips in the faulted blocks, and the actual difference in altitude on a given stratigraphic horizon between the lowest block and the area west of the zone is probably 700 feet less.

The maximum displacement of the Paradise fault, west of Nelson Mountain, is about 2,250 feet. This estimate is not certain, because of apparent variability of the Wasatch rocks exposed west of the fault, but in the writer's opinion it is not far wrong. The Paradise fault is perfectly exposed at the head of The Hole, in the southern part of sec. 34, T. 20 S., R. 6 E., where the pronounced drag of the rocks west of the fault is well displayed by the regular beds of the Flagstaff limestone, which rise at high angles toward the fault surface and abut sharply against the Star Point sandstone and the Mancos shale. (See pl. 24, *B*.) Just west of the Paradise fault at this place is a parallel fault of opposite displacement, shown on Plate 32. Less than a mile south of this place the Paradise fault veers southwestward, and this change is reflected more broadly by all the faults on the west. Throughout the length of The Hole the faulted condition of the rocks is evident in sheared masses of the Castlegate sandstone and the Blackhawk formation, and in sec. 3, T. 21 S., R. 6 E., where the fault zone changes trend, at least two sharply defined faults accompany the Paradise fault. Farther south in section 3 the second major fault of the zone appears to branch from the Paradise fault, and between the two faults lies a block in which the Castlegate sandstone is exposed near Muddy Creek, abutting on the east against the Emery sandstone member of the Mancos shale and on the west against the Blackhawk formation and the Star Point sandstone. The strip of rocks adjacent on the west to the Paradise fault is probably much shattered between Muddy Creek and Nelson Mountain.

On and near Muddy Creek the four major faults are clearly visible, as shown by Plate 26. The two blocks between the three eastern faults are narrow, and the rocks in them are considerably shattered north of Muddy Creek, but south of Muddy Creek less shattering is evident. Still farther south, in the hill northwest of Emery, the rocks are considerably shattered by minor faults and joints. The displacement of the first fault west of the Paradise fault (B, pl. 26) is probably not less than 900 feet on Muddy Creek. That of the next fault to the west is about 500 feet north of Muddy Creek but decreases southward until it is not much over 100 feet near location 488. (See pl. 32.) The westernmost block of the zone is tilted westward at angles of 10° to 14°, and the rocks in it are much jointed but not broken by minor faults on Muddy Creek. Farther south, in the ridges and canyons northwest of Emery, the rocks of this block are much shattered. The displacement of the Muddy fault, the westernmost of the zone, is about 1,300 feet on Muddy Creek. West of this fault the rocks are unbroken.

## MINING

There are no mines in the Muddy Canyon area. The coal is everywhere either too high in the cliffs or too far from markets to encourage wagon mining, and larger-scale development is probably a matter of the distant future. The town of Emery, which would afford the market for domestic coal from Muddy Canyon, receives its supply from mines in the Emery coal field, which are accessible by better roads and are not so far distant.

Prospecting, however, has been active wherever enough coal shows at the surface to engage attention. In Muddy Canyon a number of pits have been dug on the coal beds, and in the faulted block west of Emery several attempts have been made to open up the coal. At none of these places, however, is it worth while to consider mining for domestic supply, and for a number of years no prospecting has been done.

The Muddy Canyon area is divisible into three parts, in which the conditions affecting mining are different. The easternmost part is east of the Joes Valley fault zone and consists of Nelson Mountain; the middle part consists of the fault zone; and the westernmost the plateau west of the fault zone.

The principal condition affecting mining in Nelson Mountain is the difficulty of access to the coal, as the rocks are probably not faulted beyond the amount shown on Plate 32. The area underlain by coal beds is not large. Probably the best approach to the coal is by way of Dry Wash, a tributary of Ferron Creek, but any mine site on the mountain will entail the problem, usual on the plateau front, of lowering the coal 1,000 to 1,400 feet from mine mouth to tipple.

Within the fault zone the sheared condition of the rocks is the principal factor to be considered in mining plans, and to this undesirable feature is added the apparent scarcity of coal over 30 inches thick.

West of the fault zone the principal factor is again accessibility of the coal, and this part of the area, which can be reached by way of Muddy Canyon, is the most promising part for large-scale development. A railroad probably could be built in Muddy Canyon, subject to the obstacles common to all such canyons in the field, without unusual difficulty; in the lower part of the canyon the gradient of the creek ranges between 2 and 2½ per cent, and the maximum gradient within 2 miles of the point where the top of the Star Point sandstone crosses the creek is about 3 per cent. The canyon is fairly broad east of the Upper Ferron fault, but farther west it is narrow, and little choice of route is available.

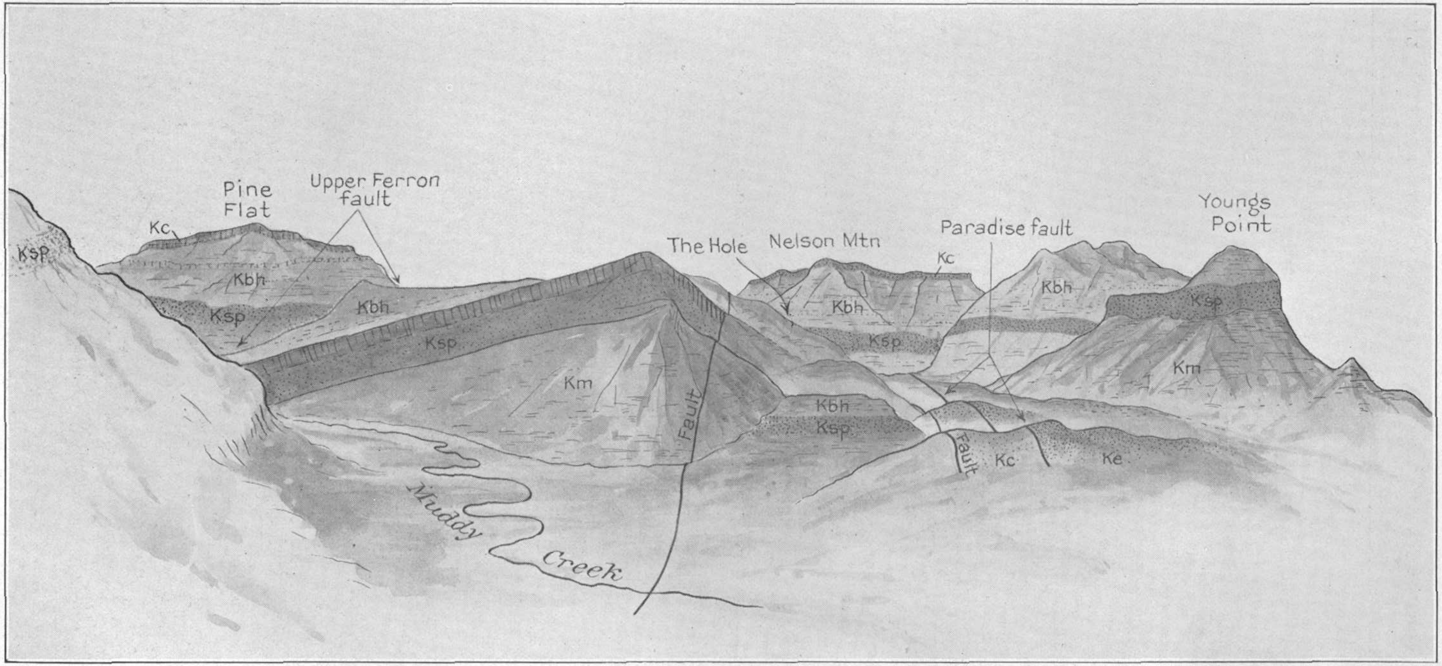
The coal may have to be hauled from the mine mouth to the railroad by tramway or other type of conveyor in all the side canyons and probably in the main canyon as well. Plates 27, *B*, and 32 give a good picture of the conditions that confront the prospective operator, and it is necessary to add here merely the statement that the cliffs are very steep and are not to be bridged by any sort of haulage system except at great expense. On the north side of the canyon, for example, just west of the Upper Ferron fault, the Hiawatha bed is 1,000 feet above the canyon bottom, and the wall rises the 1,000 feet in an average of about 1,500 feet of horizontal distance. Such a profile, with an angle over all of 35°, represents a total gradient of over 65 per cent. More favorable gradients may be obtained by choice of routes at angles other than 90° to the trend of the cliffs, but on the whole the condition above exemplified is characteristic of most of the canyon.

