Geology and Coal Resources of the Livingston Coal Field Gallatin and Park Counties Montana

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By ALBERT E. ROBERTS

GEOLOGY OF THE LIVINGSTON AREA, SOUTHWESTERN MONTANA

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A study of the Eagle Sandstone (Cretaceous), with special emphasis on its regional correlation, variation in lithology, and coal resources

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By Albert E. Roberts

ABSTRACT

The Livingston coal field lies in the east-central part of Gallatin County and the west-central part of Park County, southwestern Montana, and is at the junction of the south end of the Bridger Range near Bozeman, Mont., the west end of the Beartooth Range near Livingston, Mont., and the north end of the Gallatin Range. The mapped area of about 420 square miles includes eight 7½-minute quadrangles. The maximum relief in the area is about 4,900 feet. The lowest point, at an altitude of 4,435 feet, is in the Livingston quadrangle, along the broad terraced valley of the Yellowstone River in the eastern part of the area. The highest point, at an altitude of 9,342 feet, is in the Mystic Lake quadrangle, on the north end of the Gallatin Range.

The oldest rocks in the mapped area are Precambrian gneiss, granite, and schist exposed in the cores of the Canyon Mountain and Sourdough Creek anticlines and in the uplifted blocks of the Beartooth and Bridger Ranges. The overlying sedimentary rocks range in age from Middle Cambrian to Tertiary and are more than 20,600 feet thick. Only the Silurian and Triassic Systems are not represented. Rocks of Paleozoic age are 3,050 feet thick and are generally exposed along the axes of the major anticlines. Rocks of Jurassic age are 700 feet thick and form a prominent narrow belt along the flanks of anticlines. Rocks of Cretaceous age are 11,775 feet thick and are exposed along the flanks of anticlines and in the troughs of synclines. More than 4,900 feet of rock of Paleocene age fills the southern part of the Crazy Mountains basin, and 220 feet of sedimentary rock and more than 3,000 feet of volcanic rock of Eocene age cap the ridges in the northern part of the Gallatin Range.

The predominant structural features of the area are three major en echelon folds, which are partly overturned and overthrust. The coal beds generally dip about 40°–50° and are overturned in several localities. Large thrust and high-angle reverse faults, many normal faults, and tension fractures formed during and (or) after the folding. Intrusions of diorite are associated with some of the normal faults and tension fractures.

Commercial coal beds in the Livingston coal field are in the Eagle Sandstone of Late Cretaceous age and are distributed mostly in two well-defined zones that are persistent throughout the field. The coals are high-volatile A, B, and C bituminous in rank, and some are of coking quality.

The coal reserves were estimated as of January 1, 1965, to total more than 300 million short tons. These reserves are in beds 14 inches or more thick and are within 3,000 feet of the surface. The coal reserves are categorized by individual bed and by township and range, and are classified according to the quantity and reliability of the available data and the characteristics of the coal and associated rocks.

INTRODUCTION

PRESENT INVESTIGATION

Major chemical, smelting, and sugar-refining plants that require a large annual tonnage of coke have been built in eastern Idaho, in Montana, and in northern Wyoming. The Livingston coal field, in southwestern Montana, is centrally located to these industries and is, therefore, the subject of renewed interest. The only other Montana coal fields that have a history of coke production are the Electric field near Gardiner and the Belt field near Great Falls.

The Livingston coal field was studied during the years 1955–61. The primary objectives of the study were to appraise the coal resources and to obtain geologic data essential to other economic studies of the Crazy Mountains basin of southwestern Montana. During that period, unfortunately, the mines were closed, and most of the underground workings were either caved or flooded; therefore, field investigations of the coal deposits were concentrated on surface exposures.

Geologic maps of the eight quadrangles in the Livingston coal field have been published separately (Roberts, 1964a–h). Field mapping was done on aerial photographs at a scale of 1:23,600. Geologic data were transferred from the annotated photographs to the topographic base maps by means of Multiplex projectors—precision stereoplotting instruments that were also used in making the base maps. Compilation was at a scale of 1:15,840, and publication was at a scale of 1:24,000.

Stratigraphic units were measured by planetable and alidade and by Brunton and tape traverses. The coal beds were usually measured at intervals of a mile or less along their lines of outcrop (pl. 1) and were traced individually through areas of poor exposure by their relative position within persistent carbonaceous zones (pl. 2) and by the association of persistent sandstone beds. Representative samples were collected usually from the middle of each lithologic unit. Description of these units includes megascopic and microscopic determinations of physical properties. Rock colors are described by comparison with the National Research Council "Rock-Color Chart" (Goddard and others, 1948).

This report describes the stratigraphy and evaluates the coal resources of the Eagle Sandstone of the Livingston coal field as a part of the U.S. Geological Survey's program to evaluate the fuel resources of the United States. It is hoped that the information presented will aid in the mining and utilization of the coal, which is one of the natural bases for the potential industrial growth of this region.

PREVIOUS INVESTIGATIONS

Coal in the Livingston coal field was first known in 1867 and was examined by geologists of the Geological Survey of the Territories (Hayden, 1872, p. 46; 1873, p. 113). One of the principal functions of the Northern Transcontinental Survey, organized in 1881, was to examine and extend the bituminous coal fields near Bozeman and Helena, Mont., and near Wilkinson and Carbonado, Wash. (Pumpelly, 1886, p. 691). Accessible steam coal in large supply was vital for the railroads as well as for the growth of mining and other industries in the Northwest Territory. George Eldridge (1886, p. 746–751) was in charge of the Northern Transcontinental Survey party that examined and reported on the Bozeman (Livingston) coal field. Weed (1891, p. 349; 1892, p. 521) also reported on the Bozeman (Livingston) coal field, and Iddings and Weed (1894) discussed the stratigraphy of the area and the distribution of the coal-bearing rocks. Storrs (1902, p. 464), in a summary report on the coal fields of the Rocky Mountains, briefly described the coal-bearing area near Livingston, which he referred to as the Yellowstone field. Calvert (1912a, p. 393–400), reporting on his 1908 visit to the coal districts near Livingston and Trail Creek, briefly discussed the Livingston coal field districts. Stebinger (1914a, p. 908) also briefly discussed the area in a generalized summary of the coal fields of Montana. These reports are publications of reconnaissance studies, and none of them give a detailed description of the geology, the coal deposits, or the coal resources.

The productive areas of the Livingston coal field were first designated the Bozeman and Trail Creek coal fields by Eldridge (1886, p. 748). Weed (1891, p. 349; 1893, p. 19), in his description of the "Laramie coal measures" at Livingston, referred to this area as the Bozeman coal field. Storrs (1902, p. 463–464) very briefly discussed the coals between Bozeman and Livingston as a part of the Yellowstone coal field, and the coals in the valley of Trail Creek as the Trail Creek coal field. Calvert (1912a, p. 384) preferred to drop the previous names of Bozeman and Yellowstone and applied the name Livingston coal field to the area paralleling the Northern Pacific Railroad. He retained the name Trail Creek field for the area in Trail Creek Valley (Calvert, 1912a, p. 385). Stebinger (1914a, p. 908) preferred Trail Creek field as a geographic name for the area midway between Bozeman and Livingston. The mining areas of the Livingston coal field were described by Calvert (1912a, p. 393) as the Chestnut, Cokedale, Meadow Creek, and Timberline districts. The names of all except the Meadow Creek district were derived from the largest mine in each district. The Meadow Creek district contained several mines, but these were all small and relatively minor producers. In this report the name "Livingston coal field" is retained for the entire coal-bearing area; the Meadow Creek and Chestnut districts described by Calvert (1912a, p. 397) are combined as the Meadow Creek district; the Trail Creek field of Calvert (1912a, p. 398) is described as a district of the Livingston coal field; and the Bridger Canyon district is added.

ACKNOWLEDGMENTS

Through the generous cooperation of George R. Powe, Northern Pacific Railway Co., records on operations of some of the mines in the area were made available to the author. George H. Bottamy, Bess H. Booker, Merrill G. Burlingame, Fred J. Martin, Elizabeth M. McKean, Edward Miller, Frank M. Olson, Martha M. Palffy, Frank M. Woodward, and Llewellyn E. Williams provided information concerning mines and prospects in the area, and the author is grateful for their many kindnesses.

Field assistance was given in 1955 by J. S. Hollingsworth, in 1956 by J. F. Treckman, in 1957 by C. J. Galvin, in 1958 by G. C. Cone, and in 1961 by A. L. Benson.

Much of the early history of the mines of the Livingston coal field was compiled, with the assistance of Marguerita McDonald and Evelyn D. Roberts, from the following newspapers: Avant Courier, Bozeman Times, Bozeman Weekly Chronicle, and the Livingston Enterprise.

GEOGRAPHY

LOCATION AND ACCESSIBILITY

The Livingston coal field lies near Livingston, in the east-central part of Gallatin County and the west-central part of Park County, southwestern Montana, at the junction of the south end of the Bridger Range near Bozeman, Mont., the west end of the Beartooth Range, and the north end of the Gallatin Range. The Gallatin Range—bounded on the east by Paradise

Valley, through which the Yellowstone River flows, and on the west by the valley of the Gallatin River—extends northward to the south end of the Bridger Range. The mapped area of about 420 square miles lies between long 110°30′ W. and 111°00′ W. and lat 45°30′ N. and 45°45′ N. (fig. 1).

The transcontinental line of the Northern Pacific Railway crosses the Livingstone coal field from east to west, and the Yellowstone Park Branch of the Northern Pacific runs from Livingston southward to its terminus at Gardiner. A branch line of the Chicago, Milwaukee, St. Paul, and Pacific Railroad (starting at Three Forks) serves Bozeman. Livingston is at the junction of U.S. Highways 10 and 89 from east to west and north to south, respectively. U.S. Highway 191 courses south from Bozeman to West Yellowstone and then to Idaho. An excellent system of State and county roads provides year-round access to the main highways and principal cities.

TOPOGRAPHY AND DRAINAGE

The youthful to submature topography of the Livingston area is largely the result of stream erosion of rocks having varying degrees of resistance. In the eastern part of the area, the surface has been modified by Quaternary glaciofluvial deposits. The maximum relief in the mapped area is about 4,900 feet. The lowest point, at an altitude of 4,435 feet, is in the Livingston quadrangle—along the broad terraced valley of the Yellowstone River in the eastern part of the area. The highest point, at an altitude of 9,342 feet, is in the Mystic Lake quadrangle, on the north end of the Gallatin Range.

In the northern part of the mapped area, the topography is submature and consists of low rounded hills whose altitudes range from 4,600 to 7,900 feet above sea level. This part of the area is underlain by Upper Cretaceous and Paleocene nonmarine sedimentary rocks that include much poorly indurated shale and siltstone. The topography of the central part of the area is characterized by northwest-trending ridges of indurated Paleozoic rocks and contiguous valleys in the easily eroded Cretaceous rocks. Here, the highest points are Mount Ellis, 8,331 feet; Canyon Mountain, 8,038 feet; Pine Mountain, 7,669 feet; and Hogback Ridge, 6,617 feet. The sides of the valleys, particularly those of Trail Creek, show the effect of landsliding and slumping of the poorly indurated Cretaceous sedimentary rocks. In the southernmost part of the area, which is underlain chiefly by volcanic flows and breccias and by volcanic-derived sedimentary rocks, the youthful topography consists of sharp north-trending ridges which range in altitude from 6,400 to 9,300 feet.

Pleistocene glaciation formed many of the land features in the easternmost part of the area (Weed, 1893; Horberg, 1940). Alpine glaciers extended down the valleys along the west end of the Beartooth Range, whose summit rises more than 5,000 feet above the Yellowstone River valley bottom.

The eastern part of the mapped area is within the Yellowstone River drainage system. The Yellowstone River heads in Yellowstone National Park, in northwestern Wyoming; it flows northwestward from the park for about 25 miles and then turns northeastward to Livingston, where it makes a large bend and flows eastward across the State. The main tributaries to the Yellowstone River in the mapped area are Trail, Billman, and Fleshman Creeks from the west, and Pine, Pool, Deep, and Suce Creeks from the east. Maximum flows of the Yellowstone River at Livingston have ranged from 825 to 30,600 second-feet; minimum flows ranged from 590 to 13,590 second-feet. The annual mean discharge is 2,609,400 acre-feet, and, with the exception of 4 years in the period of record, the highest flows have been in June.

The western part of the mapped area is within the East Gallatin River drainage system. Rocky and Bridger Creeks merge with Bozeman Creek to form the East Gallatin River near Bozeman. Hackett, Visher, McMurtrey, and Steinhilber (1960) discussed the ground-water resources of this area.

CLIMATE AND VEGETATION

Topography is a major influence on the climate of the Livingston area. In general, the mountainous lands are both wetter and cooler than are the broad valleys. The annual precipitation at Livingston is about 14 inches; the recorded range for 1925–34 is 25.79–8.07 inches. Rainfall is heaviest during May, June, and (to lesser degree) September. The last killing frost of spring at Livingston occurs on about May 17, and the first frost of fall occurs on about September 21; thus, the average frost-free season is 127 days. The average monthly temperature and precipitation at Livingston and Bozeman during the 10-year period 1948–57 are shown in figure 2.

The mountain areas probably receive more precipitation than is indicated by the records compiled at valley observation points. Snow depths during winter commonly range from 5 to 13 feet and average about 7 feet.

The forest cover in the report area is largely confined to U.S. National Forest and Northern Pacific Railway Co. lands. Timber is limited to a vertical zone in the mountainous areas, where moisture is more abundant and soil conditions are favorable. The zone extends downward from timberline for a vertical distance of 2,500 feet. Trees of commercial value are the Lodgepole pine and Douglas-fir. Of lesser economic importance are Engelmann spruce, juniper or redcedar, pon-

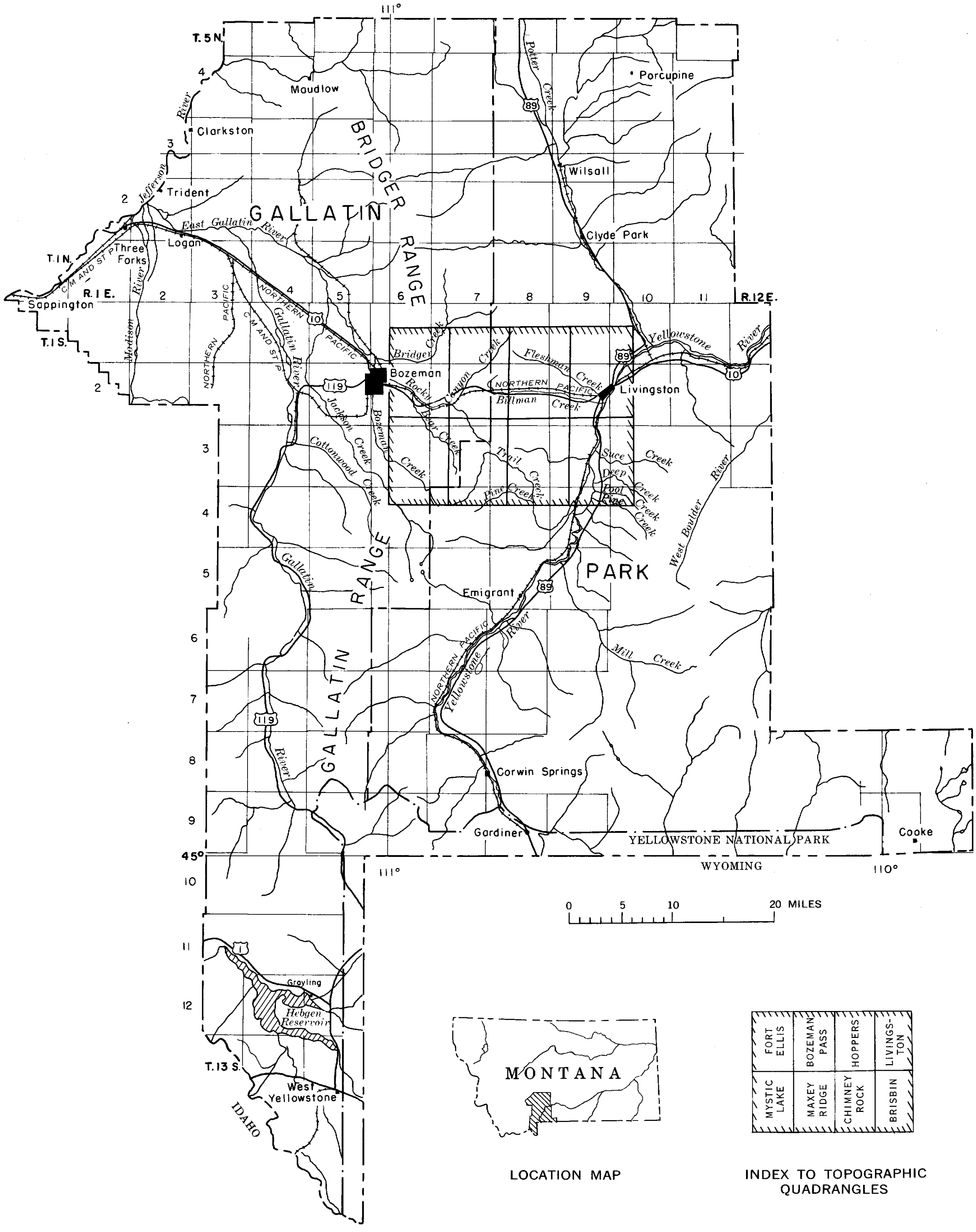

FIGURE 1.—Location of the area mapped in the Livingston coal field, Gallatin and Park Counties, Mont.

