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GEOLOGY

OF THE

GREAT FALLS COAL FIELD

MONTANA

BY

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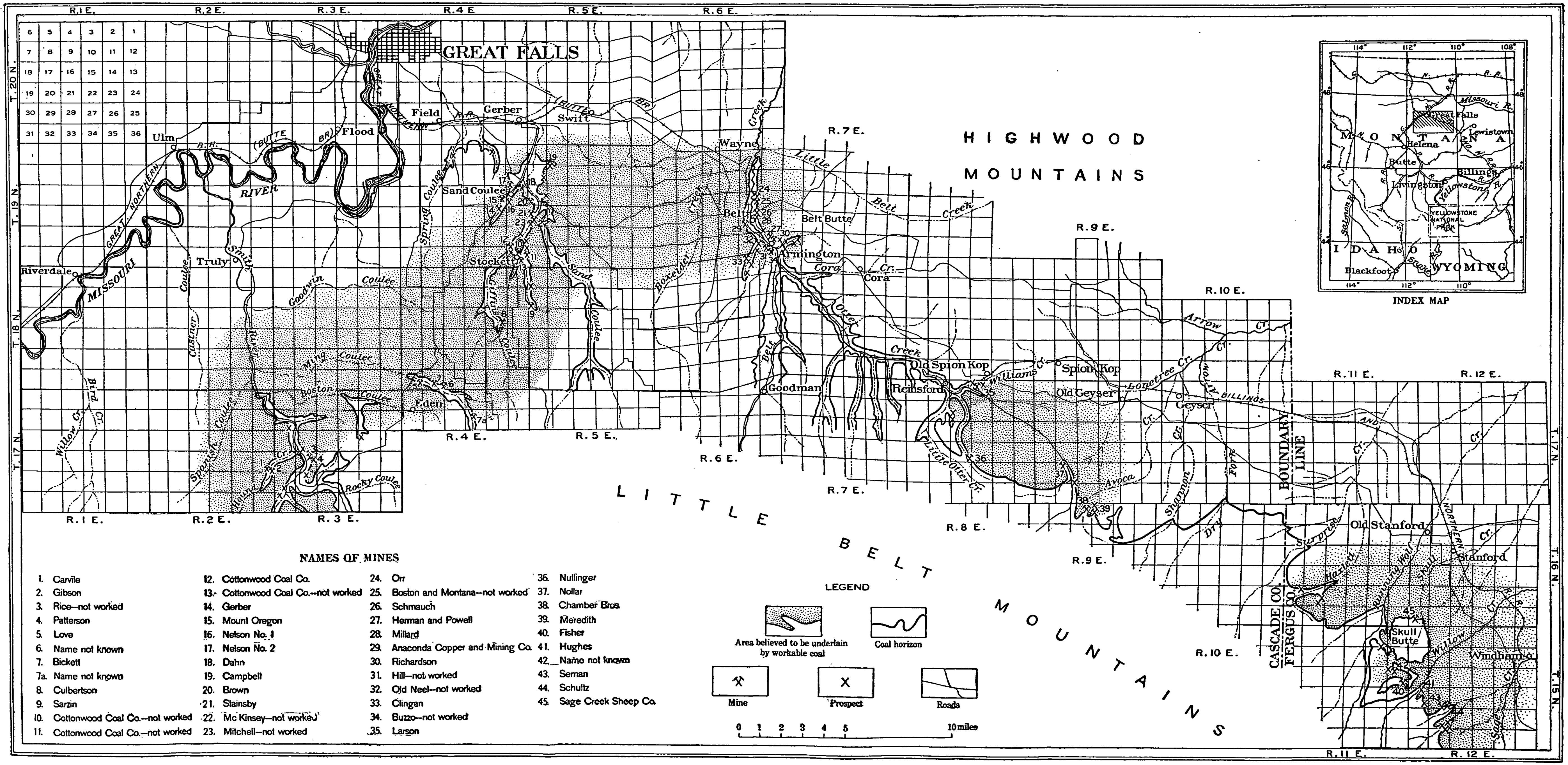

MAP OF THE GREAT FALLS REGION, MONTANA, SHOWING COAL LANDS.

GEOLOGY OF THE GREAT FALLS COAL FIELD, MONTANA.

By Cassius A. Fisher.

INTRODUCTION.

This report is the result of field studies made during the season of 1906. It is designed mainly to furnish information regarding the character and extent of the coal resources of the Great Falls region. It includes a description of the rock formations, indicating their character, distribution, structure, and stratigraphic relations, and also a brief statement of mineral resources other than coal.

The region under consideration comprises 1,500 square miles, situated mainly in north-central Montana, and extending along the base of the Rocky Mountain front range from a point 10 miles west of Judith River to a short distance beyond the Missouri. The location and orographic relations of the field are shown in the index map on Pl. I (in pocket). The field lies principally in Cascade County, but includes portions of Fergus and Chouteau counties, having as its boundary on the south the Big and Little Belt mountains and on the north the Great Plains and the Highwood Mountains.

Throughout the work the author was assisted by H. M. Eakin, who mapped portions of the area, measured many sections, and assisted in compiling the results for publication. Assistance in the field was also rendered by W. R. Calvert, J. D. Pollock, A. J. Hazlewood, and D. E. Winchester, and the author is indebted to S. B. Robbins, project engineer of the Sun River reclamation project, and to O. C. Mortson, formerly county surveyor of Cascade County, for valuable information placed at his disposal in connection with the preparation of the work.

LITERATURE.

The western half of the area here described as the Great Falls coal field has never been systematically studied by previous workers in geology, but several reports dealing with the general geology of different parts of the district to the east in the vicinity of the Highwood and Little Belt Mountains have been published.

The Great Falls of Missouri River, also the Giant Springs, are phenomena which have attracted widespread attention since the earliest explorers followed up the course of the Missouri to the northwest, and a number of descriptions of them have been published. Those appearing first set forth mainly the size and beauty of these falls, but later, as the region was settled and the town of Great Falls promised to become an important industrial center, a number of articles dealing with their utility were published in technical journals. Captain Lewis, of the Lewis and Clark expedition, which was made in 1804–1806, was the first to give an accurate account of the Great Falls and Giant Springs, and to describe certain features of the geography of the region bordering this portion of Missouri River. It is probable that other early explorers were attracted by the Great Falls and mentioned their occurrence and surroundings in describing the Northwest Territory.

The coals have been the subject of much of the geologic literature concerning this region, and many, if not most, of the more important geologic discoveries have been made in connection with a study of the nature and extent of these deposits. The investigations of the geologists of the Hayden and Transcontinental surveys in this part of the United States were confined mainly to the region lying east of Great Falls, and did not extend into the western part of the field. In 1880 W. M. Davis published an article[a] in which he gave an account of the geology of the Little Belt and Highwood mountains and the adjoining plains. During the same year George H. Eldridge described the geology of the Great Falls coal field. The next observer in the field was J. S. Newberry, who, in connection with an investigation of the surface geology of the country bordering the Northern Pacific Railroad, including the Great Falls coal field, discovered fossil plants associated with the coals, which established the Kootenai age of these deposits. After this discovery articles were published by Newberry and Fontaine dealing especially with the age of these coal-bearing rocks, as determined from their fossil floras, and their correlation with Kootenai rocks of other localities in the United States and Canada. In the spring of 1891 W. H. Weed, of the United States Geological Survey, while making a general study of the coal fields of Montana, visited this region and later described the coal deposits in considerable detail. The Geological Survey has published an annual account of coal operations in this field since 1888, and also a number of general reports on the coals of Montana and the Rocky Mountain region which have dealt principally with the production of this important coal field.

The first systematic work in this field was done in 1893–94 by W. H. Weed, assisted by L. V. Pirsson. In their published report[b]

[a] Relation of the coal of Montana to the older rocks: Tenth Census U. S., vol. 15, 1880, pp. 697–712.
[b] Highwood Mountains of Montana: Bull. Geol. Soc. America, vol. 6, 1894–95, pp. 389–422.

the topographic and geologic features, structure, and characteristic rocks of the different eruptive centers of the Highwood Mountains and vicinity are discussed at considerable length. In 1899 the Fort Benton folio,[a] which includes the eastern part of the area described, and the Little Belt Mountains folio,[b] which treats of the area adjoining on the south, both by Mr. Weed, were published by the Geological Survey. During the past few years the glacial geology of this portion of Montana has been described by Warren Upham[c] and by F. H. H. Calhoun.[d]

Since the Government irrigation project has been undertaken in Sun and Teton valleys, a number of scientific and popular articles have appeared dealing principally with the surface waters of the district. In 1906 an investigation of the underground waters of this general region was made by the writer, the results of which will soon be published by the Geological Survey.

The following bibliography contains the titles of the more important geologic papers dealing with this region, arranged in chronologic order:

LEWIS AND CLARK EXPEDITION, 1804-1806 (Coues, 4 vols., 1893).

An account of the journey up the Missouri from St. Louis to the Rocky Mountains, thence to the Pacific coast. Contains description of the region bordering on the Missouri in the vicinity of Great Falls, Mont. The falls of the Missouri were measured and described; also brief mention made of the Giant Springs.

HAYDEN, F. V., Geologic report of the exploration of the Yellowstone and Missouri rivers, U. S. War Dept., pp. 85-94. 1860.

Contains a chapter on the geology from Wind River Mountains to Fort Union on Missouri River. Gives description of a trip down Smith River and past the falls of the Missouri to Fort Benton, etc. Includes geologic map of the area.

WILLIAMS, ALBERT, JR., Mineral Resources U. S. for 1883-84: U. S. Geol. Survey, pp. 52-55. 1885.

The Montana coal fields are described briefly, and their area is estimated.

NEWBERRY, J. S., Surface geology of the country bordering the Northern Pacific Railroad: Am. Jour. Sci., 3d ser., vol. 30, pp. 337-347. 1885.

Includes a brief description of the surface geology in the vicinity of Great Falls, Mont., with special reference to glacial drift.

LINDGREN, WALDEMAR, Eruptive rocks: Tenth Census U. S., vol. 15, pp. 719-737. 1886.

The igneous intrusions of the Little Belt and Highwood mountains are described; also the dike near Sun River, including its character and mode of occurrence.

DAVIS, W. M., Relation of the coal of Montana to the older rocks: Tenth Census U. S., vol. 15, pp. 697-712. 1886.

Includes a description of the geology of the Little Belt and Highwood mountains and the plains region from Fort Benton up Missouri and Sun rivers.

ELDRIDGE, G. H., Montana coal fields: Tenth Census U. S., vol. 15, pp. 742-751. 1886.

Treats of the coals along Belt Creek, Sand Coulee, and Deep Creek (Smith River), giving a section of the geologic formations at Belt Butte, near Belt. The coals of the Sage Creek area are described as a part of the Judith Basin coal fields.

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[a] Geologic Atlas U. S., folio 55, U. S. Geol. Survey, 1899.

[b] Geologic Atlas U. S., folio 56, U. S. Geol. Survey, 1899.

[c] Outer glacial drift: Am. Geologist, vol. 34, 1904, pp. 151-160.

[d] Montana lobe of the Keewatin ice sheet: Prof. Paper, U. S. Geol. Survey No. 50, 1906.

Day, David T., Mineral Resources U. S. for 1885: U. S. Geol. Survey, pp. 36–39. 1886.

Brief reference is made to the coal production of the Belt and Sand Coulee mines.

Day, David T., Mineral Resources U. S. for 1886: U. S. Geol. Survey, pp. 262–288. 1887.

Eldridge is quoted in reference to the extent and character of Montana coal fields. (See Eldridge.) The production of the Great Falls region is given.

Newberry, J. S., The Great Falls coal field: School of Mines Quart., vol. 8, No. 4, p. 327. 1887.

Gives evidence as to the geologic age of the coal-bearing rocks in the Great Falls region, correlating them with the Kootenai formation of the Lower Cretaceous of Canada.

Chamberlin, T. C., Rock scorings of the great ice invasions: Seventh Ann. Rep. U. S. Geol. Survey, p. 77. 1888.

Discusses local "mountain wash" from Highwood Mountains, etc.

Mortson, O. C., and Ashburner, Chas. A., Mineral Resources U. S. for 1888: U. S. Geol. Survey, pp. 34–35, 289–292. 1890.

Describes the occurrence, extent, and chemical character of iron ores in the vicinity of Great Falls, Mont., pp. 34–35. Also refers to coal areas and operations in north-central Montana, pp. 289–292.

Swallow, G. C., Report of the Montana inspector of mines for the six months ending November 30, 1889, pp. 43–51.

Contains reports on various coal fields in Montana, including those of Cascade County. Analyses of Sand Coulee coal are given and comparison made with eastern coking coals. Estimates of the amount of coal in Cascade County are given.

Swallow, G. C., Report of the Montana inspector of mines, 1890.

Includes reports on various coal fields in Montana, making brief mention of those in Cascade County.

Newberry, J. S., Flora of the Great Falls coal field: Am. Jour. Sci., 3d ser., vol. 41, pp. 191–201. 1891.

Describes briefly the general geology of the Great Falls region, and gives detailed description of fossil plants collected near the mouth of Sun River, Montana.

Parker, E. W., Mineral Resources U. S. for 1889–90: U. S. Geol. Survey, pp. 228–231. 1892.

The coal product of Montana is treated by counties and the amount applied to various uses is also shown. List is given of producing mines of the Great Falls region. Sand Coulee mine is largest producer. Contains analysis of Sand Coulee coal.

Parker, E. W., Mineral Resources U. S. for 1891: U. S. Geol. Survey, pp. 269–270. 1893.

The production of Montana coal mines, including those in the Great Falls coal field, is referred to briefly.

Weed, W. H., The coal fields of Montana: Eng. and Min. Jour., vol. 53, pp. 520–522, 542–543, 1892; vol. 55, p. 197, 1893.

Describes the geologic occurrence of the coal beds and the character and extent of the coal deposits in various Montana areas, including Great Falls.

Shoemaker, C. S., Report of the Montana inspector of mines. 1893.

Includes reports on Cascade County coal mines. The equipment and output of Belt and Sand Coulee mines are treated on page 33, and they are described and a statement of their production given on page 86.

Weed, W. H., Two Montana coal fields: Bull. Geol. Soc. America, vol. 3, pp. 301–330. 1892. Abstract: Am. Geologist, vol. 11, pp. 181–182. 1893.

Describes the general geology of the Great Falls coal field, giving information concerning the character and extent of the coals. The age of the coal-bearing rocks is also discussed.

WILSON, H. M., American irrigation engineering: Thirteenth Ann. Rept. U. S. Geol. Survey, pt. 3, pp. 371–386. 1893.

The proposed irrigation system of the Sun River valley and the adjacent region is fully described, and the rainfall, topography, and amount of reclaimable land is discussed.

PARKER, E. W., Mineral Resources U. S. for 1892: U. S. Geol. Survey, pp. 436–438. 1893.

The coal production of Montana is given by counties, and classified as to varieties—bituminous, semibituminous, and lignite.

FONTAINE, W. M., Description of some fossil plants from the Great Falls coal field of Montana: Proc. U. S. Nat. Mus., vol. 15, pp. 487–495. 1893.

Gives a description of the general character of the flora, its age, and the characteristics of several new species.

PARKER, E. W., Mineral Resources U. S. for 1893: U. S. Geol. Survey, pp. 320–322. 1894.

The coal output of Montana is given by counties. Reference is made to the increased activity over previous years.

PARKER, M. S., Water power of the falls of the Missouri, Great Falls, Mont.: Eng. News, vol. 32, p. 44. 1894.

The several falls of the Missouri are described, and estimates made of their water power. Makes reference to the Giant Springs and their effect on the river water.

WEED, W. H., AND PIRSSON, L. V., Highwood Mountains of Montana: Bull. Geol. Soc. America, vol. 6, pp. 389–422. 1895.

Describes the topographic features, geologic structure, and characteristics of the rocks of each eruptive center of the Highwood Mountains. Reference is also made to the coal at Belt, Mont., its thickness, character, and age.

PARKER, E. W., Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 4, pp. 144–148. 1895.

The coals of Montana are discussed and reference is made to their geologic age. The bituminous and lignitic fields are differentiated. Production by counties is given.

PARKER, M. S., The Great Falls water power: Eng. Rec., vol. 31, No. 16, pp. 274–275. 1895.

Gives brief description of the various falls of the Missouri near Great Falls, Mont., with illustrations of the power plant at Black Eagle Falls.

SHOEMAKER, C. S., Report of the Montana inspector of mines, 1895.

Includes reports of various coal fields in Montana, their production, etc. Cascade County mines are treated on p. 42.

PARKER, E. W., Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 3, pp. 454–458. 1896.

A condensed report on Montana coal production is included.

PARKER, E. W., Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 5, pp. 551–556. 1897.

A review including the coal production of Montana by counties, from 1889 to 1896, inclusive.

BYRNE, JOHN, Report of the Montana inspector of mines, pp. 37–38. 1897.

Includes reports on coal fields of Montana, and describes Belt and Sand Coulee mines.

PARKER, E. W., Nineteenth Ann. Rept. U. S. Geol. Survey, pt. 6, pp. 456–461. 1898.

A brief review is given of production of coal in Montana, dating from 1889. The number of mines in each county (in 1896), their output, and various items of information regarding the production are included.

PARKER, E. W., Twentieth Ann. Rept. U. S. Geol. Survey, pt. 6, pp. 440–443. 1899.

Cascade County is credited with two-thirds of the entire State coal production. Tables of coal production by counties are also included.

WEED, W. H., Fort Benton folio, Montana: Geologic Atlas U. S., folio 55, U. S. Geol. Survey, 1899.

Describes the surface features, geology, structure, and history of the region. Treats in considerable detail the mineral resources, including coal, gold, and silver. Contains topographic, geologic, economic, and structural maps, also columnar sections.

PARKER, E. W., Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 6, pp. 468–471. 1900.

Includes brief classified statistical tables of Montana coal production for 1898. States that a large proportion of coal is machine mined.

BYRNE, JOHN, Report of the Montana inspector of mines: Twelfth Annual Report, pp. 53–54. 1900.

Includes reference to workings and output of coal mines at Belt, Stockett, and Sand Coulee, Mont.

PARKER, E. W., Mineral Resources U. S. for 1900: U. S. Geol. Survey, pp. 406–408. 1901.

Statistics are given of coal production in Montana for 1899. That of 1900 is stated to be the largest in the history of the State, amounting to 1,661,775 short tons; value $2,713,707. Sixty-three per cent of the total production was machine mined.

STORRS, L. S., The Rocky Mountain coal fields: Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 3, 1901, pp. 415–471. 1902.

Includes discussion of the Montana coal fields, mentioning briefly the Great Falls coal field.

PARKER, E. W., Mineral Resources U. S. for 1901: U. S. Geol. Survey, pp. 401–403. 1902.

Gives tables of Montana coal production. During 1901 the Sand Coulee mines were practically abandoned, decreasing the output of Cascade County 333,988 tons.

STORRS, L. S., Eighth Rept. Montana Bureau Agr., Labor, and Industry, pp. 374–382. 1902.

Coal statistics for the State are given, and Storrs is quoted in reference to the extent and distribution of Montana coal fields.

WILLIS, BAILEY, Stratigraphy and structure, Lewis and Livingstone ranges, Montana: Geol. Soc. Am., vol. 13, pp. 305–352. 1902.

Describes the physiography, the occurrence, and character of the Algonkian, Carboniferous, Cretaceous, and Pleistocene formations, and the geologic structure of the general region.

PARKER, E. W., Mineral Resources U. S. for 1902: U. S. Geol. Survey, pp. 396–398. 1903.

Tabulated statistics of Montana coal production are given.

ROWE, J. P., Some Montana coal fields: Am. Geologist, vol. 32, pp. 369–380. 1903.

Describes by counties the bituminous, semibituminous, and lignite coals of Montana, giving briefly their geologic age and distribution.

ROWE, J. P., Some volcanic ash beds in Montana: Bull. Montana Univ. No. 17 (geol. ser., No. 1). 1903.

Discusses the origin and physical and chemical properties of volcanic ash in Montana, describing by counties its characteristics, geologic position, and general distribution. A number of illustrations are introduced, showing the microscopic character of the volcanic ash, leaves found in the deposits, and thickness and character of beds.

PARKER, E. W., Mineral Resources U. S. for 1903: U. S. Geol. Survey, pp. 484–487. 1904.

Contains brief review of coal-mining conditions in Montana as compared with previous years, and gives statistics of the coal output of the State.

NEWELL, F. H., Third Ann. Rept. U. S. Reclamation Service, pp. 307–313. 1904.

Discusses the proposed irrigation project of the Sun and Teton river district, and describes the water supply available from streams and storage reservoirs, also the territory which can be irrigated.

LEIBERG, J. C., Forest conditions in the Little Belt Mountains Forest Reserve, Mont., and the Little Belt Mountains quadrangle: Prof. Paper U. S. Geol. Survey No. 30, 1904.

The surface waters of the region and their relation to agricultural, grazing, and forest lands are included in the discussion.

STOCKETT, LEWIS, A bituminous coal breaker in Montana: Min. World, vol. 20, March 26, 1904.

Gives section and analysis of the coal bed mined at Stockett, Mont., and a detailed description of the coal breaker used by the company.

UPHAM, WARREN, Outer glacial drift: Am. Geologist, vol. 34, pp. 151–160. 1904.

Discusses the glacial drift of the northwestern States, including Montana. Reference is made to the effect which the glaciation had on the course of Missouri River.

PARKER, E. W., Mineral Resources U. S. for 1904: U. S. Geol. Survey, pp. 512–515. 1905.

Includes a discussion of the various Montana coal fields, their geologic age and importance. The production by counties is given, and the State output tabulated from 1880, the year of first reported production.

SAVAGE, H. N., Fourth Ann. Rept. U. S. Reclamation Service, pp. 222–224. 1905.

Includes report of surveys and lands to be irrigated by the Sun River project.

PIRSSON, L. V., Petrographic province of central Montana: Am. Jour. Sci., 4th ser., vol. 20, pp. 35–49. 1905.

Treats of the various igneous occurrences in the region of Belt and Highwood mountains, including a description of the porphyry of the Wolf Butte and Square Butte (of Highwood Mountains) laccoliths, and dike near the Highwoods on Williams Creek.

ROWE, J. P., Montana gypsum deposits: Am. Geologist, vol. 35, pp. 104–113. 1905.

The gypsum deposits are classified by localities, as the north, middle, and south fields. The middle field includes Cascade and Fergus counties. Includes description of Stucco mill on Belt Creek, giving location and age of deposits.

ROWE, J. P., The Montana coal fields: Min. Mag., vol. 11, pp. 241–250. 1905.

Discusses the production and value of coal from various fields in Montana, including the Great Falls coal field. Treats of present and future development of Belt and Sand Coulee mining districts, including geologic distribution of Montana coals by counties. Boiler tests and chemical analysis of Belt coal are also given.

PARKER, E. W., Mineral Resources U. S. for 1905: U. S. Geol. Survey, pp. 631–633. 1906.

Statistics are given of the Montana coal output, also a short discussion of the different fields.

WALSH, WILLIAM, Report of the Montana inspector of mines, pp. 29–38. 1906.

Includes reports of Cascade County mines, their development, production, etc.

CALHOUN, F. H. H., The Montana lobe of the Keewatin ice sheet: Prof. Paper U. S. Geol. Survey No. 50, 1906.

Describes briefly the surface features and geology along the terminal moraine of the Keewatin ice sheet in Montana. Contains detailed description of the glacial deposits and discusses the effects of glaciation of the region on the course of Missouri River.

ROWE, J. P., Montana coal and lignite deposits: Bull. Montana Univ. No. 37 (geol. ser. No. 2). 1906.

Describes Montana coals by counties. Contains a bibliography of literature bearing on the subject.

FISHER, C. A., Great Falls coal field: Bull. U. S. Geol. Survey No. 316. 1907.

Describes briefly the coals of the Great Falls region, giving their location, topographic relation, and geologic occurrence. Detailed description of the deposit is given and representative sections introduced. The present development of the various basins within the field is treated, and the quality of the coal is briefly described, including a number of ultimate analyses of representative coals in the field.

FISHER, C. A., Southern extension of the Kootenai and Montana coal-bearing formations in northern Montana: Econ. Geol., vol. 3, pp. 77–99. 1908.

Describes the Kootenai formation in the vicinity of Great Falls, Mont., tracing it southward across the Montana-Wyoming State line into the Bighorn basin, where it is correlated with the Cloverly formation. The subdivisions of the Montana group in northern Montana, as first worked out by Stanton and Hatcher, are also traced southward to the State line. The occurrence of coal in these formations at different localities throughout the area treated is given.

FISHER, C. A., Geology and water resources of the Great Falls region, Montana: Water Supply Paper No. 221, U. S. Geol. Survey, 1908.

A brief treatment of the general geology of the region is given, with special reference to the prospects for the occurrence of underground water. The surface waters are also described, including their present and proposed uses for irrigation, waterpower, etc.

TOPOGRAPHY.

RELIEF.

The area treated in this report presents a considerable variety of geographic features, all of which have a direct or indirect bearing on the development of the coal resources of the Great Falls field. The area lies within a zone which is transitional between plains and mountain topography, including portions that present features characteristic of both provinces. Its salient features are broad, gently sloping plateaus bordering the adjacent mountain ranges. These plateaus are traversed by numerous mountain streams, which flow through valleys that are deep and relatively narrow in the central portion of the district, but that become wide and open on the plains to both the east and the west. Along the southern margin of the area, from Smith River to the eastern end of the field, the surface of the plains rises gradually by sloping plateaus, culminating in a zone of high, hilly country bordering the Little Belt Mountains, which lie to the southward. East of Belt Creek and north of the area described the Highwood Mountains, a cluster of isolated peaks, rise abruptly above the plains to an altitude of 6,700 feet. Between the Highwood and Little Belt mountains there is a divide locally known as the Otter Creek divide, whose altitude at its lowest point is about 4,500 feet. The country east of this divide is drained by Arrow Creek and its tributaries; that to the west by Belt Creek and its largest affluent, Otter Creek, from which the divide derives its name.

The range of altitude within the field is moderate. The highest points occur along the base of the Little Belt Mountains, where the more prominent summits rise to an altitude of about 5,500 feet, while the lowest portion of the field lies along Missouri River, below Big Falls, where the altitude is about 3,000 feet above sea level. The average altitude of the region is between 3,500 and 4,000 feet, and the extreme variation in altitude for any given locality is about 1,300 feet in a horizontal distance of 1½ miles. This difference in elevation occurs between Belt Creek and the summit of Belt Butte.

In the plains province the relative altitudes of the valley bottoms and the summits of the bordering plateaus range from 300 to 600 feet.