Water is plentiful in Muddy Canyon but not on Nelson Mountain and in The Hole. Muddy Creek normally contains enough water to supply a mining town, if water rights are available. Timber is plentiful on the top of the plateau and may be brought down by the existing road to Flagstaff Peak and Ferron Mountain.

### CONVULSION CANYON AREA

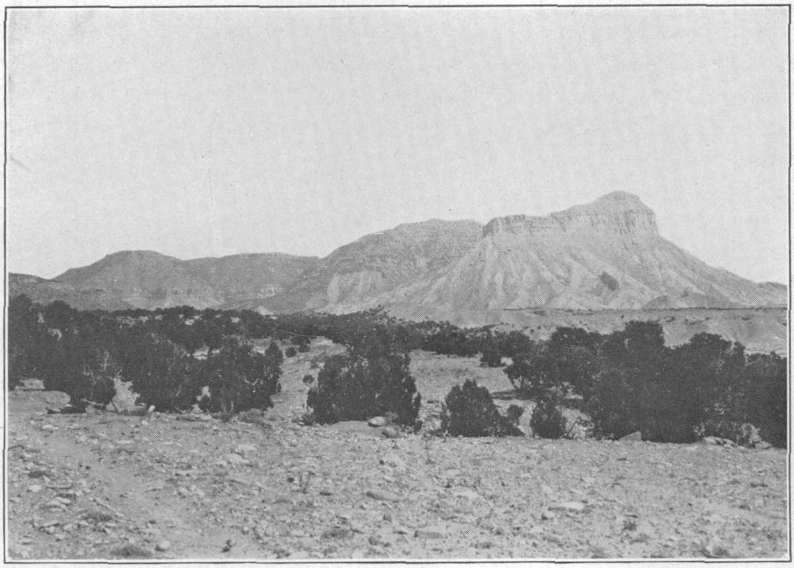
The Convulsion Canyon area is probably the richest in coal in the southern half of the field. Five beds are present in the area, and three of these are more than 4 feet thick in large tracts. Quitchupah Canyon shows the largest amount of coal; East Spring Canyon is next, and Water Hollow third.

It is unfortunate that the coal beds in just those stretches of cliff which probably contain valuable coal are burned at the outcrop to an extent that baffles an attempt at gathering data without extensive prospecting. The east side of Quitchupah Canyon is perhaps the best example of this condition. The writer examined in detail the big gulch in sec. 3, T. 21 S., R. 5 E., without finding a single place where the coal is not either burned or effectively concealed, and the remainder of the east wall of the canyon appears



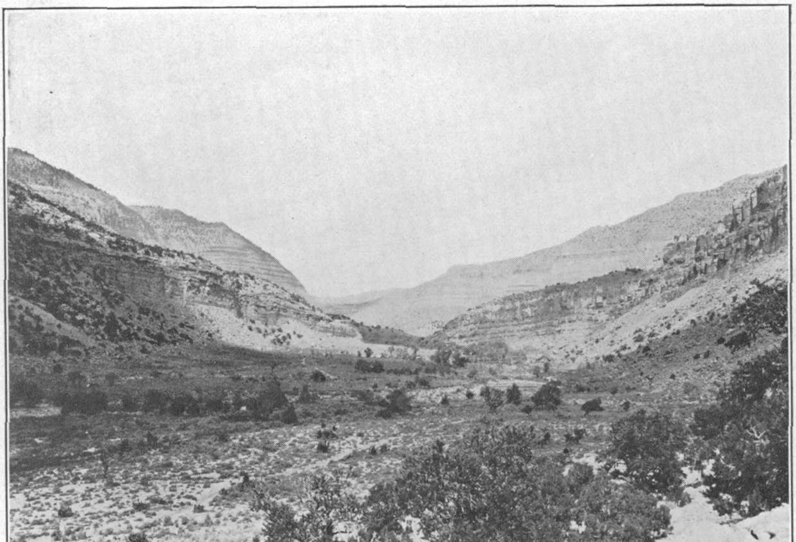

JOES VALLEY FAULT ZONE NORTH OF MUDDY CREEK

Kc, Castlegate sandstone member of Price River formation; Kbh, Blackhawk formation; Ksp, Star Point sandstone; Km, Mancos shale; Ke, Emery sandstone member of Price River formation.



*A*. YOUNGS POINT AND NELSON MOUNTAIN, FROM BENCH NORTH OF MUDDY CREEK

The upper member of the Mancos shale is nearly all exposed in the lower part of Youngs Point and is capped by the Star Point sandstone and part of the Blackhawk formation. The left sky line of Nelson Mountain is formed by the Castlegate sandstone. The locality shown in Plate 24, *B*, is behind the hill in the left middle ground.



*B*. MUDDY CANYON NEAR ITS MOUTH, IN SEC. 16, T. 21 S., R. 6 E.

Showing rugged canyon walls. The tilted sandstone in the middle ground is the Star Point, dropped about 1,300 feet on the Muddy fault from its high position in the cliffs beyond.

closely similar in general view. It is highly probable that considerable coal is present in the ridge between Link and Quitchupah Canyons, and the section measured at location 497 may well be typical of the entire ridge, with the addition of the thick coal in the Upper Hiawatha bed, which undoubtedly extends some distance east of location 500, the easternmost point at which the coal was measured in Quitchupah Canyon.

### COAL BEDS

*Hiawatha bed.*—Coal in the Hiawatha bed is confined in this area to Quitchupah Canyon. Elsewhere in the area the bed is almost entirely absent. In Quitchupah Canyon the bed is not continuously thick, but a study of the thicknesses given on Plate 29 will show that on the west side of the canyon it is well worth mining as far south as location 510, beyond which it splits and gradually disappears in the direction of Convulsion Canyon. It is certainly not present in Link Canyon, and in Water Hollow, Convulsion Canyon, and East Spring Canyon most of the sections studied show the rocks well enough to prove the absence of the bed.

*Upper Hiawatha bed.*—The Upper Hiawatha bed of this area is the thickest known coal bed south of Grimes Wash. As shown in Plate 29, the limits of the area in which it is present are the same as those for the Hiawatha bed, with the exception that the Upper Hiawatha extends farther east and, to judge by the evidence in the Muddy Canyon area (see p. 179), is likely to extend farther north as a thick bed.

The bed appears to be thickest where it crosses Quitchupah Canyon. There it is more than 18 feet thick and has attracted the attention of prospectors for many years. At the head of Link Canyon the bed is certainly not more than 5 feet thick, and on the west side of the canyon in several sections of unusually well-exposed rocks (locations 495 to 499) it does not exceed 3 feet. How far south it extends as a thick bed on the east side of Quitchupah Canyon is not known. Location 500 represents the southernmost place at which a good measurement was obtained, but the extent of burned rock at the horizon of the bed south of this place suggests that it is probably thick at least halfway to the mouth of the canyon. Its extent on the west side of the canyon is clearly shown by the sections in Plate 29, except that at location 508 b, which is incomplete. Northeast of location 508 the coal in this bed is largely burned at the outcrop. At the mouth of the canyon it is certainly absent. This thick lens of the Upper Hiawatha bed may well extend northward and slightly eastward to location 471 in Muddy Canyon, where a single section shows it to be over 5 feet thick.

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In Convulsion Canyon and in Water Hollow a bed has been found which may be continuous with the Upper Hiawatha of Quitchupah Canyon, and if so, the bed rises somewhat in the stratigraphic column near the mouth of Quitchupah Canyon. The bed in question is at the approximate horizon of the Muddy No. 1 bed of Muddy Canyon, and the reason for believing that it may be continuous with the Upper Hiawatha of Quitchupah Canyon is that at the mouth of Quitchupah Canyon the Upper Hiawatha appears to ascend somewhat in the section, and that accordingly it may occupy a higher position in the rest of the area. It is equally possible that this bed is the Muddy No. 1 bed. Whatever its identity may be, however, the sections shown in Plate 29 in Convulsion Canyon are certainly all on the same bed, and the group in Quitchupah Canyon are on the same bed; whether the two groups are on the same bed may be questioned.

As a whole this bed, despite its rather narrow horizontal extent, is one of the most promising in the field, both because it contains a large tonnage of recoverable coal and because its unusual thickness will certainly eventually attract the attention of mining men to the area.

*Muddy No. 2 bed.*—In this area a bed 4 to 7 feet thick appears at the horizon of the Muddy No. 2 bed. In places it is so near the position of the Ivie bed that correlations unsupported by tracing are not as sure as might be desired, but on the whole it appears to be a distinct bed, and in Convulsion Canyon there is small doubt of its separate identity.