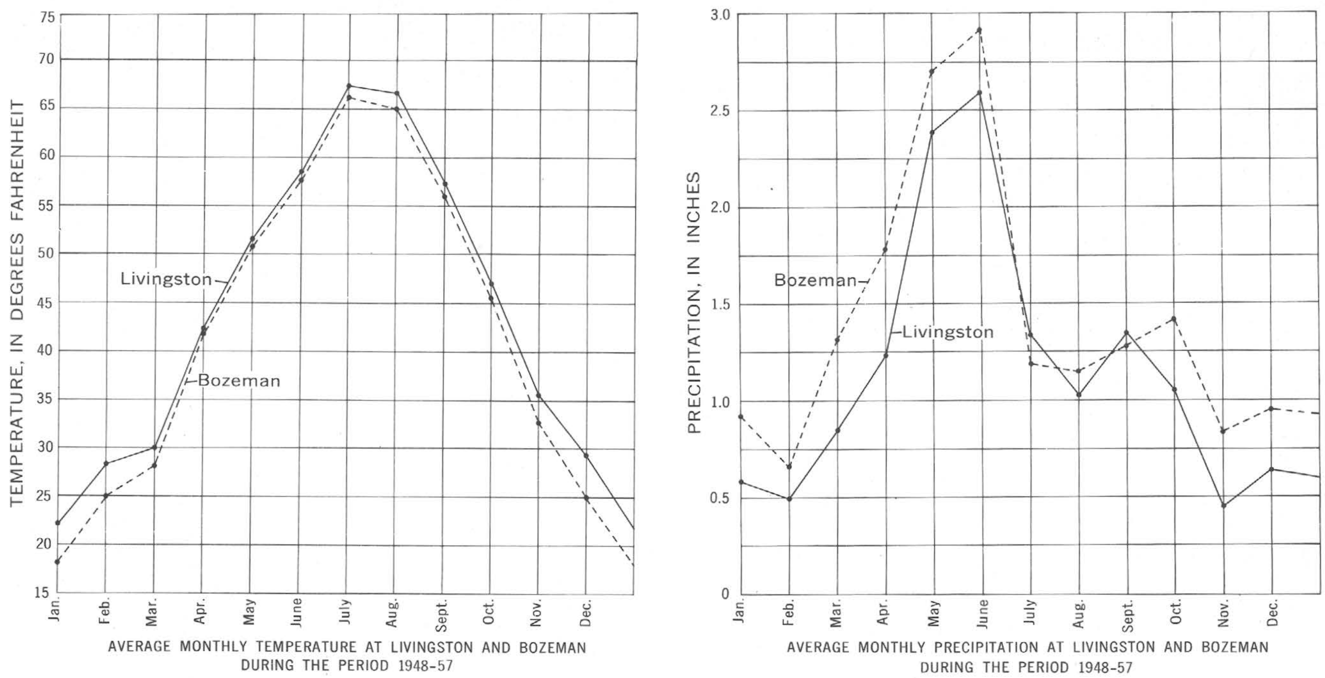

FIGURE 2.—Average monthly temperature and precipitation at Livingston and Bozeman during 1948–57. From U.S. Weather Bureau (1948–57).

derosa pine, white pine, limber pine, and alpine fir. Valleys and rolling foothills flanking the Bridger and Gallatin Ranges are largely unforested. Generally, cottonwood, aspen, and other deciduous trees mark the courses of the rivers and perennial streams.

ECONOMY

Livingston and Bozeman, the two largest cities in or near the mapped area, are the economic centers and county seats for Park and Gallatin Counties, respectively. During the early years of their growth, Livingston, at the east limit of the commercial coal deposits, and Bozeman, at the west limit, both benefited economically from the coal mining industry. Since the turn of the century, however, these cities have been supported primarily by farming and dairying, stock raising, lumbering, transportation, educational institutions, and tourism.

STRUCTURE

The oldest rocks in the mapped area are Precambrian gneiss, granite, and schist exposed in the cores of the Canyon Mountain and Sourdough Creek anticlines and in the uplifted blocks of the Beartooth and Bridger Ranges. The sedimentary rocks in the area range in age from Middle Cambrian to Tertiary and are more than 20,600 feet thick (Roberts, 1964a–h). Only the Silurian and Triassic Systems are not represented. The Paleozoic rocks are 3,050 feet thick and are generally exposed along the axes of the major anticlines. Rocks of Jurassic age are 700 feet thick and form a prominent narrow belt along the flanks of anticlines. Rocks of Cretaceous age are 11,775 feet thick and are exposed along the flanks of anticlines and in the troughs of synclines. More than 4,900 feet of Paleocene rock fills the southern part of the Crazy Mountains basin, and 220 feet of sedimentary rock and more than 3,000 feet of volcanic rock of Eocene age cap the ridges in the northern part of the Gallatin Range. From the latter part of the Late Cretaceous through the Paleocene, a gradual transition in depositional environment took place, as shown by successive deposition of the marine Telegraph Creek Formation, the brackish-water marine and nonmarine Eagle Sandstone, and the continental deposits of the Livingston Group and the Fort Union Formation.

Late in the Santonian Stage of Late Cretaceous time, epeirogenic arching began in western Montana, and the Eagle seas regressed to the east. This period of orogeny and erosion was also marked by volcanism that formed the thick Elkhorn Mountains Volcanics (Klepper and others, 1957, p. 31). After withdrawal of the Late Cretaceous Eagle seas from western Montana, the area east of the Bridger Range and north of the Beartooth Range gradually warped downward to form the Crazy Mountains basin.

The Crazy Mountains basin is elongated northwestward and is approximately 40–70 miles wide and 130 miles long. The basin is asymmetrical and contains more than 13,000 feet of sedimentary rock in the western part, derived predominantly from andesitic volcanic rock of the Elkhorn Mountains. Deposition in this part of the basin occurred during the remainder of Late Cretaceous and Paleocene time (Roberts, 1963, p. B86). On the west and southwest the basin is bounded by the Bridger Range and the Beartooth Range tectonic blocks, which were formed by uplift and by basinward thrusting, respectively eastward and northeastward. Between the Bridger and Beartooth Ranges near Livingston is an area of en echelon folds whose northwest-oriented axes parallel the axis of the Crazy Mountains basin.

The Livingston area was relatively stable in comparison with the Bridger Range to the west and the Beartooth Range to the east. As the uplifted Bridger and Beartooth blocks were forced basinward, arcuate northwest-trending en echelon folds, each convex to the southwest, formed in the Livingston coal field. Folding in the Livingston area continued until the major anticlines became asymmetric—dips on the southwest flanks became steeper than those on northeast flanks. The Canyon Mountain anticline was intensely folded and became recumbent on its southwest flank.

During the folding, lateral movement of competent sandstone beds in the Eagle Sandstone caused local folding and shearing of the intervening incompetent coal beds (fig. 3). Squeezing that accompanied this movement produced lenticular beds similar to boudinage structure. Local areas underwent considerable squeezing and shearing, and the coal beds in these areas were transformed to lenses of friable slickensided coal.

The crustal forces, which resulted from deep-seated compressional forces, continued to act until the competent rocks ruptured; and large thrust and high-angle reverse faults formed in an en echelon arrangement parallel to the folds. The general direction of dip on the plane of these faults was west to south, depending on the proximity to the Bridger or Beartooth Ranges. The high-angle reverse faults are characteristically steep but probably become flatter at depth. Faults along the southwest flank of the Canyon Mountain anticline indicate several pulses of thrusting and intervening periods of erosion (Roberts, 1964a, b).

Compressive forces continued to move the Bridger block eastward and the Beartooth block northeastward; and folding continued in the Livingston area, but with less magnitude than before. The folding of the thrust plates changed the general dip on the plane of these faults at this time to basinward, or northeastward.

Extensive erosion accompanied the folding, and by Late Cretaceous time the Bridger and Beartooth uplifts were truncated to expose Precambrian rock. The basal

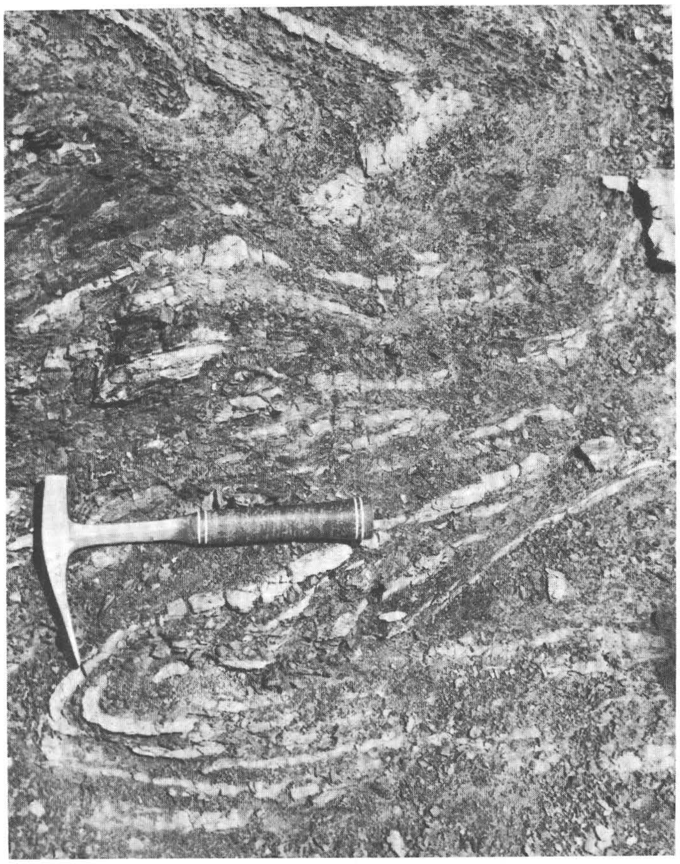

FIGURE 3.—Big Dirty coal bed (NW¼NW¼ sec. 26, T. 2 S., R. 8 E.), Livingston coal field, Montana. Folding and shearing shown in the incompetent coal bed resulted from adjustment during lateral movement of overlying and underlying competent sandstone beds.

conglomerate of the Fort Union Formation in the Livingston area, of very Late Cretaceous age, contains rock fragments derived from Precambrian, Paleozoic, and Mesozoic rocks (Roberts, 1963, p. B89).

During deposition of the Fort Union Formation in the northern part of the Livingston coal field, erosion continued in the southern part. Later, the southern part was covered by volcanic rocks or by volcanic-derived sedimentary rock, which, at their northern extent near Chimney Rock, Mont., are coarse clastics and pyroclastics. Indentification of spores and pollen from a local carbonaceous claystone near the base of this volcanic sequence by R. H. Tschudy (written commun., 1962) and petrographic comparison of the overlying rocks with stratigraphic units of known age in the northern Absaroka Range and Yellowstone National Park area, Wyoming, indicate a Wasatchian and Bridgerian provincial age (Wood and others, 1941) assignment.

In post-Paleocene time, after the folding and thrust faulting, rocks in the Livingston area were intruded—

generally along tension fractures or faults—by small dikes and sills of diorite. These intrusions are few, and only a very small number cut the coal-bearing rocks. Consequently, the loss of coal reserves in the Livingston coal field due to the effects of intrusion was small; however, in the Mountain Side mine, sec. 21, T. 2 S., R. 7 E., the east limit of the workings is in an area of natural coke produced by a diabase dike.

Nearly vertical faults—along which the movement was predominantly vertical—characterized the closing tectonic activity in the Livingston coal field. These are normal faults and are predominantly parallel to structural axes. The displacement along these faults ranges from a few feet to several thousand feet; however, on faults that cut the coal beds, the displacement is generally a few feet to several tens of feet. The faults become more numerous near the crests of the anticlines (pl. 1).

Tectonic events that occurred in or adjacent to the Livingston coal field after the deposition of the coal-bearing Eagle Sandstone probably were closely related or were virtually contemporaneous. They occurred in the following sequence:

1. Uplift accompanied by erosion of the area west of the field (now occupied by the Boulder batholith) and withdrawal of the Eagle seas to the east.
2. Volcanic activity and erosion of the uplifted area and downwarping of the Crazy Mountains basin.
3. Folding and (or) uplifting of the Bridger and Beartooth Ranges.
4. Basinward thrusting of the Bridger and Beartooth Ranges forming en echelon folds having northwest trending axes in the Livingston area.
5. Continuation of folding until the anticlines became asymmetric with the steeper dip on the southwest flank—the Canyon Mountain anticline became recumbent.
6. Failure of the folds by thrusting and high-angle reverse faulting.
7. Several pulses of thrusting and intervening periods of erosion.
8. Continuation of folding but with less magnitude than previously—thrust plates were folded.
9. Extensive erosion followed by volcanic activity south and southeast of the Livingston area.
10. Intrusion by diabasic dikes and sills, generally along tension fractures or parallel to structural axes.
11. Normal faulting, predominantly parallel to structural axes.

STRATIGRAPHY OF THE EAGLE SANDSTONE

The Eagle Sandstone exposed in the Livingston coal field consists of sandstone, siltstone, intermediate phases of transitional sandy siltstone and silty sandstone, and coal beds. This coal-bearing sequence makes up the Eagle Sandstone of the Montana Group of Late Cretaceous age (pl. 2). The Eagle Sandstone in this area consists of lagoonal, estuarine, and terrestrial deposits laid down near ancient shorelines. These strata show an alternation of marine nearshore and offshore facies interfingered with nonmarine facies. Deposition of these types results in facies of different lithology but of the same age and in facies of similar lithology but of different age.

Weed (1899, p. 2) named the Eagle Sandstone from outcrops along the Missouri River at the mouth of Eagle Creek in Chouteau County, north-central Montana. At the type locality the formation consists of three units: an upper unit of thin-bedded sandstone, a middle unit of siltstone, and a lower unit of hard massive persistent sandstone. The lower unit was later named the Virgelle Sandstone Member of the Eagle Sandstone by C. F. Bowen (Stebinger, 1914b, p. 62) from outcrops along the Missouri River near the town of Virgelle, Mont.

Weed (1893, p. 11) separated the nonvolcanic coal-bearing formation (Eagle Sandstone) from the overlying volcanic-derived sediments of his Livingston Formation (Cokedale Formation of Roberts, 1963, p. B89) on the basis of lithology and believed the two were separated by an unconformity. Stone and Calvert (1910, p. 761) correctly described Weed's Livingston Formation as conformably overlying the coal beds at Livingston. Roberts (1957, p. 47; 1963, p. B90) arbitrarily designated the top of the arkosic sandstone that overlies the Cokedale coal bed as the contact between the Cokedale Formation and the underlying Eagle Sandstone. Some andesitic sandstones are in the upper part of the Eagle Sandstone, and a few arkosic sandstones and coal beds are in the lower part of the Cokedale Formation; however, in the Livingston area this boundary is the best mappable contact. The difference between physical and chemical properties of the coals in the upper part of the Eagle (bituminous-coking) and the lower part of the Cokedale (lignite-noncoking) also supports this boundary assignment. The thin black chert-pebble conglomerate that in many places marks the top of the Eagle or base of the Claggett throughout much of the Montana was not found in the section at Cokedale.