East of the low divide between the Highwood and Little Belt mountains the country slopes gradually northeastward toward Missouri River. It is traversed by several streams draining the northeastern slope of Little Belt Mountains. These streams flow through relatively wide open valleys bordered by gravel-capped terraces of different elevation. Stanford Butte, a prominent ridge between Running Wolf and Surprise creeks, is capped by a remnant of an ancient terrace, and to the north and east of this ridge gravel-capped plateaus at lower levels occupy all the interstream spaces. Toward the Little Belt Mountains the gravel-capped terraces give way to prominent hogback ridges formed by the sandstone members of the Ellis and Kootenai formations, which extend in an irregular line along the base of the mountains. Skull Butte, a low dome-shaped uplift about 6 miles south of Stanford, rises nearly 200 feet above the surrounding region. It is considerably dissected about the periphery and in the center by numerous small streams, some of which expose the coal bed of the Kootenai formation, which encircles this uplift. South of Skull Butte there are a number of prominent ridges with long gradual slopes to the north and bold escarpments to the south, overlooking valleys which have been excavated in the softer shale of the Quadrant formation.

Throughout the area east of the low divide connecting the Highwood and Little Belt mountains the valleys leading into the mountains are wide and open on the plains, but toward the foothill zone they decrease in width, deepen, and branch into many canyon tributaries which cut the upturned edges of the coal-bearing Kootenai rocks, thus exposing the coal bed at many places. These numerous small valleys lead from the zone of coal outcrop in the higher hogback ridges down to the more nearly level plains region where the main line of the Billings and Northern Railroad has been constructed, and thus afford an easy approach to the coal.

Broadly viewed, the country between Otter Creek divide and Missouri River, which includes the largest area in the Great Falls coal field underlain by workable coal, is a high plateau sloping gently northward, and deeply dissected by numerous canyons. Otter, Belt, and Boxelder creeks, Sand Coulee, and Smith River are the principal streams traversing this area. All of these except Boxelder Creek flow through deep, narrow valleys which cut through and expose the coal, and along them, owing to the general accessibility of the beds, the principal development of the coal resources of the Sand Coulee area has taken place. The altitude of the plateau varies from 3,500 feet along Missouri River to 4,500 feet or more along the southern border of the area. The difference in altitude between valley bottom and plateau summit in the northern part of the district is 200 to 400 feet, but toward the mountains this difference increases to over 600 feet. The streams of this district all flow in a northerly direction except three of the larger tributaries of Smith River—Boston, Ming, and Goodwin coulees—which flow nearly west. Sand Coulee, which is formed by the confluence of a number of canyon tributaries 6 miles southeast of Stockett, continues northward for several miles to a point when it turns sharply to the west, and for the remainder of its course it meanders through a wide, flat-bottomed valley formed by the preglacial erosion of Missouri River.

West of the Missouri and south of Sun River the surface rises in successive plateaus to the west. The lowest of these, which lies north of Ulm station and comprises what is locally known as Ulm Bench, has an altitude of about 3,650 feet. On the west side of Ulm Bench there is a low saddle separating it from a higher plateau, only a small portion of which is included within the area described. North of Sun and Missouri rivers there is a high plateau region which farther west is deeply dissected by the valley of Muddy Creek. East of Muddy Creek only the southern edge of this plateau is included within the field. It extends eastward as a line of prominent bluffs north of Great Falls, terminating in a group of ridges and buttes of which Black Butte is a conspicuous outlier.

DRAINAGE.

The Great Falls field, being located along the base of the Rocky Mountain front range, is traversed, especially in its western half, by a number of relatively large mountain streams, some of which have been important factors in the industrial development of the district. The eastern half of the area contains no large rivers, but is drained, as previously stated, by numerous small mountain streams which flow northeastward, entering the Missouri by way of Judith River.

MISSOURI RIVER.

The principal stream of the district is Missouri River. It enters the field near Cascade, and flows in a northerly direction to the vicinity of Great Falls, where it pursues a more easterly course, continuing thus to the border of the field. The portion of the stream above Great Falls flows in a meandering course through a wide, open valley, but that below this point occupies a narrow valley bordered by precipitous bluffs, passing over a number of cataracts known as the Great Falls of Missouri River. At present only one of these falls, Black Eagle, the uppermost of the series, is utilized for the development of power. The drainage area of the Missouri at Cascade, Mont., is estimated as 18,295 square miles, and the flow of the river ranges from 2,000 to 22,000 second-feet. Its largest tributaries from the south are Smith River and Belt Creek, and from the west Sun River. A number of medium and large-sized intermittent streams with relatively large drainage areas enter the river from either side. Bird Creek, Castner Coulee, Sand Coulee and its tributaries, Boxelder Creek, and Red Coulee enter from the south, and Little Muddy Creek enters from the west. The city of Great Falls and the Boston and Montana smelters are located on Missouri River, and the Great Northern Railway has been built up its valley through the Big Belt Mountains, connecting Great Falls with the large mining centers of Butte and Anaconda.

SUN RIVER.

Sun River rises high in the Lewis Range and joins the Missouri at Great Falls. Only the lower course of the river, however, is included within this field. The main stream is formed by the union of the north and south forks of Sun River, which occurs about 3 miles below Augusta, a town located a few miles east of the base of the Lewis Range, beyond the limits of the field. The principal tributary of Sun River from the north within the area described is Muddy Creek, which drains the high plateau between Sun and Teton rivers, emptying into the latter near Vaughn. It is an intermittent stream of minor importance.

SMITH RIVER.

Smith River has its source far to the southeast, in the vicinity of Castle Mountains, and flows northwest, draining the highland between the Big and Little Belt mountains. It enters the area described near the center of the south line of T. 17 N., R. 3 E., and, flowing in a northeasterly direction, joins Missouri River at a point near Ulm. Within the district the stream flows in a meandering course through a deep and moderately narrow valley, which exposes high in its bluffs on either side the workable coal bed of the Kootenai formation throughout Tps. 17 N., Rs. 2 and 3 E. Smith River has a flow ranging from about 50 to over 400 second-feet; its largest tributary is Hound Creek, which joins it from the west near Orr post-office. The valley of Hound Creek also exposes the workable coal of the lower part of the Kootenai for about 1 mile above its mouth, and the largest mine in the Smith River district is located on this tributary, in the SW. ¼ sec. 24, T. 17 N., R. 2 E. Hound Creek, a vigorous mountain stream having a continuous flow, drains the northern end of the Big Belt Mountains, some of its tributaries extending far up the slopes of that range. From the east three intermittent streams enter Smith River—Boston, Ming, and Goodwin coulees. In the upper part of Ming Coulee, in the vicinity of Eden, the valley exposes the coal measures, and here a number of small mines have been opened. The same is true in the upper part of Boston Coulee. Smith River Valley and its principal tributaries, Ming and Boston coulees and Hound Creek, furnish a valuable means of access to the coals of this little-developed portion of the Great Falls coal field. The large flow of water in Smith River is also an important consideration in the development of this coal district, for the percentage of impurities present in the coal is sufficient to render washing necessary before it can be successfully placed on the market. In neither Boston nor in Ming coulee is there sufficient water to wash the coals that could be mined from them, but the impurities might be removed by a dry-washer process such as is now employed at Stockett.

BELT CREEK.

Belt Creek rises in the northern part of the Little Belt Mountains, flows northward across the central part of the district, draining the territory west of the Highwood Mountains, and enters the Missouri about 12 miles northeast of Great Falls. It flows through a valley about 300 feet deep, which has a width varying from one-half to three-fourths of a mile. In the vicinity of the town of Belt, where the valley crosses the area underlain by coal, it exposes in the bluffs on either side, a short distance above the valley, beds of coal of workable thickness, thus producing favorable conditions for the development of the deposits. A number of mines are located there, including the Anaconda Copper Mining Company's mine, one of the largest in the Great Falls coal field.

Belt Creek is a vigorous mountain stream which carries a large flow of water throughout all seasons of the year, especially in its upper course, but at the town of Belt all this water sinks to an underflow during the late summer months, leaving the stream bed dry. This loss is due principally to the fact that the valley floor here consists of soft, porous sandstones, into which the water passes readily. From a point a short distance below the town of Belt to its mouth the stream has a small but continuous flow. A view of the dry bed at Belt is shown in Pl. III. The sinking of the flow of Belt Creek at Belt is a disadvantageous feature from a coal-mining point of view, for it renders it necessary to sink wells in the valley in order to obtain a sufficient amount of water to wash the impurities from the coal.

The principal tributaries of Belt Creek are Otter Creek from the east and Neel Creek from the west. Otter Creek rises on the northern slope of Little Belt Mountains, and, flowing northwest, enters Belt Creek about 1 mile above Armington. It carries considerable water derived from snow on the mountains and from springs along its course. Neel Creek is a much smaller stream, having an intermittent flow. In the lower part of the valley of Neel Creek coal of

DRY BED OF BELT CREEK, NEAR BELT, MONT.

workable thickness is exposed. That part of Otter Creek Valley which lies between Spion Kop and Nollar's mine crosses an area underlain by valuable coal deposits, but in the center of this area the valley is not cut sufficiently deep to expose the coal, which, however, could be easily reached by shafting. The favorable location of this valley with respect to the limits of the coal area offers a valuable means of access to the deposits.

OTHER SMALL STREAMS.

The area between Belt Creek and Smith River is drained by Boxelder Creek and Sand Coulee. Boxelder Creek rises high on the plateaus about 3 miles west of Riceville, flows northward in a direction roughly parallel to Belt Creek, and enters the Missouri about 9 miles east of Great Falls. It carries only a small flow of water, and its valley in the upper part, where coal-bearing rocks occur, is not cut sufficiently deep to expose the coal; hence it is not an important factor in the development of this part of the Great Falls coal field. Sand Coulee, an intermittent stream with a large drainage area, is formed by the union of several small canyon tributaries southeast of Stockett. It continues northward to a point about 6 miles below Stockett, where it makes a sharp turn to the west and meanders through a wide, level-floored valley for about 7 miles, entering Missouri River about 4 miles above Great Falls. This intermittent drainageway, especially in its upper course, and its tributaries from the west, Straight and Giffen coulees, have deep narrow valleys, which cut and expose the coal-bearing zone of the Kootenai formation, thus producing favorable conditions for development. It is in the valleys of these intermittent streams, where the towns of Stockett and Sand Coulee are located, that the greatest coal mining activity has taken place.

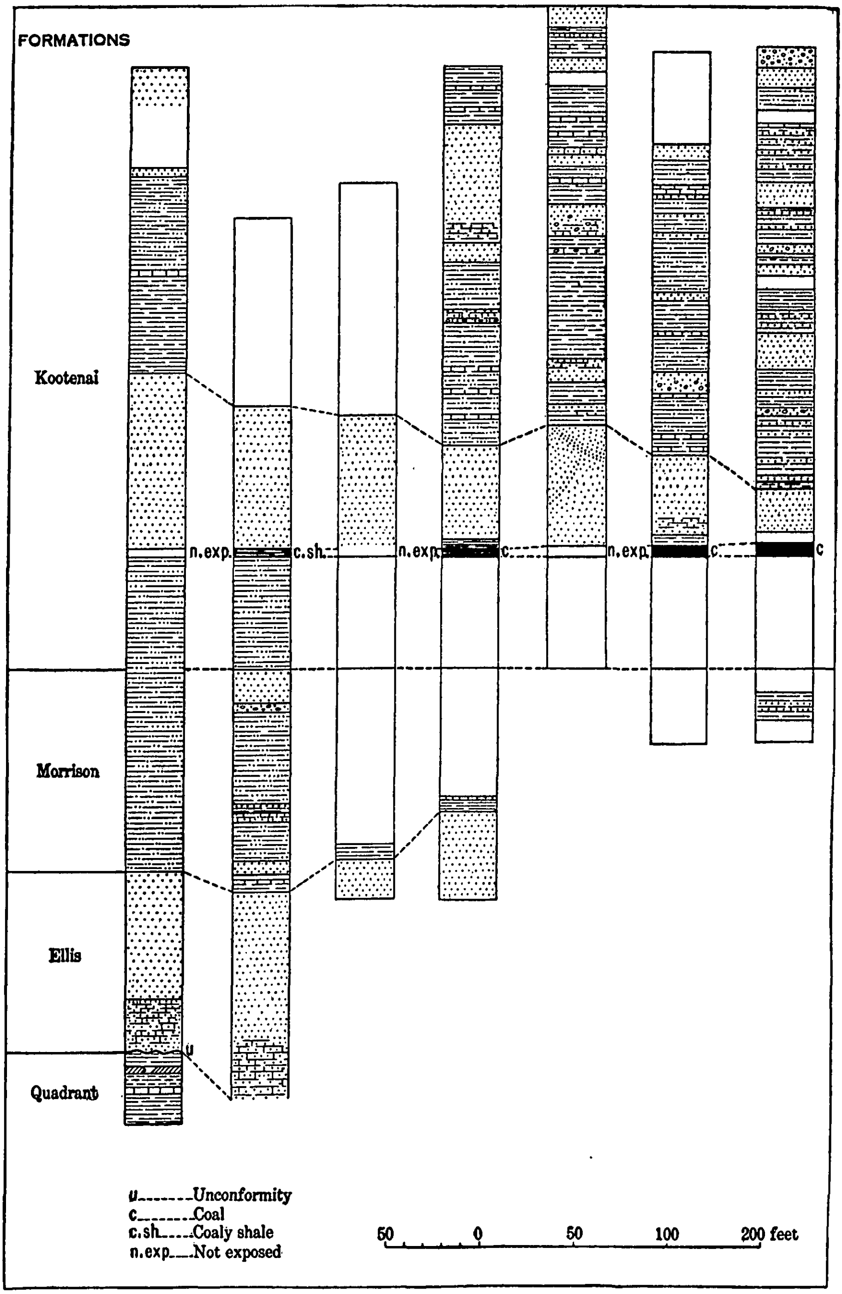
East of Otter Creek there is a prominent ridge that forms a low divide between Highwood and Little Belt Mountains. The drainage to the east of this divide, as previously stated, is all to the northeast, into Arrow Creek, a small tributary of the Missouri entering the latter a short distance above the mouth of Judith River. Arrow Creek, which has its source on the southern slope of Highwood Mountains, flows eastward, passing out of this district in T. 18 N., R. 11 E. Its principal affluents are Surprise and Running Wolf creeks, the former having its source at the base of Wolf Butte and pursuing a northeasterly course. Running Wolf Creek rises higher up the slopes of the Little Belt Mountains farther to the southeast, and flows northeastward past Stanford Butte. East of Running Wolf Creek several small branches cross the extreme southeast corner of the district and enter Judith River. These are Skull, Willow, and Sage creeks, all of which, as previously stated, expose in their upper courses workable beds of coal.

CULTURE.

Settlement in the Great Falls field, as elsewhere, is determined by geologic and climatic conditions. Along all the larger stream valleys where surface water for irrigation purposes is available settlements are numerous, while much of the upland and grazing districts is thinly populated. On the higher slopes bordering the mountains in the zone of increased rainfall there are many small farms, some of which are among the best improved places in the district.

There is one relatively large town, three medium-sized coal-mining towns, and a number of smaller trading points. Great Falls, a town of 18,000 inhabitants and a thriving business center, is located on Missouri River near the north-central portion of the field. While at present none of its railroad lines are transcontinental, they are the most important connecting lines between the Great Northern and the Northern Pacific, and when the Billings and Northern is completed it will open up a new transcontinental route through Great Falls to the northwest coast. At the present time railroads extend in four directions from Great Falls—one southwest to Helena and Butte; another northwest to Havre, a small town on the main line of the Great Northern; a third, the Montana and Great Northern, northwest to Shelby Junction; and a fourth, the Neihart branch of the same road, southeast to Neihart. The last named is connected with Stockett and Sand Coulee, two of the larger coal-mining camps, by a short branch line from Gerber station. The Boston and Montana Consolidated Copper and Silver Mining Company's smelters and refineries are located at Great Falls, as is also the Royal Milling Company's plant and a number of smaller business enterprises. The ore handled at the smelters comes from Butte and Anaconda; this, together with the coal and limestone used in the operation of the plant makes a relatively large freight traffic for Great Falls, while it also furnishes employment for a large number of men.

Belt, one of the largest coal mining towns in the district, has a population of about 1,000, composed mainly of employees of the Anaconda Copper Mining Company, the largest coal-mine operator at the place. It is located on Belt Creek, about 25 miles southeast of Great Falls, on the Neihart branch of the Great Northern Railway, and is the oldest coaling town in this region. About 10 miles southwest of Belt and nearly 20 miles from Great Falls are the two coal-mining towns of Stockett and Sand Coulee. Stockett, which has a population of about 800, composed largely of coal miners employed by the Cottonwood Coal Company, one of the two largest coal mining companies operating in the district, is located on East Fork of Sand Coulee. Sand Coulee, about 2½ miles northwest of Stockett, is a smaller mining town of about 400 people. It is situated in Cottonwood Coulee, a branch of Sand Coulee, and owes its existence mainly



COLUMNAR SECTIONS OF THE STRATIGRAPHY ALONG BELT CREEK VALLEY.

(Columns are numbered from left to right.)

1, West side of Belt Creek, 1 mile north of Goodman siding; 2, east side of Belt Creek, 2½ miles north of Goodman siding; 3, west side of Belt Creek, one-eighth mile above mouth of Otter Creek; 4, east side of Belt Creek, one-eighth mile below mouth of Otter Creek; 5, east side of Belt Creek, one-half mile above Belt; 6, east side of Belt Creek at Belt; 7, west side of Belt Creek at Belt.

to the Nelson and Gerber coal companies, which are operating at this place.

The remainder of the towns within the district are supported mainly by a ranch population.

There are no towns along Missouri River below Great Falls within the area described, but above that town there are two small stations, Ulm and Cascade. The latter, located near the base of the Big Belt Mountains, has a population of about 200, and is supported by a large ranch trade along either side of the river.

About 2 miles above the mouth of Smith River there is a post-office known as Truly, and farther up the river there was another known as Orr, which has recently been discontinued.

In Belt Creek Valley, about 2 miles above Belt, is the small town of Armington, which is situated at the junction of the Billings and Northern Railroad and the Neihart branch of the Great Northern. It is mainly a small railroad town, which receives a portion of the ranch trade of the surrounding country. Along the Billings and Northern Railroad there are a number of new towns and sidings, located at intervals of about 6 miles. These are Reinsford, Spion Kop, Geyser, Stanford, and Windham. Old Stanford and Old Geyser, which are located at some little distance from the new town sites bearing these names, are important trading points for a large ranch district along Arrow, Skull, Running Wolf, and Sage Creek valleys.

DESCRIPTIVE GEOLOGY.

STRATIGRAPHY.

GENERAL OUTLINE.

The surface formations throughout the area to which this report relates consist mainly of sedimentary rocks and igneous intrusives in the form of dikes and laccoliths, the intrusives being especially abundant throughout that part of the field bordering the adjacent mountain ranges. The strata lie in general nearly horizontal, dipping at a relatively small angle to the north and east, away from the mountains and toward the plains. Throughout most of the Great Falls field the rocks lie apparently flat, but on closer examination they are found to be gently folded into a series of shallow synclines and low anticlines. These, however, are scarcely perceptible to the casual observer, being revealed only by careful examination of the beds exposed along the sides of some of the valleys. The rocks are representative of Carboniferous, Jurassic, Cretaceous, Tertiary, and Quaternary systems. The distribution of the formations is shown on the geologic map (Pl. I), and their stratigraphy and structural relations are illustrated in the columnar and cross sections shown on Pl. IV and Pl. VII. The table on pages 22–23 shows the age, order, characteristic features, thickness, distribution, stratigraphic relations, and economic importance of the formations.

Geologic formations in the Great Falls region.

System.	Formation.	Character of deposit.	Thickness (feet).	Areal distribution.	Relation to other formations.	Economic importance.
Quaternary.	Alluvium.	Light-colored silt and clay, with local gravel beds.	20 to 40	Occupies valleys throughout the district.	Lies unconformably upon older formations.	Contains sand and gravel for masonry and clay for brick.
	Lacustrine deposits.	Fine-grained, light-colored silt and clay.	Not determined.	Occurs as a valley filling in all the larger valleys in front of the terminal moraine.	Lies unconformably on older rocks.	Clay suitable for the manufacture of building brick.
	Morainal deposits.	Unassorted mixture of sand and gravel in which bowlders of varying size are scattered but not abundant.	Not determined.	Occupies area lying south of Missouri River between Great Falls and Belt Creek; also a narrow strip north of Missouri River in the vicinity of Great Falls.	Occurs as a thin mantle on the plateaus of Cretaceous rocks and as a filling in preglacial valleys.	Contains local beds of gravel suitable for road construction, also some common varieties of clay.
Quaternary and tertiary(?).	Terrace gravel.[a]	Sand, gravel, sandy clay, and conglomerate.	25 to 40.	Principal areas lie east of Otter Creek divide.	Lies unconformably on older rocks.	Gravel suitable for general masonry.
Cretaceous.	Colorado shale.	Upper part consists of dark-colored shale with a few thin sandstone layers and a bed of volcanic ash; lower part consists of massive gray sandstone, often concretionary, iron-stained, and containing thin layers of pebbly conglomerate.	1,600.	Exposed along southern side of Highwood Mountains from Belt Creek to eastern border of district. Basal sandstones of formation cap the plateau region between Red Buttes and Missouri River; also the area between Missouri and Sun rivers; and occur north of Sun River.	Lies apparently conformably upon Kootenai rocks.	Contains sandstone suitable for building purposes; also valuable clay, bentonite, volcanic ash, etc.
	Hiatus.					
	Kootenai formation.	Massive gray sandstone, red sandy shale and clay, with an occasional bed of white limestone. The sandstone predominates in the lower portion while the red shale, clay, and limestone constitute the greater part of the upper members; bed of workable coal about 60 feet above base.	400 to 500.	Occupies surface area over a great part of the district lying between Smith River and Belt Creek and is the surface formation of high plateaus south of Otter Creek; east of Otter Creek extends as a narrow outcrop along northern side of Little Belt Mountains.	Lies apparently conformably on Morrison formation.	Valuable deposits of coal and fire clay occur in the lower part of formation, and the basal sandstones are used successfully as building stone.

Jurassic (?).	Morrison shale (?).	Variegated shale and clay, containing sandstone layers, one above the middle of the formation; cinnamon-brown color; bone-bearing; limestone layers sometimes present in lower part.	80 to 120.	Outcrops as a narrow band below Kootenai rocks in sides of canyons bordering streams draining northern slope of Little and Big Belt Mountains from Smith River to Otter Creek. East of Otter Creek its outcrop zone, which is of varying width, generally occupies an inner face of low hogback ridges of Kootenai rock bordering the Little Belt Range.	Lies apparently conformably on Ellis formation.	Contains limestone and clay.
Jurassic.	Ellis formation.	Dove-colored limestone, overlain by reddish-brown, coarse-grained sandstone, coarsely conglomeratic at base.	80 to 120.	Between Smith River and Otter Creek; the outcrop area is limited to canyons traversing the plateau region bordering the Little and Big Belt Mountains.	Lies unconformably upon Quadrant and Madison formations.	Sandstone and limestone could be used for building purposes.
	Unconformity.					
Carboniferous.	Quadrant formation.	Sandstone, red and green shales, clays, and limestone; with an occasional bed of gypsum in lower part; also one at the top.	350 to 500.	In the upper part of Belt Creek Valley and extending eastward throughout a zone of varying width along the base of the Little Belt Mountains to the east end of district.	Lies apparently conformably upon Madison limestone, but there is a very abrupt change in character of rocks along the contact.	Gypsum occurs in deposits of workable thickness in lower part of the formation, and also at the top.
	Madison limestone.	Massive, light-gray limestone and argillaceous shale.	140 exposed.	In Smith River Valley in T. 17 N. R. 3 E., in the vicinity of Stockett, along the northern base of Little Belt Mountains from Belt Creek to east end of district.		Limestone is used extensively in the Boston and Montana smelters at Great Falls for fluxing.

a The highest gravel terraces are probably of late Tertiary age.

SEDIMENTARY ROCKS.

CARBONIFEROUS SYSTEM.

MADISON LIMESTONE.

General statement.—The Madison limestone is very conspicuous along the north side of the Little Belt Mountains, but the greater part of it lies outside of the area here described. The only exposures in the district are along East Fork of Sand Coulee and its tributaries and on Smith River, where a local doming of the beds exposes 100 to 200 feet of the formation. Its distribution is shown on the geologic map (Pl. I). Along the flanks of the Little Belt Mountains outside of the area to which this report relates the limestone has a thickness of about 1,000 feet and consists of three members. The lowest member, which is more or less argillaceous, has been called the Paine shale, the more massive limestone of the middle part the Woodhurst limestone, and the top member the "Castle" limestone. In the Little Belt Mountains the Madison limestone carries a typical Mississippian fauna.

"Castle" limestone member.—The "Castle" limestone member, which forms "Sluicebox Canyon," the lower end of which is at Riceville (Pl. V), is exposed to view at numerous places in the vicinity of Stockett; farther south, in the head of Ming Coulee; and on Smith River. Within the area examined its greatest observed thickness is about 140 feet, which is found at the head of Ming Coulee, about 10 miles southwest of Stockett. Here the rock is massive, compact, and of a medium-gray color, but weathers light. It occurs in strata 15 to 20 feet thick, which at many places have weathered to rough, cavernous surfaces, forming castellated masses. Interbedded with the massive strata are thin layers of softer calcareous material. At Stockett 15 feet of oolitic limestone was observed in this formation, underlain by compact light-colored limestone. The fossils listed below were collected from the limestone at Stockett and at the head of Ming Coulee, outside of the area described:

Fossils from Stockett, Mont.

Amplexus sp.
Zaphrentis sp.
Syringopora surcularia.
Schuchertella sp.
Spirifer centronatus var.
Spiriferina solidirostris.
Seminula madisonensis.
Seminula humilis.
Cleiothyridina crassicardinalis.
Eumetria verneuiliana.

Fossils from head of Ming Coulee.

Schuchertella sp.
Spiriferina solidirostris.
Seminula madisonensis.
Eumetria verneuiliana.
Camarotœchia sp.

MADISON LIMESTONE OVERLAIN BY QUADRANT SHALE, NEAR RICEVILLE, MONT.

These fossils were determined by George H. Girty, who regards them as Mississippian in age.

The Madison limestone in the vicinity of Riceville is overlain by the brick-red sandy shale or impure sandstone of the Quadrant formation, but farther west, in Sand Coulee and its tributaries, and also at the head of Ming Coulee and on Smith River, the Quadrant is absent, the basal limestone or the calcareous conglomeratic sandstone of the Ellis formation resting upon the Madison limestone. These unconformable relations are shown in cross section C–C, Pl. I, and on Pl. VI.

QUADRANT FORMATION.