This bed is present on the north side of Convulsion Canyon near East Spring Canyon and is 4 feet or more thick near the point where it crosses Convulsion Canyon. Somewhere between that place and the mouth of Water Hollow it pinches out, but it is still 4 feet thick at location 525. This stretch in Convulsion Canyon between locations 515 and 525 is the only part of the area in which the Muddy No. 2 bed is a well-defined unit.

In Water Hollow it does not seem to be present, but the possibility exists that the bed called Upper Ivie in Water Hollow is this bed. In Quitchupah Canyon the bed may exist, but it was not seen. On the east side of the canyon the effects of burning are so strong in the general part of the section occupied by the Muddy No. 2 and Upper Ivie beds that the observer is inclined to believe them present; whether or not in considerable thickness is impossible to say. The section at location 497, in Link Canyon, contains both beds and adds strength to the belief that the beds are present in Quitchupah Canyon. Farther east in Link Canyon the beds appear to be burned so extensively that no detailed search was made. Burning at the outcrop has been more extensive on the upper beds of this area than on the lower beds.

*Upper Ivie bed.*—It is not certain that the bed here called Upper Ivie is different from the Ivie bed as defined in the Saleratus area, and the questions concerning its correlation are discussed on page 193. The Upper Ivie in East Spring Canyon is at least 13 feet 6 inches thick in a considerable part of the W. ½ sec. 12, T. 22 S., R. 4 E. Near the point where the bed crosses Convulsion Canyon it is burned, and on the south side of the canyon it is variable in thickness, and of little value. In Water Hollow it reappears in substantial thickness and is commercially valuable. The sections near the head of Water Hollow, which do not show the bed, are not final in their evidence, and it is very likely to be present there, too.

In Quitchupah Canyon the upper beds are not for the most part burned at the outcrop, and the Upper Ivie bed may be present near the head of the canyon. Near the mouth of the canyon, however, sections that seem to be inclusive do not show it. In Link Canyon it is possibly represented by a bed about 4 feet thick, the correlation of which is based entirely on its stratigraphic position.

*Upper beds.*—Complete sections of the Blackhawk formation show upper beds in places, but none of them are thick enough to be of much value, and only two, at location 497, are as much as 4 feet thick. There is little evidence of these upper beds, except that burned rock at their general stratigraphic position indicates roughly their presence in parts of Quitchupah and Convulsion Canyons. They are probably of small value.

## FAULTS

West of Emery the Joes Valley fault zone emerges from the plateau and passes southwestward along the benches formed by the Emery sandstone toward the Oak Spring Ranch, clearing the plateau front by a mile or more and thus not affecting the coal-bearing rocks of the Convulsion Canyon area. The faults of the zone are in places well shown by displaced outcrops of the Emery sandstone east of the Water Hollow Benches. (See structure section J–K, pl. 32.)

No faults have been observed in the coal-bearing area east of the head of Convulsion Canyon. The valley in which the Acord Lakes are situated is walled in by a cliff of Castlegate sandstone, the alinement of which, together with other physiographic features, strongly suggests a fault. The evidence at hand may be briefly reviewed as follows: The valley of Acord Lakes is a closed basin, from which drainage water escapes either by seepage into the rocks or by evaporation, and it was probably not produced in its present form by erosion alone. The pattern of the valleys draining into it from the west suggests that it was formerly the head of Convulsion Canyon, into which it drained through the present wind gaps north and south of the hill in the northern part of sec. 16, T. 22 S., R. 4 E. (See pl. 32.) A former extension of Broad Hollow, in sec. 33, T. 21 S., R. 4 E., also shows this relationship. The valley was probably formed by comparatively recent movement on a fault, which lowered the surface west of the line of cliffs east of the Acord Lakes, and produced the closed basin and consequently the lakes. The alinement of the valleys north of the Acord Lakes as far as the east front of White Mountain and south as far as the head of Spring Gulch, together with the presence of the escarpment bordering them on the east, is further evidence for a fault. The height of this escarpment in such places as the eastern parts of secs. 4 and 9, T. 22 S., R. 4 E., suggests that the fault existed before the Acord Lakes were formed, and that the displacement is accordingly greater than the descent from the wind gaps into the valley. The amount of displacement can not clearly be reckoned from stratigraphic data available in the valleys west of the Acord Lakes, where conglomerate and sandstone of Price River age are exposed, but no definite horizon has been distinguished. The downthrow of this fault is to the west and is probably at least 200 feet. The fault will be met by the westward extension of any mines established in Convulsion Canyon above Broad Hollow.

## MINING

There are no operating mines in the Convulsion Canyon area. The thick bed in Quitchupah Canyon has been prospected rather extensively, and in Convulsion Canyon prospecting has been active in the past. In Water Hollow the inaccessibility of the coal has largely discouraged prospecting. Here, as elsewhere in the field, the beds have been prospected chiefly in the more accessible places and in places where considerable coal is visible on the surface.

The best mine sites in this area are near the places where the coal beds pass beneath the drainage channels. The place where the Upper Ivie coal bed crosses Convulsion Canyon is the only one of these sites to which a railroad can easily be built, and the others may be connected with tipple sites in the main canyons by tramways or conveyors of other types. On the whole, there are few localities where sufficient room for surface work exists on the coal outcrop, and at most mine sites room can be made available only through digging and filling. The location of mines in the area depends more on the feasible routes for tramways or conveyors than on any other feature. No extensive faults are known in the area, and the only structural feature to be considered in the choice of mine sites is the dip of the rocks. The slight west dip makes advisable, wherever possible, the location of entries on the east sides of the north-south canyons.

The problem of transportation of coal for domestic use has never arisen in this area, as it has in areas farther north, because of the existence of more easily accessible coal in the Emery field, on which the residents of Emery and vicinity have drawn for years. The transportation of coal mined on a large scale will not require attention until a railroad is constructed in Castle Valley, probably to connect by way of Ivie Creek and Salina Canyon with the railroad in the Sevier Valley. The nearest existing railroad points are Salina, in the Sevier Valley, which is about 60 miles by road from the mouth of Quitchupah Creek, and Price, which is about 64 miles distant. The construction of a proposed line from Price to Huntington would bring a railroad 24 miles nearer.

Within the area conditions are more favorable for railroad construction than in the areas farther north. Convulsion Canyon affords a good grade and a broad, flat canyon bottom with ample room for construction in the part where coal will be mined. The rise of the canyon bottom is about as steep as that of other canyons (450 feet in 3 miles, or about 3 per cent), but there is ample room in most of the canyon for choice of location. Quitchupah Canyon is decidedly steeper, having a gradient of about 1,000 feet in 4½ miles—225 feet to the mile, or about 4 per cent—between the mouth of Quitchupah Creek and the place where the thick coal bed crosses the canyon, and the canyon is narrow and difficult to travel. A railroad might be projected to the broad space in the N. ½ sec. 9, T. 22 S., R. 5 E., and the coal brought by tramway to a tipple there, but it would be a difficult and expensive operation. Water Hollow presents much the same difficulty as Quitchupah Canyon and is narrow and fairly steep in gradient. The ruggedness of the lower parts of both these canyons is due to the presence of the Emery sandstone. The coal in East Spring Canyon can be brought by tramway down to a tipple in Convulsion Canyon, and in Convulsion Canyon itself tramways will be necessary. Link Canyon is short and steep, and the coal mined there will probably be brought down by tramway to a railroad on the bench formed by the Emery sandstone. This bench is much dissected, and the problem of finding a railroad approach to the cliffs is by no means easily solved. Many bridges may be necessary.

Timber, which is plentiful on the plateau, may be brought down to any possible mine site by existing roads or others that may be built.

Water is scarce in Link Canyon, and there a supply would have to be brought in by pipe line. Quitchupah Canyon contains a fair supply of good water, and in Convulsion Canyon there is a good stream, but the water is "alkaline" and not the best for drinking. Above the mouth of East Spring Canyon the water in Convulsion Canyon is fairly good. Numerous springs issuing from the Emery sandstone in Water Hollow yield a supply of water, but the water is "alkaline" and undesirable for domestic use.

### SALERATUS AREA

#### COAL BEDS

Coal more than 3 feet thick exists throughout the Saleratus area. In general only the Ivie bed is continuously thick, but in the northeastern part of the area the Upper Ivie bed is 3 to 6 feet thick. Exposures in the cliffs are generally good, and only in Saleratus Canyon are the slopes extensively concealed by soil.