The Eagle Sandstone conformably overlies the Telegraph Creek Formation of Late Cretaceous age (fig. 4) throughout the Livingston coal field. The upper part of the Telegraph Creek consists of thin-bedded to massive light-olive-gray very fine grained calcareous arkosic

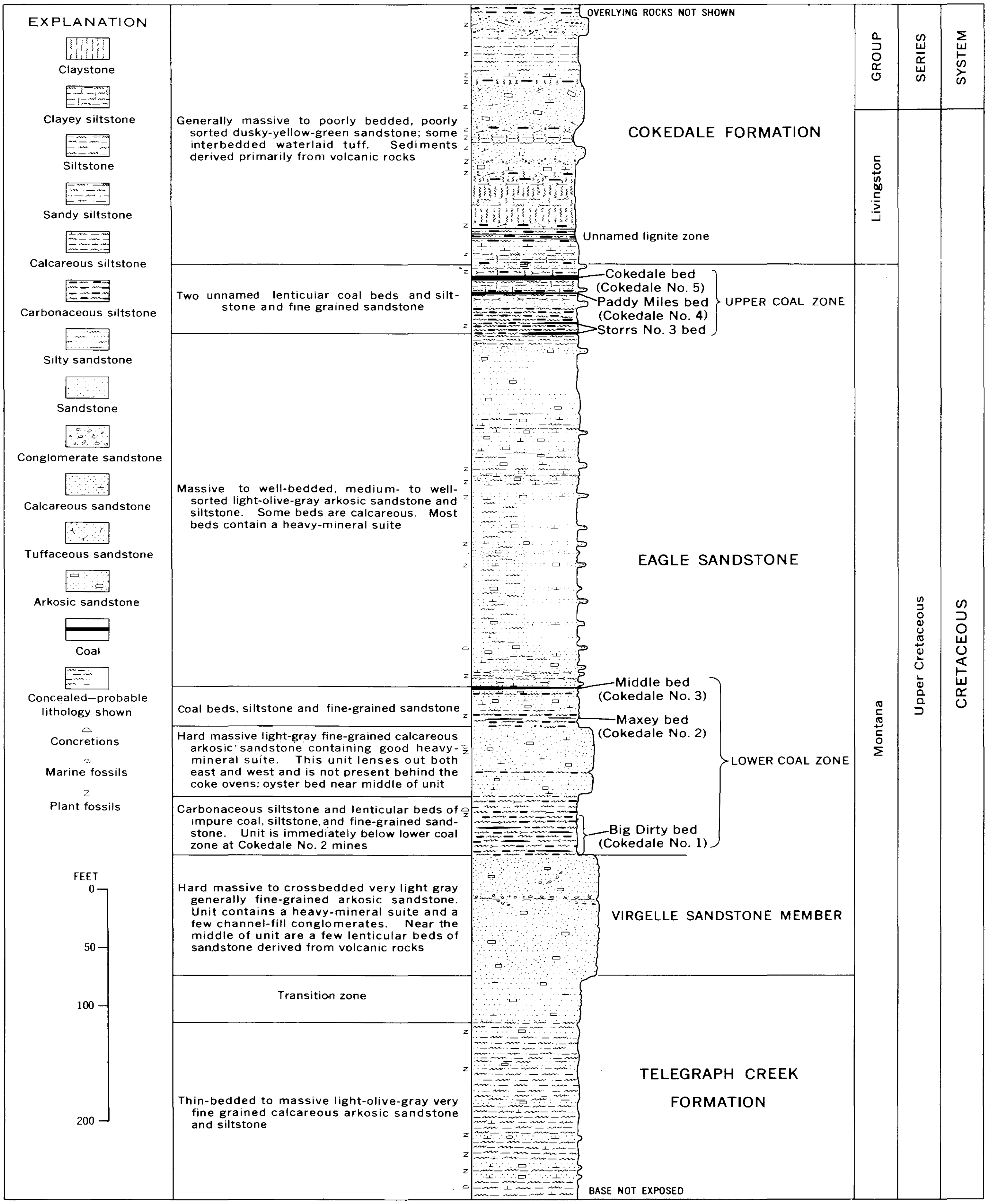

FIGURE 4.—Eagle Sandstone, NW¼ sec. 26, T. 2 S., R. 8 E., at Cokedale, Park County, Mont.

sandstone and siltstone. The boundary between the two formations is gradational.

The Cokedale Formation of Late Cretaceous age (fig. 4) conformably overlies the Eagle Sandstone in the northern part of the report area. The Cokedale consists of generally massive to poorly bedded poorly sorted dusky-yellow-green sandstone and claystone interbedded with some water-laid tuff, bentonite, carbonaceous claystones, and lignite. The sediments were derived mainly from volcanic rocks of andesitic composition. The difference in the lithologies of the Eagle Sandstone and the Cokedale Formation is conspicuous; however, the boundary is not marked by an abrupt change.

The thickness of the Eagle Sandstone within the Livingston coal field ranges from 515 to 860 feet and averages about 600 feet (pl. 2). At Cokedale, 9 miles west of Livingston, where the Eagle Sandstone is best exposed, it is 645 feet thick, including the 110-foot-thick Virgelle Sandstone Member at its base (fig. 4). The sandstone beds are very light gray to yellowish gray and of variable composition and texture. In some localities they are massive and coarse grained; in others, banded or laminated and fine grained. Generally the indurated beds are calcareous.

In the southern part of the area, the Eagle Sandstone ranges in thickness from 525 to 575 feet (pl. 2) and is composed mostly of light-colored sandstone and siltstone. The middle and upper parts of the formation are softer and thinner bedded than is the lower part. Massive light-gray sandstone, averaging 10–15 feet in thickness, is interbedded throughout the formation.

North and east of Cokedale the Eagle Sandstone thins to 470 feet at Loweth, Mont., and to 245 feet at Columbus, Mont. (J. R. Gill, oral commun., 1962). Northwest of Cokedale in the Bridger Range, the Eagle is about 600 feet thick at the south end of the range and thins to about 100 feet thick at the north end (McMannis, 1955, p. 1388, 1407). Southward from Livingston the Eagle Sandstone thickens, and at Mount Everts near Gardiner it is 780 feet thick (G. D. Fraser, oral commun., 1963). West of the report area the Eagle has been eroded (Robinson, 1963, p. 58). The overlying Livingston Group and the Fort Union Formation also thin progressively northward and eastward from Livingston (Roberts, 1963, p. B87). To the east and north, rocks of the Eagle, Livingston, and Fort Union also become finer grained, better sorted, lighter in color, and less andesitic in composition.

Tertiary flows, flow breccias, and related sedimentary deposits unconformably overlie the Eagle Sandstone in the southern part of the report area. At the north extent of the these rocks, near Chimney Rock, Mont., the stratigraphic section consists predominantly of conglomerates, flow breccias, agglomerates, and mud flows, which are rock types similar to those deposited near the periphery of large volcanic piles. At the base of the section is 160 feet of cliff-forming coarse conglomerate composed predominantly of fragments of dacitic volcanic rock and lesser amounts of Precambrian igneous and metamorphic rocks and Paleozoic and Mesozoic sedimentary rocks. Carbonaceous claystone is present locally at the base of this conglomerate (W. J. McMannis, written commun., 1962). It contains plant spores and pollen that were identified by R. H. Tschudy (written commun., 1962) as of Wasatchian provincial age. The cliff-forming conglomerate is overlain by 60 feet of loosely consolidated slope-forming conglomerate that contains only fragments of volcanic rock, which is generally of andesitic composition. A sequence, several thousand feet thick, of andesitic flows, flow breccias, agglomerates, and mud flows overlies the slope-forming conglomerate. The Wasatchian provincial age of the claystone at the base of the section and petrographic comparisons of the overlying rocks indicate that the lower conglomerate is either a lateral facies of part of the "early acid breccia" of Hague (1899), part of the Reese Formation of Calvert (1912b, p. 412), or part of the Cathedral Cliffs Formation of Pierce (1963, p. 9) of Wasatchian provincial age. The same evidence indicates that the upper conglomerate and overlying rocks are equivalent to the "early basic breccia" of Hague (1899) of Bridgerian provincial age in the northern Absaroka Range and Yellowstone National Park area, Wyoming.

LITHOLOGIC COMPOSITION

The Eagle Sandstone at Cokedale consists generally of two parts: the lower half is massive indurated cross-bedded sandstone that is intercalated with beds of coal and carbonaceous siltstone and shale; the upper half is well-bedded poorly indurated sandstone and siltstone that is intercalated with beds of coal and carbonaceous siltstone or shale (fig. 4). All gradations between sandstone and siltstone exist, but sandstone beds predominate. The sandstone generally is very fine grained to fine grained, subangular to subrounded, and moderately to well sorted.

The lower half of the Eagle Sandstone at the Cokedale No. 1 mines consists of four generalized parts—two carbonaceous units and two sandstone units (fig. 4).

The carbonaceous unit in the lower part of the Eagle Sandstone, described as the lower coal zone, consists of coals, carbonaceous siltstones, and fine-grained sandstones. In the middle of the lower coal zone is a hard massive light-gray fine-grained calcareous arkosic sandstone that contains a heavy-mineral suite, as well as oysters, *Inoceramus*, and large plant fragments. This unit lenses out along the strike and is not present north of the coke ovens in sec. 26, T. 2 S., R. 8 E., or at the Cokedale No. 2 mines in sec. 21, T. 2 S., R. 8 E. A representative sample from the middle of this unit contained a trace of coarse sand, 11.2 percent medium sand, 61.3 percent fine sand, 17.5 percent very fine sand, and 10.0 percent silt and clay. The sample was 15.7 percent carbonate by weight and contained a heavy-mineral suite. The heavy minerals, listed approximately in order of decreasing abundance, are zircon, tourmaline, garnet (colorless), brookite, rutile, apatite, staurolite, epidote, muscovite, and corundum (colorless).

The Virgelle Sandstone Member at the base of the Eagle Sandstone consists of hard massive to crossbedded very light gray generally fine-grained arkosic sandstone. It contains a few channel-fill pebble-conglomerate zones and, near the middle of the member a few lenticular beds of sandstone derived from volcanic rocks. A representative sample from the middle of the Virgelle contained 0.08 percent medium sand, 14.96 percent very fine sand, and 18.25 percent silt and clay. The sample was 23.75 percent carbonate by weight and contained a heavy-mineral suite. The heavy minerals, listed approximately in order of decreasing abundance, are zircon, tourmaline, muscovite, biotite (green and brown), apatite, diopside, corundum (colorless and red), rutile, staurolite, garnet (pink), hornblende (green), gold, and epidote(?).

The upper half of the Eagle Sandstone is divisible into two generalized parts (fig. 4): an upper carbonaceous unit (or upper coal zone) and a lower sandstone unit. The carbonaceous unit consists of coals, carbonaceous siltstones, and sandstones. The sandstone unit consists of massive to well-bedded medium- to well-sorted light-olive-gray arkosic sandstone and siltstone. The indurated beds are generally calcareous. A representative sample from the middle of this unit contained material in the following Wentworth (1922) grain scale sizes: 38.9 percent fine sand, 51.0 percent very fine sand, and 10.1 percent silt and clay. The sample was 33.4 percent carbonate by weight and contained a heavy-mineral suite. The heavy minerals, listed approximately in order of decreasing abundance, are zircon, tourmaline, augite, rutile, staurolite, apatite, anatase, muscovite, corundum (colorless), epidote, leucoxene, and garnet (colorless).

Petrographic examination of the Eagle Sandstone indicates that it consists of as much as 50 percent quartz and lesser amounts of plagioclase, feldspar, rock fragments of fine-grained andesites(?), microlite and microporphyritic andesites(?), quartzite, chert, and carbonate. Most quartz grains show straight to slightly undulose extinction and few vacuoles and inclusions, which suggests a plutonic source; some, however, show a strong undulose extinction and have no inclusions or vacuoles, which suggests a metamorphic source. The plagioclase is mostly andesine, and the feldspar is mostly orthoclase.

Carbonate is abundant. Apparently it is secondary after feldspar and is therefore difficult to distinguish from primary carbonate. In the following stratigraphic descriptions, carbonate, whether primary or secondary, was noted as calcareous under cement.

Traces of silica and zeolite minerals are also present as a cement. Other minerals present are biotite, muscovite, garnet, hematite, magnetite, ilmenite, leucoxene, allanite, tourmaline, chlorite, pyrite, apatite, epidote, sericite, and clay. Many clastic beds in the Eagle contain an abundance of carbonaceous material in the matrix.

A few tuffs are present in the Eagle Sandstone, and they generally consist of a fine-grained matrix containing abundant plagioclase microlites and laths and numerous cavites filled with carbonate and silica. Only a few samples contained more than 1 percent pyrite.

DESCRIPTION OF STRATIGRAPHIC SECTIONS

The following two sections of the Eagle Sandstone, measured near Livingston and Cokedale, are probably typical of the Eagle in this region. In reference to the bedding of the rocks, the following standard was used to indicate thicknesses: Massive, greater than 4 feet; thick-bedded, 2–4 feet; medum-bedded, 6 inches–2 feet; thin-bedded, 2–6 inches; very thin bedded, ½–2 inches; platy, 1/16–½ inch; and fissile, less than 1/16 inch. The term "arkosic" is used for the sandstone composition of quartz, plagioclase, and feldspar and does not imply sole derivation from a granitic terrane. The source of the sandstones is unknown; however, there are some indications that most of the quartz and feldspar was derived from Precambrian granite, gneiss, and schist and that the plagioclase was derived from younger igneous rocks.

SECTION 1.—*Eagle Sandstone on north side of Miner Creek in NW¼ sec. 26, T. 2 S., R. 8 E., Park County, Mont.*

[Measured by Albert E. Roberts and J. Stewart Hollingsworth in 1955]

	Ft	in.
Cokedale Formation (Upper Cretaceous).		
Eagle Sandstone (Upper Cretaceous):		
104. Sandstone, thick-bedded, indurated (slight ridge former), calcitic, very fine grained, light-olive-gray (5*Y* 6/1), arkosic. Weathers to pale-olive (10*Y* 6/2) slabs about 3–6 in. thick. Sorting, fair. Quartz grains comprise 50 percent. Contains heavy-mineral suite	3	0

SECTION 1.—*Eagle Sandstone on north side of Miner Creek in NW¼ sec. 26, T. 2 S., R. 8 E., Park County, Mont.*—Continued

		Ft	in.
Eagle Sandstone (Upper Cretaceous)—Continued			
103. Siltstone, thick-bedded, tuffaceous, olive-gray (5*Y* 4/1), and thin interbedded very fine grained sandstone Weathers to dusky yellow (5*Y* 6/4). Contains fragments (fine grained) of volcanic rocks and plant fragments. Unit poorly exposed		2	0
102. Siltstone, very carbonaceous, tuffaceous, clayey (roof)		5	0
101. Coal (Cokedale coal bed or locally the Cokedale No. 5 bed), attitude N. 84° W., 40° NE		5	0
	in.		
Siltstone, very carbonaceous, tuffaceous	2		
Siltstone, tuffaceous	1		
Bone	3		
Coal	8		
Siltstone, altered, tuffaceous, carbonaceous	2.5		
Coal	11		
Siltstone, altered, tuffaceous, carbonaceous	.5		
Bone	5		
Coal	19		
Bone	2		
Siltstone, very carbonaceous, clayey	6		
100. Siltstone, massive, light-gray (*N*7), clayey. Poorly exposed. Weathers to light-olive-gray (5*Y* 6/1) soil		6	0
99. Sandstone, indurated (slight ridge former), very fine grained, dusky-yellow-green (5*GY* 5/2). Sorting, fair. Weathers to yellowish orange (10*YR* 7/6). Rock appears to be transition of Eagle Sandstone and Livingston Group lithologies. Weathers along fractures (N. 60° W.) and bedding planes. Attitude N. 80° W., 40° NE		2	0
98. Siltstone, thick-bedded, light-olive-gray (5*Y* 6/1), clayey, carbonaceous. Weathers to moderate yellowish brown (10*YR* 5/4). Small granule-size grains near base		3	0
97. Coal (probably Paddy Miles coal bed or locally the Cokedale No. 4 bed)		1	0
	in.		
Bone	3		
Coal	9		
96. Siltstone, medium-bedded, olive-gray (5*Y* 4/1). Weathers to moderate yellowish brown (10*YR* 5/4)		1	6
95. Siltstone, very carbonaceous (almost bone)			2
94. Siltstone, massive, pale-olive (10*Y* 6/2), tuffaceous. Weathers to moderate greenish yellow (10*Y* 7/4). Forms a crumbly soil		4	0
93. Sandstone, indurated, slabby, crossbedded, very fine grained, yellow-green (5*GY* 6/2); slight ridge former. Irregular thickness, from 4 to 6 ft		5	0