Character and extent.—The Quadrant formation comprises a succession of beds of variable character and thickness which immediately overlie the Madison limestone in most places throughout the Little Belt Mountains region. These beds, although different in character, have been regarded by Weed as the stratigraphic equivalent of the Quadrant formation near Quadrant Mountain in the Yellowstone Park region, where the name was first applied. The Quadrant formation in the Great Falls field consists of sandy shale or argillaceous sandstone and limestone with beds of gypsum in the lower part and near the top. It is not coal bearing, and consequently is not included in the area studied except at a few localities, notably on Belt Creek near Riceville, on Little Otter Creek 2½ miles above its mouth, along the base of Little Belt Mountains from Geyser Creek to near the southeast corner of the area described, and in the central part of Skull Butte. No careful study was made of the stratigraphy of the formation except on Belt Creek near Riceville, where the basal member consists mainly of red and green sandy shale with an occasional bed of white gypsum and a few thin layers of white limestone. Very few typical sandstone members were observed at this locality, although Weed [a] has applied the name Kibbey sandstone to the basal member of the Quadrant in this general region. The upper member of the section, which the same writer has designated the Otter shale, consists largely of red and green sandy shale with limestone layers occurring at frequent intervals. No gypsum was observed in this part of the section except near the top. The following section of a part of the formation was measured near Riceville:

Section of part of Quadrant formation on east side of Belt Creek near Riceville, Mont.

	Ft.	in.
Shale, dark green	51	
Limestone, white	1	
Shale, green, sandy	1	

[a] Weed, W. H., Description of the Fort Benton district: Geologic Altas U. S., folio 55, U. S. Geol. Survey, 1899.

Section of part of Quadrant formation on east side of Belt Creek near Riceville, Mont.—Continued.

	Ft.	in.
Limestone, white, compact, laminated	2	6
Shale, dark greenish	20	
Shale, greenish, sandy	20	
Limestone, dove-colored, thinly laminated	1	
Shale, red and green, containing hard limestone layers 68 inches thick	25	
Limestone, alternating layers of, and shale, greenish	7	
Shale, red, containing layers of dove-colored limestone in lower part	14	
Limestone, blue, compact, porous	3	
Limestone and shale, gray, alternating layers of white and dove-colored limestone thinly laminated, with an occasional bed of gray shale	20	
Soft sandy material	11	
Limestone, hard, gray, compact	3	6
Shale, dark green, sandy	20	
Limestone, hard, gray, compact	1	6
Soft sandy material	8	6
Gypsum, white	3	6
Gypsum, impure, and dark-gray shale, with nodules of black flint	6	
Shale, greenish, sandy, containing thin layers of white limestone	34	
Limestone, white		6
Shale, green, sandy	6	
Limestone, white		8
Shale, green, sandy	29	
Limestone, white, compact	2	
Gypsum, white	2	
Shales, red and green, sandy	34	6
Beds concealed	7	
Shale, red	17	
Madison limestone.		
Total	352	2

The total thickness of the formation as observed near Riceville is less than 500 feet, but according to Weed[a] its thickness greatly increases toward the southeast, reaching a total of 1,400 feet near Utica. Farther east, along the Little Belt and Big Snowy mountains, W. R. Calvert[b] has observed that the Quadrant has a thickness varying from 450 to 750 feet, while its lithologic character is not materially different from that shown on Belt Creek, except for the absence of beds of gypsum.

The Quadrant formation is overlain unconformably by the basal limestone and conglomeratic sandstone of the Ellis formation, and rests with apparent conformity on the underlying Madison. There is, however, a very abrupt change in the character of the rocks at

[a] Weed, W. H., Twentieth Ann. Rept. U. S. Geol. Survey, pt. 3, 1898–99, p. 295.

[b] Calvert, W. R., Geology of the Lewistown coal field, with special reference to coal: Bull. U. S. Geol. Survey (in preparation).

the Quadrant-Madison contact, probably indicating a hiatus. The details of distribution of this formation are shown in Pl. I.

Age.—Previous workers in this field have published statements concerning the age of the Quadrant which are somewhat at variance, having assigned the formation to both the "Lower" and "Upper" Carboniferous. While, as previously stated, no special study was made of the Quadrant formation during the investigation of the Great Falls coal field, subsequent observation has thrown some light on the age of these beds. Along the north side of the Little Belt Mountains, in the vicinity of Utica, a few miles beyond the eastern border of the Great Falls coal field, W. R. Calvert and the writer obtained a large collection of fossils from the Quadrant, and Calvert made additional collections from this formation farther east in the Judith basin.[a] These collections have all been studied by George H. Girty, who makes the following statements concerning their age:

> The several collections made in the Quadrant in this area indicate a single uniform fauna. A definite opinion as to the age of the Quadrant fauna must be reserved until more complete evidence has been obtained and more extensive investigations have been undertaken, for the facies is very largely new to the American Carboniferous. At present it seem probable that the Quadrant will prove to be of early Pennsylvanian or Pottsville age. Faunas which have an upper Mississippian facies and are younger than the Madison have been cited from the Little Belt Mountains and referred to the Quadrant. They are considerably different from the Quadrant fauna of this report, and it seems possible that three distinct faunas will be involved in the problem—a Madison fauna, a late Mississippian fauna, and a post-Mississippian fauna. The fauna of the typical Quadrant is at present unknown.

JURASSIC SYSTEM.

ELLIS FORMATION.

Character and extent.—The Ellis formation includes a basal limestone of variable thickness, ranging from 15 to 60 feet, which in places merges upward into a coarse conglomerate that passes into a medium-grained sandstone, light brown to gray in color, and more or less thin bedded. In other localities, however, the change from limestone to conglomerate is abrupt. The limestone and conglomerate contain marine Jurassic invertebrate fossils. Some of those in the conglomerate are fragmentary, but more are complete, with pebbles of limestone and quartzite several inches in diameter. The component parts of the conglomerate are bound together by a calcareous cement. The total thickness of the formation is about 80 to 120 feet. It rests unconformably upon the shale of the Quadrant formation in certain parts of the field, and upon the Madison limestone in others. (Pl. VI.)

The exposed area of the Ellis formation is not large throughout the Great Falls region. It is exhibited in the sides of the bluffs bordering Smith River and its tributary, Hound Creek, also along Sand Coulee

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[a] Op. cit.

and its various branches in the vicinity of Stockett, and along Belt Creek from Armington to the southern border of the district. East of Belt Creek the formation is exposed in the head of Otter Creek and its numerous branches from the south; also throughout a zone of varying width extending to the southeast along the northern slope of the Little Belt Mountains. Skull Butte is encircled by a narrow band of the formation. The details of distribution of the Ellis formation are shown on the geologic map (Pl. I).

The following sections illustrate the succession of the beds of the formation in different parts of the field:

Section of Ellis formation near Goodman siding, Montana.

	Feet.
Sandstone, massive, light brown to gray, weathering tan, conglomeratic and fossiliferous at base	66
Limestone, reddish brown, fossiliferous	6
Beds concealed (estimated)	18
	90

Section of Ellis formation at head of Ming Coulee, Montana.

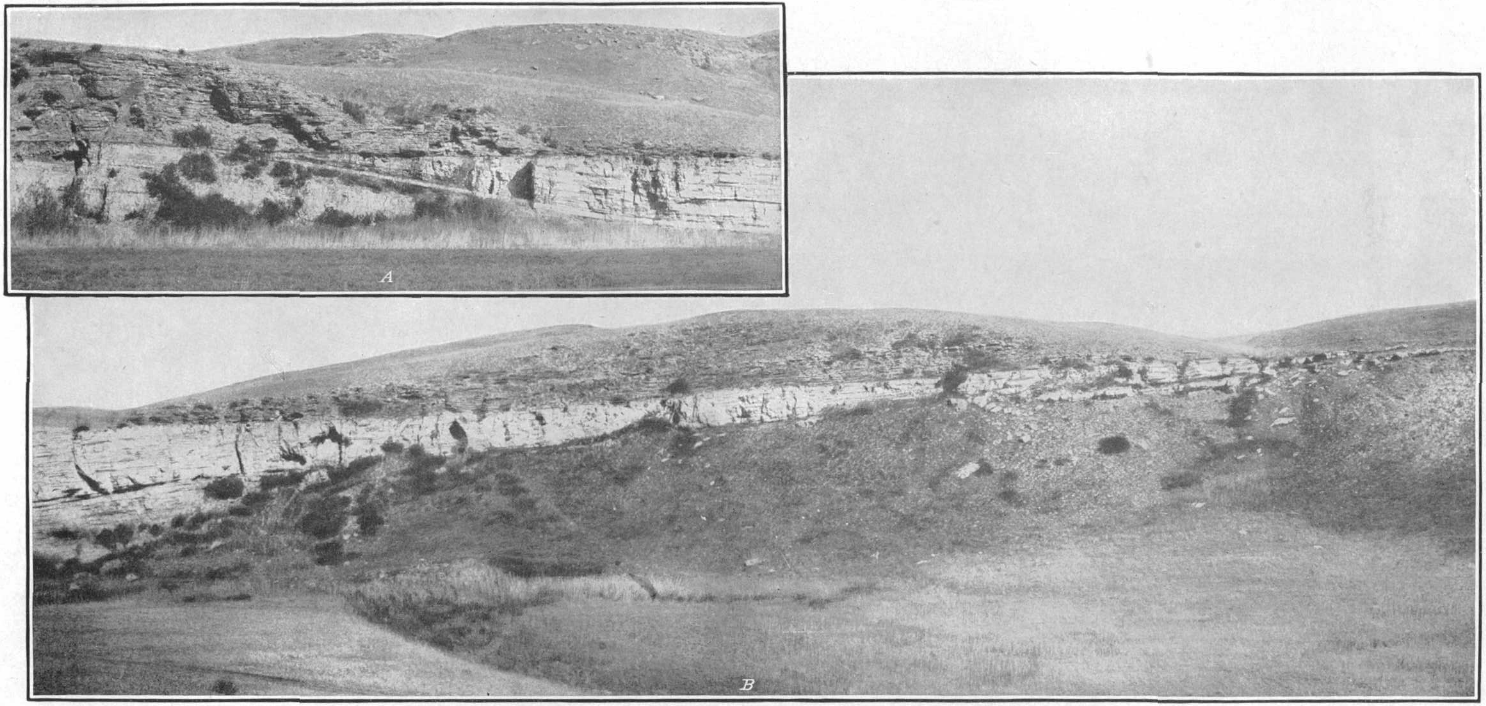
	Feet.
Sandstone, gray, weathering brown, thin bedded	60
Sandstone, gray, conglomeratic, containing marine Jurassic fossils	29
Limestone, dove colored, massive; basal member brecciated and containing Jurassic fossils	60
	149

Fossils.—Fossil invertebrates, mainly *Ostrea* and *Camptonectes*, are present in great abundance in the two lower members of the above section. The numerous specimens of these genera and a few other forms are sufficient to determine that the rocks belong to the Ellis formation, which in the Yellowstone National Park and neighboring areas yields a characteristic upper Jurassic fauna. The sandstone of the Ellis formation throughout the Great Falls region is usually not fossiliferous, but the conglomerate and underlying limestone contain an abundance of Jurassic fossils. Near the head of Hazlett Creek, in sec. 31, T. 16 N., R. 11 E., forms were collected from thin layers of limestone near the base of the Ellis formation, and were identified by T. W. Stanton as *Rhynchonella myrina* Meek?, *Ostrea strigilecula* White, *Camptonectes* sp., and *Belemnites* sp.

From the conglomerate sandstone of the Ellis formation on the east side of Otter Creek a small collection of fossils was made, from which T. W. Stanton recognized a smooth, simple form of *Ostrea*, very abundant; *Ostrea* (*Alectryonia*) sp.; and *Eumicrotis curta* Hall?.

MORRISON SHALE (?).

Character and extent.—The Morrison formation, which is extensively exposed along the Rocky Mountain front range in southern Montana



BASAL JURASSIC SANDSTONE LYING UNCONFORMABLY ON MADISON LIMESTONE NEAR STOCKETT, MONT.

A is about 1 mile south of B.

and Wyoming, is also believed to occur along the northern base of the Little Belt Mountains. In previous investigations in this field by Weed and others the Morrison formation has not been recognized, and the beds comprising it have been grouped with the Kootenai and included in the "Cascade" formation. During the last field season dinosaur bones provisionally regarded by C. W. Gilmore as of Jurassic age were found at one horizon in many different localities; and at one exposure in sec. 3, T. 16 N., R. 2 E., about 30 feet below the bone-bearing bed, a green shale containing a distinctly fresh-water fauna later than the Ellis formation was seen. These rocks, here provisionally regarded as constituting the Morrison formation, consist of sandstone and bright-colored sandy shale with scattered layers of impure limestone, many of them in lenticular form. The formation lies with apparent conformity on the Ellis and is overlain conformably by the Kootenai. The thickness ranges from 60 to 120 feet, but the exact limits of the formation are in many places difficult to determine. Fragments of bone have been found at different horizons throughout the overlying Kootenai formation, but thus far none that are sufficiently well preserved for specific determination have been discovered in this region. It is possible that future investigation may prove that the rocks here tentatively regarded as belonging to the Morrison constitute in reality a basal member of the Kootenai.

The formation is generally exposed in a narrow band on the inner rim of a low ridge formed by the harder overlying rocks of the Kootenai formation. It outcrops all along the base of the Little Belt Mountains, from the east end of the district to Smith River. Good exposures occur along the upper courses of Sage, Skull, Running Wolf, Hazlett, Surprise, Geyser, and Otter creeks and in the bluffs for some distance back from the mountains along Belt Creek, Sand Coulee, Smith River and its principal tributary, Ming Coulee. The following sections show the succession of the beds:

Section of supposed Morrison formation on the north side of Smith River in the SW. ¼ sec. 29, T. 17 N., R. 3 E., Montana.

	Feet
Kootenai formation.	
Morrison formation:	
Shale, soft, sandy	52
Limestone, light-colored, nodular	4
Shale, variegated	33
Sandstone, gray, massive	11
Shale, greenish gray, sandy	20
Ellis formation.	
	120

Section of supposed Morrison formation on the east side of Belt Creek in the NE. ¼ sec. 30, T. 18 N., R. 7 E., Montana.

	Feet.
Kootenai formation.	
Morrison formation:	
Shales, maroon and green	52
Shale, green, capped by 1½ feet of sandstone, gray	5
Sandstone, calcareous, weathering light brown	5
Shale, greenish	20
Sandstone, massive, weathering light brown	7
Shale, dark green, containing thin limestone layers	9
Ellis formation.	
	98

Section of Morrison and part of Kootenai formation in the NE. ¼ sec. 3, T. 16 N., R. 10 E., near Shannon Creek, Montana.

	Ft.	in.
Kootenai formation:		
Sandstone, gray, massive	60	
Coal (estimated)	6	
Beds concealed	60	
Morrison formation:		
Beds, concealed	22	
Shales, red and green, containing ironstone layers at base	46	
Limestone, light colored, fossiliferous	5	
Shale, green, sandy, fossiliferous	25	
Limestone, white, fine-grained, thin bedded		6
Shale, green, sandy	13	
	237	6

Fossils.—Invertebrate fossils collected from a locality where Shannon Creek was measured have been examined by T. W. Stanton, who reports three species of *Unio*, apparently all undescribed; *Neritina* sp. and *Valvata* cf. *scabrida* M. and H. Mr. Stanton's comments on this collection are as follows:

This is a fresh-water fauna later than the Ellis and suggestive of the Morrison, although there are no identical species, with the possible exception of the *Valvata*.

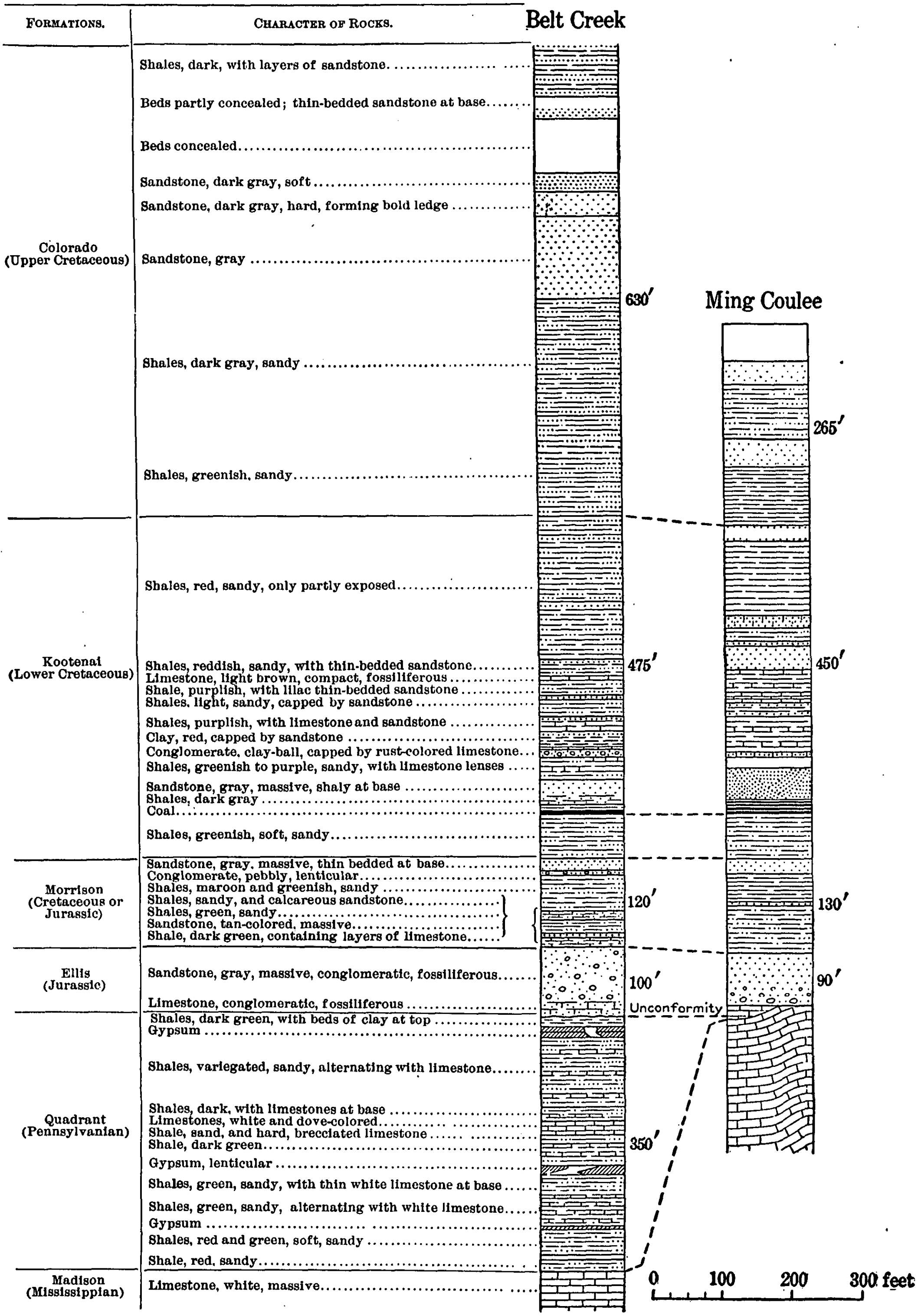
From the red and green shales about 1 mile west of the above-described locality were collected saurian bones which C. W. Gilmore describes as "a portion of the centrum of a large vertebra, which, from its size, might well represent one of the large herbivorous dinosaurs of the Jurassic (Morrison)."

CRETACEOUS SYSTEM.

KOOTENAI FORMATION.

General statement.—The Kootenai formation, as determined by the present investigation, comprises the upper one-third of the Cascade and Dakota and the basal red shale included in the Colorado shale, as described by Weed[a] in the Fort Benton folio. The name Cascade,

[a] Weed, W. H., Geologic Atlas U. S., folio 55, U. S. Geol. Survey, 1899.



COLUMNAR SECTIONS SHOWING STRATIGRAPHY IN DIFFERENT PARTS OF GREAT FALLS REGION, MONTANA.

as referred to a Cretaceous formation, was first used by that author in his description of the rocks of the Fort Benton quadrangle, to apply to a series of beds ranging in thickness from 225 to 500 feet. The lower part of the formation, as originally described, consisted of lavender-tinted sandstone containing at its base a workable bed of coal. During the present investigation, as previously stated, saurian bones believed by C. W. Gilmore, of the United States National Museum, to be of Jurassic age, were discovered in the lower half of the so-called "Cascade" formation, indicating that these beds are probably of Morrison age, although vertebrate remains occur in the sandstones of the overlying Kootenai. Between a horizon 45 feet below the coal bed and the top of the "Cascade" formation as above defined fossil plants of Kootenai age were collected at five different horizons, establishing beyond question the Lower Cretaceous age of this portion of the formation. On the east side of Spanish Coulee, a tributary of Smith River, at a horizon about 150 feet above the "Cascade" formation; in beds the equivalent of which in the vicinity of Belt have been provisionally regarded by Weed as of Dakota age, a large collection of Kootenai plants was procured from dark-colored shale associated with red and green shales and clay. Overlying this plant-bearing bed is about 200 feet of rocks consisting of red shale and sandstone not differing materially in stratigraphy or lithologic character from beds immediately underlying the plant horizon. The close lithologic resemblance of this upper member to the underlying well-defined Kootenai rocks, together with the apparent absence of Dakota floras in it, has been regarded by the writer as sufficient evidence for provisionally including the beds in question as of Kootenai or Lower Cretaceous age. These beds are overlain by dark-colored shale and sandstone of the Colorado formation, in the lower part of which were discovered marine saurian remains.

In this report it does not seem advisable to employ the name "Cascade" for the following reasons: First, the term has not been so extensively used in the literature as the term Kootenai; second, its usage would necessitate redefining the term, in order to separate its lowest member, which is now believed to be Morrison; third, the beds immediately overlying the "Cascade" formation can not be differentiated paleontologically from it, both being of Lower Cretaceous age, rendering it necessary to place the upper limit of the formation in question purely on lithologic grounds.

Character and extent.—The Kootenai formation consists of alternating layers of sandstone and shale, with the former predominating, especially in the lower half. The sandstones range in thickness from 10 to 60 feet, and are more or less massive in character. In the upper part shales are more abundant and are interbedded with thin layers of impure sandstone. At Belt, on the east side of Belt

Creek, where a complete section was measured, the basal member of the formation consists of a sandy shale interbedded with sandstone, the latter predominating, the whole having a thickness of about 60 feet. This member consists locally of firm, massive sandstone with only a small percentage of shale. It is overlain by coal, which here has a thickness of 6 feet, including a few thin partings. Above the coal there is a dark, coaly shale 5 to 6 feet thick, covered by 38 feet of massive light-gray sandstone. This sandstone is overlain by 138 feet of beds, consisting in ascending order mainly of alternating layers of sandstone, red shale, and clay, with an occasional limestone lens in the lower part. Above this alternating series there is about 200 feet of red shale, which constitutes the topmost member of the formation. The total thickness is about 450 feet, which may be regarded as representative of the Kootenai formation as exposed along the Belt Creek valley.

In previous reports on the geology of this region by Weed a greatly exaggerated thickness (736 feet) was assigned to beds lying between the base of the Ellis and the coal bed of the Kootenai formation. Of this amount the lower 215 feet was regarded as belonging to the Ellis and the remainder to the Kootenai formation, the presence of the Morrison between these two formations not having been recognized. During the present investigation a number of detailed sections measured along Belt Creek proved conclusively that the stratigraphic interval between the base of the Ellis and the Kootenai coal, to which Weed had assigned a thickness of 736 feet, is in reality only about 300 feet. According to the present classification the lower 120 feet of these beds has been assigned to the Ellis; an equal thickness immediately overlying, in which fresh-water invertebrates and land animals occur, to the Morrison; and the upper 60 feet, which is plant bearing, to the Kootenai. Pl. IV, which contains a number of columnar sections measured along Belt Creek valley, illustrates the character and thickness of the various formations.

On the north side of Skull Butte the base of the Kootenai consists of a soft light-gray massive sandstone, but in other respects the portion of the formation exposed in this locality agrees closely with the beds exhibited at Belt Butte. A section of the Kootenai on the north side of Skull Butte is given below:

Section of a part of Kootenai formation on north side of Skull Butte, Montana.

	Ft.	in.
Shale, reddish, sandy.		
Sandstone, gray, thin bedded	1	6
Shale, reddish, sandy, with layers of sandstone in lower part	21	
Sandstone, greenish, gray, weathering dark; thin bedded above, clay-ball conglomerate below	4	
Shale, reddish, sandy, with layers of sandstone in lower part	27	
Sandstone, gray, cross-bedded; clay-ball conglomerate in lower part	5	6

Section of a part of Kootenai formation on north side of Skull Butte, Montana—Cont'd.

	Ft.	in.
Shale, reddish, sandy	30	
Sandstone, soft, thin bedded	20	
Sandstone, gray, massive; clay-ball conglomerate	3	6
Shale, red; sandy	38	
Sandstone, gray, massive; clay-ball conglomerate	5	
Shale, red, sandy	24	
Sandstone, calcareous, alternating with sandy shale	20	
Sandstone, light and dark gray, massive, fine grained	86	
Coal (estimated)	6	
Sandstone, gray, massive, soft	62	
	353	6

The Kootenai has the greatest areal distribution of all the formations outcropping within the area. It caps the surface for a great part of the district lying between Smith River and Belt Creek, and is the surface formation of the high plateaus south of Otter Creek. Beyond Otter Creek it is exposed as a band of varying width which narrows toward the east.

Fossils.—The Kootenai formation of the Great Falls district carries an abundant fossil flora of Lower Cretaceous age. Fossil plants of Kootenai age were first discovered in the Great Falls coal field in 1889 by J. S. Newberry.[a] From these fossils, which consisted of only a few species, it was possible to correlate the rocks of the Great Falls region with the Kootenai north of the international boundary line, described by George M. Dawson. In 1890, during the construction of the Great Northern Railway line between Helena and Great Falls, Mont., a larger collection of Kootenai plants was made from a railroad cut near the flood siding on the Missouri; these were reported on by Newberry in 1891.[b] About the same time that the above collection was obtained F. H. Knowlton and A. C. Peale made a small collection of plants from the same railroad cut, and the following year W. H. Weed also procured plants from this locality which were studied and described by W. M. Fontaine in 1892.[c] In 1894–95 Kootenai plants were found at a number of localities by W. H. Weed and L. F. Ward, mainly south and east of Geyser. These were described by W. M. Fontaine in Ward's second paper on the "Status of the Mesozoic floras of the United States."[d]

During the present investigation fossil plants, all of which were studied and reported on by F. H. Knowlton, were collected from five different horizons—15, 60, 70, 150, and 300 feet above the base of the Kootenai formation. The lowest horizon was on Hazlett Creek, where the following species were collected from a dark-colored sandy

[a] School of Mines Quart., vol. 8, July, 1887, p. 329.
[b] Am. Jour. Sci., 3d ser., vol. 61, 1891, pp. 191-201, Pl. XIV.
[c] Proc. U. S. Nat. Mus., vol. 15, 1892, pp. 487–495, Pls. LXXXII-LXXXIV.
[d] Mon. U. S. Geol. Survey, vol. 48, 1905, pp. 284-315, Pls. LXXI-LXXIII.

shale 45 feet below the coal horizon and 15 to 20 feet above the base of the formation:

Cladophlebis heterophylla Fontaine.
Thyrsopteris elliptica Fontaine.
Zamites articus Göppert.
Zamites apertus Newberry (?).