In and north of Saleratus Canyon, where the cliffs were scaled at a few points, measured sections are spaced well enough to show the amount of coal present. In Trough Hollow and Mill Hollow, however, the few sections measured were examined under conditions that did not permit the gathering of more detail. Observations made in these canyons, however, indicate the strong probability that the thicknesses observed on the Ivie bed are representative, and on the whole the amount of valuable coal in the area is probably fairly ascertainable from the data at hand.

*Hiawatha bed.*—In this area the Hiawatha bed is completely absent, as far as records show. Carbonaceous shale appears at its normal horizon in one or two sections, but generally it is represented by sandstone or sandy shale.

*Upper Hiawatha bed.*—At locations 557 and 562 a thin bed of coal has been noted at the approximate stratigraphic position of the Upper Hiawatha bed, but the bed is neither extensive nor valuable. It may extend throughout the general area represented by the outcrop in Saleratus Canyon, but complete sections taken in adjoining canyons indicate its absence.

*Ivie bed.*—The identification of the Ivie bed in this area, its relation to the Upper Ivie bed, and the identity of the bed named Upper Ivie in the Convulsion Canyon area present a problem in correlation which is briefly reviewed in the following paragraphs, in order to explain the usage here adopted. In following this discussion, the reader should refer to Plates 29 and 30, on which the positions of the coal beds with reference to the Star Point sandstone are shown.

The Ivie bed was first defined and named in the Ivie Creek drainage basin, where it is prominently developed and continuously present in considerable areas. There it may be readily identified by its association with an underlying white sandstone, and this key to recognition, added to its stratigraphic position above the Star Point sandstone, which is nearly everywhere determinable, makes safe its identification in Ivie Creek and neighboring parts of the Saleratus Creek drainage area. In the Convulsion Canyon area, however, the white sandstone is lacking, and in neighboring parts of the Saleratus area the Ivie bed, as identified by means of the white sandstone, varies in stratigraphic distance above the Star Point sandstone through a range of 40 feet. Stratigraphic position is therefore an unreliable criterion for the identification of coal beds near this horizon in the Convulsion Canyon area.

In Saleratus Canyon the Ivie bed, as identified by the white sandstone beneath it, appears to descend northward in the stratigraphic section, almost to the horizon of the Muddy No. 1 bed of areas on the north, and another bed appears above it, at the normal position for the Ivie bed. A purely graphic interpretation of the sections in Plate 30, however, would yield the conclusion that between locations 562 and 555 the Ivie bed pinches out, and a new bed appears below it, continuing as far as the north wall of Saleratus Canyon and there dying out. This alternative is possible, but the writer concludes that the lower bed is the Ivie bed, because of its general appearance and its association with the white sandstone, and that the upper bed is a separate one, here called the Upper Ivie bed.

The Upper Ivie bed of Saleratus Canyon pinches out north of location 557 but reappears at location 546. The bed at locations 546 to 543 is almost certainly the same as the bed at the same position on the north side of the divide in Water Hollow, in the Convulsion Canyon area. That bed is therefore called the Upper Ivie. It is not certain, however, that the Upper Ivie of both areas is not the true continuation of the Ivie bed and that the lower bed at locations 559 to 544 is not a separate bed, possibly the Muddy No. 2 or the Muddy No. 1. In that case the Ivie bed is lacking between locations 557 and 546 but reappears farther north.

In the Saleratus area the Ivie bed, as here identified, is continuously present at the outcrop and, as shown on Plate 30, is 5 to 10 feet thick. Its extent westward is not known, but it is believed to be present at least as far as the western limits of the area. However, if the generally observed north-south trend of thick lenses in coal beds of this field applies here, that estimate may require modification. In the Salina Canyon district,[67] on the other hand, a thick bed of coal has been observed at the stratigraphic position of the Ivie bed, and that bed may be continuous across the intervening area.

*Upper Ivie bed.*—On the northern edge of the area, in the escarpment north of Saleratus Creek, the Upper Ivie bed is over 6 feet thick for a short space near location 543. As noted above, it is

[67] Spieker, E. M., and Baker, A. A., Geology and coal resources of the Salina Canyon district, Sevier County, Utah: U. S. Geol. Survey Bull. 796, pp. 153–155, 1927.

probably continuous with the bed called Upper Ivie in Water Hollow. In Saleratus Canyon it is probably present almost throughout, but it is not more than 2 feet thick. It is probably absent in the sections that do not show it between locations 547 and 557. The possibility that this bed is really the Ivie bed has been discussed in the description of that bed.

*Other beds.*—No valuable coal is known to exist in this area above the horizon of the Ivie and Upper Ivie beds. At location 558 a bed at least 6 feet thick is imperfectly exposed about 37 feet above the Ivie bed, but the exposure is in a timbered gulch, and it is possible that the fault not far distant may cross the line of the measured section, and that the bed is the Ivie bed repeated.

*Saleratus bed.*—At locations 546 and 548 a bed was found about 160 feet above the Star Point sandstone. This bed, though thin, has been found at several places and is here referred to as the Saleratus bed. The following sections show its character:

*Sections of Saleratus coal bed*

**Location 546**

| | Ft. | in. |
|---|---|---|
| Shale, gray | 5 | 6 |
| Coal | 1 | 10 |
| Shale, sandy, gray | 2 | 4 |
| Coal | 2 | |
| Shale | 2 | 6 |
| Total coal | 3 | 10 |
| Total bed | 6 | 2 |

**Location 548**

| | Ft. | in. |
|---|---|---|
| Sandstone, thin bedded, brown | 8 | |
| Shale, gray, flaky | | 8 |
| Coal, resinous | 2 | 5 |
| Shale, yellow | | 6 |
| Sandstone, massive, gray | 1 | 4 |
| Coal | 1 | 6 |
| Shale, gray | | 8 |
| Sandstone, soft, platy | 35 | |
| Total coal | 3 | 11 |
| Total bed | 5 | 9 |

**Location 500 (Ivie Creek)**

| | Ft. | in. |
|---|---|---|
| Shale, gray clay. | | |
| Coal, fair to poor | 1 | 8 |
| Sandstone, gray, friable; about | 2 | |
| Total coal | 1 | 8 |

**Location 559 (Saleratus Canyon)**

| | Ft. | in. |
|---|---|---|
| Sandstone, massive, about | 25 | |
| Coal | 1 | 6 |
| Shale, carbonaceous | 1 | 7 |
| Shale, gray | 5 | 6 |
| Total coal | 1 | 6 |
| Total bed | 3 | 1 |

**Location 569 (Old Woman Mountain)**

| | Ft. | in. |
|---|---|---|
| Shale, gray | 4 | 6 |
| Coal | 1 | |
| Shale, carbonaceous | | 6 |
| Coal | 2 | 4 |
| Shale, carbonaceous | 1 | |
| Shale, gray. | | |
| Total coal | 3 | 4 |
| Total bed | 4 | 10 |

The last two sections are in the Ivie area, but they are given here in order to keep together the data on the bed, which is not known to be of commercial importance but which appears to be present at the same horizon in a rather large area and may prove somewhere to be thicker.

### FAULTS

The faults of the Saleratus area nearly all lie east of the plateau, outside the area occupied by the Blackhawk formation, and few of them affect the coal considered in this report. The faults of the Joes Valley zone disturb considerably the sandstones in the Mancos shale, and they affect such coal as is present underground in the Ferron sandstone, but that coal belongs to the Emery field, which has been described by Lupton [68] and is not considered here. Three faults have been found in the Saleratus area west of the main fault zone, in the cliffs on Saleratus Creek. The easternmost of these faults, which appears in the southward-facing escarpment north of Saleratus Creek, cuts the coal measures and drops the beds 20 feet on the east side. In Saleratus Canyon and the gulch just north of it are two faults, between which a block has dropped about 60 feet. These faults are approximately parallel. They are plainly shown in both gulches but do not appear either north or south of them. None of these faults affect greatly the mining possibility in the parts of the area they cross.

### MINING

No coal has ever been mined in the Saleratus area, largely because of the difficulty of access to the coal and because the residents of near-by parts of Castle Valley can obtain coal for domestic use from the Emery field, southeast of Emery. Prospecting in the area has not been active, probably for similar reasons and also because the coal beds are ordinarily well enough exposed in the cliffs to require no extensive digging to show the amount of coal present.

The principal problem to be solved in mining plans for the Saleratus area is that of reaching the coal. The geologic structure is generally favorable, and sufficient coal to support large operations is present.