SECTION 1.—*Eagle Sandstone on north side of Miner Creek in NW¼ sec. 26, T. 2 S., R. 8 E., Park County, Mont.*—Continued

		Ft	in.
Eagle Sandstone (Upper Cretaceous)—Continued			
92. Siltstone, massive, olive-gray (5*Y* 4/1), carbonaceous. Poorly exposed		13	0
91. Siltstone, thick-bedded, medium-dark-gray (*N*4), carbonaceous. Weathers to light olive gray (5*Y* 6/1). Slightly more indurated than overlying siltstone. Breaks with conchoidal fracture. Manganese stain common on fracture surfaces. Spheroidal weathering		2	0
90. Coal, probably Storrs No. 3 coal bed (upper part); not described, as bed is burned along the outcrop from the valley to top of the hill		2	0
89. Siltstone, very carbonaceous, grayish-brown (5*YR* 3/2), weathers to pale yellowish brown (10*YR* 6/2). Contains plant fragments		1	0
88. Siltstone, massive, greenish-gray (5*GY* 6/1). Weathers to yellowish gray (5*Y* 8/1). Poorly exposed		6	0
87. Coal, probably Storrs No. 3 coal bed (lower part)		2	0
	in.		
Bony coal	1		
Coal	8		
Siltstone, very carbonaceous	3		
Coal	8		
Bony coal	1		
Siltstone, very carbonaceous	3		
86. Siltstone, massive, light-olive-gray (5*Y* 6/1), tuffaceous; weathers to yellowish gray (5*Y* 8/1). Poorly exposed		11	0
85. Sandstone, massive, very light gray (*N*8), fine-grained, arkosic. "Salt-and-pepper" appearance. Contains heavy-mineral suite. Somewhat porous; considerable limonitic staining near top of unit. Slightly crossbedded. Sorting, fair. Massive spheriodal weathering. Weathers to yellowish gray (5*Y* 7/2)		6+	0
84. Concealed; probably fine-grained very light gray arkosic sandstone		36	6
83. Sandstone, massive, very light gray (*N*8), fine-grained, arkosic. "Salt-and-pepper" appearance. Contains heavy-mineral suite. Sorting, fair. Massive spheroidal weathering. Weathers to yellowish gray (5*Y* 7/2)		18+	0
82. Sandstone, massive, slabby, arkosic, calcareous, mixture of very fine grained sand and pods or lenses of silt (definite brackish-water deposit), yellowish-gray (5*Y* 7/2). Mottled where silt is concentrated. Weathers to grayish yellow (5*Y* 8/4). Many worm tubes or pelecypod burrowings (some 12 in. long)		15	0
81. Siltstone, thick-bedded, mottled, yellowish-gray (5*Y* 7/2), sandy. Brackish-water deposit. Weathers to grayish yellow (5*Y* 8/4)		2	0

SECTION 1.—*Eagle Sandstone on north side of Miner Creek in NW¼ sec. 26, T. 2 S., R. 8 E., Park County, Mont.*—Continued

Eagle Sandstone (Upper Cretaceous)—Continued	Ft	in.
80. Sandstone, thick-bedded, indurated, very fine grained, arkosic, very calcareous, light-olive-gray (5*Y* 6/1). Weathers to yellowish gray (5*Y* 7/2). Contains heavy-mineral suite	3	0
79. Sandstone, massive, poorly consolidated, light-greenish-gray (5*GY* 8/1), fine-grained to very fine grained, arkosic. Very poorly exposed. Weathers to yellowish gray (5*Y* 7/2)	4	0
78. Sandstone, massive, indurated, fine-grained, calcareous, light-gray (*N*7), arkosic. Weathers to yellowish gray (5*Y* 7/2). Contains heavy-mineral suite. Vertical worm tubes. Little banding along indistinct bedding planes noted in middle of unit	5	0
77. Sandstone, thick-bedded, fine-grained, poorly indurated, very light gray (*N*8), arkosic. Weathers to yellowish gray (5*Y* 8/1)	2	0
76. Sandstone, massive, fine-grained, light-olive-gray (5*Y* 6/1), indurated, calcareous, arkosic. Weathers to light brown (5*YR* 6/4). Conspicuously jointed N. 75°–85° W. normal to base of bed. Lower 1–2 ft shows faint, indistinct bedding. A few worm tubes(?) associated with irregular lenses and pods of poorly sorted mottled sandy siltstone	12	0
75. Sandstone and siltstone, thin-bedded, light-olive-gray (5*Y* 6/1), arkosic, indurated, calcareous (very calcareous in lower half), very fine grained; weathers to yellowish gray (5*Y* 7/2). Contains heavy-mineral suite	2	0

	in.
Siltstone	4
Sandstone	7
Siltstone	2
Sandstone	7
Siltstone	4

	Ft	in.
74. Sandstone, indurated, very fine gained, light-gray (*N*7), arkosic, very calcareous. Weathers to yellowish gray (5*Y* 7/2). Contains heavy-mineral suite. Sorting, fair. Attitude N. 75° W., 39° NE	1	0
73. Siltstone, light-olive-gray (5*Y* 6/1), calcareous. Weathers to yellowish gray (5*Y* 7/2)		6
72. Sandstone, platy, light-gray (*N*7), arkosic, fine-grained, calcareous. Weathers to yellowish-gray (5*Y* 7/2) thin sheets (½ in. or less thick). Contains a heavy-mineral suite that is banded along many bedding planes like varves	6	0
71. Sandstone, medium-bedded, very fine grained, light-olive-gray (5*Y* 6/1), silty, poorly sorted, carbonaceous, arkosic, slightly calcareous; contains calcareous lenses 1 ft thick. Weathers to yellowish gray (5*Y* 7/2). Contains macerated plant fragments and heavy minerals	1	6
70. Sandstone, massive, very fine grained, light-olive-gray (5*Y* 6/1), arkosic, very calcareous. Weathers to yellowish gray (5*Y* 7/2). Contains a few plant fragments and heavy minerals. Poorly developed spheroidal weathering	5	0
69. Siltstone, platy (⅛ in. or less), olive-gray (5*Y* 4/1), slightly carbonaceous, very calcareous. Weathers to yellowish gray (5*Y* 7/2)	1	0
68. Sandstone, platy, very fine grained, light-olive-gray (5*Y* 6/1), arkosic, very calcareous, indurated. Weathers to light olive gray (5*Y* 5/2). Contains heavy-mineral suite	2	0
67. Siltstone, very carbonaceous		3
66. Sandstone, massive, poorly indurated (except for very calcareous pods and lenses), poorly sorted, silty, very fine grained, arkosic, pale-olive (10*Y* 6/2); contains very calcareous pods and lenses. In places, mottled by concentration of silt. Typical of brackish-shallow-water deposit. Contains plant fragments and heavy minerals	5+	0
65. Concealed; probably thin-bedded very fine grained arkosic sandstone. Considerable sandstone float for this interval	6	0
64. Sandstone, thin-bedded, light-olive-gray (5*Y* 6/1), fine-grained, arkosic, calcareous. Bedding <¼ in. thick, marked by bands of heavy minerals. Weathers to yellowish-gray (5*Y* 7/2) ½–2-in. slabs. Contains disseminated plant fragments. Attitude N. 84° W., 41° NE	2	0
63. Sandstone, thin-bedded, silty, very fine grained, arkosic, calcareous, light-olive-gray (5*Y* 6/1). Weathers to yellowish gray (5*Y* 7/2). Less indurated than overlying sandstone. Base not exposed	4+	0
62. Concealed; probably thin-bedded silty very fine grained sandstone	23	0
61. Sandstone, thin-bedded, light-olive-gray (5*Y* 6/1), indurated (slight ridge former), very fine grained, calcareous. Weathers to yellowish-gray (5*Y* 6/2) slabs ½–2 in. thick. Contains plant fragments and heavy-mineral suite	2+	0
60. Concealed; probably thin-bedded silty very fine grained sandstone	12	0
59. Sandstone, platy, light-olive-gray (5*Y* 6/1), calcareous, arkosic, very fine grained. Weathers to slabs about ½ in. thick. Contains heavy-mineral suite and plant fragments—one fair quality leaf impression noted. Attitude N. 89° W., 42° NE	4	0
58. Concealed; probably thin-bedded silty very fine grained sandstone	4	0

SECTION 1.—*Eagle Sandstone on north side of Miner Creek in NW¼ sec. 26, T. 2 S., R. 8 E., Park County, Mont.*—Continued

Eagle Sandstone (Upper Cretaceous)—Continued	Ft	in.
57. Sandstone, platy, light-olive-gray (5*Y* 6/1), calcareous, arkosic, very fine grained. Weathers to slabs about ½ in. thick. Contains heavy-mineral suite and plant fragments	4	0
56. Concealed; probably thin-bedded silty very fine grained sandstone	8	0
55. Sandstone, platy, indurated (slight ridge former), calcareous, arkosic, very fine grained, light-olive-gray (5*Y* 6/1). Angular to subangular grains. Sorting, fair. Crossbedded. Weathers to yellowish gray (5*Y* 7/2). Few poorly preserved leaf impressions. Calcite veinlets $<$¼ in. thick along fracture surfaces	2	0
54. Concealed; probably thin-bedded silty very fine grained sandstone	20	0
53. Sandstone, platy, indurated (slight ridge former), calcareous, arkosic, very fine grained, light-olive-gray (5*Y* 6/1). Angular to subangular grains. Sorting, fair. Crossbedded. Weathers to yellowish gray (5*Y* 7/2)	3	0
52. Concealed; probably thin-bedded silty very fine grained sandstone	8	0
51. Sandstone, platy, indurated, calcareous, arkosic, very fine grained, light-olive-gray (5*Y* 6/1). Weathers to yellowish gray (5*Y* 7/2). Attitude N. 83° W., 49° NE	3	0
50. Concealed; probably thin-bedded silty very fine grained sandstone	17	0
49. Sandstone, platy, indurated (slight ridge former), calcareous, arkosic, very fine grained, light-olive-gray (5*Y* 6/1). Angular to subangular grains. Sorting, fair. Crossbedded. Weathers to yellowish gray (5*Y* 7/2)	3	0
48. Concealed; probably thin-bedded silty very fine grained sandstone	12	0
47. Sandstone, platy, indurated (slight ridge former), calcareous, arkosic, very fine grained, light-olive-gray (5*Y* 6/1). Angular to subangular grains. Sorting, fair. Crossbedded. Weathers to yellowish gray (5*Y* 7/2)	2	0
46. Concealed; probably thin-bedded silty very fine grained sandstone	4	0
45. Sandstone, platy, indurated (slight ridge former), calcareous, arkosic, very fine grained, light-olive-gray (5*Y* 6/1). Angular to subangular grains. Sorting, fair. Crossbedded. Weathers to yellowish gray (5*Y* 7/2). Large very calcareous olive-gray (5*Y* 5/1) concretionary lenses of sandstone (some as large as 2×5 ft). They weather to yellowish gray (5*Y* 6/2) with pronounced spheroidal weathering	5 4	 0
44. Sandstone, platy, slightly indurated, arkosic, calcareous, very fine grained, light-olive-gray (5*Y* 6/1); interbedded thin-bedded silty very fine grained sandstone. Weathers to yellowish gray (5*Y* 6/2)	14	0

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SECTION 1.—*Eagle Sandstone on north side of Miner Creek in NW¼ sec. 26, T. 2 S., R. 8 E., Park County, Mont.*—Continued

Eagle Sandstone (Upper Cretaceous)—Continued	Ft	in.
43. Sandstone, thin- to medium-bedded, indurated (slight ridge former), calcerous, very fine grained, arkosic, light-olive-gray (5*Y* 6/1). Angular to subangular grains. Sorting, fair. Weathers to yellowish gray (5*Y* 6/2)	2	6
42. Sandstone, thin-bedded, silty, very fine grained, light-olive-gray (5*Y* 6/1). Weathers to yellowish gray (5*Y* 6/1). Poorly exposed	2	6
41. Tuff, microlitic, medium-bedded, medium-dark-gray (*N*4), indurated, silty, very fine grained, calcareous (few small secondary calcite crystals), andesitic. Angular grains. Poorly sorted. Weathers to olive gray (5*Y* 3/1). Rock composed mostly of volcanic rock fragments and plagioclase (andesine). Many vugs $<$1/4 in. in diameter. Attitude N. 68° W., 38° NE	1	0
40. Sandstone, thick-bedded, dark-greenish-gray (5*GY* 4/1), poorly sorted, silty, medium-grained, angular grains, slightly calcareous, andesitic. Composed of volcanic rock fragments and plagioclase. Weathers to greenish gray (5*GY* 6/1). Faint, poorly formed bedding. Poorly sorted	3	0
39. Siltstone, massive, tuffaceous, light-olive-gray (5*Y* 5/2). Contains disseminated plant fragments. Weathers to yellowish gray (5*Y* 7/2)	4	0
Possible fault of less than a few feet displacement.		
38. Tuff, microlitic, massive, calcareous, medium-light-gray (*N*6), indurated, very fine grained, andesitic. Angular grains. Poorly sorted. Breaks with conchoidal fracture. Composed of volcanic rock fragments and plagioclase (too altered for composition determination). Weathers to dark yellowish brown (10*YR* 4/2). Many small vugs—some coated first with calcite and later with silica	4	0
37. Coal (Middle coal bed or locally the Cokedale No. 3 bed)	1	0

	in.
Coal	5
Siltstone, carbonaceous	1
Bone	2
Siltstone, very carbonaceous	2
Siltstone, carbonaceous	2

	Ft	in.
36. Sandstone, indurated, thin- to medium-bedded, fine-grained, slightly arkosic, yellowish-gray (5*Y* 7/2). Contains heavy-mineral suite. Weathers to yellowish brown (10*YR* 5/2)	1	0
35. Siltstone, poorly exposed, carbonaceous	3	0
34. Sandstone, thin-bedded to massive, yellowish-gray (5*Y* 7/2), slightly arkosic, very fine grained, very calcareous. Weathers to yellowish gray (5*Y* 6/2)	12	0

SECTION 1.—*Eagle Sandstone on north side of Miner Creek in NW¼ sec. 26, T. 2 S., R. 8 E., Park County, Mont.*—Continued