Fragmentary plant remains were observed in the dark-colored clay underlying the coal at a number of localities; and a few small collections were made, the largest being from the Meredith mine, on the east side of a small coulee tributary to Geyser Creek, about 6 miles southwest of Geyser, Mont. The following were obtained:

Cladophlebis heterophylla Fontaine.
Cladophlebis constricta Fontaine.
Cladophlebis fisheri Knowlton.
Thyrsopteris elliptica Fontaine.
Acrostichopteris fimbriata Knowlton.
Dryopteris? kootaniensis Knowlton.
Adiantum montanense Knowlton.
Oleandra graminæfolia Knowlton.
Ginkgo sibirica Heer.
Podozamites lanceolatus (L. and H.) Schimper.
Zamites articus Göppert.
Nilsonia schaumburgensis (Dunker) Nathorst.

On the north side of Skull Butte, the following fossil plants were obtained from a light-colored impure sandstone about 150 feet above the base of the formation and 86 feet above the coal:

Cladophlebis heterophylla Fontaine.
Cladophlebis browniana (Dunker) Seward.
Protorhipis fisheri Knowlton.
Sequoia reichenbachi (Geinitz) Heer.
Coniferous leaves?

The highest horizon in the Kootenai formation at which plants were collected was on the east side of Spanish Coulee, a small tributary of Smith River in sec. 11, T. 17 N., R. 2 E., where the following were secured:

Thyrsopteris elliptica Fontaine.
Chiropteris spatulata Newberry.
Sequoia gracilis Heer.
Zamites apertus Newberry.

One mile south of Flood siding, about 5 miles southwest of Great Falls, on the Great Northern Railway between Great Falls and Helena, a collection of plants was made, some of which are listed below:

Dryopteris montanensis (Fontaine) Knowlton.
Sequoia gracilis Heer.
Podozamites nervosa? Newberry.
Pterophyllum montanense (Fontaine) Knowlton.

In the bluffs of Missouri River, near the Boston and Montana smelter, a large collection of Kootenai plants was made by O. C. Mortson. In this collection representatives of the following species occur:

Dryopteris montanensis (Fontaine) Knowlton.
Sequoia gracilis Heer.
Sequoia ambigua Heer.

On the south side of Missouri River, opposite the Boston and Montana smelter, a specimen of *Ginkgo sibirica* was observed by the writer, but was not collected.

The collection of fossil plants obtained from the Kootenai formation in the Great Falls region during the present investigation of the coal resources of the district is not large, but it is of unusual interest in that it contains a number of species before unknown in the Kootenai rocks of the United States, although present in the Canadian beds of this age; it contains also a species of the genus *Protorhipis* not previously found in North America, as well as some believed to be new to science.

In addition to the plants, some fresh-water invertebrates were collected from the upper part of the Kootenai during the investigation. A list is given below:

Unio farri Stanton?
Unio sp.
Corbula sp.
Campeloma harlowtonensis Stanton?
Goniobasis ortmanni Stanton?
Viviparus? sp.

These fossils are too imperfect for positive identification, but the species with which they are compared occur a few miles south of Harlowton, Mont., in beds that belong to either the Kootenai or the Morrison.

The following bibliographic list contains the more important paleobotanical papers published on the Kootenai formation:

DAWSON, SIR WILLIAM, On the Mesozoic floras of the Rocky Mountain region of Canada: Trans. Royal Soc. Canada, vol. 3, sec. 4, Pls. I–IV, pp. 1–22. 1885.

The name "Kootanie series" is first given and defined in this paper, p. 2.

NEWBERRY, J. S., The Great Falls coal field, Montana: School of Mines Quart., vol. 8, pp. 327–330. 1887.

DAWSON, SIR WILLIAM, Cretaceous floras of the Northwest Territories of Canada: Am. Naturalist, vol. 22, pp. 953–959. 1888.

NEWBERRY, J. S., Flora of the Great Falls coal field, Montana: Am. Jour. Sci., 3d ser., vol. 61, Pl. XIV, pp. 191–201. 1891.

DAWSON, SIR WILLIAM, Correlation of early Cretaceous floras in Canada and the United States: Trans. Royal Soc. Canada, vol. 10, sec. 4, figs. (in text) 1–16, pp. 79–93. 1892.

FONTAINE, W. M., Description of some fossil plants from the Great Falls coal field of Montana: Proc. U. S. Nat. Mus., vol. 15, Pls. LXXXII–LXXXIV, pp. 487–495. 1892.

WARD, L. F., AND FONTAINE, W. M., Flora of the Kootanie formation: Mon. U. S. Geol. Survey, vol. 48, Pls. LXXI-LXXIII, pp. 277-315. 1905.

FONTAINE, W. M., Notes on some Lower Cretaceous (Kootanie) plants from Montana: Mon. U. S. Geol. Survey, vol. 48, Pls. LXXI-LXXIII, pp. 284-315. 1905.

KNOWLTON, F. H., Description of a collection of Kootenai plants from the Great Falls coal field of Montana: Smithsonian Misc. Coll., vol. 50, pt. 1, pp. 105-128, Pls. XI-XIV. 1907.

COLORADO SHALE.

General statement.—The rocks overlying the Kootenai formation in this district consist mainly of dark-colored shale with a number of prominent sandstone members in the lower part. This shale and sandstone constitute the well-known Fort Benton formation of the Meek and Hayden upper Missouri River section, the name being derived from the town of Fort Benton, on Missouri River, about 40 miles below Great Falls. The exposures on which the original descriptions were based and by which the stratigraphic limits of the formation were determined lie far to the east in Nebraska. In northeastern Nebraska, along Missouri River, throughout the Black Hills, and along the Rocky Mountain front, the Benton formation is usually underlain by Dakota sandstone and overlain by Niobrara limestone. In the present investigation no evidence was found of the presence of Dakota sandstone as a separate formation in the Great Falls field, nor is the formation here overlain by Niobrara limestone. It is possible that in this region the Niobrara is represented by dark shale, as Stanton has suggested,[a] and there is some paleontologic evidence in support of this belief. If the upper members of the shale and sandstone series do represent deposition during Niobrara time, they can not be separated stratigraphically from the underlying Benton. For this reason the rocks which lie between the top of the Kootenai and the base of the Eagle sandstone are described as the Colorado shale. This name was used in the same sense by Weed in the Fort Benton folio.

Character and extent.—The Colorado shale is well developed in this general region, being represented by about 1,600 feet of beds. The entire formation does not occur within the area, but only the lower three-fourths, the upper members being exposed to the north in the higher portions of the Highwood Mountains. In the vicinity of Fort Benton, only a few miles to the northeast, the Colorado is essentially a shale formation with very thin beds of impure sandstone. The Mowry shale member, which constitutes a conspicuous division of the formation to the southeast along the Rocky Mountain front, is present here, but is not conspicuous, owing to the flat dips which prevail throughout the area. Along the south side of the Highwood

[a] Geology of Yellowstone National Park: Mon. U. S. Geol. Survey, vol. 32, 1899, p. 605. Geology and paleontology of the Judith River beds: Bull. U. S. Geol. Survey, No. 257, 1905, p. 11.

Mountains and in Belt Butte the formation contains a bed of volcanic ash. The rock is pale yellowish gray, weathering white. It resembles porcelain and is overlain by rock of similar character and appearance. Samples of this rock were collected from Belt Butte and from a locality about 8 miles northeast of Stanford. Thin sections have been examined by Albert Johannsen, who describes the first as follows: "Cryptocrystalline in texture. It is very slightly anisotropic, as a devitrified glass might be. There are a few irregular anisotropic patches which are too small to be determined. There is also a little brownish decomposed material. It may be an indurated volcanic tuff or rhyolitic glass." The second is described as "a very fine grained, compact glass, consisting almost entirely of angular fragments very slightly devitrified, and a very few small, irregular grains, apparently of quartz, but too small to be determined. The rock is very homogeneous and uniform in appearance throughout the section."

The presence of a bed of volcanic ash in the Colorado shale is a local feature, for it is absent in the western part of the field.

Southwest of Great Falls, where the Colorado is well developed, its basal member consists of a soft massive sandstone, somewhat concretionary, about 30 feet thick. Above this sandstone is approximately 35 feet of rocks composed largely of dark-colored shale with a few sandstone beds. This shale is overlain by gray, coarse-grained, massive sandstone containing concretionary layers and an occasional thin bed of soft sandy shale, the whole having a thickness of about 80 feet. Above the sandstone for 300 feet the beds consist mainly of alternating layers of sandstone and shale. These are followed by 700 feet of beds composed of uniformly dark-colored sandy shale, which constitutes the uppermost member of the Colorado as exposed in this field. A good exposure of the lower half of the formation is found in Belt Butte, where the beds consist of alternating layers of massive gray sandstone and dark-colored shale with the volcanic ash member mentioned above present. A section of the beds as exposed on the west side of Belt Butte follows:

Section of Colorado shale in Belt Butte, Montana.

	Feet.
Shale, dark gray, sandy, with thin layers of sandstone	80
Sandstone, dark gray	10
Volcanic ash	30
Shale, dark colored, sandy, with thin layers of sandstone	80
Shale, sandy; or impure sandstone	20
Shale, dark, sandy	75
Sandstone, gray; forming belt around Belt Butte	50
Shale, dark, sandy in lower part	125
Shale, dark, sandy; containing massive sandstone members; locally calcareous at top	180
Kootenai formation.	
	650

The Colorado shale is exposed in a wide area extending along the south side of the Highwood Mountains from Belt Creek southeastward to the east border of the district, although much of the area, especially the eastern half, is covered by terrace gravel. Its basal sandstone members occupy the summits of Red Butte and continue westward as a plateau capping to the Missouri River valley. Smith River and its tributary Goodwin Coulee cut the basal sandstone of the Colorado, exposing the underlying Kootenai rocks. The Colorado shale occupies the surface of the highland lying between Missouri and Sun rivers, also north of these streams across the northern border of the district. Its areal distribution is about equal in extent to that of the Kootenai, as is shown by the geological map (Pl. I).

Fossils.—Invertebrate fossils were found in the Colorado shale at several localities, notably near Geyser, where collections were made at four different localities at a point 1¼ miles northwest of Geyser, *Inoceramus labiatus* Schloth. (?) and fragments of an unidentified *Inoceramus* were obtained. A mile farther northwest the following were collected:

Inoceramus—large, probably undescribed species.
Leda sp.
Nucula sp.
Cardium sp.
Prionotropis sp.

These fossils have been examined by T. W. Stanton, who regards them of Benton age. The fossils from the last-named locality are believed to represent the upper part of the Colorado shale. A few fragmentary specimens of *Inoceramus* were found on the west side of Belt Butte, on the south side of Stanford Buttes, and 7 miles northeast of Stanford, Mont. The fossils were collected in all these places at a horizon a few feet below the bed of volcanic ash above referred to. At the north end of Square Butte, which lies about 2 miles west of the area here discussed, fossils were collected at a horizon believed to be near the top of the Colorado. These were *Ostrea* sp., possibly *Gryphæa*, and fragments of *Scaphites ventricosus* M. and H. Fragmentary remains of a swimming saurian, believed by C. W. Gilmore to be a plesiosaur, were collected from a bluish shale underlying a prominent sandstone member of basal Colorado on the west side of Spanish Coulee, in sec. 10, T. 17 N., R. 2 E.

The Colorado shale rests with apparent conformity upon the underlying Kootenai, and is overlain conformably by the Eagle sandstone, the lowest member of the Montana group. Although conformable relations appear to exist between the Kootenai and Colorado formations in this region, the Dakota, which occupies a position between these two formations in other localities, is, as previously stated, believed not to be present. If this is true, there is a hiatus at this contact representing at least several hundred feet of beds. It is possible that Dakota time is here represented by marine sediments not easily separable from the Colorado shale.

TERTIARY AND QUATERNARY SYSTEMS.

TERRACE GRAVEL.

General statement.—Throughout a great part of the territory lying east of the Otter Creek divide the plateaus of different levels which occupy the interstream spaces are covered by gravel; and the intermediate slopes, especially those of gentle inclination, are in many places strewn with material which has worked down from the higher terraces. A few isolated areas of terrace deposits are found west of the divide, notably those between Williams and Otter creeks, on either side of Belt Creek below the town of Belt, and on the south side of the Missouri, below the mouth of Smith River. Smaller areas lie along the sides of the creeks and at low levels in some of the larger valleys, especially Belt Creek. These are generally too small to be shown on the geologic map. To the northwest are terraces believed to be contemporaneous in age with those of the Great Falls field, reaching far out on the plains east of the Lewis Range, but these do not extend into the area covered by this report.

Character.—The terrace gravel is diversified in character, depending on its location relative to the different portions of the adjoining mountains whence it was derived. Those deposits which occur opposite the higher portions of the Little Belt Mountains, where crystalline rocks are exposed, contain a relatively high percentage of igneous rock, but to the east, where sediments from the crest of the mountains and crystalline rocks have not been uncovered, the amount of igneous material in the gravel is small. The deposits in general consist of sand and gravel with local beds of clay. The component parts of the gravel are of varying size, ranging from that of a pea to 10 inches in diameter. In the area bordering the mountains there are some bowlders exceeding a foot in diameter. The pebbles are rounded to subangular, and none were seen which contained striations.

Mode of occurrence.—Terrace deposits of three distinct levels are found in the eastern part of the Great Falls region. The highest has been definitely recognized at only one locality—on the summit of Stanford Butte. This deposit, which has been described by Weed[a] as the Stanford conglomerate, consists of medium to large sized pebbles, not well assorted, cemented into a firm conglomerate. Remnants of this or possibly of some higher terrace gravel are found on some of the prominent points in the hilly zone bordering the Little Belt Mountains, but the correlation of the material of these localities with that of Stanford Butte is by no means certain.

The second terrace is about 100 feet below the level of the Stanford conglomerate, and carries one of the most extensive terrace deposits of the district. It occupies the high ridge east of Skull Creek, along

[a] Weed, W. H., Geologic Atlas U. S., folio 55, U. S. Geol. Survey, 1899.

either side of Surprise Creek, in the vicinity of Stanford Butte, and extends far to the east as a prominent topographic feature on either side of Arrow Creek.

The third and lowest terrace covers the broad flat of Running Wolf Creek valley east of Stanford, and is also found at low levels on Geyser Creek and its principal tributaries. East of Stanford this terrace is only a few feet above the flood plain of the present valley. The thickness of the deposit ranges from 5 to 35 feet in different parts of the field. It lies along either side of the streams, and has smooth surfaces which slope gently away from the mountains toward the plains.

Origin of terraces.—It is apparent from a study of the composition of the gravel deposits that their source was mainly in the Little Belt Mountains to the southwest, but little definite evidence could be obtained as to the manner in which they were laid down. It is believed that the gravels were brought down by streams from the Little Belt Mountains, and spread by them over the lower plains country, as their courses were shifted from time to time, but it seems probable that the cause which resulted in the development of the different terrace levels was not normal to the streams of that period, but was accidental. Whether the terraces resulted from uplift in the region, with subsequent rejuvenation of the streams, or from changes in climatic conditions is difficult to determine. The latter seems more probable, especially in the case of the more recent terraces, which were probably formed during Pleistocene time. No definite evidence could be found to show that the older terraces were not formed by uplift.

Age.—The age of the different gravel terraces in the Great Falls field can not be definitely stated. The two higher terraces are post-Miocene to early Quaternary in age; the third and smaller subsequent terraces date from the occupation of this area by the Keewatin ice sheet, in Wisconsin time, nearly to the present day.

The conclusion regarding the age of the earlier terraces is based on the following considerations: (1) Previous workers in the Little Belt Mountains place the date of the last uplift in this general region at the close of the Miocene. After this period the region was base-leveled. Whether the oldest terrace was formed as a result of this base-leveling or at some later period is not known, but it is certain that it was not earlier than the close of Miocene time. (2) Terrace gravel believed to be contemporaneous with the oldest deposits here described occurs northwest of Great Falls, on the high divide between Sun and Teton rivers, a few miles beyond the area to which this report relates. (3) In the bottom of Sun River valley near Augusta, at least 300 feet below the highest gravel terrace to the north, terminal moraines of mountain glaciers are found. According to Calhoun,[a] in the region

[a] Calhoun, F. H. H., The Montana lobe of the Keewatin ice sheet: Prof. Paper U. S. Geol. Survey No. 50, 1906, p. 46.

to the north material derived from local glaciers is overlain by deposits of the continental ice sheet, and from this and other observations made throughout the general region to the north he regards the local glaciers of the Lewis Range as but slightly older than those of the Keewatin ice sheet, which occupied this area during Wisconsin time. Prior to both the local and continental glaciation of this region, therefore, a period must have elapsed sufficient for the erosion of Sun River valley nearly to its present stage after the gravel capping the high divide between Sun and Teton rivers was laid down. The erosion of this valley required considerable time, so that it seems probable that the high terrace gravels north of Sun River, which are believed to be contemporaneous with the older terrace gravels in the area described, should be regarded as of early Quaternary or possibly late Tertiary age.

GLACIAL DEPOSITS.

General statement.—Glacial deposits of Wisconsin age occupy a considerable area throughout the Great Falls region. The terminal moraine of the Montana lobe of the Keewatin ice sheet enters the district at a point about 10 miles due northeast of Great Falls, extending southward across Missouri River to Sand Coulee near Gerber station. At this point it makes a sharp bend to the east and continues thus past the head of Red Coulee, thence northeastward to Belt Creek, where it crosses the northeastern margin of the district. Its location and extent, as first worked out by Calhoun[a] and later examined more in detail by the writer, are shown on the geologic map (Pl. I). In addition to the morainal deposits, extensive lake sediments were laid down in front of the terminal moraine during the occupation of this general region by the ice. Much of this material has been removed by postglacial erosion, especially on the higher lands, but all the larger valleys in front of the moraine are filled with it. Lake deposits of two different periods, an earlier and a later, have been recognized by glaciologists in this region. The limits of the earlier lake can be ascertained only by bowlders lodged on the summits of the plateaus, but a considerable part of the deposits of the more recent lake still remains as a filling in the larger valleys.

Drift.—The drift consists of crystalline erratics, small pebbles, sedimentary rocks, and a matrix of sand and clay. The greater part of the material, however, is a sandy clay of dull-green color, generally unstratified, which stands in vertical faces where trenched by streams. The character of the rocks composing the drift has been studied in detail by Calhoun,[b] who describes them as follows:

> The crystalline erratics are of such variety as to furnish specimens of the whole rock series. In a small area, not over 5 square yards in extent, the following rocks were found: Limestone, sandstone, shale, coal, granites (both fine and coarse grained and

[a] Op. cit., Pl. V. [b] Op. cit., p. 27.

with different percentages of quartz and feldspar), syenites, diorites, basalts, and hornblende, mica, and garnetiferous schist, and all gradations between these and gneissic rocks. The granite and the syenite rocks predominate. Basalt and rocks containing a large proportion of the ferromagnesian minerals are not so common.

In his general study of the Montana lobe of the Keewatin ice sheet Calhoun observes little variation in the nature of the bowlders throughout the length of the moraine. Limestone bowlders are more common in the northern part and sandstone bowlders in the southern part, but the character of the crystalline bowlders remains the same. The small pebbles which make up a varying proportion of the bowlders of the drift are believed by Calhoun to be of mountain origin, having been derived from a quartzite gravel formation to the northeast. Crystalline bowlders are generally common on the surface of the drift, but in the body of the material not many are found. Here even smaller pebbles sparingly occur. An explanation of the position of these bowlders in the drift is given by R. D. Salisbury.[a] The thickness of the drift within the area treated is variable, the maximum observed being between 150 and 200 feet.

Lake sediments.—The lake deposits are mainly of two kinds—large bowlders deposited on the high land by floating ice in waters of the

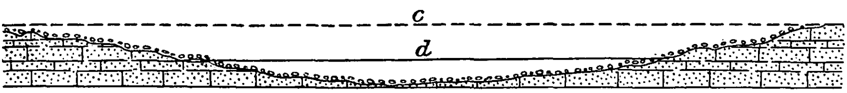


FIG. 1.—Ideal cross section showing relations between the two lake deposits in Missouri River valley west of Great Falls. *c*, Level of the more extended lake; *d*, level of the smaller lake. After Calhoun.

older and more extensive lake and finely laminated sandy clay laid down by the smaller lake in the larger valleys of the Great Falls region (figs. 1 and 2). A detailed examination of the composition of these lake sediments was not made by the writer, but they were carefully studied by Calhoun, whose description is here given.[b]

The deposits of the more restricted lake consist of a finely laminated clay which when dry is hard and cleaves like shale. When wet it becomes soft and pliable, and would make an excellent molding clay. Interstratified with the clay are small crystalline pebbles one-fourth to one-half inch in thickness. They usually consist of quartz or feldspar crystals, or of small fragments containing several minerals, showing that the rock from which they were derived was granite, syenite, or basalt. Very seldom a large crystalline bowlder is found embedded in the clay.

The maximum thickness of this clay within the area treated was not ascertained, but along the Missouri near Ulm Calhoun observed[c] a thickness of 40 feet, the material containing the small crystalline pebbles characteristic of the formation farther north. Its distribution is not shown separately on the geologic map, as it is included with the alluvium. The accompanying ideal sections (figs. 1 and 2) by the

[a] Jour. Geology, vol. 8, 1900, pp. 426-432. [b] Op. cit., pp. 30-31. [c] Op. cit., p. 31.

above-named author[a] illustrate the relation of the two lake deposits to the drift and ice dam.

ALLUVIUM.

General statement.—The alluvial deposits of the Great Falls region present rather unusual features. They occur intimately associated with glacial-lake sediments of the Keewatin ice sheet, and on the geologic map are not differentiated from those sediments. As previously stated, during the occupation of the region by the continental glaciers the waters of the Missouri and its larger tributaries were dammed and an extensive lake existed first in front of the ice and later in front of the terminal moraine. Sediments of this lake in its various stages filled all the larger valleys in the vicinity of Great Falls. Although much of the material constituting these sediments was brought down by streams from adjoining mountainous region, and to this extent they correspond to normal alluvial deposits along any large stream, a certain amount was contributed by the melting ice from the glacier. The alluvium, therefore, of the Missouri and its larger tributaries in this immediate district has been derived from

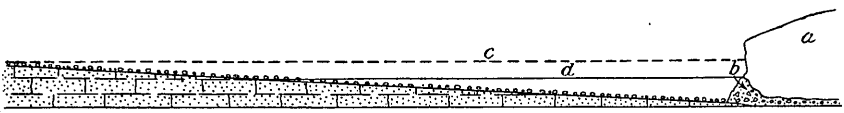


FIG. 2.—Ideal longitudinal section showing the relation of the two lake deposits shown in fig. 1 to the drift dam and the ice dam. *a*, Ice edge; *b*, moraine; *c*, level of the more extended lake; *d*, level of the smaller lake. After Calhoun.

two distinct sources. That brought in by the river may be regarded as local and that by the glacier as foreign.

Character and extent.—The alluvium of the Missouri, together with that of Sun and Smith rivers, its principal tributaries, ranges from half a mile to 3 miles in width. It consists mainly of fine silt and sand, with local beds of clay and gravel. Light colors prevail throughout the material. From the base of the Big Belt Mountains northeastward to Great Falls the Missouri meanders through a wide flood plain of an old valley, but east of Great Falls it flows through a narrow valley which is much younger and in which only small detached areas of alluvium are found. Alluvial deposits of small extent occur along Belt Creek and all the minor streams, but these are not shown on the geologic map.

DUNE SAND.

Character and extent.—Deposits of dune sand occupy a number of small areas in the vicinity of Great Falls. They are confined mainly to the Missouri River valley, but some are found on the lower plateaus bordering the streams. These areas, though small, present the characteristic dune-sand topography of hillocks and basins with no

[a] Op. cit., p. 30.

developed drainage. The dunes range from 10 to 20 feet in width. They are of recent origin and in many places travel before the wind. Perhaps the largest accumulation of these deposits occurs about 1 mile southeast of Great Falls, on a plateau of the Kootenai rocks which lies approximately 100 feet above the town. Here a belt of low sand hills nearly one-half mile in width extends for 1½ miles in a northeasterly direction. Another noteworthy dune area is on the west side of the Missouri River valley about 4 miles above the mouth of Sand Coulee. Smaller areas are to be found in the larger bends of Missouri River between Great Falls and Cascade. In the valley on the west side of Smith River, near the confluence of that stream with the Missouri, there are deposits of sand which have been blown about by the wind but have not been formed into distinct dunes. At many places throughout the flood plain of the Missouri sagebrush and other small shrubs hold the sandy soil about their roots and collect additional material blown about by small wind currents to such an extent that mounds 1 to 2 feet high are built up about each bush, giving the appearance of miniature dune-sand topography. The distribution of the eolian deposits is not shown on the map.

Source.—The dune sand of the Great Falls region is derived principally from alluvial deposits of the Missouri Valley. It consists mainly of loose, fine-grained sand which in many places is not covered by vegetation, so that it is readily caught up by the wind and carried about. The sand thus transported is generally redeposited in the form of dunes in the valley or on the slopes of the adjoining highlands, but sometimes it is blown out of the valley and lodged on the bluffs above. It is believed that the deposits south of Great Falls originated in this way.

IGNEOUS ROCKS.