In the northern part of the area, in Saleratus Canyon and the gulches northeast of it, the cliffs are steep, but places are available where gravity planes might be established. In the southern part, in Trough and Mill Hollows, the vertical cliff formed by the Star Point

[68] Lupton, C. T., Geology and coal resources of Castle Valley in Carbon, Emery, and Sevier Counties, Utah: U. S. Geol. Survey Bull. 628, 1916.

sandstone is continuous and impossible to cross by ordinary means. The approach to the cliffs by railroad is also difficult in the northern part of the area, where the rugged, sharply dissected benches formed by the Emery sandstone afford few if any favorable routes. In the southern part of the area feasible railroad grades may be found with less difficulty, because the country at the base of the cliffs is more open and not so sharply dissected.

Good water is scarce in this area. Saleratus Creek contains a small amount of "alkaline" water, and the other drainage courses are usually dry. Water for mining would have to be brought from the top, where a few springs are present. Timber is fairly plentiful on the top, and it could be brought down to mine sites by roads ordinarily not more than 5 miles long.

## IVIE AREA

### COAL BEDS

Two coal beds more than 30 inches thick are known to be present in the Ivie area. The Ivie bed is developed within the Ivie Creek drainage basin, which covers a strip not more than 3 miles wide on the northern border of the Ivie area and may be said to contain practically all of the commercially valuable coal of the area. A second bed, of little importance because of its inaccessibility, is present in the upper part of the north fork of Last Chance Creek at the approximate horizon of the Upper Hiawatha; but the bed is not named, largely because of its slight known extent.

The country adjacent to Ivie Creek consists largely of rounded slopes, and natural exposures of the coal are rare. Between the point of Old Woman Mountain and Clear Creek cliffs of the usual plateau-front type prevail, and the coal beds are on the whole not difficult to find, but farther west they are more effectively concealed under the mantle of soil. A number of prospect pits, however, aid materially in the examination of the coal. South of Ivie Creek exposures of coal diminish sharply, and apparently no important beds are present between Ivie Creek and Last Chance Creek. Near the head of Last Chance Creek exposures of coal return for a short space, but farther south the rocks in general are very poorly exposed. In most of the area the coal is not exposed.

*Ivie bed.*—The sections of the Ivie bed in this area, shown graphically in Plate 30, give practically all the available information concerning the bed. It is 3 to 11 feet thick throughout the area controlled by exposures in Ivie, Clear, and Red Creeks, and only at the westernmost exposures does any sign of inferiority appear.

There the bed is split, and it is unfortunate that no exposures are available farther west, so that the extent of the area of poor coal is not known. Information on the coal in this part of the area will be available through drilling or mining only.

*Bed in Last Chance Creek.*—In the southernmost stretch of cliffs in the field, in the north fork at Last Chance Creek, a bed about 20 feet above the top of the Star Point sandstone appears to be 6 to 7 feet thick throughout the mile of exposures where it is known, except between locations 601 and 604 (pl. 33), at the west end of the cliff, where it probably thins to 4 feet and less. Sections measured in this part of the area are shown in Figure 11.

*Higher beds.*—Coal beds are present at places in the part of the Blackhawk formation above the Ivie bed, but none of the higher beds are known to be persistent. In the gulch above location 585 (pl. 33) the following condensed section shows the coal beds present above the Ivie bed:

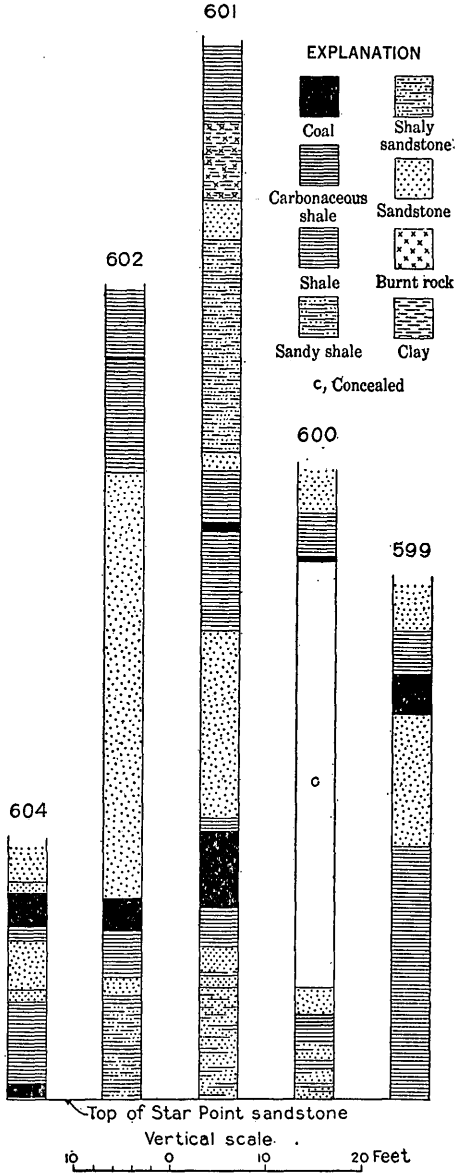


FIGURE 11.—Short columnar sections of lower part of Blackhawk formation on north fork of Last Chance Creek

*Section of part of Blackhawk formation above Ivie coal bed northwest of location 585*

| | Ft. | In. |
|---|---|---|
| Sandstone and shale | 65 | |
| Coal, irregular | | 2 |
| Carbonaceous shale | 1 | 2 |
| Coal | | 8 |

| | Ft. | in. |
|---|---|---|
| Shale, with some sandstone | 22 | |
| Carbonaceous shale, containing stringers of coal | 7 | |
| Coal, impure at top | 2 | 6 |
| Sandstone, shale at base | 3 | |
| Coal | 1 | 4 |
| Carbonaceous shale, impure coal in places | 2 | |
| Shale, containing thin sandstone | 9 | |
| Coal | | 9 |
| Coal, impure | | 9 |
| Coal, highly resinous | 2 | 3 |
| Bone | 1 | |
| Sandstone and shale | 78 | |
| Coal | 1 | 2 |
| Shale, containing thin beds of sandstone | 31 | |
| Ivie coal bed. | | |
| | 228 | 9 |

On the north side of the valley of Red Creek, about half a mile above location 583, the following section, whose base is believed to be 125 to 150 feet above the Ivie coal bed, was measured.

*Section on north side of Red Creek*

| | Ft. | in. |
|---|---|---|
| Sandstone, buff, with white layer at top | 9 | |
| Shale, gray | 7 | |
| Coal (may be thicker) | 2 | 6 |
| Shale, largely covered | 11 | |
| Coal (may be thicker) | 1 | 6 |
| Sandstone, buff | 3 | |
| | 34 | |

About 75 feet up the hill from the top of this section, the succession of rocks continues as shown in the following section. The rocks are possibly faulted at this place, and a fault may lie between the two sections; hence they can not be certainly joined.

*Section on north side of Red Creek beginning 75 feet above the foregoing section*

| | Ft. | in. |
|---|---|---|
| Sandstone, massive, brown | 15 | |
| Carbonaceous shale | 2 | |
| Coal | 1 | |
| Carbonaceous shale and bone | 3 | |
| Shale, gray | 11 | |
| Carbonaceous shale | 3 | |
| Shale and sandstone (coal seamlets in some of the shale) | 22 | |
| Coal | 2 | 7 |
| Shale, carbonaceous to gray, with coal seamlets | 8 | |
| Sandstone, massive | 15 | |
| | 82 | 7 |

On the south side of Ivie Creek, just northwest of the mouth of Tommy Hollow, is a prospect digging which shows the following section:

*Section in prospect north of mouth of Tommy Hollow*

| | Ft. | in. |
|---|---|---|
| Sandstone, buff. | | |
| Shale, gray clay | 5 | |
| Shale, carbonaceous | 2 | 6 |
| Shale, gray clay | 1 | |
| Coal | 1 | 8 |
| | 10 | 2 |
| Shale, gray clay. | | |

This bed is probably one of the upper beds shown in the other sections. On the north side of Ivie Creek, above location 581, a coal bed 1 foot 8 inches thick is present 80 feet above the Ivie bed, and above this bed are a number of thinner beds, none of which show more than 15 inches of coal on the outcrop. These sections are probably characteristic of the part of the Blackhawk formation 250 feet above the Ivie coal bed, and in the upper part of the formation no coal beds have been noted. It seems probable that little or no coal thicker than 30 inches is present in the Ivie area above the Ivie bed.