	Ft	in.
Eagle Sandstone (Upper Cretaceous)—Continued		
33. Siltstone, platy, greenish-gray (5*GY* 6/1), sandy. Contains disseminated plant fragments. Weathers to yellowish gray (5*Y* 8/1)	7	0
32. Coal (Maxey coal bed or locally the Cokedale No. 2 bed)	6	0
Siltstone, very carbonaceous, with coaly streaks (almost bone) — Ft 1		
Siltstone, very carbonaceous, approaches character of coal bed. Many tuffaceous siltstone partings — 5		
31. Sandstone, platy, carbonaceous, light-olive-gray (5*Y* 5/1), very calcareous, silty, very fine grained, arkosic. Weathers to grayish-yellow (5*Y* 7/4) slabs ½–2 in. thick. Few plant fragments. Attitude N. 89° W., 35° NE	5	0
30. Sandstone, very massive (cliff former directly opposite Miner Creek junction), light-gray (*N*7), fine-grained, crossbedded, arkosic. Good heavy-mineral suite. Calcareous. Massive spheroidal weathering. Weathers to grayish yellow (5*Y* 7/4). Unit lenses out eastward and westward and does not occur behind the coke ovens. Large plant fragments (some several feet across) and several beds of oysters near middle of unit on east side. Many intraformational breccias about 1–2 ft thick	42	0
29. Siltstone, platy, carbonaceous, sandy; calcareous concretions <3 in. diameter, dark yellowish brown (10*YR* 4/2), moderate yellowish brown (10*YR* 5/4). Carbonized plant fragments. Poorly exposed. Immediately east of section this unit becomes very carbonaceous (almost characteristic of coal bed)	2	0
28. Sandstone, massive to thin-bedded, light-olive-gray (5*Y* 6/1), very fine grained, indurated, calcareous, slightly carbonaceous. Contains heavy-mineral suite. In places, resembles brackish-water deposition. Weathers to yellowish gray (5*Y* 8/1). Unit thins abruptly eastward. Contains leaf impressions. A few vertical worm tubes	18	0
27. Siltstone, massive, greenish-gray (5*GY* 6/1); poorly exposed	5	0
26. Siltstone, very carbonaceous, with coaly streaks	1	0
25. Siltstone, massive, dark-greenish-gray (5*GY* 4/1). Contains disseminated plant fragments. Limonitic concretions noted. Weathers to light olive gray (5*Y* 6/1)	5	7
24. Siltstone, bone, and streaks of coal, very carbonaceous. Many carbonaceous, tuffaceous, sandy siltstone partings (as much as 3 in. thick, generally <2 in.). Just east of section the unit is cut out by a fault. Behind the coke ovens this unit is approximately the same thickness. Much of the adjustment during the orogeny of folding and thrusting was taken up in the coal and siltstone beds, which display considerable shearing and many tight folds that do not occur in overlying and underlying resistant sandstones. There are undoubtedly many bedding-plane faults as indicated by bedding-plane shears. Many partings now have a boudinagelike structure. Some carbonaceous siltstone beds contain macerated plant fragments. This unit correlates with the Big Dirty coal bed or, locally, the Cokedale No. 1 bed	46	0
Total Eagle Sandstone above Virgelle Member	535	0
Virgelle Sandstone Member:		
23. Sandstone, massive, indurated (cliff former), generally noncalcareous, very light gray (*N*8), fine-grained, arkosic. Although very massive, bedding can be delineated by dark ⅛–1/16-in. bands of heavy minerals. Unit is almost entirely crossbedded. Crossbedding is generally 2–3 ft long, or less, and generally truncated. Massive spheroidal weathering. Weathers to yellowish gray (5*Y* 7/2). Contains a few channel-fill deposits of pebbles and cobbles of siltstone	25	6
22. Sandstone, medium-bedded, fine-grained, light-olive-gray (5*Y* 5/2), calcareous, arkosic. Weathers to moderate yellowish brown (10*YR* 5/4)	1	0
21. Sandstone, medium-bedded, very poorly sorted, olive-gray (5*Y* 4/1), fine- to medium-grained, noncalcareous; derived from volcanic rock. Bottom 5 in. is olive-black (5*Y* 2/1) tuffaceous siltstone. Entire unit contains many small channel-fill deposits of silt and sand	1	0
20. Sandstone, massive, generally noncalcareous, very light gray (*N*8), fine-grained, arkosic. Less indurated than overlying units	4	0
19. Sandstone, massive, indurated, generally noncalcareous, very light gray (*N*8), fine-grained, arkosic. Siltstone-pebble conglomerate generally at base	8	0
18. Sandstone, thin-bedded (½–4 in. thick), indurated, calcareous, greenish-gray (5*GY* 6/1), very fine grained, arkosic. Weathers to olive gray (5*Y* 4/1). Has 2-in. siltstone both in middle and at base of unit	1	6
17. Sandstone, medium-bedded, calcareous, very light gray (*N*8), fine- to medium-grained, arkosic. Contains abundant heavy-mineral suite. Many small channel-fill deposits of siltstone pebbles. Bed is irregular in thickness and generally crossbedded.		

SECTION 1.—*Eagle Sandstone on north side of Miner Creek in NW¼ sec. 26, T. 2 S., R. 8 E., Park County, Mont.*—Continued

	Ft	in.
Eagle Sandstone (Upper Cretaceous)—Continued		
Angular to subrounded grains. Sorting, fair. Weathers to yellowish gray (5*Y* 7/2)	1	0
16. Sandstone, medium-bedded, indurated, calcareous, greenish-gray (5*GY* 6/1), very fine grained, arkosic. Weathers to olive gray (5*Y* 4/1)	1	0
15. Sandstone, medium-bedded, very light gray, fine-grained, arkosic. Contains calcareous pods or lenses. Crossbedded. A few plant fragments. Contains heavy-mineral suite. Poorly sorted; some small channel-fill deposits of coarse-grained sandstone	2	0
14. Sandstone, poorly sorted, very fine grained, dark-greenish-gray (5*GY* 4/1), noncalcareous, andesitic. Crossbedded. Weathers to light olive gray (5*Y* 5/2)	1	0
13. Siltstone, thin-bedded, olive-gray (5*Y* 4/1). Weathers to light olive gray (5*Y* 5/2). Contains disseminated plant fragments		6
12. Sandstone, massive, very poorly sorted, coarse-grained, pale-olive (10*Y* 6/2). Weathers to yellowish gray (5*Y* 7/2). Contains sporadic pebbles of siltstone. Contains 4-in. olive-gray siltstone bed in middle of unit	4	0
11. Sandstone, medium-bedded, indurated, calcareous, fine-grained, pale-olive (10*Y* 6/2). Weathers to yellowish gray (5*Y* 7/2)	1	0
10. Sandstone, thick-bedded, very light gray, fine-grained, arkosic	3	0
9. Transition to overlying sandstone	1	0
8. Sandstone, indurated, olive-gray (5*Y* 4/1), very fine grained, andesitic. Weathers to dark yellowish brown (10*YR* 4/2). Noncalcareous		6
7. Transition from underlying sandstone	1	0
6. Sandstone, massive, very light gray, fine-grained, arkosic	4	0
5. Sandstone, medium-bedded, poorly sorted, very fine grained, andesitic, dusky-yellow-green (5*GY* 5/2). Weathers to moderate yellowish brown (10*YR* 5/4)	1	0
4. Sandstone, medium-bedded, poorly sorted, medium- to coarse-grained, very light gray (*N*8), arkosic, crossbedded. Weathers to yellowish gray (5*Y* 7/2)	1	0
3. Sandstone, medium-bedded, very light gray, fine-grained, arkosic	1	0
2. Sandstone, platy, very light gray (*N*8), indurated, calcareous, fine-grained, arkosic, with thin (2 in. or less) stringers of coarse-grained sandstone. Crossbedded in part. Weathers to olive gray (5*Y* 4/1)	2	0
1. Sandstone, massive, very light gray (*N*8), fine-grained, arkosic, slightly calcareous, crossbedded. Contains quartz, orthoclase, andesine, heavy minerals, and fragments of andesite. Contains many vertical worm(?) tubes. Cliff-former. 4-ft zone of very poorly sorted sandstone containing silt that gives rock a mottled appearance 4 ft from top of unit. Massive spheroidal weathering. Angular to subrounded grains. Sorting, fair. Weathers to yellowish gray (5*Y* 7/2)	44	0
Total thickness of Virgelle Sandstone Member	110	0
Total thickness of Eagle Sandstone	645	0

Telegraph Creek Formation.

SECTION 2.—*Eagle Sandstone measured on west side of the Yellowstone River, NE¼ sec. 27, T. 2 S., R. 9 E., and adjusted with Deerfield Oil Corp. Strong well 1, SW¼ sec. 11, T. 2. S., R. 9 E., Park County, Mont.*

[Measured by Albert E. Roberts in 1961]

	Ft	in.
Cokedale Formation (Upper Cretaceous)		
Eagle Sandstone (Upper Cretaceous):		
28. Sandstone, medium-bedded, feldspathic, micaceous, fine- to medium-grained, light-olive-gray; rounded to subrounded grains; contains heavy-mineral suite and chert grains	2	0
27. Siltstone, thin- to medium-bedded, carbonaceous, olive-gray; thin interbedded coal beds (correlates with Cokedale coal bed)	8	0
26. Sandstone, medium- to thick-bedded, calcareous, micaceous, volcanic rock fragments, dusky-yellow-green; transition of Eagle Sandstone and Livingston Group lithologies; angular grains. Thin coal bed near middle of unit (correlates with Paddy Miles coal bed)	24	0
25. Shale, massive, silty, pyritic, pale-olive	20	0
24. Sandstone, thick-bedded, calcareous, very fine grained to fine-grained, yellow-green; angular grains	16	0
23. Siltstone, thin-bedded, olive-gray; thin interbedded olive-gray shale	45	0
22. Shale, thin-bedded, sandy, carbonaceous, gray; contains abundant orange (heulandite(?)) specks	10	0
21. Sandstone, medium-bedded, calcareous, micaceous, pyritic, medium- to coarse-grained, very light gray; contains heavy-mineral suite	8	0
20. Shale, massive, silty, pyritic, olive-gray	22	0
19. Sandstone, medium-bedded, silty, calcareous, micaceous, very fine grained, light-gray; contains heavy-mineral suite	10	0
18. Shale, massive, sandy, olive-gray; contains abundant orange (heulandite(?)) specks; thin interbedded olive-gray siltstone	18	0
17. Sandstone, thick-bedded, calcareous, micaceous, medium- to coarse-grained, very light gray; contains heavy-mineral suite	27	0

SECTION 2.—*Eagle Sandstone measured on west side of the Yellowstone River, NE¼ sec. 27, T. 2 S., R. 9 E., and adjusted with Deerfield Oil Corp. Strong well 1, SW¼ sec. 11, T. 2 S., R. 9 E., Park County, Mont.*—Continued

	Ft	*in.*
Eagle Sandstone (Upper Cretaceous)—Continued		
16. Sandstone, thin- to medium-bedded, silty, calcareous, micaceous, very fine grained to fine-grained, very light gray; contains heavy-mineral suite	10	0
15. Sandstone, thin-bedded, silty, calcareous, micaceous, very fine grained to medium-grained, light-olive-gray; thin interbedded siltstone and shale	30	0
14. Sandstone, thick-bedded, calcareous, micaceous, pyritic, fine- to coarse-grained, light-gray; contains orange (heulandite(?)) specks; contains heavy-mineral suite; angular grains	32	0
13. Sandstone, thin-bedded, silty, calcareous, very fine grained to fine-grained, light-olive-gray; thin interbedded siltstone and shale	18	0
12. Sandstone, thick-bedded, calcareous, micaceous, very fine grained to fine-grained, light-olive-gray; thin interbedded siltstone	25	0
11. Shale, massive, sandy, pyritic, light-gray; contains orange (heulandite(?)) specks and thin interbedded siltstone	27	0
10. Siltstone, thin-bedded, sandy, micaceous, medium-dark-gray; thin interbedded shale	8	0
9. Shale, massive, silty, micaceous, olive-gray	15	0
8. Sandstone, thick-bedded, calcareous, very fine grained to coarse-grained, light-gray; predominantly quartz grains; rounded to subangular grains	32	0
7. Sandstone, thin-bedded, silty, calcareous, very fine grained to fine-grained, light-gray; contains orange (heulandite(?)) specks	8	0
6. Shale, massive, sandy, pyritic, medium-gray to olive-gray with orange (heulandite(?)) specks	36	0
5. Sandstone, massive, arkosic, medium- to coarse-grained, light-olive-gray (5*Y* 6/1); interbedded silty very fine grained sandstone and carbonaceous siltstone in the lower 10 ft	28	0
4. Coal (Big Dirty coal bed—measured at caved portal of Williams mine)	17	0

	In.
Bone	1
Coal	26
Bony coal	4
Siltstone, carbonaceous, sandy	3
Siltstone, very carbonaceous	3
Coal	2
Sandstone, fine-grained, arkosic	2
Siltstone, carbonaceous	12
Coal	5
Bone	1
Coal	1
Siltstone, carbonaceous	12
Sandstone, fine-grained, arkosic	9
Siltstone, very carbonaceous	3
Coal	21

SECTION 2.—*Eagle Sandstone measured on west side of the Yellowstone River, NE¼ sec. 27, T. 2 S., R. 9 E., and adjusted with Deerfield Oil Corp. Strong well 1, SW¼ sec. 11, T. 2 S., R. 9 E., Park County, Mont.*—Continued

	Ft	*in.*
Eagle Sandstone (Upper Cretaceous)—Continued		
Sandstone, very fine grained	2	
Coal	2	
Siltstone, very carbonaceous; stringers of coal	16	
Sandstone, very fine grained, arkosic	10	
Bone	3	
Sandstone, very fine grained	2	
Siltstone, carbonaceous	4	
Coal	20	
Siltstone, carbonaceous	3	
Coal	1	
Sandstone, very fine grained	3	
Bone	4	
Bony coal	10	
Coal	4	
Siltstone, very carbonaceous	15	
Total Eagle Sandstone above Virgelle Member	496	0
Virgelle Sandstone Member:		
3. Sandstone, massive, indurated, calcareous, light-gray (*N*7), fine- to medium-grained, arkosic; weathers to grayish yellow (5*Y* 7/4)	62	0
2. Siltstone, micaceous, carbonaceous; interbedded fine- to medium-grained sandstone	27	0
1. Sandstone, massive, indurated, light-gray (*N*7), fine-grained, arkosic. Contains heavy-mineral suite. Weathers to yellowish gray (5*Y* 7/2)	28	0
Total thickness of Virgelle Sandstone Member	117	0
Total thickness of Eagle Sandstone	613	0

Telegraph Creek Formation.

AGE AND CORRELATION

Fossil leaves that were collected by members of the Northern Transcontinental Survey from beds presumably in the lower part of the Livingston Group were described by Lesquereux (1873, p. 404–417) and assigned to the early Eocene. Knowlton (1892) examined this and subsequent collections from other localities in this area, including some from the Eagle Sandstone, and designated the entire collection as the fossil flora of the Bozeman coal field of Laramie (Late Cretaceous) age. According to Pumpelly (1886, p. 692), the coal-bearing horizon at the Bozeman coal field was "about 3,700 feet above the Jurassic and some distance above fossils of Benton or Niobrara age and yet so low in the Cretaceous column as to be apparently below the Laramie." Davis (1886, p. 698) stated that "the horizon of workable coals near the Muir tunnel, east of Bozeman, [Bozeman Pass, 5 miles west of Cokedale] is without question lower than the Laramie formation to which the lignitic coals of the Rocky Mountain region have generally been referred." However, Weed (1893, p. 18) again assigned the coal-bearing formation at Livingston to the Laramie Formation, partly on the basis of Knowlton's work and partly because of the conformable relation with underlying rocks (Telegraph Creek Formation) which he believed to be of Montana age. The basal massive sandstone (Virgelle Sandstone Member of the Eagle Sandstone) was assigned by Weed (1893, p. 19) to the Fox Hills Sandstone. The Laramie Formation, according to Weed (1893, p. 34), was overlain unconformably by his Livingston Formation. T. W. Stanton (in Stone and Calvert, 1910, p. 659–660) identified marine fossils of early Montana age from beds at the base of the coal-bearing formation east of the Bridger Range and correlated the formation in that area with the Eagle Sandstone in the northern part of the Crazy Mountains basin, where the Eagle had been established by Stone (1909, p. 78).

The first comprehensive study of a megafauna from the Eagle Sandstone and related formations in the western interior of the United States was made by Reeside (1927). Collections from localities north of Livingston containing a marine fauna were assigned to the lower part of the Montana Group of the Upper Cretaceous (Reeside, 1927, p. 1).

The Eagle Sandstone in the Livingston coal field contains a few sporadic poorly preserved *Inoceramus* sp. and *Ostrea* sp. To the north, in SE¼ sec. 24, T. 4 N., R. 7 E., J. R. Gill and the author collected *Inoceramus* sp., *Ostrea* sp., *Crassatella* sp., and *Tellina* sp. from the Eagle Sandstone. G. D. Fraser (written commun., 1961) collected the following fossils, which were identified by W. A. Cobban, from the upper part of the Eagle near Gardiner, Mont., 0.9 mile east-southeast of the mouth of the Gardiner River on the south bank of the Yellowstone River: *Inoceramus* sp., *Ostrea coalvillensis* Meek, and *Cymbophora arenaria* (Meek)?. According to Cobban (written commun., 1961), this fauna indicates that the top of the Eagle Sandstone at Gardiner is no younger than the lower part of the Eagle of central Montana and that even an older age is possible. The Eagle Sandstone in the Livingston coal field is considered by the author to be the same age as the Eagle at Gardiner, as the two localities are on the depositional strike of the formation. Correlation and stratigraphic relations of the Eagle Sandstone of the Livingston area with rocks of other areas in Montana and Wyoming are shown in figure 5.