Igneous rocks occur in the Great Falls region mainly in the form of dikes and sheets, although stocks and unexposed laccoliths are also to be found. The dike rock of most common occurrence is a basalt, of which there are a number of varieties. It is usually very dark colored and dense, presenting on the surface a spotted appearance, due to the presence of large crystals of basaltic augite. Much of the intruded material is sufficiently hard to resist weathering better than the soft sedimentary rocks and stands out as an irregular wall or ridge. Less commonly the intrusive material is soft and crumbles easily, so that it can be traced only by lines of green vegetation growing on the surface of the decomposed rock. Rocky Ridge is formed by one of the harder basaltic dikes extending from a point near the base of Highwood Mountains southwest to Williams Creek. The intrusive rocks in this region do not, so far as known, cut or disturb to any considerable extent the areas underlain by workable coal, and consequently they are not of very great importance in the present discussion. In several places, however, intrusives appear at the surface on the margin of areas believed to be underlain by workable coal, notably on the northern border of the Otter Creek coal area, near the mouth of Williams Creek, on the upper part of Hazlett Creek, on the west side of the Sage Creek coal area, and on the northeast side of Belt Butte along the east side of the Sand Coulee coal area. In none of these localities can the intrusive rocks be traced by surface outcrops into the area underlain by workable coal, but they may possibly continue, although unexposed, sufficiently far to cut and disturb valuable coal beds. No special examination was made of the petrographic character of the intrusive rock in the eastern part of the Great Falls field, for it forms a portion of a large petrographic province of central Montana which has been studied in a detailed and comprehensive way by Weed and Pirsson. For a more extensive account of these rocks and of the larger petrographic province of which they form a part, the reader is referred to the following publications:

Weed, W. H. Two Montana coal fields: Bull. Geol. Soc. America, vol. 3, 1892, pp. 301–330.

——— Little Belt Mountains folio (No. 56), Geologic Atlas U. S., U. S. Geol. Survey, 1899.

——— Geology of the Little Belt Mountains, Montana: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 3, 1900, pp. 271–461.

Weed, W. H., and Pirsson, L. V. Igneous rocks of Yogo Peak, Montana: Am. Jour. Sci., 3d ser., vol. 50, 1895, pp. 467–479.

——— ——— Highwood Mountains of Montana: Bull. Geol. Soc. America, vol. 6, 1895, pp. 389–422.

——— ——— Geology of the Castle Mountain mining district, Montana: Bull. U. S. Geol. Survey, No. 139, 1896.

——— ——— The Bearpaw Mountains, Montana: Am. Jour. Sci., 4th ser., vol. 1 1896, pp. 283–301, 351–362; vol. 2, 1896, pp. 136–148, 188–199.

——— ——— Missourite, a new leucite rock from the Highwood Mountains of Montana: Am. Jour. Sci., 4th ser., vol. 2, 1896, pp. 315–323.

——— ——— Geology of the Little Rocky Mountains: Jour. Geology, vol. 4, 1896, pp. 399–428.

——— ——— Geology and mineral resources of the Judith Mountains of Montana: Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1898, pp. 446–616.

Pirsson, L. V. Petrography of the igneous rocks of the Little Belt Mountains, Montana: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 3, 1900, pp. 463–581.

——— Petrography and geology of the igneous rocks of the Highwood Mountains, Montana: Bull. U. S. Geol. Survey No. 237, 1905.

In the vicinity of Cascade, Mont., on the eastern side of Missouri River, in sec. 20, T. 17 N., R. 1 E., a large dike extends into the area from the main bed of intrusive rock constituting the north end of the Big Belt Mountains. As this dike radiates from an igneous mass at a considerable distance from those above described, samples from it were collected for the purpose of having thin sections prepared and studied. These sections have been examined by Albert Johannsen, of the Geological Survey, whose preliminary report is as follows:

Tentative name: Andesite porphyry with latite affinities.

Megascopic: A dark-gray porphyritic rock, weathering a dirty yellow. The black phenocrysts, up to one-eighth inch in diameter, become very pronounced on the weathered surface.

Microscopic: Porphyritic; about one-fifth phenocrysts. The groundmass has an intersertal texture in which the irregular areas are of a dirty-brown serpentine. The phenocrysts, which are chiefly augite, are generally in broad, lath-shaped sections. A few of the feldspar crystals of the groundmass are larger than the remainder and may be classed with the phenocrysts. The groundmass consists of dirty yellowish-brown serpentine, less augite, about the same amount of magnetite, much less orthoclase, and some pseudomorphs, now serpentine, which have the form of olivine. The feldspar consists of plagioclase and orthoclase; the plagioclase varies in composition from andesine to andesine labradorite. Apparently none is more basic than Ab_{50}, An_{50}. The index of refraction is ± 551.

METAMORPHIC ROCKS.

Very few metamorphic rocks are found in the plains portion of the Great Falls region, although in the mountainous districts surrounding the field the sedimentary rocks have been highly metamorphosed by intrusive dikes, sheets, and laccoliths. The Highwood Mountains bordering this field on the north have been caused by igneous intrusion in Cretaceous rocks, which were metamorphosed to such an extent that they have resisted subsequent erosion and now stand out from the surrounding plains as a cluster of high peaks. Intrusions in the form of stocks and laccoliths are more or less common along the base of the adjoining mountain ranges. From some of these intruded rock masses the overlying sediments have been removed, exposing a central core of igneous rock, around which contact-metamorphic phenomena are well exhibited. A good illustration of these conditions is found on the east side of Little Otter Creek, about 3 miles south of Mann, outside of the area here discussed.

As previously stated, intrusive rock in this district is most commonly found in the form of dikes. In most localities these have metamorphosed the sediments into which they were intruded for some distance back from the contact, converting sandstone into quartzite and shale into slate. Phenomena of this character were observed at several places, notably on the north side of the Big Belt Mountains, about 7 miles southwest of Orr, in the vicinity of Rocky Ridge, and throughout that portion of the field which lies east of Stanford. No places were observed where the intrusives had cut the workable coals and thereby altered them by metamorphism along the contact. For this reason no special study was made of the character of the contact-metamorphic rocks of the field. It is highly probable that the intrusives which cut the sediments on the northeast side of Belt Butte have had some effect on the Kootenai coals of that district, providing they extend so far east, but as there are no exposures of the coal beds the phenomena could not be observed. There are also, on the upper part of Hazlett Creek, dikes which in their northeast extension may cut and alter by metamorphism workable coals, but these dikes could not be traced on the surface into the coal area. The same is true of the dike forming Rocky Ridge, which extends southward from Highwood Mountains, but disappears at the northern edge of the Otter Creek coal area.

STRUCTURE.

PLAINS PROVINCE.

GENERAL CONDITIONS.

Throughout the plains portion of the region described the structure is relatively simple. The rocks as a rule lie nearly horizontal, dipping with a small angle to the north and east, away from the mountains, but in the mountainous portion the structure is more complex. Although low dips of 3° to 5° prevail throughout the plains province, and the district is one of little disturbance, the rocks on closer examination are found to be gently folded into a series of shallow synclines and low anticlines. This structural feature is scarcely perceptible to the casual observer, being revealed only by a careful examination of the beds exposed along the sides of the larger streams, such as Otter and Belt creeks and Smith River and its principal tributaries. The major axes of these folds appear to be roughly parallel to the Little Belt Mountains uplift, but the folds are only of slight magnitude and the individual warps are broad. The largest and most perceptible of the synclinal depressions crosses Otter Creek between the mouth of Williams Creek and the Nollar mine. Its effect is to carry the coal-bearing rocks of the Otter Creek area about 100 feet below Otter Creek valley for a distance of 3 or 4 miles.

The slight deformation of the coal-bearing rocks has had an important bearing on the development of the coal beds of this field. Wherever stream valleys cross the coal-bearing areas and cut sufficiently deep to expose the coal, they produce favorable conditions for mining. Owing to the horizontal position of the beds, entries can be driven for long distances nearly at right angles to the direction of the dip, which is in general to the north, without producing an appreciable lift in the haulage of the coal. The gentle northward dip of the coal-bearing rocks can be turned to advantage in mining by driving the main entry at an angle greater than 90° with the direction of the dip, thus causing the entry to extend up the dip sufficiently to produce natural drainage of the workings. Though in general the rocks lie nearly horizontal throughout the Great Falls field, there are minor undulations in the strata which are too local to be observed on the surface, but which are shown in the maps of the mine workings. Some of these cause more or less difficulty in mine haulage, making it necessary to use special appliances to fit the topographic conditions in the mine.

DOMES.

Local doming of the strata, due to laccolithic intrusion of igneous rock, is more or less common along the north side of the Little Belt Mountains and in the vicinity of the Judith Mountains, farther east. Skull Butte, in the plains province at the east end of the district, is without doubt a domal uplift of this character. It is nearly circular in outline, its greatest diameter being about 1½ miles, and its quaquaversal dips ranging from 20° to 30°. Erosion of its center has not advanced sufficiently to uncover igneous rocks. This uplift exposes the coal in the steeply dipping beds about its base.

In the vicinity of Stockett local uplift and erosion occurred prior to the deposition of Jurassic sediments, as is shown by the unconformable relations of Jurassic sandstone and Madison limestone. Exposures of the limestone occur in which the strata are tilted and eroded, with Jurassic sandstone deposited across the upturned ends. The strongest dip of the limestone beds seen was about 10°. The various formations in this vicinity are perceptibly thinner than elsewhere, a stratigraphic feature probably due to the presence of the dome during the deposition of these sediments. The unconformable relations of the Carboniferous and Jurassic formations, and the moderately steep dips of the latter as exhibited in Sand Coulee, about 2 miles east of Stockett, are shown in Pl. VI. This doming of the Carboniferous rocks in the Stockett region is probably not of wide extent, but its exact limits can not be ascertained owing to the lack of exposures. Its north-south dimension, as shown by outcrops along Sand Coulee, is about 4½ miles, but its east and west boundaries are not known. At Stockett and along Sand Coulee valley, owing to the thinning of the Jurassic and Lower Cretaceous formations, also to the absence of the Quadrant in the vicinity of the dome, the coal horizon occurs only about 150 feet above the Madison limestone, which is exposed in the bottom of the valley. This feature might be misleading to prospectors who are not familiar with the local conditions about Stockett, for in other parts of the Great Falls coal field, especially along Belt Creek and in the Otter and Sage Creek areas, the coal bed is separated from the Madison limestone by about 650 feet of rock.

At the head of Ming Coulee, where coal of workable thickness is exposed, the beds dip steeply to the northwest. These local dips are due to a large dome farther south, outside of the area treated in this report. The Quadrant formation is also absent, causing the coal bed to occur about 250 feet above the top of the Madison.

On Boston Coulee, about 2½ miles west of Eden, a local dome of the strata exposes the coal-bearing bed along Boston Coulee for about 1½ miles, and also to the southward up a small tributary of that coulee for an equal distance. This small uplift, which causes the coal outcrop to take a T-shaped form, is shown on the coal map (Pl. II).

FAULTS.

No large faults occur within the area here discussed, but minor faults are not uncommon, especially in the vicinity of Belt and Stockett. The throw of these faults ranges from 5 to 20 feet, and their presence is usually difficult to detect on the surface. They are generally first encountered by miners who are working the coal bed, and in some places their presence has caused considerable difficulty in mining operations. At Belt, on the west side of Belt Creek, such a fault extends nearly west for about 1½ miles, displacing the coal bed a few feet and causing difficulty in operations along the north side of the underground workings of the Anaconda Copper Mining Company's mine. In Armington Coulee, about half a mile above the mouth, a sharp fold in the beds trends northward toward Belt Butte. The beds may possibly be more or less fractured along its axis, but exposures at this place were inadequate for positive determination of this point. Other small displacements have been reported from some of the smaller mines along the east side of Belt Creek in the vicinity of Armington and Belt, notably in the Richardson mine and to a less degree in the Smauch and Millard mines, but these faults appear not to cause any appreciable displacement of the sediments at the surface. On the north side of Stockett a small fault in the Madison limestone has a throw of about 15 feet, extending east and west. The Cottonwood Coal Company reports that a small north-south fault in the coal-bearing rocks was encountered in mining about three-fourths of a mile east of the town; but no evidence of this fault was observed on the surface. The minor faults throughout the Great Falls coal field are not shown on the geologic map. It is possible that many such small faults are scattered over the field and will be discovered on more extensive development of the coal deposits, but it is difficult if not impossible to locate them, owing to the fact that their throw is generally insufficient to be perceptible on the surface.

LITTLE BELT MOUNTAINS.

The general structure of the Little Belt Mountains, which border this area on the south, is that of an anticlinal uplift with sharply dipping sides and a flat summit. In the central portion of the range the stratified rocks lie nearly horizontal, but along the northern flank of the uplift, as found on the head of Geyser Creek, the limestone dips at an angle of 15° to 20° toward the lower plains country. As previously stated, the simple structure of the northern part of the uplift has been considerably modified by the intrusion of igneous rocks in the form of laccoliths, which have caused local doming of the strata in many places. Only one of these laccolithic domes lies within the area described, but there are others, such as those east of Kibby and in the head of Dry Wolf Creek, whose marginal structure extends into the district. In the vicinity of the larger intruded masses of igneous rock the dips are in many places steep and variable, but in that portion of the mountain front where local intrusions have not disturbed the strata, they dip away normally from the uplift at angles of 6° to 12°, lessening gradually toward the lower plains country.

HIGHWOOD MOUNTAINS.

The Highwood Mountains, which border on the north the east end of the area described in this report, are structurally of a different type from the Little Belt Range. They consist of a group of isolated peaks, which were formed by igneous intrusions in Cretaceous rocks that were horizontally bedded or slightly inclined toward the east. Subsequent to this intrusion stream erosion carved out this cluster of peaks from the surrounding plains.

ECONOMIC GEOLOGY.

GENERAL STATEMENT.

The mineral resources of the area treated in this report are somewhat varied, but the principal one at present is coal. Fire clay of a superior quality is found in beds of workable thickness along Belt Creek and its tributaries, and at many places throughout the district raw materials suitable for the manufacture of Portland cement can be obtained. Gypsum deposits occur at different horizons in the Quadrant formation near Riceville, and at Goodman this mineral has been mined in a small way for a number of years. Building stones of different varieties, also limestone, are common in many parts of the field. Sand and gravel can usually be obtained locally. Iron pyrite is mined as a by-product with the coal and shipped to Great Falls, where it is used in the process of pyritic smelting.

COAL.

GEOLOGIC OCCURRENCE.

Throughout the Great Falls coal field the coal occurs in the lower part of the Kootenai, or Lower Cretaceous rocks, mainly at a horizon about 60 feet above the base of the formation. Coal of workable thickness is not continuous, however, at this horizon, but varies locally.

This irregularity of occurrence is a characteristic feature of the beds of this field which was early observed in the investigation, and an effort was made to ascertain as far as possible, from a study of the outcrop, the limits of the areas underlain by workable coal. These coal areas, or basins, as they have previously been designated by Weed,[a] are three in number and include a total area of approximately 334 square miles. The largest, comprising about 231 square miles, lies south of Great Falls, extending from a point a short distance east of Belt Creek beyond Smith River. (See Pl. II.) It is possible that the coals of this basin continue to the south throughout the territory lying between the Little and Big Belt mountains, but no examination was made of this region. The district examined is drained by Sand Couleé and its tributaries, and is known as the Sand Coulee area. To the east the next district underlain by coal of commercial importance lies between Little Otter and Geyser creeks, and is designated the Otter Creek area; it is the smallest coal area in the field, including only about 37 square miles. Still farther east, in the vicinity of Skull Butte, there is a third coal area, which, owing to its nearness to Sage Creek, the main drainage channel of the district, is called the Sage Creek area. It includes about 66 square miles.

SAND COULEE AREA.

LOCATION AND EXTENT.

The Sand Coulee coal area, which lies south of Great Falls, is 6 miles wide and from 30 to 40 miles long. The exact limits of the area underlain by workable coal are difficult to determine, for it is only along the valleys of streams that cross the area, such as Belt Creek, Sand Coulee, and Smith River and their tributaries, that the coal bed can be studied with respect to its disposition to thicken or thin in any given direction. In the plateau district between these valleys the coal is concealed by 200 to 300 feet of overlying Kootenai rocks, which the smaller streams traversing the plateaus have not cut down sufficiently to expose the coals. As the rocks dip gently away from the mountains, the outcrop of the coal bed extending across the plateau from one stream valley to another occurs far up the slope in the foothill zone, where the coal is usually represented by a thin bed of carbonaceous shale. Under these conditions it is apparent that the width of the coal basin can only be inferred from the thickness of the beds along the stream valleys. As these valleys are more or less widely separated, the lateral extent of the coal area in the plateau region is largely conjectural.

Along Belt Creek, which crosses the east end of the area, the coal bed thins rapidly to the south and becomes shaly at a point near the

[a] Weed, W. H., Bull. Geol. Soc. America, vol. 3, 1892, pp. 301-330.

mouth of Otter Creek. Toward the north the same is true, although in a less marked degree, to a point a short distance above the mouth of Little Belt Creek, where the dip of the rock carries the coal beneath the river. The bed is thickest in the vicinity of Armington and Belt, and in either direction from this zone there is a perceptible thinning. The eastern border of the workable coal area can not be definitely determined, for the coal east of Belt is not exposed, but along the lower part of Otter Creek the workable bed thins rapidly to the east, a condition which is believed to indicate that the eastern limit of the workable coal should be placed not more than 2 miles east of Belt Creek.

According to exposures along Sand Coulee, the coal bed thins to the south, near the northern line of T. 18 N.; and to the north in sec. 2, T. 19 N., R. 4 E., it is only a few inches thick. The bed reaches its maximum thickness between Straight and Giffen coulees, where the larger coal mines are located. In the Smith River valley, near the mouth of Hound Creek, the coal bed has a good workable thickness, which it maintains toward the north, possibly with slight thinning as far as sec. 1, T. 17 N., R. 2 E., where the bed passes beneath the river. How far workable coal extends northwest of this point is not known, but it seems probable that it continues for at least 2 or 3 miles. The southern limit of the Sand Coulee area was not ascertained, for the investigation did not extend beyond the southern border of T. 17 N., where a local fold of the strata carries the coal beneath the river; as it is of workable thickness at the southernmost point examined, it may possibly continue thus for some distance.

On upper Ming Coulee the coal bed has a maximum thickness of 8 feet, but 2 miles farther up this stream the dips are steep and the bed occupies the summits of high hills, where the covering is thin and the coal more or less shaly. Along the north side of the wagon road leading from Ming Coulee to Rocky Coulee the coal bed has been prospected at many places, especially in secs. 21, 22, and 14, T. 17 N., R. 3 E. In most of these prospects the coal horizon was marked by only a few inches of carbonaceous shale, which locally thickens and in one place becomes nearly workable. From these observations it is believed that the southern limit of the Sand Coulee area in this part of the field lies some distance north of the wagon road. The limits of this area as based on the evidence are shown on Pl. II.

CHARACTER AND THICKNESS OF COAL BED.

The Sand Coulee area is underlain by one coal bed of commercial importance. In this bed, consisting of coal interbedded with layers of bone, shale, and clay, the coal content ranges in thickness from 6 to 14 feet in different parts of the field. At Belt, in the northeast end of the area, where the bed has been opened at many places, the average thickness of twenty-six measured sections is 4 feet 7 inches. At Sand Coulee fourteen measured sections give an average thickness of 8 feet 7 inches, and along Smith River, where fewer openings have been made, an average of five sections shows a total thickness of 7 feet 6 inches of coal. In the vicinity of Belt the coal is divided into three distinct benches—a lower, middle, and upper. The lower and upper benches are in many places about equal in thickness, the middle bench being considerably thinner. (See Pl. VIII.)

At Sand Coulee the coal bed generally occurs in two principal benches, the upper being much thicker than the lower. (See Pl. X.) Above the uppermost bench worked, however, there are in some places, notably in the Smith River district, two higher layers of coal which have a maximum measured thickness of 5 feet 8 inches. From a comparison of the average thickness, number, and order of the various coal benches in the Belt, Sand Coulee, and Smith River mining districts, it is apparent that the coals of this basin are of broadly lenticular character and it seems probable that the total thickness of coal contained in the coal-bearing zone is greatest in the Sand Coulee mining district.

Graphic sections of the coal in the Sand Coulee, Otter, and Sage Creek areas are shown in Pls. X–XII. In the following discussion of the coals of these areas individual sections are referred to by numbers corresponding to those used on these plates.

DEVELOPMENT.

Development of the coal resources of the Great Falls coal field was first begun in the Sand Coulee basin at Belt, where, in 1876, a small mine was opened, the coal being shipped overland to Fort Benton, a town situated near the head of navigation on Missouri River. For the first few years the coal output of this field was small, but with the opening of mines at Sand Coulee, on Smith River, which took place a few years later, the amount was increased. In 1885 the combined production of the Belt and Sand Coulee mines was 1,900 tons, of which 1,200 were from the Belt mines. During the following year the output of these two localities amounted to only 1,400 tons, the greater part being supplied by the Sand Coulee mines. The reports on Cascade County for 1887 give a relatively small yield, but during the following year, with the completion of railroad facilities to Sand Coulee, the total coal production of the region was materially increased. From 1888 to 1892 the annual coal output of the Sand Coulee basin grew steadily with the improvements made in the facilities for handling coal at the Sand Coulee mines; during 1893 the total production of the region increased over 100 per cent. Since 1880, when the first systematic record of the coal production of Montana was kept, Cascade County has been one of the largest producing counties in the State. Its relative output, with respect to that of the State as a whole, is shown in the following table:

Coal production of Montana and Cascade County from 1880 to 1906, inclusive.[a]

[Short tons.]

Year.	Montana.	Cascade County.	Year.	Montana.	Cascade County.
1880	224		1895	1,504,193	713,877
1881	5,000		1896	1,543,445	1,101,298
1882	10,000		1897	1,647,882	1,138,590
1883	19,795		1898	1,479,803	988,821
1884	80,376		1899	1,496,451	965,378
1885	86,440	1,900	1900	1,661,775	1,123,395
1886	49,846	1,400	1901	1,396,081	789,407
1887	10,202		1902	1,560,823	761,572
1888	41,467	4,600	1903	1,488,810	733,064
1889	363,301	166,480	1904	1,358,919	599,158
1890	517,477	200,435	1905	1,643,832	826,026
1891	541,861	198,107	1906	1,838,635	991,417
1892	564,648	242,120			
1893	892,309	516,460	Total	22,730,990	12,702,465
1894	927,395	638,960			

[a] Mineral Resources U. S., 1880 to 1906, inclusive, U. S. Geol. Survey.

Although at the present time coal prospects and small mines are located at many different places throughout the Sand Coulee area, development is confined chiefly to three localities where stream valleys crossing the district cut and expose the coal-bearing rocks. These districts of principal development are along Belt Creek, Sand Coulee, and Smith River.

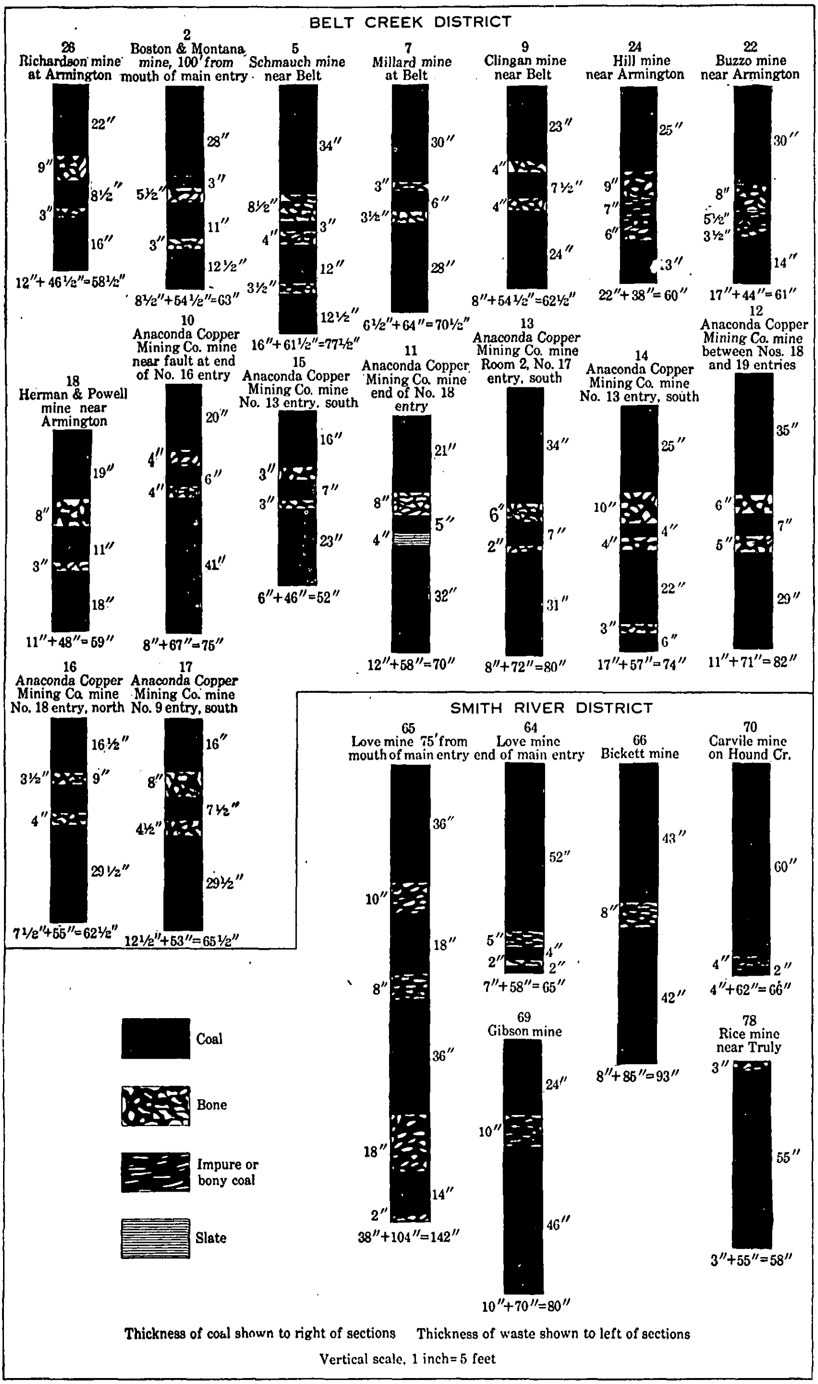
BELT CREEK MINES.

GENERAL STATEMENT.

Along Belt Creek and its tributaries near the town of Belt the coal bed has been extensively prospected and a number of mines are now being operated. The mine of the Anaconda Copper Mining Company is the largest in the district, but there are four smaller ones which are worked continuously, and seven abandoned mines, some of which have produced considerable coal in the past. Prospecting has been extensive, especially along Neel Creek, on either side of Belt Creek, and in Armington Coulee. A number of diamond-drill prospect holes have been bored by the larger companies on the plateau west of Belt Creek in order to determine the character of the coal bed underlying their holdings. The location of the mines are shown on Pl. II; sections of the coal beds are shown on Pl. VIII.

MINES OPERATED.

Anaconda Copper Mining Company mine.—The mine owned and operated by the Anaconda Copper Mining Company, of Anaconda, Mont., is located on the west side of Belt Creek, at the town of Belt. (See Pl. IX.) The principal coal holdings of the company, which



SECTIONS OF COAL IN BELT CREEK AND SMITH RIVER DISTRICTS, MONT.

comprise several acres, lie in secs. 26 and 27, T. 19 N., R. 6 E. This mine was first opened in 1895, and has been in continuous operation since that time. At present the company employs a large force of men and produces a considerable tonnage. The mine, however, is not worked at its full capacity, the output being controlled by the requirements of the company's plant at Anaconda, a point to which much of the coal is shipped.