## FAULTS

The faults of the Joes Valley zone cross the southeastern part of the Ivie area diagonally, and in the drainage basin of Last Chance Creek they cut the coal-bearing rocks, but on Ivie Creek they lie east of the plateau front and affect none of the Mesaverde coal. The Paradise fault, which is the easternmost one of the zone in the vicinity of Emery, lies east of the prominent hill east of the Oak Spring ranch and continues southwestward, in the general direction of Post Hollow, toward Last Chance Creek. (See pls. 33 and 4, *C*.) In T. 25 S., R. 4 E., it is visible on Last Chance Creek, as mapped by Lupton,[69] but between that place and the mouth of Post Hollow, in sec. 5, T. 24 S., R. 5 E., the exact trace of the fault is not visible. However, the alinement of the faults at the two places and the surface features of the intervening area suggest strongly that the fault is continuous. The faults at least represent the same general downward displacement on the west and are closely related if not exactly continuous.

East of the Paradise fault, on Deer Peak and in the hills north of it, are other faults, which were not located in the present work. West of the Paradise fault between Ivie and Last Chance Creeks are several smaller faults, most of which cut the coal-bearing rocks. The ridge south of Ivie Creek is cut east of location 598 (pl. 33) by a

[69] Lupton, C. T., op. cit., pl. 12.

fault which has a displacement of about 300 feet, down on the west, bringing the Emery sandstone against the Star Point sandstone. Southeast of location 599 is a fault whose downthrow is about 100 feet to the east. Neither of these faults affects seriously the coal-bearing part of the area. Near the northwest corner of sec. 30, T. 24 S., R. 5 E., the outcrop of the Star Point sandstone is cut off abruptly, in a manner suggesting faulting, but no definite fault is observable. Near location 600, southwest of Johns Peak, the Star Point sandstone is cut by two faults which appear to trend nearly east-west; the downthrow of both faults is toward the south, and the northern one has a displacement of about 100 feet. These faults appear not to cut the coal-bearing rocks west of location 600.

In the valley of the north fork of Last Chance Creek the cliffs of the Star Point sandstone and the Blackhawk formation near locations 601 to 604 are cut by six faults, shown on Plate 33. The displacement of the easternmost fault, which cuts off the cliff of Star Point sandstone on the east, is not known. The second fault has a displacement of 50 feet, down on the west; the third 100 feet, down on the east; the fourth about 100 feet, down on the west; the fifth 110 feet, down on the east; and the sixth about 100 feet, down on the west. South of this stretch of cliff the rocks are almost completely covered by a mantle of soil and basalt boulders, and the territory was not mapped.

On Ivie Creek the rocks are undisturbed by faults as far west as Red Creek, but in the valley of Red Creek four faults, shown on Plate 32, are known to be present, and others may be present but not observable in the rounded slopes. Above the mouth of Red Creek the rocks of the Blackhawk formation in the valley of Ivie Creek appear to be cut by faults, but no individual faults were located in the present work.

## MINING

Practically no coal has been mined in the Ivie area. In 1923 an opening was begun on the Ivie bed at location 580, on the north side of Ivie Creek, but in that year little coal was mined. The market for coal in near-by parts of Castle Valley is supplied by the Emery field, and the need for wagon mines in this area is not great.

On Ivie and Clear Creeks the coal has been opened by prospectors at a number of places. The Ivie bed is the only one of commercial value in the northern part of the area, and it has on that account received practically all of the attention.

In the gulch west of Old Woman Mountain, in sec. 35, T. 23 S., R. 4 E., several old coal prospects are present, and on the west side of the gulch an adit has been driven. The mouth of the adit is caved, and its depth is unknown. Just west of the mouth of Red

Creek, on the north side of Ivie Creek, two adits have been driven, and they show the Ivie bed to be seriously split by shale partings. The mine begun in 1923 at location 580, however, shows a good bed of clear coal not far east of these openings.

In a small side gulch less than a mile from the mouth of Clear Creek, are two old adits on the Ivie bed, and the one on the north side of the gulch was in good condition when visited by the writer in 1921. It is about 75 feet long and shows the coal to be very hard and resistant to weathering. The pit on the opposite side has caved.

East of Clear Creek are several other old pits on the Ivie bed, in most of which the thickness of the coal may be determined after some clearing away of the soil that has washed in. South of Ivie Creek the coal is not plentiful enough to encourage prospecting, and none has been attempted in the cliffs of the Blackhawk formation on Last Chance Creek.

Access to the coal in the Ivie area is on the whole not difficult. Mine sites may be found at many places on Ivie Creek, and west of Clear Creek the coal lies at tipple height for a sufficient distance to permit the establishment without unusual difficulty of mines without tramways or conveyors. On Red Creek and on Ivie Creek west of Tommy Hollow the coal is underground and might be reached by shaft or slope from a rather wide choice of mine sites. A railroad line was once surveyed in Ivie Creek Canyon, to connect Salina, in the Sevier Valley, with Price, in Castle Valley.

Red and Clear Creeks, which furnish the flow of Ivie Creek, contain an abundant supply of good water, enough for all the mining that may be done in the Ivie area. Timber is fairly plentiful on the plateau to the north and may be reached by existing roads.

## TONNAGE ESTIMATES

The making of tonnage estimates for a largely undeveloped area such as the Wasatch Plateau coal field involves several problems, the solution of each one of which is at best an approximation. The correlation of the coal beds is perhaps the first problem to confront the estimator, because the most serviceable estimate is that which takes separate account of each coal bed. Such a procedure is obviously impossible if the beds are not clearly correlated throughout the area. A second problem concerns the adequacy of the data on the thickness of the beds, and a third the persistence of the beds under cover, away from the outcrop. A fourth problem, and one which may be treated in many different ways, with vast differences in the resulting figures, concerns the drawing of the lower limit of thickness of beds to be included in the estimate.

In dealing with all these problems the writer has attempted to avoid extremes, and wherever the choice of a mean has presented uncertainty, he has endeavored to put his decision on the conservative side. Wherever individual beds have been correlated with fair certainty, estimates have been made for them separately, but where correlations are uncertain a total average thickness of the coal present in all known beds over 30 inches thick has been used. As exposures are poor at many places it is practically certain that the observed thicknesses fall short of the true amount of coal present. The present estimate is based on observed coal, however, with some allowance made for places where beds are obviously burned or otherwise only partly visible at the outcrop.

In the determination from data on the outcrop of the probable extent and thickness of the coal beds under cover, the general principles followed in the classification of the public lands[70] have been used. These principles, used in conjunction with the principle above stated for the determination of thickness, have resulted in an estimate which may be too small but which is certainly not too large. The determination of the lower limit of thickness to be adopted for the estimate presents an important question, particularly for places where thin beds are plentiful. Most estimates of coal in the fields of the western United States attempt to take into account all coal beds over 14 inches thick. The writer believes that for a field such as this it is both useless and misleading to make detailed estimates of the coal in beds that are too thin to be worked under the economic conditions that are likely to prevail for the next few generations, and the estimates here presented take into account only the coal in beds 30 inches or more in thickness. It is generally held by mining engineers that ordinarily under present-day conditions a coal bed in this field less than 40 inches thick is not profitably workable, but in order to allow for the possibility of future changes in conditions 30 inches is taken as the minimum workable thickness. Many beds which maintain for the most part thicknesses above this minimum fall below it for certain areas, the elimination of which would be not only difficult but useless because mines, once started on the thicker coal, would probably extract much of the thinner coal in the course of extending over a given area.

Perhaps the least uncertain factor entering into the estimate is the weight of an acre-foot of the coal. The average specific gravity of seven samples representing four beds at widely separated parts of the field (see table, p. 66) is 1.328. A cubic foot of coal of specific gravity 1.328 weighs 82.867 pounds, and an acre of such coal

[70] Smith, G. O., and others, The classification of the public lands: U. S. Geol. Survey Bull. 537, pp. 83–91, 1913.

1 foot thicks weighs 1,804.8 tons. In computing the tonnage here presented, the gross unit of 1,800 tons to the acre-foot has been used throughout the field.

The attempt is sometimes made, in estimates such as this, to calculate the amount of coal extractable. To do this successfully it is obviously necessary to decide in advance how efficient the mining of the coal will be, and the writer believes, in view of the great variety of mining conditions and practice that will prevail in this field, as well as the possibility that future methods will surpass the present, that the percentage of extractable coal can not safely be estimated. The figures here given therefore represent total tonnage only.

No attempt has been made to account for the amount of coal that has been extracted from existing mines or lost in the process of mining. The coal mined to date represents a very small percentage of the total coal present in the field.