COAL DEPOSITS IN THE EAGLE SANDSTONE

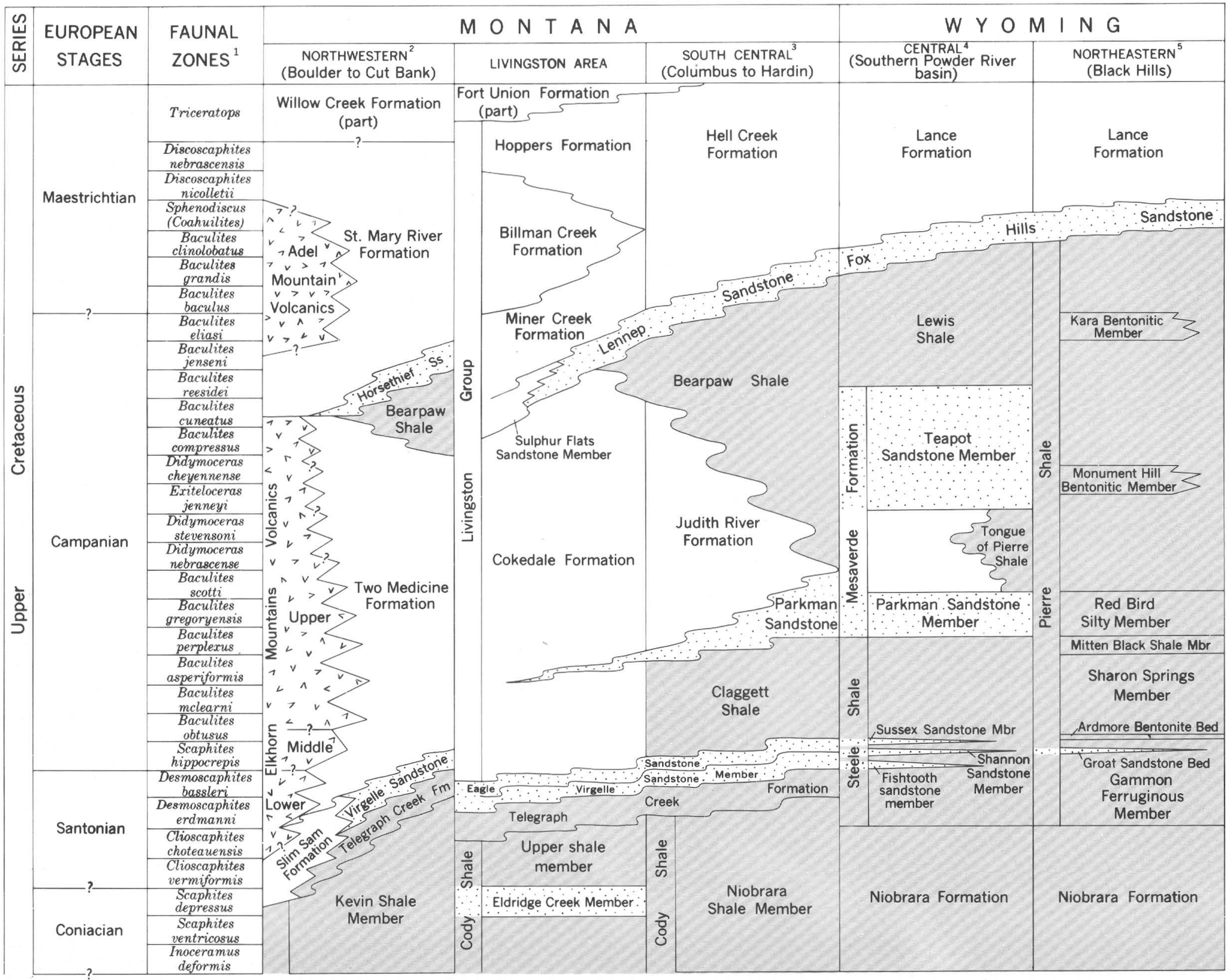
The Livingston coal field is a T-shaped approximately 35-square-mile area between Livingston and Bozeman. The coal field was formerly much larger than at present; however, uplift and folding accompanied by erosion in the northern part of the Gallatin Range has left comparatively small segments of coal-bearing rocks—generally in a narrow belt along the flanks of the large anticlines and in the narrow troughs of the synclines (pl. 1). Considerable faulting and folding took place during this interval of Late Cretaceous and early Tertiary orogeny. Few coal beds dip less than 30°, and most dip much more; in several localities the beds are overturned. As a result of the faulting and folding, much crushing of the coal took place; hence, in each mine the large amount of slack was a serious drawback for marketing the coal.

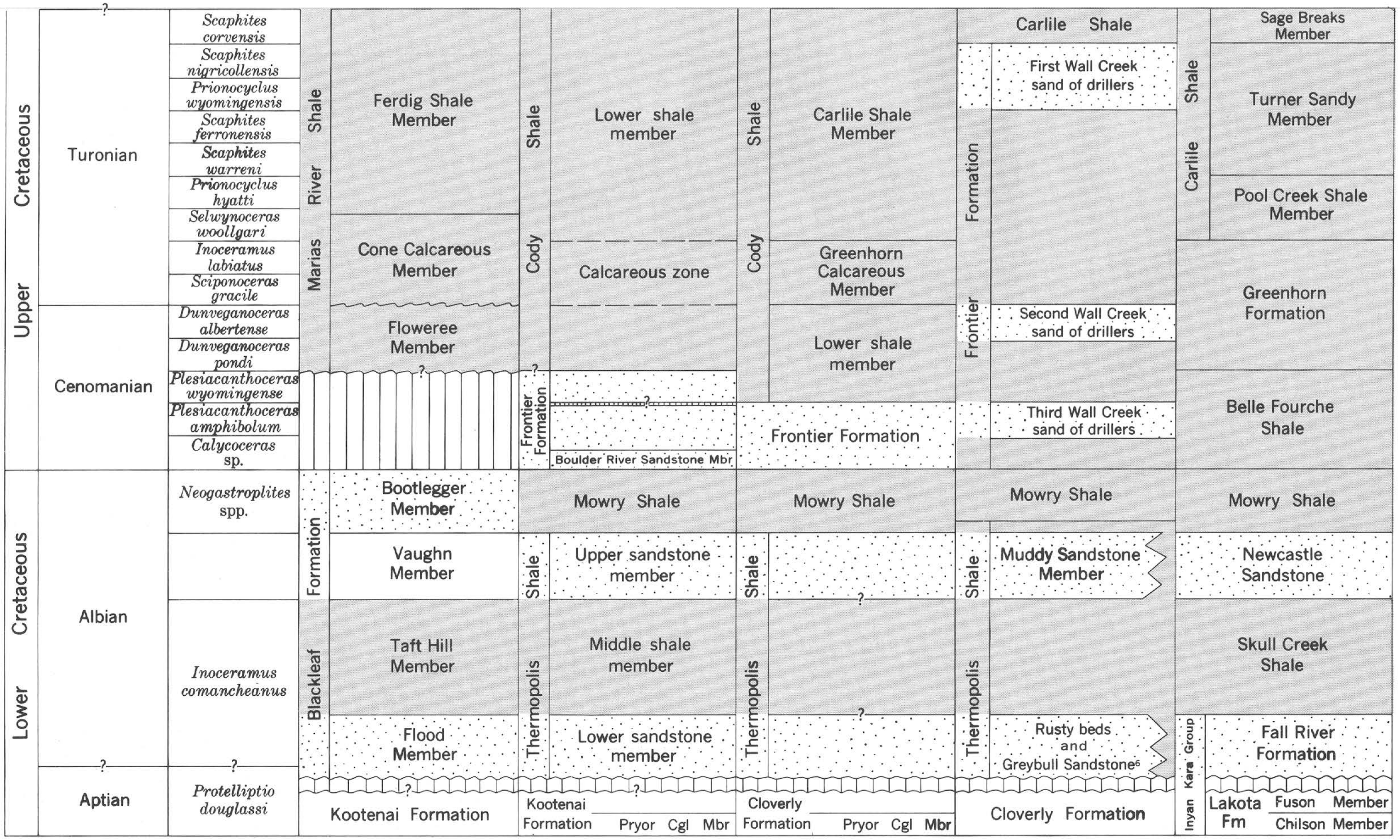
Coal was originally widespread in the Eagle Sandstone in southwestern Montana. Coal beds in the Eagle were mined or prospected from Livingston eastward to the Albertson mine, near Dean (Calvert, 1916, p. 207); northward to the Musselshell River, near Shawmut (Stone, 1909, p. 81–87); and southward to the Electric coal field, near Gardiner (Calvert, 1912b).

Coal beds were most extensively developed near Livingston and south to the Electric coal field. East of Livingston the coal beds in the Eagle Sandstone that were exposed in many prospects indicate that the beds become thinner and have more clastic partings. No large producing mines were developed there (Calvert, 1916; Richards, 1957, p. 418). North of Livingston, in the western part of the Crazy Mountains basin, considerable prospecting took place, but no producing mines were developed (Stone, 1909). The coal beds are thinner, have more partings, and have been broken and crushed by folding and faulting. The existence of quality coal in commercial quantities seems very unlikely in this area.

STRATIGRAPHIC POSITION AND CHARACTER OF COAL BEDS

Most coal beds in the Livingston coal field occur in two well-defined zones, designated the upper and lower coal zones (Roberts, 1957, p. 42). These zones represent coal-bearing coastal-swamp deposits laid down during regressive stages of the Eagle sea in much of southwestern Montana. These two zones are more persistent than any of the individual coal beds. The thickness of individual beds ranges from a few inches to more than 10 feet, but it averages 3–4 feet. Coal-bed outcrops and zones and localities measured and sampled are indicated on plate 1. These measured sections, arranged stratigraphically, are shown on plates 3 and 4. The coal beds in these zones are intercalated with carbonaceous shale, siltstone, and sand-


SERIES
EUROPEAN STAGES
FAUNAL ZONES[1]
MONTANA
NORTHWESTERN[2] (Boulder to Cut Bank)
LIVINGSTON AREA
SOUTH CENTRAL[3] (Columbus to Hardin)
WYOMING
CENTRAL[4] (Southern Powder River basin)
NORTHEASTERN[5] (Black Hills)
Upper Cretaceous
Maestrichtian
Campanian
Santonian
Coniacian
Triceratops
Discoscaphites nebrascensis
Discoscaphites nicolletii
Sphenodiscus (Coahuilites)
Baculites clinolobatus
Baculites grandis
Baculites baculus
Baculites eliasi
Baculites jenseni
Baculites reesidei
Baculites cuneatus
Baculites compressus
Didymoceras cheyennense
Exiteloceras jenneyi
Didymoceras stevensoni
Didymoceras nebrascense
Baculites scotti
Baculites gregoryensis
Baculites perplexus
Baculites asperiformis
Baculites mclearni
Baculites obtusus
Scaphites hippocrepis
Desmoscaphites bassleri
Desmoscaphites erdmanni
Clioscaphites choteauensis
Clioscaphites vermiformis
Scaphites depressus
Scaphites ventricosus
Inoceramus deformis
Willow Creek Formation (part)
St. Mary River Formation
Adel Mountain Volcanics
Horsethief Ss
Bearpaw Shale
Two Medicine Formation
Elkhorn Mountains Volcanics
Upper
Middle
Lower
Virgelle Sandstone
Telegraph Creek Fm
Slim Sam Formation
Kevin Shale Member
Fort Union Formation (part)
Hoppers Formation
Billman Creek Formation
Miner Creek Formation
Livingston Group
Sulphur Flats Sandstone Member
Cokedale Formation
Eagle
Virgelle
Sandstone
Sandstone
Member
Creek
Formation
Telegraph
Upper shale member
Eldridge Creek Member
Cody Shale
Hell Creek Formation
Lennep Sandstone
Bearpaw Shale
Judith River Formation
Parkman Sandstone
Claggett Shale
Niobrara Shale Member
Lance Formation
Fox Hills Sandstone
Lewis Shale
Mesaverde Formation
Teapot Sandstone Member
Tongue of Pierre Shale
Parkman Sandstone Member
Steele Shale
Sussex Sandstone Mbr
Shannon Sandstone Member
Fishtooth sandstone member
Niobrara Formation
Pierre Shale
Kara Bentonitic Member
Monument Hill Bentonitic Member
Red Bird Silty Member
Mitten Black Shale Mbr
Sharon Springs Member
Ardmore Bentonite Bed
Groat Sandstone Bed
Gammon Ferruginous Member
Niobrara Formation



[1] Modified from Cobban (1958), Zapp and Cobban (1960), and Cobban (1962a, 1962b).

[2] Modified from Lyons (1944), Klepper, Weeks, and Ruppel (1957), Cobban and others (1959), Schmidt and Zubovic (1961), W. A. Cobban (oral communication, 1962), M. R. Klepper (oral communication, 1962), and R. G. Schmidt (oral communication, 1964).

[3] Modified from Hancock (1918) and Richards (1955).

[4] Modified from Horn (1955) and Cobban (1958).

[5] Modified from Spivey (1940), Cobban (1958), Robinson, Mapel, and Cobban (1959), Gill and Cobban (1961, 1962), and Knechtel and Patterson (1962).

[6] As used by Eicher (1960).

EXPLANATION

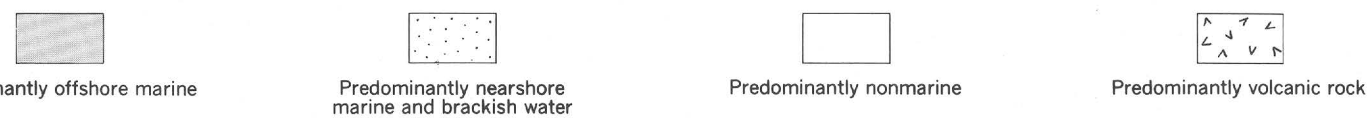


FIGURE 5.—Correlation and stratigraphic relations of Cretaceous rocks in the Livingston area and other areas in Montana and Wyoming.

stone; a band of coal at any one locality may change to bone and (or) carbonaceous shale within a short distance laterally. Correlation and lateral variations of the coal beds of the two zones throughout the coal field are also shown on plates 3 and 4. Coal-bed names are those used by the miners during mining operations. All the coal beds vary in thickness laterally (pl. 2); the frequent change in thickness is in part due to the original depositional character and in part due to postdepositional tectonic alteration.

The upper coal zone contains the Cokedale, Paddy Miles, Storrs No. 3, and one or more unnamed coal beds (pl. 2). Of these, the Cokedale is the thickest and of the best quality. It contains fewer partings, is more persistent over a wider area, and is generally of coking quality. This bed was extensively mined at Cokedale, Timberline, and Chestnut.

The lower coal zone contains the Middle, Maxey, Big Dirty, and four or more unnamed lenticular coal beds (pl. 2). Of these, the Maxey bed has been the largest producer.

In 1907 J. W. Groves collected samples from the Washoe Coal Co. No. 3 mine (Belden and others, 1909, p. 14). Their samples 166–D and 167–D were probably collected from the Cokedale bed, as is indicated by the distance from the portal to the location from which the two samples were collected; and the 40-ton run-of-mine sample must have been from the Storrs No. 3 bed, which was the main bed being mined at the time (pl. 5). The bed assignment is also supported by the large difference in British thermal units between the two mine samples and the run-of-mine sample (Belden and others, 1909, p. 15). Coal from the Cokedale bed is 100–200 Btu higher than that from the Storrs No. 3 bed in this district. The run-of-mine sample was used in three washing tests (table 3) and four coking tests (tables 4, 5).

COKEDALE DISTRICT

The Cokedale district lies along the strike of the coal beds on the northeast flank of the Canyon Mountain anticline in secs. 21–28, T. 2 S., R. 8 E., and secs. 27–30, T. 2 S., R. 9 E. Most mines in the district were developed near Cokedale along the drainages of Miner and Eldridge Creeks. The location and extent of the district, the location of the mines and measured coal sections, and the relative position of the coal beds and the general structure are shown on plate 1. The geology of the district was mapped in detail by Roberts (1964c, d). The area is accessible from U.S. Highway 10 by the Cokedale road, constructed on the abandoned grade of the Cokedale Branch of the Northern Pacific Railway Co.