The bed at this place has an average thickness of 6 feet, including partings, and occurs in three benches. The lowest bench is about 2 feet 6 inches thick, and is overlain by 2 to 4 inches of bone, followed by the middle bench, which is usually about 7 inches thick. Above this 7-inch layer occurs bone parting 3 to 8 inches thick, followed by a bed of coal 1 to 3 feet thick, constituting the uppermost bench. There appears to be little difference in the physical properties of the coal in the different benches. The bed usually has a shale roof and floor and lies nearly horizontal, dipping only slightly to the north. Sulphur in the form of pyrite nodules occurs in all the benches. A number of graphic sections of the coal bed in this mine are shown in Pl. VIII.

The underground workings of the mine are very extensive. The main entry has been driven for about 1½ miles from the outcrop, with numerous side entries to the north and south one-half mile or more in length. The entire workings cover an area of about 600 acres. The coal is taken out by the room-and-pillar system and brought to the surface by cable haulage. The mine is provided with a double entry, and ventilation is effected by a large fan located near the entrance. Electric lighting is used only in the main entries, and the water is removed by large pumps.

Owing to the large amount of impurities present in the bed it is necessary to wash the machine-mined coal. The method employed is as follows: The coal is carried from the mine in pit cars having a capacity ranging from 2 to 2½ tons each, by means of a cable and tail rope. A trip consists of 48 cars, which on arriving at the mouth of the mine are uncoupled and allowed to run one by one down a gravity incline from which the car is switched onto one of three tipples, according to the character of the coal it contains. After the cars are unloaded they are gathered again on a single track and returned to the mine.

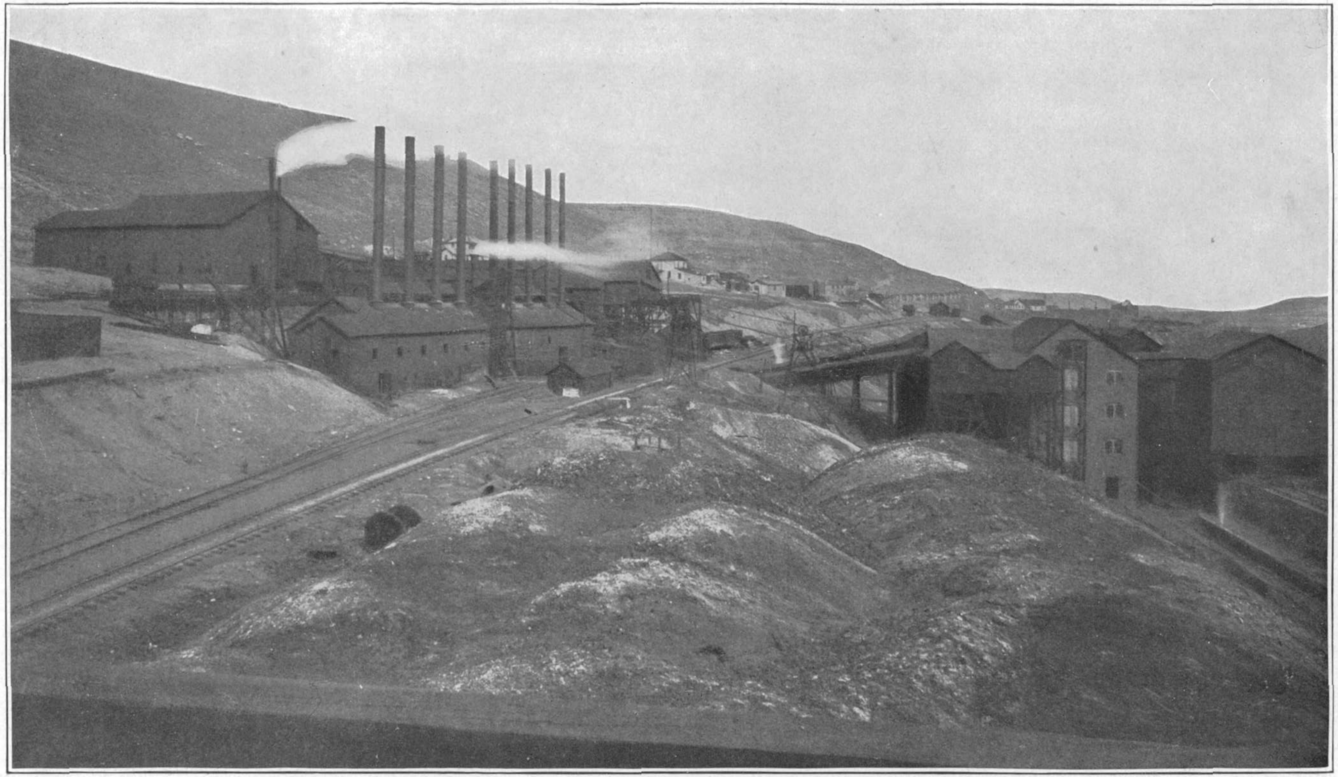
The tipple over which the hand-mined coal is dumped is connected directly by chute to the railroad cars below. The two remaining tipples are connected with a heavy sharp-toothed crusher by long chutes, which are sufficiently large to serve as temporary storage bins. At the crusher all the machine-mined coal is reduced to a small size. It is then carried by means of an inclined conveyor to the top of the washery, which consists of three large washers and a number of jigs. The amount of coal cleaned at this plant ranges from 250 to 300 tons a day.

The large washer consists of a steel chamber in the form of an inverted cone, inside of which are projecting arms and stirring plates revolved by a driving gear above. The water supply enters at the bottom from a perforated pipe. The coal is introduced at the top from a chute and is kept in a continual state of agitation by a current of water. As it is lighter than the impurities, it remains at the top and passes out through the overflow into conveyors, while the water and sludge drain through the hopper into a sludge tank. The impurities sink into a lower chamber of the washer, which is provided with two valves, one above and one below. When this chamber is filled, the upper valve is closed and the lower opened to discharge the refuse. By this process the coal is cleaned rapidly, but the results on the whole are not so satisfactory as those obtained by the jigs.

The jig washer consists essentially of a large wooden tank divided into two compartments, one containing a screen on which are placed a number of small pieces of feldspar, the other provided with a piston moved up and down by means of an eccentric, imparting to the water the necessary pulsations. By this means the water is forced up through the screen, lifting the unassorted material and allowing it to settle again, thus affording an opportunity for the products of different specific gravity to adjust themselves according to the law of equally falling particles. The coal remains at the top of the wooden tank, the slate next below, and the pyrite at the bottom. These products of separation are drawn off through gates placed at proper heights in the sides of the jig and are carried away by screw conveyors—the coal to a large bin, where it is allowed to drain; the pyrite to an elevator, where it is rinsed and dropped into railroad cars; and the slate to the waste pile. The water used in the washery is taken to a tank outside the plant, and after the sediments which it contains have settled to the bottom, the clear water is drawn off from the top and pumped back into the washer.

The iron-pyrite nodules removed by the above-described process are shipped as a by-product to the large smelters at Great Falls, where they are used as an additional fuel and flux in the blast-furnace charge. By this utilization the pyrite pays for its separation from the coal.

Coal from the middle bench of the Belt Creek bed was formerly coked, and 100 ovens having a capacity of 3 tons each were built for this purpose. It was found, however, that the bench of coking coal was too thin to pay for its separation from the other varieties of coal, and consequently the coke ovens are not now used. A view of the Anaconda Copper Mining Company's plant at Belt is shown in Pl. IX.



ANACONDA COPPER MINING COMPANY'S COAL PLANT AT BELT, MONT.

Schmauch mine.—The Schmauch mine, situated on the east side of Belt Creek at Belt, nearly opposite the Anaconda Copper Mining Company's mine, is probably the largest of the smaller openings. This mine is worked continuously by a few men, but it has only a small output, which is sold to ranchmen in the vicinity of Belt. The entry extends several hundred feet from the outcrop, but the exact length could not be measured owing to cavings in the mine. The bed lies nearly horizontal, dipping slightly to the north. A representative section shows a thickness of about 6½ feet, consisting of three benches. The lowest is 28 inches thick, containing a bone parting 3½ inches thick 12½ inches above the base. Above this bench is a 4-inch layer of bone, followed by 3 inches of coal, constituting the middle bench. This is overlain by 8½ inches of bone, which is followed in ascending order by a bed of coal 34 inches thick—the top bench (5). The occurrence of a bony layer in the lower bench of coal is unusual in this district.

Millard mine.—The Millard mine is situated a few hundred yards south of the Schmauch mine, on the same side of Belt Creek. Here an entry has been driven about 700 feet from the outcrop, with side entries leading to the north and south. The bed is about 6 feet thick, containing partings which separate the coal into three benches, the lower 28 inches, the middle 6 inches, and the top 30 inches (7). The lowest bench is regarded by the miners as containing the best quality of coal, that of the middle and uppermost benches being of a slightly inferior grade. The Millard mine has a very small output, and most of the coal is sold in the town of Belt.

Richardson mine.—On the east side of Belt Creek at Armington is another mine, owned by Matthew Richardson, which is worked during the winter months. The coal here exhibits the usual thickness of about 4½ feet, including partings. The three characteristic benches are represented—a lower, middle, and upper. The uppermost has a thickness of 1 foot 10 inches, the middle and lowest are 8½ and 16 inches thick, respectively. A section of this bed is shown in Pl. VIII, No. 26. The coal is bright and clean looking, and in composition does not differ materially from the average coal found near Belt. The output of the mine, which is small, is sold in Armington and to ranchmen along Belt Creek valley.

Orr mine.—About 1½ miles north of Belt, on the east side of Belt Creek, there is a mining property owned by the Orr Brothers, which is worked to a certain extent, chiefly in the way of development. A main entry has been driven 700 feet from the outcrop, with side entries of considerable length.

The coal appears to be of inferior quality and the large amount of material taken out in excavating the entries could not be placed on the market. The coal is dull or lusterless and is not firmly bedded.

An analysis of an air-dried sample shows about 44 per cent fixed carbon, 21 per cent volatile matter, 28 per cent ash, and a small amount of sulphur. A representative section of the mine shows five benches of coal, with an aggregate thickness of 4 feet 5 inches. The lowest bench is 10 inches thick, followed by 3 inches of bone, which in turn is overlain by 10 inches of coal. Above this coal is a 12-inch layer of bone overlain by 7 inches of coal of a rather inferior variety. Over this coal is 10 inches of bone followed by 22 inches of coal, constituting the uppermost bench of the bed. A comparison of this coal bed with those in the Schmauch and Millard mines indicates that partings have developed in both the lower and upper coal benches.

ABANDONED MINES.

The remaining small mines of the Belt district are the Hill, Buzzo or Hill, Boston and Montana, Herman & Powell, Watson, Brady, and American Smelting and Refining Company.

Hill mine.—An abandoned mine, said to be now owned by J. J. Hill, is located on the west side of Belt Creek at Armington. A large entry has been excavated, and, to judge from the size of the dump, considerable coal was taken out. A section of the bed shows 3 feet 2 inches of coal, not including three layers of bony coal which occur near the middle (24). The coal is apparently of good quality, but contains the usual amount of sulphur in the form of iron-pyrite nodules. The uppermost bench is characterized by joint planes running in opposite directions, separating the coal into small cubical blocks.

Buzzo or Hill mine.—About one-fourth mile south of the abandoned Hill mine, on the same side of Belt Creek, there is another opening known as the Buzzo mine, also owned by J. J. Hill. This mine is more or less caved at the mouth of the entry, but the general succession of the members in the coal bed was obtained. Three benches of coal are present, the lowest 14 inches, the middle, which is very impure, 5½ inches, and the uppermost 30 inches thick (22). The coal appears to be of good quality in the uppermost bench, but that found in the middle bench is inferior. No analysis was made. The entry is said to be 500 feet long, but as the mine was flooded it was impossible to examine in detail the underground workings. The mine has a sandstone roof and a clay floor.

Boston and Montana mine.—The Boston and Montana mine, located about 500 yards south of Orr Brothers' mine, in the SE. ¼ sec. 23, T. 19 N., R. 6 E., contains a bed of coal similar in many respects to that found in the Orr mine. It has a sandstone roof and shale floor. A graphic section of the bed is given in Pl. VIII, No. 2. The three benches have an aggregate thickness of 54½ inches. The lowest contains a layer of bone, or bony coal, 12½ inches above the base. This bench is overlain by 5½ inches of bone, which is followed by the middle bench of coal, 3 inches thick. Above the middle bench there is a thin bony parting underlying 28 inches of impure coal, the top bench of the bed. A comparison of the sections at the Orr and at the Boston and Montana mine appears to indicate that the quality of the coal becomes better to the south.

Herman & Powell mine.—About 300 yards north of the Richardson mine, on the eastern side of Belt Creek at Armington, there is an abandoned opening known as the Herman & Powell mine. Two entries 75 feet apart have been excavated on the bed. The south entry is 250 feet long, extending in a southeasterly direction, but has no side entries. A section of the coal bed in this entry shows 4 feet of coal separated into three benches, the lowest 18 inches, the middle 11 inches, and the uppermost 19 inches thick (18). The mine has a slate roof and a clay floor. The north entry is 350 feet long and runs in a northeast direction. It has one entry on the southeast, which branches from the main tunnel 75 feet from its mouth. A section of the bed in this entry shows a thickness of 54½ inches divided into lower, middle, and upper benches, measuring 16½, 11; and 27 inches, respectively. The roof is dark-colored shale and the floor clay. This mine has not been operated for several years, but according to reports considerable coal was formerly taken out.

Watson mine.—About one-fourth mile south of the Richardson mine a tributary canyon known as Armington Coulee enters Belt Creek valley. On both sides of this coulee the coal bed is exposed, and several openings have been made. The largest on the south side of the coulee is known as the Watson mine. Here an entry has been excavated for a distance of 160 feet, exposing a bed of coal, including partings, 5 feet 1½ inches thick. Of this amount 4 feet 1 inch consists of coal, the remainder of dark-colored bony material. Three benches are recognized, the lowest 13 inches thick, the middle 13½ inches, and the uppermost 22½ inches. The middle bench appears to be of an inferior quality, although no analysis has been made. The lower bench contains a large amount of sulphur in the usual form. The bed has a slate roof and shale floor.

Brady mine.—On the north side of Armington Coulee, directly opposite the Watson mine, there is an abandoned opening known as the Brady mine. The entry at this place extends 150 feet from the outcrop, with one room on either side. The coal bed has a total thickness of 55½ inches. The coal of the lower bench is bright looking, but contains much sulphur in nodular form. The coal in the upper part of the top bench has a dull appearance and is probably of inferior grade.

American Smelting and Refining Company mine.—On the west side of the main road between Armington and Belt, near the Belt cemetery, there is an abandoned entry which was excavated by the American Smelting and Refining Company. This entry is well timbered, and the indications are that plans were laid for extensive development. The property is now abandoned, and the entry is caved so that it could not be examined for more than a few feet from the mouth. No information was obtained regarding the quality of the coal.

PROSPECTS.

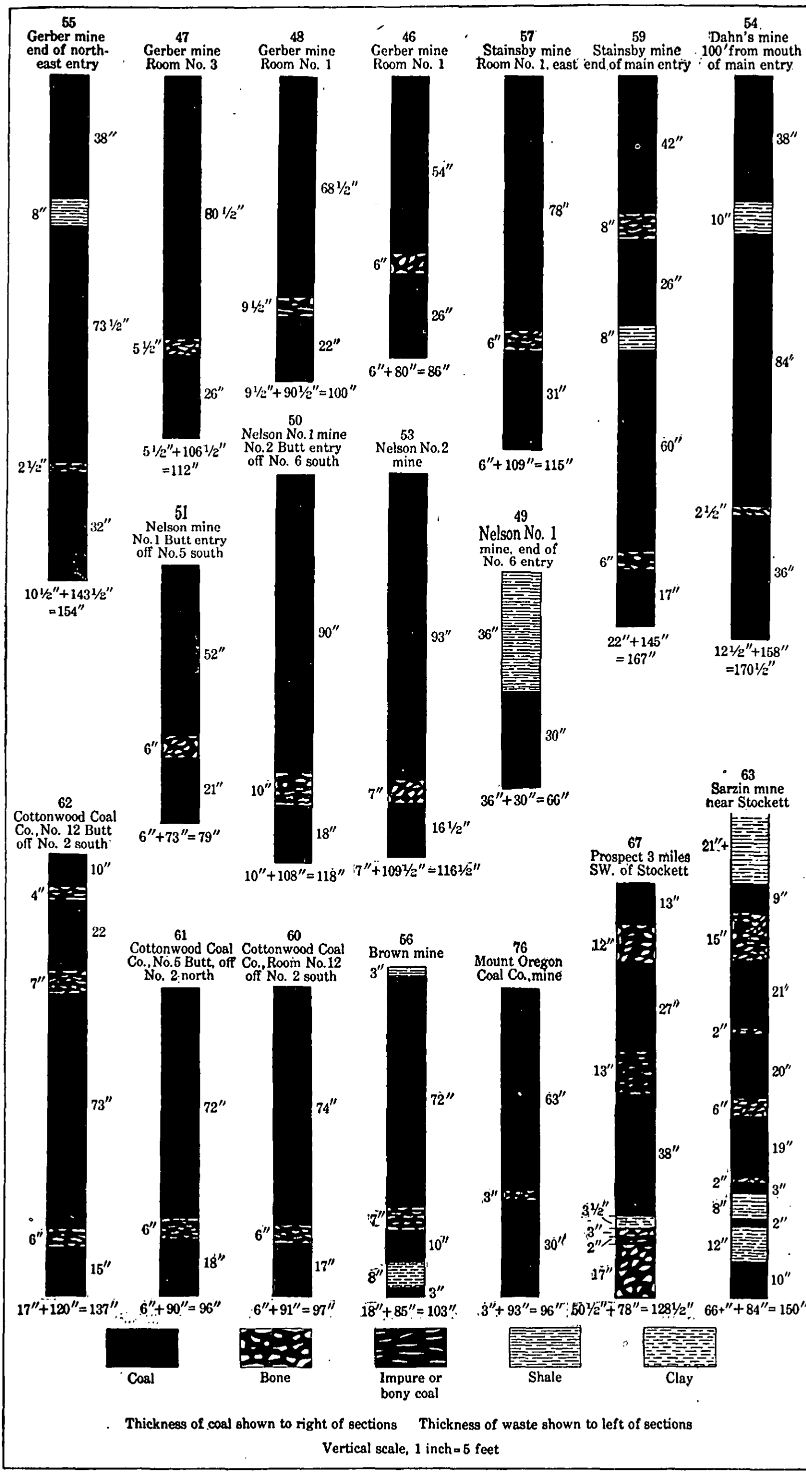
Entry prospects.—Considerable prospecting has been carried on in Belt and vicinity. Along Neel Creek, one of the principal tributaries of Belt Creek from the west, coal prospects can be seen at short intervals on either side of the canyon. Few of these prospects extend more than a few feet from the outcrop and they appear to have been opened more to determine the thickness of the coal bed than with the intention of developing a mine. One of the largest of these prospects, which may be regarded as a small mine, is owned by E. R. Clingan and is located in sec. 2, T. 18 N., R. 6 E. A section of the bed at this place shows 54½ inches of coal, excluding partings. The three characteristic benches are present, the lowest having a thickness of 24 inches, the middle of 7½ inches, and the uppermost of 23 inches.

Diamond-drill prospects.—In addition to the above prospecting, more or less diamond-drill boring has been done on the high plateau west of Belt Creek, in order to ascertain the thickness of the coal beds in different parts of property owned by large mining companies. No logs of these borings were obtained.

SAND COULEE MINES.

GENERAL STATEMENT.

Three large coal companies are now operating along Sand Coulee and its tributary canyons in the vicinity of Stockett. These are the Cottonwood Coal Company at Stockett, and the Nelson and Gerber coal companies at the town of Sand Coulee. In addition there are a number of prominent individual producers; those deserving especial mention are the Mount Oregon Coal Company and the owners of the Dahn, Brown, and Stainsby mines. This locality was the second to receive attention in the development of the coal resources of the Great Falls field, and at present is the largest producing district of the entire field and one of the largest in the State. Branch railroad lines connect Stockett and Sand Coulee with the Neihart branch of the Great Northern Railway at Gerber station, and a large amount of coal is shipped from these towns to Great Falls and also some to more distant points along the Great Northern main line both to the east and west. The location of the mines is shown on Pl. II; sections of the coal beds are shown on Pl. X.



SECTIONS OF COAL BED IN SAND COULEE DISTRICT, MONTANA.

MINES OPERATED.

Cottonwood Coal Company mine.—The mine operated by the Cottonwood Coal Company, which is owned by the Great Northern Railway, is located at Stockett, where the company has extensive holdings. Five mines have been opened since 1898—Nos. 1, 2, and 3 in 1890; No. 4 in 1900; and No. 5 in 1903. All are in sec. 36, T. 19 N., R. 4 E., mine No. 1 in the eastern part, No. 2 in the SE. ¼ SE. ¼, No. 3 in the NE. ¼ SW. ¼, No. 4 in the NW. ¼, and No. 5 in the NW. ¼ NW. ¼. This company has carried on extensive mining operations from the opening of the first mine in 1898. At present Nos. 1, 2, 3, and 4 are abandoned. The thickness of the coal bed worked in mine No. 5 (Pl. XI, *A*) is from 5 to 10 feet, not including partings. Four benches of coal are present in this mine, the lowest having a thickness of 15 inches, the next higher 73 inches, the third 22 inches, and the fourth and top bench 10 inches. Only the first and second benches, however, are mined. The bed worked has a bone roof and clay floor. It lies nearly horizontal, dipping slightly to the north. A graphic section showing the thickness of the benches and bone partings is given in Pl. X, No. 62. The coal contains sulphur in characteristic nodular form.

The Cottonwood Coal Company's mine has probably the best-equipped plant in the Great Falls coal field. It is provided with modern appliances for furnishing air, light, and water, both to the plant and to the underground workings. The impurities found in the different benches of the coal bed are sufficient to make it necessary to clean the coal before it can be placed on the market, and this is done by a dry process which separates the sulphur nodules and the bone from the coal.

The coal is carried from the mine in pit cars of a capacity averaging about 1½ tons. After being weighed on an automatic scale it is dumped by a cross-over tipple above a bar screen, with spaces between the bars 2 inches wide. This screen separates out the smaller pieces of coal, which constitute about 30 per cent of the total, allowing them to fall on a shaking screen having 1-inch round perforations. The slack passes through the screen and is loaded directly into railroad cars or taken to the boiler room by means of a wire-rope conveyor. The coal that passes over the shaking screen slides into a hopper from which it is fed into an elevator that carries it to the top of the building.

The coal that passes over the bar screen falls upon a traveling belt 4 feet 6 inches wide and 26 feet long. Men stationed on either side remove from this belt any large pieces of slate or other foreign matter such as machine picks, car couplings, or sprags, and throw them into a rock elevator. The belt is operated by a clutch, so that in case a large quantity of impurities appear it can be thrown out of gear, and all the impurities can be removed before the coal goes on. The belt delivers the coal to rollers, which reduce it to a size not exceeding 4 inches in largest dimension. It is necessary to reduce the coal to this size in order to detect and remove the sulphur balls present. The rollers are of removable-tooth style, 36 inches in diameter, 48 inches wide, and revolve 75 times per minute.

From the rollers the coal is elevated by a continuous elevator having buckets with a capacity of 110 pounds of coal when level full, operated at a speed equivalent to 200 tons per hour. The capacity of the fine-coal elevator is 90 tons per hour, giving a combined elevating capacity of 290 tons per hour, or 2,900 tons per day of ten hours, an amount which, added to the slack separated out by the shaking screen, gives a total capacity of 3,200 tons per day.

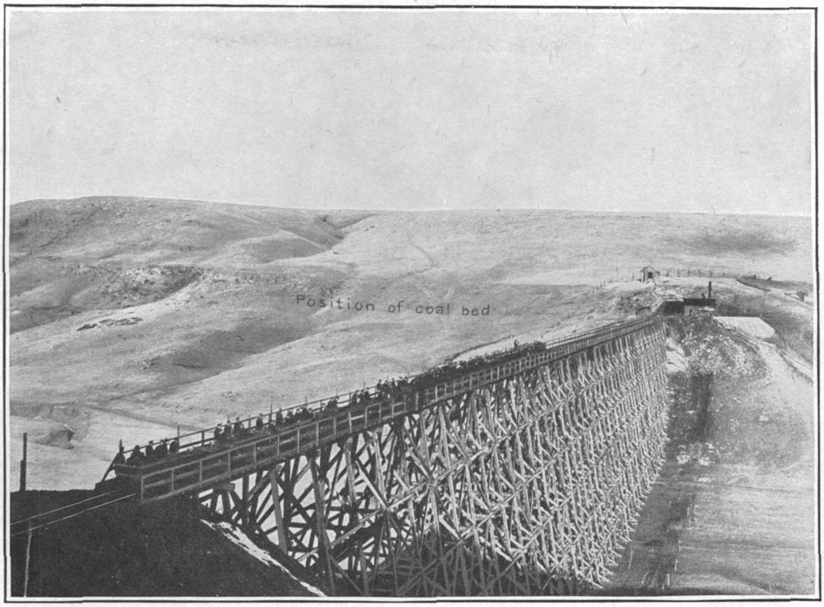
The coal raised by the elevators is evenly divided over an inclined shaking screen 5 feet wide and 46 feet long, whose plates have 1, $1\frac{1}{2}$, 2, $2\frac{1}{2}$, and 3 inch round perforations which separate the coal into slack, pea, nut, stove, egg, and broken sizes.

The slack resulting from the breakage of the coal is clean, and, not needing any further preparation, it descends through a hopper to the top strand of a conveyor, which carries it directly to the mixed-coal bin. The other sizes are fed by means of other hoppers into spiral separators which separate out the greater part of the impurities by means of centrifugal force and gravity. These impurities pass either to the lower strand of the conveyor, being taken thence to the rock elevator, or from one set of spirals to the bins by means of chutes, which gives an opportunity to repick the refuse by hand and save any coal that may still remain. The refuse is finally loaded into railroad cars and used for the purpose of widening banks along the railroad.