The estimates are given for separate townships, and the townships are subdivided wherever the interests of clearness are served by so doing. The subdivisions are defined in the column headed "Remarks." The data on which these estimates are based are nearly all given in the maps and sections accompanying this report, and a fair test of the estimates may be made by any reader who so desires.

In order to determine roughly how much coal is present in all beds over 14 inches thick, a study was made of several complete and representative sections of the Blackhawk formation from all parts of the field, and it was found that the average amount of coal in beds over 30 inches thick is about 60 per cent of the average amount in all beds over 14 inches thick. This percentage, applied to the total for the field of 7,800,000,000 tons in beds over 30 inches thick, shows that probably 13,000,000,000 tons of coal is present in all beds over 14 inches thick.

The total amount of coal over 30 inches thick is too great for ready comprehension unless it is expressed in terms of the time it would last under given conditions of production. When it is considered in terms of the amount annually produced in the United States, which averaged 507,459,000 tons [71] in the period from 1918 to 1921, it does not seem so great, because at that rate it would last not quite 16 years. The maximum annual production for the State of Utah, however, was 6,005,199 tons, in 1920,[72] and of this amount the Wasatch Plateau produced a little less than half, although in future it may well become the leading field of the State. It is impossible to predict future production for this field with the same degree of assurance

[71] Tryon, F. G., and Hale, S. A., Coal in 1919, 1920, and 1921: U. S. Geol. Survey Mineral Resources, 1921, pt. 2, p. 461, 1923.

[72] Idem, p. 462.

as that with which the future production can be estimated for a large area, such as the United States, because the market for Utah coal, and consequently the production, is subject to many relatively local conditions, which may change completely at any time. For example, the depletion of fuel-oil reserves in California would greatly increase the market, and a favorable change in freight rates to near-by markets would doubtless do likewise. However, it is evident that under any probable future conditions the reserve of coal in the field will last a very long time.

Finally, it should be remembered that these estimates do not cover large areas in the central and western parts of the Wasatch Plateau which doubtless contain coal at considerable depth, and that consequently they should not be taken to represent the entire coal reserve of the Wasatch Plateau.

*Estimate of original tonnage contained in workable coal beds of Wasatch Plateau coal field*

| T. S. | R. E. | Coal bed | Area covered by estimate (acres) | Average thickness (feet) | Tons (2,000 pounds) | Remarks |
|---|---|---|---|---|---|---|
| 11 | 8 | All beds | 640 | 20 | 23,000,000 | Sec. 36. |
| 11 | 9 | do | 1,280 | 20 | 46,000,000 | Secs. 31 and 32. |
| 12 | 6 | Castlegate "A" | 3,896 | 5 | 35,000,000 | |
| 12 | 7 | All beds | 7,225 | 13 | 170,000,000 | Part of township in Pleasant Valley, secs. 1–3, 12, 13, 21–28, 34–36. |
| | | do | 2,885 | 10 | 52,000,000 | Part of township on Fish Creek, secs. 2, 3, 10–15, 22, 23. |
| 12 | 8 | do | 15,360 | 17 | 470,000,000 | Part of township (24 sections) included in Beaver area. |
| 12 | 9 | do | 20,920 | 20 | 753,000,000 | All except secs. 1, 2, and 3, where coal is more than 3,000 feet deep. |
| 13 | 6 | Castlegate, "A" | 11,621 | 9 | 188,000,000 | Part of township in Upper Huntington and Pleasant Valley areas. |
| | | Bob Wright (?) | 11,621 | 5 | 105,000,000 | |
| 13 | 7 | Castlegate "A" | 1,451 | 9 | 24,000,000 | West of Pleasant Valley. |
| | | All beds | 11,930 | 16 | 344,000,000 | Secs. 1–3, 10–15, 21–28, 33–36. |
| 12, 13 | 7 | do | 3,636 | 21 | 138,000,000 | Area east of Pleasant Valley, between Utah mine and Ingalls Canyon, and west of fault in Miller Creek. |
| 13 | 8 | Hiawatha | 8,827 | 7.3 | 118,000,000 | |
| | | Bed 50 feet above Hiawatha. | 240 | 5 | 2,000,000 | Bed at location 59 b. |
| | | Gordon | 320 | 4 | 2,000,000 | |
| | | Castlegate "A" | 7,619 | 5.3 | 73,000,000 | |
| 14 | 6 | do | 6,120 | 6.0 | 66,000,000 | |
| | | Candland | 4,840 | 6.0 | 52,000,000 | |
| | | Upper beds | 5,440 | 4.0 | 39,000,000 | |
| 14 | 7 | Castlegate "A" | 3,144 | 6.9 | 39,000,000 | East of Pleasant Valley fault. |
| | | do | 3,732 | 7.4 | 50,000,000 | West of Pleasant Valley fault. |
| | | Candland | 795 | 3.0 | 4,000,000 | |
| | | Bob Wright | 2,445 | 9.0 | 40,000,000 | East of Pleasant Valley fault. |
| | | do | 2,157 | 5.0 | 20,000,000 | West of Pleasant Valley fault. |
| | | Upper beds | 5,760 | 2.5 | 25,000,000 | |
| 15 | 6 | Blind Canyon | 6,440 | 3.0 | 35,000,000 | East of Joes Valley fault. |
| | | Castlegate "A" | 6,446 | 6.0 | 70,000,000 | Do. |
| | | Candland | 3,2[illegible]0 | 4.0 | 24,000,000 | Do. |
| 15 | 7 | Hiawatha | 4,970 | 2.2 | 29,000,000 | Western two tiers of sections. |
| | | do | 14,194 | 4.9 | 125,000,000 | Eastern four tiers of sections. |
| | | Blind Canyon | 1,315 | 3.5 | 19,000,000 | Secs. 17–21. |
| | | do | 3,512 | 5.5 | 24,000,000 | Secs. 2 –34. |
| | | Upper beds of Blind Canyon group. | 1,352 | 7.5 | 18,000,000 | Two beds; third and fourth of columnar section. |
| | | Wattis | 6,280 | 5.5 | 62,000,000 | Northeastern part of township. |
| | | Castlegate "A" | 8,216 | 5.0 | 71,000,000 | |
| | | Candland | 4,100 | 4.0 | 30,000,000 | |
| | | Sixth bed | 1,147 | 3.0 | 6,000,000 | Sixth bed of columnar section in Huntington Canyon. |

*Estimate of original tonnage contained in workable coal beds of Wasatch Plateau coal field*—Continued