The Eagle Sandstone in the Cokedale district contains six principal coal beds (fig. 4): the Cokedale bed (miners refer to it as the Cokedale or Cokedale No. 5); the Paddy Miles bed (referred to as the Cokedale No. 4); the Storrs No. 3, which was unnamed; the Middle bed (the Cokedale No. 3 or the Little bed); the Maxey bed (the Cokedale No. 2); and the Big Dirty bed (the Big Dirty or Cokedale No. 1). In the district the Cokedale, Paddy Miles, Middle, and Big Dirty beds were mined. Only the Cokedale was mined extensively, however.

The Big Dirty bed in this district is immediately above the Virgelle Sandstone Member and consists of carbonaceous shale and lenticular layers of impure coal, siltstone, and fine-grained sandstone. The bed ranges in thickness from 16 to 45 feet. It was prospected along its strike in secs. 27, 28, and 29, T. 2 S., R. 9 E.; however, the only known development was at the Williams mine (loc. 67, pl. 1).

The Maxey bed at Cokedale, which is 100 feet stratigraphically above the Big Dirty bed in this district, ranges in thickness from 1 to 2 feet. This bed has had no commercial development.

The Middle bed, 23 feet above the Maxey bed in this district, ranges in thickness from a few inches to 5½ feet and averages 3½ feet near Cokedale (locs. 28–30, pl. 3). The Cokedale No. 3 mine, SW¼ sec. 22, T. 2 S., R. 8 E. (near loc. 29, pl. 1), was developed on this bed in the early 1900's. Later, the Hubbard mine, SE¼ sec. 21, T. 2 S., R. 8 E., also produced coal from this bed. The most recent work in the Cokedale area was on the Middle bed at the McCormick prospect (loc. 28), SW¼ sec. 22, which was opened in 1955 and abandoned in 1956.

The Storrs No. 3 bed, at Cokedale, is 330 feet above the Middle bed and consists of upper and lower benches, each 2 feet thick, separated by 7 feet of carbonaceous siltstone. Although this bed was prospected throughout secs. 22–24 and 26, T. 2 S., R. 8 E., it was not developed commercially because it is thin and lenticular and has many partings.

The Paddy Miles bed in the Cokedale district is 26 feet stratigraphically above the Storrs No. 3 bed. Its thickness, which changes abruptly, ranges from 1 to 7 feet (locs. 27, 54, pl. 3). The bed was mined in the Cokedale No. 2 mines from the James entry, but production was small. The Paddy Miles bed was prospected throughout secs. 22–24 and 26, T. 2 S., R. 8 E., but no coal was produced because the beds are thin and lenticular and have many partings. In the lower workings of the Cokedale No. 1 mines, a crosscut revealed that the Paddy Miles bed contained coking coal, but the bed was too thin to be mined.

The Cokedale bed in this district is 11 feet above the Paddy Miles bed and is 2–9 feet thick. Throughout the northern part of the Livingston coal field, the

FIGURE 6.—Cokedale coal bed near main entry at Cokedale No. 1 mines in the Livingston coal field (loc. 54, pl. 1) showing general attitude and characteristic parting 1½ feet below top of the bed.

Cokedale bed contains a carbonaceous siltstone parting 1–2 feet below the top of the bed (fig. 6). At Cokedale the coal below this parting coked better than the coal above, and in places this upper bench was left in the roof. The Cokedale bed was the source of most coal and the only large source of coking coal mined in the district as well as in the entire Livingston coal field. The Cokedale Nos. 1 and 2, Sulphur Flats, Spangler, Kangley, Johnson, Buckskin, and the Northern Pacific Coal Co. mines all produced coal from this bed.

TIMBERLINE DISTRICT

West of the Cokedale district are mines and prospects of the Timberline district, in secs. 23–26, T. 2 S., R. 7 E., and secs. 30–32, T. 2 S., R. 8 E. (pl. 1). In contrast to the extensive faulting near the western part of the Cokedale district, the coal beds are tightly folded in the Eldridge Creek syncline. West of the syncline the coal beds encircle the northern plunge of the Center Hill anticline, and the Timberline mines and prospects are along the strike of the beds. Stratigraphy of the beds is shown on plate 3, and the geology of the district was mapped in detail by Roberts (1964e, h). Exploration in this district was concentrated on the Cokedale and Paddy Miles beds in the upper coal zone (pl. 2).

The Cokedale bed was the largest coal source in the Timberline district, and the Timberline No. 3 mine on this bed was one of the largest producers in the Livingston coal field. The bed is 4½–17 feet thick and generally contains many partings (locs. 11–75, pl. 3). The Cokedale and Paddy Miles beds united at one part of the workings in the Timberline No. 3 mine; this resulted in nearly 20 feet of good coal, which was called the Bonanza bed. All mines of the Timberline district were on the Cokedale bed.

The Paddy Miles bed is 3–4 feet thick and has a 2-foot-thick rider 4 feet above the main bed (pl. 3). The bed is thickest near Timberline. At the Timberline No. 3 mine and southward, the bed contains many partings. Near the Timberline No. 1 and Pendleton mines, the Paddy Miles bed contained 4 feet of good coal. Although this bed was proved commercial, it was not developed because of its proximity to the thicker Cokedale bed.

The Storrs No. 3 bed in this district, referred to by local miners as the Penman bed, is thin and impure and contains many partings. It was not developed commercially, although at the Timberline No. 3 mine it was 2 feet thick, including two partings (pl. 3, loc. 11).

Coal beds in the lower coal zone in the Timberline district are lenticular and contain many partings. Also, they crop out near the bottom of the valley and, therefore, are more costly to mine. Thus, there was little exploration and no development of these beds.

MEADOW CREEK DISTRICT

The Meadow Creek district, T. 2 S., R. 7 E., is west of the Timberline district and north of the Trail Creek district. The boundary between this district and the Timberline district in this study was established on the basis of difference in the directions of coal transportation. The boundary between the Meadow Creek and Trail Creek districts was near the drainage divide between the two creeks. Many mines and prospects of the Meadow Creek district are along or near the drainages of Meadow and Rocky Creeks. The location and extent of the district, the location of the mines and measured coal sections, the relative position of the coal beds, and the general structure are shown on plate 1. The geology of the district was mapped in detail by Roberts (1964e, f, h).

The Meadow Creek district flanks the south end of the Meadow Creek syncline and the north ends of the Storrs anticline, Goose Creek syncline, and Chestnut Mountain anticline. On the north end of Chestnut Mountain, the Meadow Creek district is bounded by a large fault that parallels the axis of the Kelly Canyon syncline. As a result of these folds and related minor folds and faults, structure of the district is complex.

The dip of the coal-bearing rocks throughout the district is steep—generally more than 45°—and in many places is nearly vertical. In the largest continuous underground workings (the Rocky Canyon mine), the dip of the coal ranged from 60° to 86° NE. and probably averaged about 80°.

Several diabase dikes intrude the coal-bearing rocks in this district. In sec. 28, T. 2 S., R. 7 E., a dike intruded along the axis of the Goose Creek syncline and formed a barrier between the mines on both flanks of the syncline. A dike in sec. 21, T. 2 S., R. 7 E., created areas of natural coke.

The six principal coal beds of the Eagle Sandstone are present in the Meadow Creek district (pl. 2), and all but the Middle bed have been extensively mined or prospected.

The Big Dirty bed ranges in thickness from 10 to 25 feet and consists of alternate bands of coal, bone, and carbonaceous shale. The only mines that produced coal from the Big Dirty bed were the Moran and the Washoe Coal Co. No. 4 (pl. 1). Several bands of coal in the Washoe Coal Co. No. 4 mine yielded coke of superior quality; however, they were too thin to be economic.

The Maxey bed is about 90 feet stratigraphically above the Big Dirty bed in this district. It is 2–8 feet thick in the southern part of the district but contains many partings; it thins northward, and near Chestnut it is less than 1 foot thick (pl. 2). The bed was worked in the Harrison, Monroe, and Planishek mines—all very small producers.

The Middle bed, 130 feet stratigraphically above the Maxey bed, consists of 3–10 feet of dirty coal and many partings. It was not commercially developed.

The unnamed bed at the base of the upper coal zone near Chestnut may correlate with the Bottamy bed in the Trail Creek district. This bed was prospected northwest of Chestnut but was not mined.

The Storrs No. 3 bed, 250 feet stratigraphically above the Middle bed in the Meadow Creek district, is 8–9½ feet thick, including 5–10 partings (locs. 7–39, pl. 4). The bed is thick and contains few partings near the community of Storrs; it was referred to as the Storrs No. 3 by the Washoe Coal Co. No. 3 miners. Other mines in the district that worked this bed were the Payne, Miller No. 1, Meadow Creek Nos. 2 and 3, Whitehead-Robinson, and Harris-Murphy (pls. 4, 5).

The Paddy Miles bed is 75–110 feet stratigraphically above the Storrs No. 3 bed in the Meadow Creek district. The bed generally is 3½–6 feet thick; however, in the crosscut driven from the north end of the workings on the Storrs No. 3 bed in the Washoe Coal Co. No. 3 mine (pl. 5), the bed where first encountered was 12 feet thick, of which 7–9 feet was coal. Extensive exploration to the north in this mine proved that such thickening was local. The Paddy Miles bed, in most places, has a parting near the middle composed of 2–6 inches of soft white sandstone interbedded with as much as 18 inches of coal and bone. The bed was extensively prospected in the vicinity of Storrs but was not mined.

The Cokedale bed in the Meadow Creek district is 0–95 feet stratigraphically above the Paddy Miles bed. The interval between these beds decreases northward, and at Chestnut the two unite (loc. 1, pl. 4). The Cokedale bed is 2½–18½ feet thick and contains several clastic partings and layers of bone. Northwest of the Chestnut mine the thickness of the bed decreases, and the number and thickness of clastic partings increase. North of the Bailey and Beadle mine, the bed seems to be merely a carbonaceous zone. The Cokedale bed was the source of most of the coal mined in the district. The Rocky Canyon (Chestnut), Mountain Side, Maxey, Bailey and Beadle, Hodson, Miller No. 2, Meadow Creek No. 1, and Lasich mines all produced coal from this bed.

TRAIL CREEK DISTRICT

The Trail Creek district joins the Meadow Creek district to the south and includes parts of Tps. 3 and 4 S., R. 8 E. In the northern part of the district, the coal-bearing Eagle Sandstone is confined to the trough of the Trail Creek syncline; in the southern part the coal-bearing rocks crop out southeastward, then westward, around the foothills to the Pine Creek syncline. The location and extent of the district, the location of the mines and measured coal sections, and the relative positions of the coal beds and faults are shown on plate 1. The geology of the district was mapped in detail by Roberts (1964b, e).

Center Hill, Pine Mountain, and the Hogback flank the district on the northeast. They form a high narrow range composed predominantly of upper Paleozoic rocks. A lesser range, composed mostly of Cretaceous and lower Tertiary rocks, lies to the south.

The structure of the Trail Creek district is complex and, because much of the coal-bearing strata is concealed and the mines and prospects are caved, many of the fault locations can only be approximated. Eldridge (1886, p. 748) first mentioned that the coal along Trail Creek was in a small synclinal remnant of the original deposit. Storrs (1902, p. 464) briefly referred to this district as a small synclinal basin in which the strata were overturned along the east edge. Calvert (1912a, p. 391) said that the coal occurred in a syncline bounded on the northeast side by two large (presumably normal) faults. Skeels (1939, p. 829) reinterpreted the faults described by Calvert to be one large thrust fault. Geologic mapping in the Maxey Ridge quadrangle (Roberts, 1964e) indicated that the fault dips 60°–90° NE. over most of its length; therefore, it is shown as a high-angle reverse fault (pl. 1). The coal beds in the northwest limb of the syncline adjacent to this fault are overturned.

On the north side of Trail Creek in the northern part of the district, the beds generally dip 45° NE.

They are upright west of the synclinal axis and ovreturned east of the axis. In the southern part near Trail Creek, dips vary considerably, and some beds are vertical. Several large normal faults were mapped near the Maxey Bros. mines; a diabase dike parallels and, doubtless, intrudes one of these faults in secs. 18–19, T. 3 S., R. 8 E. (pl. 1). Between Trail and Pine Creeks the district lies mostly in the irregular Pine Creek syncline, whose axis roughly parallels the Trail Creek syncline; the larger faults bound the lower valley of Trail Creek (pl. 1). The coal beds in the Livingston coal field that have the lowest recorded dips are those in the Pine Creek syncline.

Correlation of the coal beds in the Trail Creek district is very difficult because of the complex structure, erosion of the beds in the upper coal zone, and abrupt physical changes in all the beds. In the Mountain House mine at Hoffman, the upper coal zone—with the exception of the sequence between the Paddy Miles and Cokedale beds—is alternately layered coal and carbonaceous clastic rock (loc. 82, pl. 4). Designation of beds is by the interval at which they are mined, and correlation is based on their stratigraphic position and consistent clastic beds. The coal layers between the designated beds are generally discontinuous or lenticular.

The Big Dirty bed was prospected throughout the district but was not mined. The bed is 6–12 feet thick and consists of alternate bands of carbonaceous shale and impure coal.

The Maxey bed is the thickest and has fewer partings in the Trail Creek district, particularly near the Maxey Bros. mines (loc. 88, pl. 4). The Maxey coal bed at the Maxey Bros. mines is 9 feet thick and has two small partings 5–6 feet from the base. The bed thins progressively to the north and is only 1½ feet thick at the Monroe mine. The Maxey bed, which is 20–50 feet stratigraphically above the Big Dirty bed (pl. 2), was the source of most of the coal mined in the district.

The middle coal bed in this district is 40–90 feet stratigraphically above the Maxey bed. The bed is 3½ feet thick in the Gasaway tunnel; 7 feet thick at the Maxey Bros. mines (loc. 89, pl. 4); 5 feet thick 1 mile south of the Maxey Bros. mines (loc. 90, pl. 4); and 7 feet thick in Maxey Bros. drill hole MB–2 in sec. 3, T. 4 S., R. 8 E. The bed contains several partings (pl. 4); however, minable thicknesses of coal are present.

The Bottamy bed, 75 feet stratigraphically above the Middle bed, is thickest in the southern part of the Trail Creek district. It may correlate with the unnamed bed at the base of the upper coal zone near Chestnut. The Bottamy bed is 4–6 feet thick and contains several partings (locs. 91–95, pl. 4). Only the Bottamy Nos. 1 and 2 mines, near Pine Creek (pl. 1), produced coal from this bed.

The Storrs No. 3 bed is approximately 120 feet stratigraphically above the Bottamy bed in this district and consists of alternate bands of coal, bone, carbonaceous shale, and sandstone (pl. 1). Just north of the Sheep Corral workings of the Mountain House mine, this bed splits (loc. 79, pl. 4); in the southern workings of the Mountain House mine, the upper and lower splits of this bed are 30 feet apart. The bed ranges in thickness from 5 feet to more than 37 feet near Hoffman and from 7 to 8 feet near Chimney Rock; it contains many partings (locs. 82, 83, 87, pl. 4). The largest producer on the Storrs No. 3 bed in the Trail Creek district was the Mountain House mine. The Stevenson and Kountz mines also produced coal from this bed. Miners of the Sheep Corral workings of the Mountain House mine referred to this bed as the "Peacock" bed, owing to its iridescence.

The Paddy Miles bed is 4–25 feet above the Storrs No. 3 bed and is 3–4 feet thick (pl. 4). The bed was exposed in workings of the Mountain House and Kountz mines, but no coal was mined.

Very little is known about the Cokedale bed in this district. Miners cut a 4-foot bed in a crosscut near the bottom of the main slope of the Mountain House mine, at the approximate stratigraphic position (70 ft above the Paddy Miles bed) of the Cokedale bed (loc. 82, pl. 4). So far as is known, no coal was mined from this bed in the Trail Creek district.

BRIDGER CANYON DISTRICT

The Bridger Canyon district is a coal-bearing area east of Bridger Canyon and north of the Meadow Creek district (pl. 1). This district has been prospected intermittently for coal; however, no mines were developed. Two coal beds 20–25 feet apart, which cross the SE¼ sec. 34 and the NW¼ sec. 35, T. 1 S., R. 6 E., are interbedded in massive indurated sandstones. The beds dip 30°–85° NE. and are overturned. Correlatives of these beds in the other districts of the Livingston coal field have not been identified; however, the beds are in the lower coal zone and are perhaps equivalent to the Big Dirty and Maxey beds. The geology of this district was mapped in detail by Roberts (1964f).