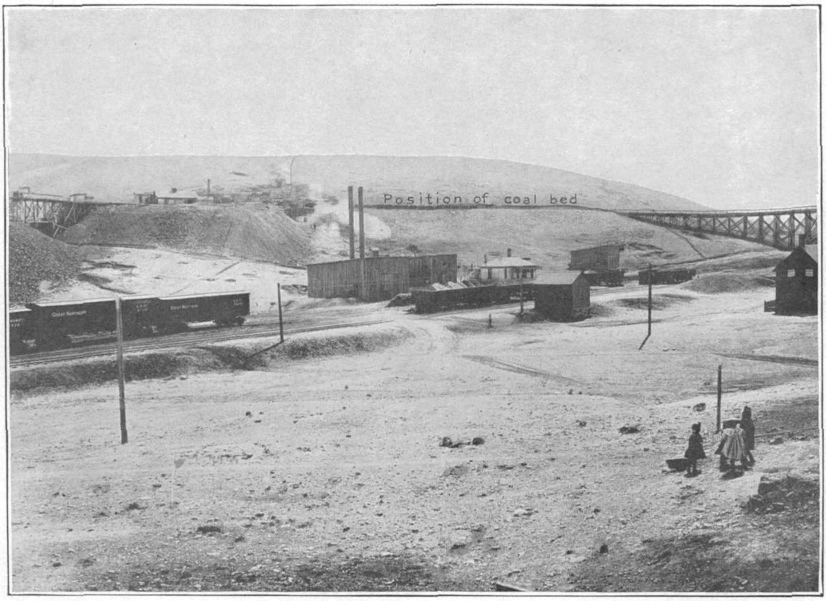
The coal from the spirals drops onto two picking bands 4 feet wide and 50 feet long, which convey it to the mixed-coal bin and give an opportunity to pick out by hand any impurities not already removed. From one set of the spirals inclined chutes carry the coal into bins for loading straight sizes, any remaining impurities being removed by hand while the material is on the chutes.

On account of the slight difference in specific gravity of coal and bone, the spirals are adjusted so as to retain only the slate and flat sulphur balls, leaving the bone to be removed by hand. The round sulphur balls, which on account of their shape are the first to leave the spirals and go with the coal, also have to be removed by hand.

The rock elevator, having continuous buckets 12 by 30 inches in size, elevates the impurities into a bin, from which they are loaded into a 6-ton car and hoisted by a pair of gear-tailed rope engines with 10 by 18 inch cylinders to the top of the adjoining hill and dumped automatically.



A. COTTONWOOD COAL COMPANY'S MINE NO. 5, NEAR STOCKETT, MONT.



B. NELSON COAL MINE AND PLANT AT SAND COULEE, MONT.

The machinery of the entire plant is driven by a double engine with 13 by 18 inch cylinders, running 150 revolutions per minute.

The percentage of refuse in the various sizes after being treated in the above-described process is stated below:

Refuse remaining in coal at Cottonwood Coal Company's mine, Stockett, Mont.

	Per cent.
Pea	4
Nut	3
Stove	3
Egg	2
Broken	1
Mixed	2.5

Of 2,000 tons of mine product daily dumped into the breakers, 200 tons of the various impurities are removed, and these impurities do not contain on an average over 1 per cent of coal.

For greater detail concerning the breaker used at this plant, including diagrams, the reader is referred to a report by Lewis Stockett,[a] of Stockett.

Nelson mines.—The Nelson mines, the oldest operated in the Sand Coulee basin, are located at the town of Sand Coulee (Pl. XI, *B*). There are two mines; No. 1 is situated on the east side of Sand Coulee, and No. 2 is on the west side, a short distance below the town. Mine No. 2 was first opened by Charles Locery in 1905 and was later sold to the Nelson-Jenks Coal Company. It is not being worked at the present time. Mine No. 1 was extensively worked by the Cottonwood Coal Company before that concern moved to its present location at Stockett. Operations were begun by the Nelson Coal Company at this mine in 1903, and since then the property has been worked continuously. The main entry has been driven in an easterly direction to a distance of about 3,000 feet from the outcrop, and the total acreage of the underground workings is considerable. The coal-bearing rocks at this mine are locally disturbed, the miners having encountered numerous rolls; and in places the coal is entirely absent. The bed ranges in thickness from 6 to 9 feet. It lies nearly level, with a general but low dip to the north, and is composed of benches like those worked at the Gerber mine, described below. The lower bench has a thickness of about 1 foot 6 inches and the upper of about 7 feet 6 inches (50). Between the two is a layer of dark-colored bone 6 to 10 inches thick. The coal of both benches is clear, firm, and noticeably free from foreign material. The sulphur is present in the usual form, but is not abundant. A layer of dark-colored shale 8 inches thick forms the roof. It is overlain by another bench of coal which is not mined at present. The floor consists of dark-colored shale.

[a] Stockett, Lewis, A bituminous coal breaker in Montana: Min. World, vol. 20, March 26, 1904.

The company employs about 175 men, who work continuously, and in general the plant is very well equipped for handling coal. Ventilation is furnished by a 12-foot fan, and the water is taken out by three large pumps. The coal is machine mined, by the pillar and block system, and is cleaned and assorted into different sizes by means of a 20-foot picking table and a 44-foot shaking screen. Horse haulage is employed.

Gerber mine.—One of the three large mines in the Sand Coulee district is owned by the Rock Springs or Gerber Coal Mining Company. It is located on the west side of Straight Coulee, a tributary to Sand Coulee, about half a mile south of the town of Sand Coulee, in the NE. ¼ sec. 23, T. 19 N., R. 4 E. The mine was opened in 1890 and has been worked continuously since that time. A large force of men is employed and the underground workings are extensive. Though slight local dips are more or less common, the coal bed lies nearly level, dipping only slightly to the north. It is from 6 to 9 feet thick, including partings. It is believed that the coal worked comprises the lower part of the coal bed as exposed in certain parts of this mine and at other places in the Sand Coulee district. Two benches are present—a lower, which has a thickness of about 2 feet, overlain by 2 to 6 inches of dark-colored bone, followed by an upper bench 4 to 7 feet thick (46, 47, 48). Above the upper bench worked there is in some places a coal bed 38 inches thick (55). The coal of all benches is firm, clean-looking, and noticeably free from bony partings. Sulphur, in characteristic nodular form, is present in considerable abundance. The roof consists of a strong dark-colored shale and the floor is a firm, compact clay. A few rolls occur at different places in the bed, but in general it is not much disturbed.

The Gerber Mining Company has a well-equipped plant, with the usual modern appliances for handling coal. There is considerable water in the mine, a portion of which is taken by steam pumps to a reservoir outside the mine, the remainder being pumped to a large tank on the hillside, from which the boilers are supplied. The tipple is located about 600 feet from the mouth of the mine at the end of the railroad. The coal is all machine mined, the bed being worked by the room and pillar system. The coal is fairly free from impurities, and such as exist are taken out by hand picking in the mine and screening at the tipple, no elaborate process being employed. The haulage is effected by means of horses and a small donkey engine. A 12-foot fan furnishes sufficient air to keep the mine well ventilated. Most of the output is shipped to points north, east, and west, local sales being small.

Mount Oregon Coal Company mine.—The Mount Oregon Coal Company mine, which is the largest of the smaller mines in the Sand Coulee district, is located near the town of Sand Coulee in the SE. ¼ sec. 14,

T. 19 N., R. 4 E. This mine is at present worked by Thomas Mokko, and was opened in the spring of 1902. The bed worked has a thickness of about 8 feet. It consists of two benches, a lower bench 30 inches thick, overlain by 3 inches of clay, followed by 63 inches of coal, constituting the upper bench (76).

The main entry extends several hundred feet from the outcrop, with numerous side entries. In working the bed the room and pillar system is carried out. Sufficient provision has been made for the proper ventilation of the underground workings and the water is taken out by a gravity system. The haulage is effected by horses, and a coal bin of 20 tons' capacity is located at the mouth of the mine. The impurities are removed by hand picking and screening. The company employs 18 men and has a daily output of about 45 tons.

Dahn mine.—The Dahn mine, located at Sand Coulee, in the northeast corner of sec. 13, T. 19 N., R. 4 E., is another of the smaller mines of this district. It was first opened in 1890, and has been worked intermittently up to the present time, changing hands several times in the interval. The coal bed underlies a hill covering about 20 acres. Most of the coal in this hill has been worked out. At present the output is 10 to 15 tons a day and only a few men are employed, but prior to 1903 the mine was operated in a more extensive way, 40 to 50 men being employed, with an output of about 100 tons a day.

The coal is between 13 and 14 feet thick. Three benches are present; the lowest is 3 feet thick, the middle 7 feet, and the uppermost 3 feet 2 inches. Between the lowest and the middle bench there is a 2½-inch layer of bone, and above the middle bench a 10-inch layer of shale (54). Only the lowest and middle benches are worked in the Dahn mine. The mine has a shale roof and floor.

Brown mine.—A small coal opening owned and operated by William Brown is located in the SW. ¼ SW. ¼ sec. 18, T. 19 N., R. 5 E. The main entry extends about 500 feet from the outcrop, with two small entries on either side. The mine has been worked for only about two years. Although the beds are nearly horizontal, they are considerably broken and disturbed, making progress slow. The coal is about 7 feet thick, divided into three distinct benches, the lowest 3 inches, the middle 10 inches, and the uppermost 6 feet (56). Shale forms the roof and floor. The output is very small, and operations are carried on only during the winter months.

Stainsby mine.—On the west side of Cottonwood Coulee, about 2 miles below Stockett, near the center of sec. 19, T. 19 N., R. 5 E., is a small mine owned by William Stainsby. Two men are employed, and a small amount of coal is taken out. The bed has a thickness of 12 feet, not including partings, which are about 22 inches thick. There are four benches of coal in all—the lowest 1 foot 5 inches thick, the next higher 5 feet, the next above that 2 feet 2 inches, and the top bench 3 feet 6 inches (59). The coals of the different benches do not appear to vary materially in quality, except that the top bench contains an unusually large amount of sulphur in the characteristic nodular form.

ABANDONED MINES.

In addition to the above-described mines there are in the Sand Coulee district three abandoned openings, known as the Mitchell, McKinsey, and Sarzin mines (Pl. X, 63). These are all small and of minor importance. A number of diamond-drill prospect holes have been sunk by some of the larger coal companies holding property in the immediate vicinity.

SMITH RIVER MINES.

GENERAL STATEMENT.

In the bluffs bordering Smith River and its tributaries, Hound Creek and Ming Coulee, the coal-bearing zone is exposed at many places. Coal has been mined intermittently throughout this district for more than twenty-five years, and within the last decade considerable prospecting has been done in order to ascertain the extent of the bed. Several small mines are now operated, and there are a few abandoned mines from which coal is occasionally taken. Those worked are the Carville, Gibson, Patterson, Bickett, and Love mines, which have a combined annual output of only a few hundred tons. The locations of the prospects and mines are shown on Pl. II; sections of the coal beds are shown on Pl. VIII.

MINES OPERATED.

Carville mine.—The Carville mine, situated on the west side of Hound Creek, in the SW. ¼ SE. ¼ sec. 24, T. 17 N., R. 2 E., is one of the largest in the Smith River district. Coal has been taken out at this place for about seven years. The main entry extends 375 feet west from the outcrop, with a side entry to the south 75 feet long and 40 feet wide, branching from the main entry 90 feet from its mouth. On the north side of the main entry there is another side entry with four large rooms. This mine is not operated in an extensive way, but it is worked continuously, the total annual output being about 1,800 tons. It supplies coal to ranchmen throughout a considerable territory to the south and west. The bed mined is 5 feet 6 inches thick with no appreciable partings. The lower 6 inches of coal is dull looking and in places bony, but it is firm and as a fuel gives good satisfaction. Above this bed there is a bright coal said to be suitable for blacksmithing, which contains numerous iron-pyrite nodules. The thickness and character of the bed remain relatively uniform throughout the workings. The rocks at this place dip slightly to the north and west and are little disturbed.

Gibson mine.—The Gibson mine is located in the extreme southeast corner of sec. 24, T. 17 N., R. 2 E., on the east side of Hound Creek, opposite the Carville mine. It is operated only during the fall and early winter months, and the annual output is about 1,200 tons. The bed worked is slightly thicker than that exposed in the Carville mine, measuring 5 feet 10 inches (69). The upper 2 feet is a bright, firm-looking coal. Beneath this member is a dull bony coal 10 inches thick, followed by 46 inches of dull-looking coal which is said to burn well and as a domestic fuel is in general satisfactory. The main entry extends for about 300 feet at right angles to the face of the bluff. It has two large rooms on the north and one side entry on the south extending diagonally from the main entry to a distance of about 430 feet. This entry is cut across by another side entry, which leaves the main entry at right angles near the back end. The rocks lie nearly horizontal, dipping slightly to the northwest, and are not badly disturbed. The mine is worked by the room and pillar system and little difficulty is experienced with water.

Patterson and Rice mines.—The Patterson mine is situated high in the bluffs on the east side of Smith River, a short distance above the mouth of Hound Creek. The first opening was made in 1903, and the main entry now extends to a distance of 150 feet. A short distance to the east is located the Rice mine, from which, it is said, coal was taken nearly twenty-five years ago. The bed mined has a total thickness of 4 feet 10 inches (78) and the coal appears to be of good quality.

Bickett mine.—On the north side of Ming Coulee, about 1¼ miles above the Eden creamery, a small tonnage of coal is extracted from the Bickett mine. The coal zone or bed is about 18 feet thick and dips at a small angle to the northwest. The upper 10 feet does not contain workable coal, but below this there are two benches of about equal thickness, separated by 8 inches of bone (66). Freshly exposed surfaces of both benches exhibit bright, firm coal. The base of the lower bench, however, contains considerable sulphur in nodular form. The floor and roof of the mine are composed of clay and shale, respectively.

Love mine.—The Love mine consists of a small opening in the bluffs on the south side of Ming Coulee about one-half mile above the Eden creamery, in the E. ½ SE. ¼ sec. 31, T. 18 N., R. 4 E. It has been worked in a desultory way for the last ten years, but only a small amount of coal has been taken out and the mine is poorly developed. The coal bed is unusually thick at this place, measuring over 8 feet, and though the rocks are more or less broken at the surface, it is believed that an entry driven some distance into the hill would encounter the coal undisturbed. The coal zone shows the usual variation, both in number and thickness of coal beds. Four different benches were recognized, of which only the first and second, counting from the base, are mined. The lowest bench is 14 inches thick. It is underlain by bone containing thin streaks of coal and resting on clay. Above the lowest bench of coal there is 1½ feet of bone, followed by 3 feet of coal constituting the upper bench mined. This coal is overlain by 8 inches of bone, forming the roof of the mine. Above the roof there are two coal benches, the lower 18 inches and the upper 3 feet thick; they are separated by 10 inches of bone (65).

PROSPECTS.

In addition to the above-described mines the Smith River district contains a number of prospects, some of which exhibit coal of workable thickness. One opening of this character, owned by Mr. Hoag, is located in the northwest corner of sec. 31, T. 17 N., R. 3 E., and there are others in this immediate vicinity. The location of prospects and mines in this part of the Sand Coulee basin is shown on Pl. II.

OTTER CREEK AREA.

LOCATION AND EXTENT.

The Otter Creek area, which is located southwest of Geyser, extending along Otter Creek for a distance of about 10 miles, lies mainly in T. 17 N., Rs. 8 and 9 E., and includes a small portion of T. 16 N., R. 9 E. The southern limits of the area are definitely marked by the outcrop of the coal, along which a sufficient number of prospect pits occur to indicate its workable character; but to the east, north, and west the extent of the coal can only be inferred from a study of a comparatively small number of exposures. To the east the last exposure of coal of workable thickness is found on the east side of Avoca Creek, at the Chamber Brothers mine. A quarter of a mile farther east, in a small tributary of Avoca Creek, the Meredith prospect shows that the coal of this horizon is not only of less than a workable thickness, but also of inferior quality. Still farther east, in another tributary of Avoca Creek, 1½ miles distant, prospects show that only a few inches of coaly shale occur at the coal horizon. From these prospects and natural exposures of the coal to the east it is assumed that the eastern limit of the Otter Creek area must lie somewhere between the Chamber Brothers mine and the Meredith prospect.

Nor can the northern extension of workable coal be more than approximately located. As previously stated, the coal-bearing rocks of this general vicinity dip gently northeast, passing beneath the overlying Colorado shale, and exposures are therefore few. At the mouth of Williams Creek, however, that stream has cut sufficiently deep to expose the coal bed, which is not of workable thickness. Northwest of this place, on either side of Otter Creek, where the coal is poorly exposed, the bed consists of only a few inches of coaly shale containing thin streaks of coal. On the east side of a small tributary of Little Otter Creek, about 2 miles south of Mann, there are two prospects which demonstrate that the coal horizon shows mainly impure coaly shale. From this evidence it seems highly probable that coal of workable thickness does not continue beyond a line extending northeastward from the coal exposures on the ridge between the Chamber Brothers mine and the Meredith prospect nearly to the mouth of Williams Creek, thence westward along the south side of Otter Creek nearly to Little Otter Creek, thence southward to the vicinity of the Nullinger mine. The limits of the area are shown in Pl. II; sections of the coal beds are shown on Pl. XII.

CHARACTER AND THICKNESS OF COAL BED.

The Otter Creek area is underlain by one bed of coal which ranges in thickness, as indicated by exposures, from 3 to 6 feet; the maximum thickness, however, in the center of the basin probably exceeds 6 feet. The coal generally occurs in two benches, although at one mine three distinct benches were observed. The maximum thickness of workable coal is 4 feet, as shown by the section at the Nollar mine, where it occurs in one bed with no partings. At other places, wherever two benches are present, the lower is generally the thicker and contains the better coal.

The parting between the two benches is commonly bone. At the mine where three benches occur their total thickness is 2 feet 3 inches. It is difficult to give an average section of the coal bed in the Otter Creek area, for only one mine has been opened which may be regarded as representative of the coal in the central part. This mine, owned by Mr. Nollar, shows a total thickness of 4 feet, as above stated. It is probable that over a considerable area the coal retains this thickness, possibly increasing somewhat, but throughout the marginal portions it doubtless becomes thinner.

DEVELOPMENT.

GENERAL STATEMENT.

The coals of the Otter Creek area have not been mined to any considerable extent. Though coal has been taken out of different openings for a number of years, the area as a whole is practically undeveloped. The Billings and Northern Railroad now being constructed will pass near the northern limit of the field, thus affording transportation facilities. At the present time only three small mines are worked—the Nollar, Nullinger, and Chambers mines. Of these only the Nollar is of sufficient size to be regarded as a factor in the production of coal.

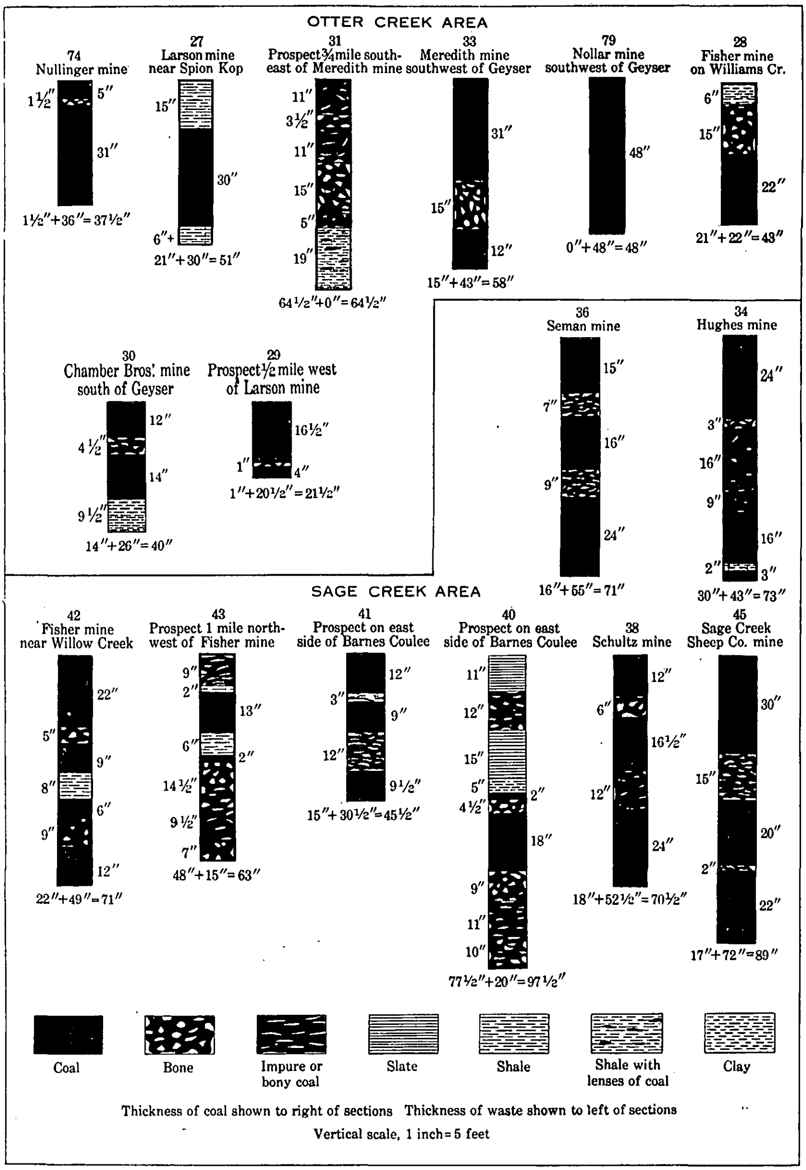
The locations of mines and prospects in the Otter Creek area are shown on Pl. II; sections of the coal bed are shown in Pl. XII.

MINES OPERATED.

Nollar mine.—The Nollar mine is situated at the base of the bluffs on the west side of Otter Creek in the NW. ¼ sec. 29, T. 17 N., R. 9 E. The mine was first opened in 1902 and during the four years of its operation the total output has not exceeded 300 tons. It is not worked continuously, but a few tons of coal are kept on hand to supply a small local trade. The coal occurs in what is apparently one bench 4 feet thick (79), in which no partings of appreciable thickness were observed. The coal is bright and firm, and on close examination shows fine banding on the surface. It contains the characteristic sulphur nodules found in other portions of the field. The entry extends 275 feet from the outcrop in a southwesterly direction. The direction of the main entry at this place is not at right angles to the dip, which here is about due north, but at a slightly greater angle in order to make the entry gradually rise, thus obtaining better drainage. Two side entries extend at right angles from the main entry, one about 80 feet and the other about 200 feet from the face. Each is 75 feet long and is provided with rooms parallel to the main entry. Opposite the first entry to the south there is a front entry leading northward from the main entry; this is provided with a large room nearly 50 feet long. From the end of the second entry to the south there is a narrow cross entry, which extends parallel to the main entry, past the south end of the first entry to the south and thence to the surface.

Chamber Brothers' mine.—Coal is taken during the winter months from the Chamber Brothers' mine, which is located in the NE. ¼ of sec. 4, T. 16 N., R. 9 E., on the east side of West Fork of Avoca Creek. This mine was opened in 1903 and at present has an entry which extends nearly due east for about 125 feet from the face. The coal, which is 2 feet 2 inches thick, is separated into two benches, the lower 14 inches and the upper 12 inches thick. Between the lower and upper benches is a 4¼-inch bed of coaly material. Above the upper bench there is 17 inches of light bluish-gray clay, forming the roof, overlain by dark shale which contains thin streaks of coal. This member is followed by a gray massive sandstone. The floor of the mine consists of dark-colored clay. A complete section is given in Pl. XII, No. 30.

Nullinger mine.—The Nullinger coal mine, situated on the east side of a small tributary of Little Otter Creek, in the SE. ¼ sec. 21, T. 17 N., R. 8 E., is also a very small mine, at the present time furnishing coal



SECTIONS OF COAL BED IN OTTER CREEK AND SAGE CREEK AREAS MONTANA.

for only a few ranches near by. The coal bed has a thickness of 3 feet, and is separated by a 1½-inch layer of bone into two benches (74). It is a bright and firm-looking coal, which doubtless warrants more extensive development. The entry has a pitch of about 60° and extends for about 100 feet from the face in a northeasterly direction, at considerably less than a right angle to the direction of the dip, which is here nearly north.

ABANDONED MINES.

There are three small abandoned mines in the Otter Creek area, two at the mouth of Williams Creek. The one on the south side of the creek is known as the Larson. On it several openings have been made. The opening nearest the road, from which a sample was taken, has an entry 50 feet long. Here the total thickness of the coal is 28 inches, with an appreciable amount of foreign material. About 200 feet east of this opening there is another mine which is said to extend 150 feet into the hill. This was flooded, rendering it impossible to examine the underground workings. About 150 feet still farther east and at a slightly higher level there is another opening with an entry 135 feet long. In excavating this entry a dike of intrusive material at 60 feet from the surface, trending south-southwest, was encountered, and the remainder of the entry was excavated along one side of this dike. The coal in this entry is about 2½ feet thick and is overlain and underlain by compact gray shale. A graphic representation of the section is given in Pl. XII, No. 27.

About 500 feet farther east on the same side of Williams Creek another small opening exhibits a coal bed similar to the one just described.

North of Williams Creek, at the mouth, is the Fisher mine, in which the coal is 22 inches thick. The bed is overlain by 15 inches of bone, followed by 6 inches of coaly shale, above which 15 feet of massive gray sandstone is exposed. A graphic representation of this bed is given in Pl. XII, No. 28; No. 29 represents an exposure of the same bed in a railroad cut one-half mile farther west.

SAGE CREEK AREA.

LOCATION AND EXTENT.

The Sage Creek area, situated in the eastern part of the Great Falls coal field, a few miles south of Stanford, in the vicinity of Skull Butte, lies mainly in Tps. 15 and 16 N., Rs. 11 and 12 E., but embraces small portions of Tps. 15 and 16 N., R. 13 E. The area described encircles Skull Butte, where the dome-shaped uplift exposes rocks older than the coal-bearing measures. This area ranks second in the field in point of size, being slightly larger than the Otter Creek area and considerably smaller than Sand Coulee area. The southern limit of the Sage Creek coal area is definitely marked in most places by the outcrop of the coal, but to the north and to a certain extent to the east and west, the limits of the workable coal must be inferred from geologic evidence. In Barnes Coulee, a tributary of Spring Draw, which is the easternmost locality at which the coal is exposed within the area investigated, the coal bed thins from more than 7 feet on the west side of the coulee to less than 3 feet on the east side, in a distance of less than half a mile. The relative percentages of shale and coal change rapidly in this distance, the former predominating on the east side of the coulee. This rapid change toward the east in both the thickness and the quality of the coal in Barnes Coulee, together with the apparent absence of workable coals for several miles farther east, is regarded as sufficient evidence for placing the eastern limit of the Sage Creek coal area not far beyond this coulee.