| T. S. | R. E. | Coal bed | Area covered by estimate (acres) | Average thick-ness (feet) | Tons (2,000 pounds) | Remarks |
|---|---|---|---|---|---|---|
| 15 | 8 | Hiawatha | 3,482 | 6.8 | 43,000,000 | North half of township. |
| | | do | 3,927 | 9.5 | 67,000,000 | South half of township. |
| | | Intermediate beds | 2,240 | 8.5 | 34,000,000 | Two or three beds between Wattis and Hiawatha beds. |
| | | Wattis | 4,523 | 7.0 | 58,000,000 | |
| | | Bed above Wattis | 640 | 6.4 | 7,000,000 | Bed of location 129 c. |
| | | Tank | 1,600 | 4.3 | 12,000,000 | |
| | | Other upper beds | 2,430 | 4.1 | 18,000,000 | |
| 16 | 6 | Hiawatha | 10,775 | 4.5 | 87,000,000 | |
| | | Bear Canyon | 10,775 | 6.5 | 126,000,000 | |
| | | Castlegate "A" | 1,745 | 5.0 | 16,000,000 | |
| 16 | 7 | Hiawatha | 16,606 | 6.0 | 179,000,000 | |
| | | Blind Canyon | 7,163 | 4.5 | 58,000,000 | |
| | | Bear Canyon | 5,788 | 10.0 | 104,000,000 | Secs. 1–12. |
| | | do | 10,494 | 12.0 | 226,000,000 | Secs. 29–35. |
| | | Upper Bear Canyon. | 392 | 7.0 | 5,000,000 | Sec. 24. |
| | | Castlegate "A" | 455 | 5.0 | 4,000,000 | |
| | | Bed 340 feet above Hiawatha. | 220 | 6.3 | 2,500,000 | |
| 16½ | 8 | Hiawatha | 4,233 | 14.4 | 110,000,000 | Secs. 1–12. |
| | | do | 4,778 | 4.0 | 34,000,000 | |
| | | Bear Canyon | 3,914 | 3.5 | 25,000,000 | |
| | | Upper Bear Canyon. | 175 | 3.0 | 1,000,000 | |
| | | Upper beds | 7,600 | 4.0 | 55,000,000 | |
| 17 | 6 | Hiawatha | 16,217 | 5.0 | 145,000,000 | |
| | | Upper beds | 16,000 | 2.5 | 72,000,000 | |
| 17 | 7 | Hiawatha | 8,377 | 7.0 | 105,000,000 | Secs. 1–18. |
| | | do | 7,533 | 13.0 | 176,000,000 | Secs. 19–36. |
| | | Cottonwood | 700 | 4.0 | 5,000,000 | |
| | | Blind Canyon | 2,560 | 9.3 | 43,000,000 | Huntington Canyon side only; bed not workable on Cottonwood Creek. |
| | | Bear Canyon | 600 | 5.0 | 5,000,000 | Small area in Meetinghouse Canyon. |
| | | do | 7,320 | 4.0 | 40,000,000 | |
| | | Upper Bear Canyon. | 7,300 | 4.6 | 44,000,000 | |
| | | Upper bed of Grimes Wash. | 3,520 | 2.8 | 18,000,000 | |
| 18 | 6 | Hiawatha | 3,662 | 6.3 | 42,000,000 | Secs. 1–3, 10–12, 14. |
| | | do | 12,562 | 4.5 | 102,000,000 | Secs. 4–19, 13, 15–36. |
| | | Blind Canyon | 1,920 | 6.0 | 21,000,000 | |
| 18 | 7 | Hiawatha | 290 | 9.0 | 5,000,000 | Secs. 4–6. |
| | | do | 5,630 | 5.0 | 50,000,000 | Secs. 7, 17–21, 28–33. |
| | | Blind Canyon | 5,120 | 9.5 | 88,000,000 | |
| 19 | 5 | Hiawatha | 3,560 | 5.0 | 32,000,000 | Secs. 13, 14, 23–26, 36. |
| | | do | 960 | 3.0 | 5,000,000 | Secs. 12 (part) 35. |
| | | Upper Hiawatha | 1,405 | 3.0 | 8,000,000 | |
| 19 | 6 | Hiawatha | 11,872 | 4.0 | 85,000,000 | Secs. 1–5, 8–11, 14–16, 21–23, 25–28, 33–36. |
| | | do | 2,619 | 3.1 | 14,000,000 | Secs. 1, 11–14, 24, 25. |
| | | do | 1,307 | 5.0 | 12,000,000 | Secs. 18, 19, 30, 31. |
| | | Upper Hiawatha | 8,791 | 3.5 | 55,000,000 | |
| | | Upper beds | 10,240 | 4.0 | 74,000,000 | East of Joes Valley fault zone. |
| 19 | 7 | Hiawatha | 1,635 | 9.6 | 28,000,000 | Secs. 4–9. |
| | | do | 937 | 2.5 | 4,000,000 | Secs. 18–20, 29–31. |
| | | Upper Hiawatha | 937 | 3.0 | 5,000,000 | |
| | | Blind Canyon | 720 | 11.0 | 14,000,000 | |
| | | Bear Canyon | 1,420 | 3.5 | 9,000,000 | |
| | | Upper bed | 1,400 | 3.1 | 8,000,000 | |
| 20 | 5 | Hiawatha | 435 | 3.0 | 2,000,000 | Sec. 1. |
| | | do | 1,165 | 2.5 | 5,000,000 | Secs. 24–26, 35, 36. |
| | | Upper Hiawatha | 1,958 | 2.5 | 8,000,000 | Parts of secs. 13, 24–26, 35, 36. |
| | | Muddy No. 1 | 1,548 | 4.0 | 11,000,000 | Parts of secs. 26, 27, 34–36. |
| | | Muddy No. 2 | 1,388 | 4.0 | 10,000,000 | Parts of secs. 26, 27, 34–36. |
| | | All beds | 9,900 | 11.0 | 196,000,000 | Remainder of east half of township. |
| 20 | 6 | Hiawatha | 2,217 | 3.0 | 12,000,000 | Secs. 5–8. |
| | | do | 319 | 3.0 | 2,000,000 | Little Nelson Mountain. |
| | | do | 2,007 | 4.0 | 14,000,000 | Secs. 28–33. |
| | | Upper Hiawatha | 392 | 3.5 | 2,500,000 | Secs. 3, 4, 9, 10. |
| | | do | 3,630 | 3.0 | 20,000,000 | Secs. 19–21, 28–33. |
| | | do | 1,720 | 4.0 | 12,000,000 | Nelson Mountain. |

*Estimate of original tonnage contained in workable coal beds of Wasatch Plateau coal field*—Continued

| T. S. | R. E. | Coal bed | Area covered by estimate (acres) | Average thickness (feet) | Tons (2,000 pounds) | Remarks |
|---|---|---|---|---|---|---|
| 20 | 6 | Muddy Nos. 1 and 2. | 960 | 5.0 | 9,000,000 | Southwest corner. |
| | | Slide Hollow | 212 | 6.0 | 2,000,000 | Includes small parts in T. 19 S. R. 6 E., for which thickness is 7 feet. |
| | | All beds | 3,200 | 5.0 | 31,000,000 | Secs. 17-20, parts of 29, 30. |
| 21 | 4 | Upper Hiawatha | 1,760 | 6.0 | 19,000,000 | Southeast corner of township. |
| | | Upper Ivie | 6,300 | 6.0 | 68,000,000 | Do. |
| 21 | 5 | Hiawatha | 1,900 | 4.5 | 15,000,000 | Parts of secs. 29-33. |
| | | Upper Hiawatha | 4,010 | 8.0 | 58,000,000 | Secs. 19-22, 27-34. |
| | | do | 800 | 14.0 | 20,000,000 | Parts of secs. 29, 32, 33. |
| | | do | 1,155 | 3.2 | 7,000,000 | Parts of secs. 22, 23, 36, 27, 34, 35. |
| | | Muddy No. 1 | 2,435 | 5.0 | 22,000,000 | Parts of secs. 1, 2, 11, 13, 14, 24; sec. 12. |
| | | Muddy No. 2 | 1,755 | 4.0 | 13,000,000 | Parts of secs. 1, 2, 11, 13; sec. 12. |
| | | Upper beds | 6,400 | 6.0 | 69,000,000 | Southern third of township. |
| | | All beds | 7,680 | 17.0 | 235,000,000 | Part of township not included in estimates for separate beds. |
| 21 | 6 | Hiawatha | 1,133 | 4.2 | 9,000,000 | |
| | | Upper Hiawatha | 1,133 | 2.5 | 5,000,000 | Secs. 5, 6, 8 (part). |
| | | do | 3,504 | 2.7 | 17,000,000 | Western part of fault zone. |
| | | Muddy No. 1 | 348 | 5.0 | 3,000,000 | |
| | | Muddy No. 2 | 173 | 4.0 | 1,000,000 | |
| 22 | 4 | Upper Hiawatha | 3,160 | 3.5 | 20,000,000 | |
| | | Muddy No. 2 | 3,520 | 3.5 | 22,000,000 | Secs. 1, 2, 11-14. |
| | | Ivie | 16,310 | 8.0 | 235,000,000 | |
| | | Upper Ivie | 6,860 | 4.5 | 55,000,000 | |
| | | All beds | 3,840 | 15.0 | 104,000,000 | Western tier of sections in Convulsion area. |
| 22 | 5 | Hiawatha | 425 | 7.0 | 5,000,000 | Parts of secs. 4, 5, 8. |
| | | do | 809 | 5.0 | 8,000,000 | Parts of secs. 5-8. |
| | | Upper Hiawatha | 425 | 12.0 | 9,000,000 | Parts of secs. 4, 5, 8. |
| | | do | 2,000 | 6.0 | 22,000,000 | Parts of secs. 5-8, 17, 18. |
| | | do | 210 | 5.0 | 2,000,000 | Parts of secs. 18, 19. |
| | | Muddy No. 2 | 400 | 5.0 | 4,000,000 | |
| | | Ivie | 320 | 5.0 | 3,000,000 | |
| | | Upper Ivie | 3,157 | 5.0 | 28,000,000 | |
| 23 | 4 | Ivie | 19,016 | 7.5 | 257,000,000 | |
| 24 | 4 | do | 10,352 | 6.0 | 112,000,000 | Secs. 1-18, 21-24. |
| | | Other beds | 6,400 | 4.0 | 46,000,000 | Irregular area in part of township south of Ivie Creek. |

Total coal, 7,800,000,000 tons.

# INDEX

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