To the northeast, farther down Sage Creek valley, where the coals are covered by an increasing thickness of overlying rocks, a number of diamond-drill prospect holes have been bored in order to ascertain the thickness of the coal in this direction. The results of these drillings have not been made public, but in some localities the drilling has been followed by shafting, which indicates that a bed of workable thickness was found. The northern border of this area is arbitrarily placed a short distance beyond the Billings and Northern Railroad from the eastern limit of the district to Stanford, thence westward nearly to Surprise Creek, and thence southwestward to the coal outcrop in the vicinity of Hazlett Creek.

On Hazlett Creek, near the western edge of the area, the coal has been prospected at a number of places. Here the bed is barely of workable thickness and is very shaly. About 3 or 4 miles farther north, on small tributaries of Surprise Creek, the coal bed is represented by only a few inches of impure coal, associated with coaly shale. The same is true on Dry and Shannon creeks, farther west. From the above considerations it seems probable that the western limit of the area underlain by workable coals in the Sage Creek basin lies somewhere between Hazlett and Surprise creeks. The extent of the Sage Creek area and the location of the mines and prospects are shown on Pl. II; sections of the beds are shown in Pl. XII.

CHARACTER AND THICKNESS OF COAL BED.

So far as known there is only one coal bed in this area. Its thickness, including partings, ranges from 6 to 18 feet. Within this thickness of beds, deposited under coal-forming conditions, the aggregate of the coal ranges from 2½ to 7 feet. The coal usually occurs in the form of three distinct benches, which are generally recognized by miners in the district. The lowest bench is about 2 feet thick and is regarded as the best. Above this is commonly a 2 to 6 inch parting, overlain by a middle bench 12 to 16 inches thick. Next is generally 1 to 6 inches of bone, followed by the uppermost bench of coal, which ranges from 1 to 2 feet in thickness. The coal is usually covered by 1 or 2 feet of dark-colored shale, which forms the roof of the mine. Above the shale there are in many places impure coaly layers interbedded with brown and black sandy leaf-bearing shale having a thickness of several feet. The next member in ascending order is a gray massive sandstone ranging in thickness from 20 to 60 feet. In the outer portion of the area the base of this sandstone locally forms the roof of the mine.

DEVELOPMENT.

GENERAL STATEMENT.

The coals of the Sage Creek area have not been extensively worked. Coal has been mined in this vicinity for many years, but owing to the lack of transportation facilities the output has never exceeded the amount necessary to supply a small local demand. At the present time mining is carried on at only three small mines, owned by Messrs. Schultz, Seman, and Hughes. The annual output of the Schultz mine is about 1,000 tons; that of the Seman is somewhat smaller. Neither of these mines is well improved. The Hughes mine has only recently been opened.

MINES OPERATED.

Schultz mine.—The Schultz mine, the largest of the three mines now operated in this district, is located in the SE. ¼ SE. ¼ sec. 20, T. 15 N., R. 12 E., on the west side of Spring Draw, a small tributary of Sage Creek. It was opened in 1894, and, according to the best information obtainable, though operations have been continuous, the output of the mine has never been large. The present annual production amounts to 1,000 tons, which is consumed by ranchmen and inhabitants of small towns within a radius of 10 to 15 miles. The coal zone has an aggregate thickness of slightly over 12 feet, but only the coal of the lower half is mined, none of that in the upper part being regarded as of sufficient thickness to be worked. The coal of the lower part occurs in three benches, which have a total thickness of 4 feet 4½ inches, not including the 6-inch layer of bone 1 foot below the top and the 1 foot of bony coal 2 feet above the base. The lowest bench is 2 feet thick and constitutes the most important coal of the mine. It is black, with a dull luster, and contains more or less pyrite in nodular form. The middle bench has a thickness of about 16½ inches and generally has a bright luster. It, too, contains some pyrite nodules. The uppermost bench is about 12 inches thick and is generally more or less free from sulphur (38). Immediately overlying this bench in the upper part of the zone is a layer of bone 2 feet thick, which forms the roof of the mine. This is followed by 12 inches of dark sandy shale containing thin beds of coal, which in turn is overlain by 21 inches of coal containing a small percentage of bone. Above this coal there is an 8-inch layer of light-colored sandstone, followed by 6 inches of dark coaly shale which immediately underlies massive gray sandstone several feet in thickness.

Seman mine.—The Seman mine is located in the SW. ¼ SE. ¼ sec. 20, T. 15 N., R. 12 E., a few hundred yards west of the Schultz mine and on the same side of Spring Draw. It is considerably smaller than the Schultz mine and is worked only during the winter months, having a very small output, which rarely exceeds 150 tons a season. Coal has been taken out of this opening for the last decade, but little attention has been given to the proper development of the underground workings.

The coal bed mined here is almost identical with that worked at the Schultz mine, except in the uppermost bench, which appears to be somewhat thicker. Three benches occur; the lowest bench has a thickness of 2 feet and is overlain by 9 inches of bony coal. Above this is the middle bench, which has a thickness of 16 inches and is followed by a 7-inch layer of bone. Next is 15 inches of bright, firm-looking coal, which constitutes the uppermost bench. A complete section is shown in Pl. XII, No. 36. The deposit has the characteristic shale roof and clay floor exhibited in the Schultz mine.

In physical properties the coals of the different benches closely resemble those of the Schultz mine. The characteristic sulphur balls are present, especially in the lowest bench; the middle bench has the usual bright luster, and in practical use these two coals seem to give equal satisfaction. The main entry extends about 400 feet from the face in a meandering but westerly direction. About 200 feet from the mouth of this entry a side entry extends at right angles, approximately 30 feet to the south.

Hughes mine.—In 1904 a small mine was opened on the Hughes ranch, on the east side of Willow Creek, in the NE. ¼ sec. 19, T. 15 N., R. 12 E. This mine is about 2 miles northwest of the Schultz and Seman mines, near the southern limit of the Sage Creek area. The total thickness of the bed worked is 5 feet 8 inches, including a 9-inch layer of bony coal 16 inches above the base and excluding a 3-inch bed of true bone 2 feet below the top of the bed. Coal occurs in three benches, as is common in other parts of the area. The lowest bench is slightly thinner than usual, being only about 16 inches thick. This is due to a 2-inch layer of clay that occurs at the base of the bench and separates it from a 3-inch bed of coal not mined at this place. The middle bench is 16 inches thick and is bright and firm, but contains a few thin layers of bone. A 3-foot bed of good-looking coal constitutes the uppermost bench. It is overlain by dark-colored sandy shale, which forms the roof. A graphic section of the bed is given in Pl. XII, No. 34.

ABANDONED MINES.

In addition to the above-described mines, there are in the Sage Creek area four abandoned mines from which considerable coal has been taken during the last ten years. These are the Corwin & McGregor (now owned by Mr. Schultz), the Fisher, the West Fork of Willow Creek, and the Sage Creek Sheep Company mines. Graphic sections of all except the Corwin & McGregor mine are given in Pl. XII, Nos. 42, 43, and 45.

Corwin & McGregor mine.—The abandoned Corwin & McGregor mine, located on the west side of Spring Draw, between the Seman and Schultz mines, was one of the first to be operated in the immediate vicinity, and it has probably been more extensively worked than either of the adjoining mines. At the face of this opening the coal horizon presents the usual succession of beds, but they were too badly weathered to permit accurate measurements of the individual layers, and, as the mine was flooded, the underground workings could not be examined.

The face of the mine presents one unusual feature. The coal in the upper part of the coal bed, as exposed at the Schultz mine, here appears to have reached a thickness of 2½ feet. The percentage of this bed that might prove to be coal when examined on a freshly exposed surface could not be ascertained.

Fisher mine.—Another abandoned mine, known as the Fisher mine, is located on the east side of a low hill of isolated coal-bearing rocks, which occur as an outlier on the south side of the area, in the SE. ¼ sec. 13, T. 15 N., R. 11 E. It has not been worked for a number of years, but to judge from the size of the excavation, considerable coal has been taken out in the past. The bed is not deeply covered nor extensive, comprising at most only a few acres, and for this reason probably the mine was abandoned. It is very doubtful if the deposits are sufficiently extensive to warrant any further development. A section of the face of this opening is given in Pl. XII, No. 42.

West Fork of Willow Creek mine.—At the head of West Fork of Willow Creek there is an abandoned mine from which, apparently, considerable coal has been taken out, but it has caved to such an extent that it was impossible to examine the details of the underground workings. It is located near the southern edge of the coal area, in the NW. ¼ sec. 13, T. 15 N., R. 11 E. A section of the outcrop shows very poor coal in the lower bench (43).

Sage Creek Sheep Company mine.—An abandoned opening on the north side of Skull Butte, in the SW. ¼ sec. 31, T. 16 N., R. 12 E., is known as the Sage Creek Sheep Company mine. A small amount of coal was taken out of this mine, but it has not been worked for several years (45).

PROSPECTS.

Entry prospects.—The Sage Creek area has been considerably prospected for coal. In many of the coulees where the coal is exposed small openings have been made to ascertain the character and thickness of the bed. Some of these prospects have caved so as to obscure the coal bed, but more commonly a good section can be obtained. In Barnes Coulee, a small tributary of Spring Draw on the east, the coal has been opened at five or six places on either side of the ravine. J. D. Barnes has the largest prospect in this vicinity. It is located on the west side of the coulee about 100 feet up the slope, in the SE. ¼ sec. 29, T. 15 N., R. 12 E. An entry has been driven 80 feet from the face, which exhibits over 7 feet of coal distributed through 13 feet of coal-bearing beds. The coal is overlain by gray sandstone and underlain by dark-colored shale.

Directly opposite the Barnes prospect on the other side of the coulee the coal has been opened at five places, the northernmost opening being an entry 15 feet deep which exhibits 4 feet of coal interbedded with considerable bone. About 150 feet south of this prospect another opening extends 120 feet from the face, showing 3 feet of coal. The lower 21 inches, however, is of a very inferior quality.

About 400 feet farther south on the same side of the coulee the entry of another small abandoned mine extends 150 feet from the face. At the mouth the coal bed has a total thickness of 7 feet 2½ inches, with only 18 inches of pure coal near the middle; 9 inches below this and 10 inches above the bottom of the section there is an 11-inch bed of bony coal (40). At the end of the main entry, 150 feet from the mouth of the mine, the section shows 9½ inches of coal at the base, which probably corresponds to the 11 inches of bony coal at the mouth. Overlying the 9½-inch layer of coal is 12 inches of bone, corresponding to the 9 inches of true bone in the section taken at the outcrop. The next member in ascending order at the back end of the entry is a 9-inch bed of coal followed by 3 inches of shale, and this in turn by 12 inches of coal. These three members are believed to be represented in the outcrop section by 18 inches of coal. The sections at the outcrop and at the back end of the entry are shown in Pl. XII, Nos. 40 and 41.

Nearly 300 yards south of this abandoned mine a small prospect shows very bony coal.

A comparison of the sections in these five prospects on the east side of Barnes Coulee with the Barnes prospect on the opposite side indicates not only that the percentage of coal in the bed is decreasing to the east but that the quality of the coal is rapidly becoming inferior in that direction.

Diamond-drill prospects.—Considerable prospecting has been done with the diamond drill in the Sage Creek coal area, mainly to determine the thickness of the coal bed in the northern part of the field, where the gradual dip of the beds to the northward carries it considerably below the surface. Five borings have been made, as follows: The Sage Creek Sheep Company's home-ranch boring, in the SW. ¼ sec. 14, T. 15 N., R. 12 E.; the McComb boring, in the NE. ¼ NE. ¼ sec. 18, T. 15 N., R. 12 E.; the upper Sage Creek boring, in the NE. ¼ NW. ¼ sec. 2, T. 14 N., R. 12 E.; and the Dry Coulee boring, in the SW. ¼ SW. ¼ sec. 20, T. 13 N., R. 12 E. These borings are said to range in depth from 300 to 900 feet, but no definite information regarding the thickness of the coal bed or the depth at which it was penetrated in any particular well could be obtained.

CHARACTER OF COAL.

GENERAL STATEMENT.

The coal of the Great Falls field differs in physical characteristics as well as in chemical composition from those of neighboring fields in Montana and northern Wyoming. As it occurs in rocks of Lower Cretaceous age, it is among the oldest coals in this general region, the nearest contemporaneous deposits being the Cambria coals of the Black Hills and the Lethbridge coals of Canada. It is of the same age as the coal of Judith basin (which in reality is a part of the same field) and is considerably older than the Bull Mountain, Miles City, Sheridan, and Red Lodge coals, most of which are of Tertiary age. In physical properties and chemical composition it shows little regional variation and closely resembles deposits of the same age in Judith basin to the east. It also bears some likeness to the Cambria coals of the Black Hills.

PHYSICAL PROPERTIES.

The coal of the Great Falls field is in general black to grayish black in color, with bands of pitch-black coal running through it. A great part of the coal is dull, but contains thin bands of bright coal which have a vitreous or glassy luster. It is a moderately dense variety of bituminous coal distinctly bedded and characterized by a banded structure, which consists of alternating layers of bright and dull coal parallel to the bedding. The bright bands range in thickness from a mere film to one-fourth of an inch, and usually constitute only a small percentage of the whole, the duller coal greatly predominating. A close examination of the dull bands, which consist partly of mineral charcoal and partly of dull-lustered coal, shows that many of them contain minute lenses of bright coal, giving to the whole a schistose appearance.

The coal usually separates or breaks into blocks that are roughly rectangular in outline, with the face and butt cleat nearly at right angles. Even where fine fragments are separated either by crushing or weathering they are in general rudely prismatic. The face cleat commonly presents a smooth, even surface having a subdued glistening or vitreous luster; the butt cleat has a more irregular surface and a much brighter luster. The fracture of the dull coal is irregular or uneven, but that of the bright coal is small conchoidal. The coal separates more or less easily along the bedding plane, the surface of which at many places exhibits blades of mineral charcoal lying in different directions, the whole giving a fibrous texture and velvet luster. Less commonly the surface of the bedding plane contains remnants of bright-lustered coal adhering to the duller variety. It is under these circumstances that the bright coal exhibits to the best advantage its small conchoidal fracture.

The dull coal is moderately soft and tough; the bright coal is considerably harder and more brittle. The hardness of the former is about 1 and that of the latter about 2.5. The streak ranges from brown to brownish black, seldom black. The coal is more or less sooty and soils the fingers readily. The specific gravity varies considerably in different benches of the same bed; it ranges from 1.30 to 1.70, the average being about 1.40.

As previously stated, sulphur is present in the coal in considerable quantities. It occurs in the form of iron-pyrite nodules which are rudely reniform in outline, although spherical forms are not uncommon. In size these nodules range from that of a pinhead to about 4 inches in diameter, the average being about 1 inch. Their major axes are usually parallel with the bedding, although some smaller nodules are seen at varying angles to that plane. Few of them occur in joint planes. About the nodules the coal shows a foliated or compressed structure, which has probably been developed by the force exerted in the crystallization of the pyrite. Resin is rarely present.

The minable coal is separated into benches by carbonaceous shale or bone and by bony coal. The former appears to be of fairly uniform character throughout the field. It has shaly structure and breaks with subconchoidal fracture. It is grayish black in color, fine grained and homogeneous in character, soft, moderately tough, and has a specific gravity of about 2. It is usually a true parting between the coal benches, separating easily from the coal both above and below. In thickness it ranges from a fraction of an inch to 1 foot, the average being about 3 to 4 inches. In some places it weathers light gray, standing out in strong contrast to the coal.

CHEMICAL PROPERTIES.

During the investigation here reported a number of samples of the coal were taken in different localities for the purpose of chemical analysis. These samples were collected in a uniform manner. A channel was cut perpendicularly across the face of the coal bed from roof to floor, of such a size as to yield at least 5 pounds of coal per foot in thickness of coal bed. All material encountered in this cut was included in the sample, except partings more than three-eighths of an inch in thickness, and lenses and concretions of sulphur or other impurities greater than 2 inches in diameter. The coal thus obtained was pulverized sufficiently fine to pass through a sieve of half-inch mesh, and after thoroughly mixing was divided into quarters, opposite quarters being rejected. This process was continued until the amount was reduced to about a quart sample. The material was then placed in a galvanized can, sealed by adhesive tape, and shipped to the chemical laboratory of the Survey fuel-testing plant at St. Louis, F. M. Stanton, chemist in charge, where the analyses were made.

Analyses of coal samples from Great Falls coal field.

	Sage Creek area.		Otter Creek area.			Sand Coulee area. Belt district.		
Laboratory No	3756	3753	3758	3759	3757	3515	3512	3514
Analysis of sample as received:								
Prox. Moisture	11.26	9.27	10.18	8.76	13.07	3.51	7.05	6.37
Prox. Volatile matter	25.85	29.57	24.82	25.72	21.79	26.39	25.47	27.55
Prox. Fixed carbon	46.49	45.90	45.25	50.36	43.26	50.60	49.34	45.20
Prox. Ash	16.40	15.26	19.75	15.16	21.88	19.50	18.14	20.88
Ult. Sulphur	4.56	3.96	3.01	3.91	1.30	3.74	1.67	2.04
Ult. Hydrogen	4.51	4.78	....	4.40	4.23	4.13	4.36	3.92
Ult. Carbon	53.47	58.13	....	58.93	49.95	61.51	58.10	56.14
Ult. Nitrogen	.69	.79	....	.79	.69	.60	.64	.73
Ult. Oxygen	20.37	17.08	....	16.81	21.95	10.44	17.09	16.29
Calories	5,122	5,675	....	5,626	4,639	6,045	5,623	5,481
British thermal units	9,220	10,215	....	10,127	8,350	10,881	10,121	9,866
Loss of moisture on air drying	5.50	4.60	4.60	4.80	6.00	1.60	2.60	2.70
Analysis of air-dried sample:								
Prox. Moisture	6.09	5.00	5.85	4.16	7.52	1.93	4.57	3.77
Prox. Volatile matter	27.35	31.00	26.01	27.02	23.18	26.81	26.15	28.30
Prox. Fixed carbon	49.18	48.00	47.43	52.90	46.02	51.44	50.65	46.46
Prox. Ash	17.38	16.00	20.71	15.92	23.28	19.82	18.63	21.47
Ult. Sulphur	4.82	4.15	3.15	4.11	1.38	3.80	1.71	2.08
Ult. Hydrogen	4.12	4.48	....	4.03	3.79	4.02	4.17	3.73
Ult. Carbon	56.57	60.93	....	61.90	53.14	62.51	59.65	57.70
Ult. Nitrogen	.73	.83	....	.83	.73	.69	.65	.74
Ult. Oxygen	16.38	13.61	....	13.21	17.68	9.16	15.19	14.28
Calories	5,420	5,949	....	5,910	4,951	6,094	5,824	5,633
British thermal units	9,756	10,707	....	10,637	8,888	11,058	10,391	10,139
Fuel ratio	1.79	1.55	1.82	1.96	1.98	1.91	1.93	1.64

Analyses of coal samples from Great Falls coal field—Continued.

	Sand Coulee area.							
	Belt district.			Stockett-Sand Coulee district.		Smith River district.		
Laboratory No.	3755	3513	3754	4115	4119	4118	4117	4114
Analysis of sample as received:								
Prox. Moisture	9.58	4.62	10.88	6.01	7.49	4.82	6.17	4.54
Prox. Volatile matter	23.24	30.51	20.27	28.43	27.29	27.17	27.03	27.44
Prox. Fixed carbon	52.24	46.14	41.97	51.42	51.44	46.13	52.03	47.95
Prox. / Ult. Ash	14.94	18.73	26.88	14.14	13.78	21.88	14.77	20.07
Ult. Sulphur	2.00	3.59	1.79	2.38	2.32	2.84	4.36	4.09
Ult. Hydrogen	4.28	....	3.72	4.46	4.68	4.36	4.43	4.23
Ult. Carbon	58.74	....	47.37	63.61	62.21	56.98	61.62	58.66
Ult. Nitrogen	.67	....	.52	.91	.88	.72	.93	.87
Ult. Oxygen	19.37	....	19.72	14.50	16.13	13.22	13.89	12.08
Calories	5,518	....	4,301	6,196	6,115	5,578	6,077	5,818
British thermal units	9,932	....	7,742	11,153	11,007	10,040	10,939	10,472
Loss of moisture on air drying	5.00	2.10	5.40	2.40	2.60	1.90	2.20	1.70
Analysis of air-dried sample:								
Prox. Moisture	4.82	2.57	5.76	3.70	5.02	2.98	4.06	2.89
Prox. Volatile matter	24.46	31.17	21.42	29.13	28.02	27.69	27.63	27.91
Prox. Fixed carbon	55.00	47.13	44.42	52.68	52.81	47.03	53.20	48.79
Prox. / Ult. Ash	15.72	19.13	28.40	14.49	14.15	22.30	15.11	20.41
Ult. Sulphur	2.10	3.70	1.89	2.43	2.38	2.90	4.46	4.13
Ult. Hydrogen	3.91	....	3.30	4.33	4.51	4.24	4.25	4.18
Ult. Carbon	61.85	....	50.08	65.17	63.88	58.08	63.02	59.66
Ult. Nitrogen	.70	....	.55	.92	.89	.73	.95	.88
Ult. Oxygen	15.72	....	15.78	12.66	14.19	11.75	12.21	10.74
Calories	5,808	....	4,546	6,348	6,278	5,678	6,213	5,918
British thermal units	10,454	....	8,184	11,427	11,300	10,244	11,185	10,654
Fuel ratio	2.25	1.51	2.07	1.81	1.88	1.70	1.93	1.75

The analysis of each coal sample is given in two forms, one showing the composition of the sample as received at the laboratory, which may be regarded as representing the condition of the coal in the mine, the other showing the composition of an air-dried sample. Ultimate analyses were obtained of all except two samples. The analyses under laboratory Nos. 3756, 3757, and 3754 can not be regarded as representative of the coals of this field, for each of these samples was collected in a shallow entry near the surface, and consequently contained weathered coal. Sample No. 3754 was obtained on the margin of a coal-bearing area, where the coal was recognized in the field to be of a quality too inferior to work.

The coal of the Great Falls field contains on an average about 49 per cent of fixed carbon, 26 per cent of volatile matter, 18 per cent of ash, and 3 per cent of sulphur. Its fuel ratio, obtained by dividing the percentage of fixed carbon by the percentage of volatile matter, ranges from 1.51 to 2.07, with an average of 1.84. The calorific value of the coal is good, ranging in representative samples from about 10,000 to 11,500 British thermal units, the average being 10,750 in an air-dried sample. They are superior in this respect to the coals of Red Lodge, the next largest coal-producing locality in Montana. Their heat value is also considerably higher than that of the coals of the Bull Mountain and eastern Montana fields. The coal does not slack to any appreciable extent on exposure to the air. Certain benches of the coal possess coking properties and formerly a number of coke ovens were operated by the Anaconda Copper Mining Company at Belt. The separation of coking from noncoking coal, however, was too expensive to render the work profitable, and the ovens were abandoned. As a domestic and steam fuel it gives perfect satisfaction and its relative freedom from slacking makes it a good shipping coal.

From the analyses and the physical properties, therefore, the coal of the Great Falls field is regarded as medium-grade bituminous. It is superior in quality to the Red Lodge, Bridger, and Sheridan coals of southern Montana and northern Wyoming, and compares favorably in composition with the Cambria coal of the Black Hills region.

FUTURE DEVELOPMENT.

The Great Falls coal field, owing to its geographic position with respect to other coal fields and the quality of the product itself, is destined to become the most important coal-mining district of north-central Montana. The territory which this field may be expected to supply with coal in the future lies mainly to the north and northwest. To the southeast there are a number of coal localities along Musselshell River, which with the development of proper railroad facilities would probably become large coal-producing districts. Throughout the area bordering the Great Falls coal field on the north different conditions prevail. Here, although coal-bearing rocks occupy extensive areas both to the northeast in the vicinity of Havre and to the northwest along the base of the Rocky Mountain front range, yet from the best information which can be obtained the area underlain by coal of workable thickness is not large nor are the deposits of high grade, so that much of this part of Montana will probably be supplied from the Great Falls field. The Lethbridge coal field, north of the international boundary line, is a large coal-producing district, but with the present tariff of 60 cents per ton and the increasing settlement of this part of the British possessions much of the output will probably be consumed in Canada, leaving a relatively small amount to be shipped into Montana.

A summary of the transportation facilities, present and prospective, has already been given (p. 20). Another factor to be considered in the general development of this region is the unharnessed water power contained in the Great Falls of Missouri River, located a few miles below the town of Great Falls. At present the Black Eagle Falls, one of the smallest and the only one of this series of cataracts which has been utilized, furnishes power for the large smelters owned by the Boston and Montana Consolidated Copper Mining Company, the Royal Milling Company's flour mills, and other minor industries. With the proper utilization of Rainbow, Crooked, and Big Falls, located farther down the river, sufficient power could be generated to supply many more large industrial enterprises. The presence of so large an amount of undeveloped water power within a relatively short distance of the large mining centers, Butte and Anaconda, makes Great Falls a favorable site for smelters.

The Great Falls region was formerly a grazing district and only sparsely populated. Small tracts of land were irrigated here and there along the valleys, but with the growth in population and the increased demand for agricultural produce irrigation began to be more generally practiced along the larger streams, resulting eventually in the construction of several large canals by private individuals or small companies organized among the ranchmen. Extensive operations are now being carried on, both by the Government and by private enterprise, to reclaim larger tracts of land along Sun and Teton rivers and the highland lying between these two streams.

Although the Great Falls district is not at present very thickly settled, it is believed that the increasing railroad facilities, the completion of the Government irrigation projects, which will reclaim thousands of acres of fertile farming land, and the almost unparalleled advantages for the development of water power will combine to cause a rapid increase in population within the next decade. This increase will be attended by an increased demand for coal, both for domestic and steam purposes, and though the coal is only of medium grade and the deposits are not extensive, it is believed that the Great Falls coal field will experience material development within the next few years.

TIMBER.

The area included in this report is essentially a grazing district, with very little timber except along the valleys of the larger streams, where deciduous trees are more or less abundant, and along the hilly zones bordering the mountains, where there is a scanty growth of coniferous forests. The Little Belt Mountains to the south are irregularly forested throughout a considerable part of the uplift, and though there have been numerous fires, large areas of good timber remain. Nearly all the districts containing valuable timber lie inside the Little Belt Mountain Forest Reserve, the location of which is shown on the index map (Pl. I). The most abundant trees growing in the Little Belt Mountains are lodgepole pine, red fir, and Englemann spruce. Of these species the red fir is most extensively used for mine timbering in the Great Falls coal field, much of the supply being derived by rail from the Neihart district of the Little Belt Range. For some of the smaller mines, however, timber is procured in the foothills belt and hauled overland. The fact that all the larger mines are located out on the plains, at some distance from the forested area of the mountains, makes timber an expensive item in mine operations, especially at Stockett and Sand Coulee, which are farthest from the source of supply.

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