The lower bed, which is 4 feet thick including many thin partings of bone and clay, is soft and exceedingly dirty throughout. This bed has no economic value both here and for several miles north and south. In the NE¼SE¼ sec. 34, a horizontal drift was driven 300 feet north on the strike of the lower bed. The quality of the coal remained poor, and the prospect was abandoned. Similarly, about 500 feet south of Bridger

Creek, another tunnel was driven south along the strike of this bed and later was abandoned.

The upper bed is 6 feet thick and, like the lower bed, is soft and dirty; it contains five distinct partings of bone or brown dirty coal. The bed may, therefore, be described as a series of partings 4–12 inches thick, between which are dirty bands of soft coal.

RANK AND QUALITY OF THE COAL

In the United States, coals are ranked in accordance with a standard classification adopted by the American Society for Testing Materials (1955) (table 1).

The coals of the Livingston coal field are high-volatile A, B, and C bituminous in rank (Combo and others, 1949, p. 14) and are generally of coking quality. Chemical analyses of the coal beds are listed in table 2. Most of these analyses predate the improved laboratory techniques of today; however, they are the only available analyses and differ but very slightly from those prepared according to improved techniques. All the coal beds in the Livingston coal field have one or more partings, and the mined coal must be washed to obtain a product with a sufficiently low ash content. Differences in chemical analyses of washed and unwashed coal samples from the Storrs No. 3 coal bed are listed in table 3.

The physical and chemical characters of the coal beds of the Livingston coal field vary greatly in different parts of the field primarily owing to conditions of formation. Tectonic deformation also affected the quality of the coal throughout the field. Local differences are so pronounced that, were it not for the evidence of the containing strata, correlation would be most difficult. The coal has been crushed in many areas by folding and faulting, and mines in these areas produced a large amount of fine-sized coal that was not of economic value at the time.

During the peak period of exploration in the Livingston coal field, Eldridge (1886, p. 748–750) examined the coal exposed in the many prospects and mines and observed the local variation from solid blocks to friable slickensided chips. This variation in the character of

TABLE 1.—*Classification of coals by rank*

[Standard Classification adopted by the American Society for Testing Materials (1955, p. 1022)]

Explanation: FC, fixed carbon; VM, volatile matter; Btu, British thermal units. This classification does not include a few coals which have unusual physical and chemical properties and come within the limits of fixed carbon or Btu of the high-volatile bituminous and subbituminous ranks. All these coals either contain less than 48 percent dry mineral-matter-free fixed carbon or have more than 15,500 moist mineral-matter-free Btu.

Class and group	Limits of fixed carbon or Btu mineral-matter-free basis	Requisite physical properties
I. Anthracitic:		
1. Meta-anthracite	Dry FC, 98 percent or more (dry VM, 2 percent or less)	
2. Anthracite	Dry FC, 92 percent or more and less than 98 percent (dry VM, 8 percent or less and more than 2 percent).	
3. Semianthracite	Dry FC, 86 percent or more and less than 92 percent (dry VM, 14 percent or less and more than 8 percent).	Nonagglomerating.[1]
II. Bituminous [2]:		
1. Low-volatile bituminous coal	Dry FC, 78 percent or more and less than 86 percent (dry VM, 22 percent or less and more than 14 percent).	
2. Medium-volatile bituminous coal	Dry FC, 69 percent or more and less than 78 percent (dry VM, 31 percent or less and more than 22 percent).	
3. High-volatile A bituminous coal	Dry FC, less than 69 percent (dry VM, more than 31 percent); and moist [3] Btu, 14,000 [4] or more.	
4. High-volatile B bituminous coal	Moist [3] Btu, 13,000 or more and less than 14,000 [4]	
5. High-volatile C bituminous coal	Moist Btu, 11,000 or more and less than 13,000 [4]	Either agglomerating or nonweathering.[5]
III. Subbituminous:		
1. Subbituminous A coal	do.[4]	Both weathering and nonagglomerating.
2. Subbituminous B coal	Moist Btu, 9,500 or more and less than 11,000 [4]	
3. Subbituminous C coal	Moist Btu, 8,300 or more and less than 9,500 [4]	
IV. Lignitic:		
1. Lignite	Moist Btu, less than 8,300	Consolidated.
2. Brown coal	do	Unconsolidated.

[1] If agglomerating, classify in low-volatile group of the bituminous class.

[2] Noncoking varieties may occur in each group of the bituminous class.

[3] Moist Btu refers to coal containing its natural bed moisture but not including visible water on the surface of the coal.

[4] Coals having 69 percent or more fixed carbon on the dry mineral-matter-free basis shall be classified according to fixed carbon, regardless of Btu.

[5] There are three varieties of coal in the high-volatile C bituminous coal group—namely, variety 1, agglomerating and nonweathering; variety 2, agglomerating and weathering; variety 3, nonagglomerating and nonweathering.

the coal resulted, in part, from varying lateral readjustments in the coal beds during the folding. The folding and shearing that took place in the coal beds in this area are excellently indicated by the numerous contorted partings at an exposure of the Big Dirty bed, NW¼NW¼ sec. 26, T. 2 S., R. 8 E. (fig. 3). The chippy coal was easily mined by pick, whereas most of the blocky coal required undercutting and blasting.

The upper coal zone beds generally consist of bright-banded coal having a prismatic cleat. Beds in the lower coal zone generally include bright- and dull-banded coal having a blocky to platy cleavage. Most coal beds in both zones contain impurities and widespread shale or clay partings.

Coking properties of coal vary between beds and within a bed. The localities that yielded good coke are along the flanks of the anticlines. Coal from synclines and the plunging end of the anticlines yielded poor coke or would not coke. The synclines are much tighter than the anticlines, and the plunging end of the anticlines is much more faulted than are the flanks (pl. 1). Thus, coal having the best coking properties is found in areas of the least tectonic influence in the Livingston coal field. This fact indicates that coking properties are probably gradually destroyed by the amount of cleavage, thereby permitting a greater surface of coal per volume to unite with oxygen.

All the coal mined at Cokedale from the Cokedale and Middle beds yielded coke; however, owing to the folding and shearing of the beds, many small partings became admixed with the coal, and washing was required to reduce the ash content. Samples of the Cokedale coke were well fused, fine grained, and of bright metallic luster. Smith [1] made the following proximate analysis of coke from a sample of the Middle bed taken from a pillar in the Cokedale No. 3 mine: Fixed carbon, 81.54 percent; volatiles, 1.96 percent; and ash, 16.50 percent.

During 1902–07 the Washoe Coal Co. invested nearly $1 million in developing mines and constructing facilities for producing coke at Storrs, Mont. The mines were along the strike of the coal beds in a tightly folded syncline. The coal was generally crushed or broken and admixed with some of the clastic partings; much of the clastic material could not be separated from the coal either during the mining or by washing. In 1908, just after the Washoe Coal Co's. operations closed, coking tests (table 4) and chemical analyses of the coke from the Storrs No. 3 coal bed (table 5) were made. These tests showed a high ash content, which could not be reduced within the 20-percent allowed limit for coke.

[1] Smith, G. R., 1954, Carbonization of Montana coal: Bozeman, Montana State College unpub. M.S. thesis, p. 36.

More than 20 localities in the Livingston coal field were examined radiometrically by Hail and Gill (1953, p. 2). No abnormal radioactivity was detected in the coals in the field, nor did any sample contain more than 0.002 percent uranium in the ash.

Comparison with coal from other coal fields in Montana.—The coal-bearing formations in Montana are of Jurassic, Cretaceous, and Tertiary age. The Fort Union Formation of Paleocene age contains more than 90 percent of the total State reserves (Combo and others, 1949, p. 3). Other coal-bearing units are the Morrison Formation of Late Jurassic age, the Eagle Sandstone and Judith River Formations of Late Cretaceous age, the Tullock Member of the Fort Union Formation of Paleocene age, and the Wasatch Formation of Eocene age. The average proximate analysis of coal from major beds in selected coal fields of Montana and a generalized stratigraphic section of coal-bearing formations (fig. 7) show that coal from the Livingston coal field is among the best in the State.

COAL PRODUCTION

Coal for local domestic use was produced in the Livingston coal field during the 1870's. The coal-mining industry of this field began in the early 1880's (U.S. Dept. Interior, 1886, p. 899) with the production of 224 short tons of coal from the Rocky Canyon mine. Coal mining in the Livingston field increased from 1880 to 1910 owing to the increased use of coal for railroad operations, domestic fuel, and smelting. Maximum annual production of 601,598 tons was recorded in 1895 (U.S. Geol. Survey, 1897, p. 552). In the early 1900's an improved method for smelting copper that required much less coke initiated the decline of coal production in this field. Also, coal production for railroad operations began to decline (ending in 1910) in the Livingston field, while production for railroad operations from mines at Red Lodge, Mont., increased. Production sharply declined from 1910 to 1916, the last year of record before World War I. After World War I, annual production was only a few thousand tons, or less, for domestic trade; and in some years no production was recorded. Open-pit coal mining in eastern Montana, which supplied most of the Montana coal market after 1924, discouraged redevelopment in the Livingston field. In response to local needs for lower cost domestic fuel during the depression of the 1930's, coal production in the Livingston field revived slightly, but by 1942 it had ceased. The total recorded coal production, in short tons, and its value in Gallatin and Park Counties are given in table 6; production of individual mines, if known, is given under the description of the mine.

TABLE 2.—*Chemical analyses of coals from the Livingston coal field, Montana*

[U.S. Bur. Mines analyses made before 1913 and bearing sample numbers below 16100 were made by methods for determining volatile matter and fixed carbon which were not standard with respect to temperature; consequently, determinations made before this date are not closely comparable with those made after 1913, when a standard temperature was adapted. Sources of data: Eldridge (1886, p. 780 and 782); Belden, Dalamater, and Groves (1909, p. 15); Calvert (1912a, p. 46); Lord and others (1913, p. 133); USBM (U.S. Bur. Mines, 1932, p. 48–49, 54–55). Kind of sample: M, mine; S, surface; T, tipple. Form of analysis: A, as received; B, dried until weight is constant; C, moisture free; D, moisture and ash free]

Location (sec.)	Mine or prospect	Coal bed	Source of data	Measured coal section No. on plate 1	Thickness of coal analyzed (in.)	Laboratory No.	Kind of sample	Form of analysis	Analyses, in percent: Proximate: Moisture	Volatile matter	Fixed carbon	Ash	Ultimate: Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Air-drying loss (percent)	Heating value (Btu)	Remarks
T. 2 S., R. 6 E.																				
13	Bailey and Beadle mine.	Cokedale	Calvert		38	6621	T	A	2.1	16.4	73.2	8.31	4.08	81.03	1.28	4.44	0.86		14,090	
								B	.6	16.7	74.3	8.44	3.97	82.26	1.30	3.16	.87	1.5	14,310	
								C		16.7	74.8	8.48	3.93	82.72	1.31	2.68	.88		14,390	
								D		18.3	81.7		4.29	90.39	1.43	2.93	.96		15,720	
T. 2 S., R. 7 E.																				
20	Thompson No. 2 prospect.	Cokedale	Eldridge	1	75	7	S	A	10.64	34.64	42.86	11.86					0.32	3.94		Excluding partings, aggregating.
					117	8	S	A	9.74	31.43	38.25	20.53					.40	3.16		Including bone and clay partings, aggregating.
	Chestnut mine rock tunnel.	Storrs No. 3	do	7	85	1	M	A	1.03	39.48	41.37	18.12					.64	1.02		5 benches, aggregating. Coke; good. Sample from intersection of tunnel and coal bed.
21	Rocky Canyon coal mine.	Cokedale	do		36	10	M	A	3.78	23.08	59.27	13.87					.66	.77		Sample location unknown.
					18	11	M	A	3.91	33.48	52.04	10.57					.46	.83		Coal cokes. Sample location unknown.
					12	2	M	A	.75	20.00	61.74	8.51					.66	.75		Upper middle bench. Sample location unknown.
					14	3	M	A	.80	14.68	71.56	12.96					.58	.19		Lower middle bench. Sample location unknown.
	Mountain Side mine.	do	Calvert			3667	M	A	5.4	27.0	37.0	30.63	4.24	50.58	0.81	13.41	.33		9,030	Sample location unknown.
								B	2.7	27.7	38.1	31.51	4.04	52.04	.83	11.24	.34		9,300	
								C		28.5	39.1	32.37	3.85	53.46	.86	9.11	.35	2.8	9,550	
								D		42.1	57.9		5.69	79.04	1.27	13.48	.52		14,120	
	Unnamed prospect	do	Eldridge	9	33	5	S	A	16.48	34.30	40.22	9.00					.36	3.61		Excluding partings.
				9	75	6	S	A	14.01	30.11	32.35	23.53					.27	4.94		Including clay partings.
	Unnamed prospect	Unnamed bed at base of upper coal zone.	do	10	23	4	M	A	1.58	42.11	48.66	7.65					.61	.82		3 benches of coal (total thickness 3 ft 7 in.) aggregating. Coke; good. Sample location unknown.
24	Timberline No. 1 mine.	Cokedale	do	15		[6]	M	A	3.02	36.14	43.45	17.39					.45	1.04		Sample from dump.
							M		5.48	5.84	77.89	10.79					.43	1.35		Analysis of the coke.
					43		M	A	1.83	38.35	50.20	9.62					.52	1.10		4 benches aggregating. Coke; good. Sampled at portal.
				16	18	9	M	A	9.37	35.70	49.77	5.16					.45	3.17		Upper bench. Sample from face 60 ft from portal.
					37	10	M	A	3.62	35.01	44.50	16.87					.43	1.06		Lower bench, excluding 2-in. parting. Sample from face 60 ft from portal.
				17	11	1	M	A	1.97	41.55	51.13	5.35					.54	.68		Top bench. Coke; good. Sample from face 195 ft from portal.
					8	2	M	A	1.76	29.38	26.28	42.58					.47	.52		Upper middle bench. Coke; poor. Sample from face 195 ft from portal.
					10	3	M	A	1.12	31.77	49.72	17.39					.45	.47		Middle bench. Coke; good. Sample from face 195 ft from portal.
					8	4	M	A	1.60	38.57	50.91	8.92					.57	1.08		Lower middle bench. Coke; good. Sample from face 195 ft from portal.
					4½	5	M	A	1.28	38.71	45.89	14.12					.59	1.13		Upper bottom bench. Coke; good. Sample from face 195 ft from portal.
					10	6	M	A	1.66	37.71	46.46	14.17					.52	1.43		Bottom bench. Coke; good, rather dense. Sample from face 195 ft from portal.

					11	7	M	A	1.13	41.18	53.91	3.78					.59	.97		Top bench. Coke; good but dense. Sample from face 220 ft from portal.
					7	8	M	A	1.69	25.30	21.81	51.20					.64	1.26		Upper middle bench. Sandy coke. Sample from face 220 ft from portal.
				18	20½	9	M	A	1.27	36.94	52.62	9.17					.58	1.08		Lower middle bench. Coke; fair. Sample from face 220 ft from portal.
					18	10	M	A	1.29	35.52	43.44	19.75					.52	1.11		Bottom bench. Coke; fair. Sample from face 220 ft from portal.
				19	48½	14	M	A	1.57	35.66	48.88	13.89					.58	.59		4 benches, aggregating. Coke; fair. Sample from face 231 ft from portal.
	Hyer's prospect	do	Eldridge	44	45½	13	M	A	8.20	34.18	45.15	12.47					.50	2.95		5 benches, aggregating. Sample from face 33 ft from portal.
					79	(6)	M	A	2.74	39.63	48.88	8.75					.65	1.18		9 benches, aggregating. Coke; good. Sampled at portal.
				45			M		4.48	9.82	76.25	9.45					.71	1.21		Analysis of the coke.
							M	A	1.99	37.76	47.43	12.82					.77	.88		Coke good. Sample location unknown.
					18	11	M	A	9.37	33.78	47.19	9.66					.42	2.75		Upper bench, excluding waste streaks. Sample from face 60 ft from portal.
				46	20	12	M	A	8.89	35.23	38.76	17.12					.46	2.65		Middle bench, excluding waste streaks. Sample from face 60 ft from portal.
					38	13	M	A	5.59	34.46	49.41	10.54					.49	1.71		Lower bench, excluding waste streaks. Sample from face 60 ft from portal.
					13	1	M	A	1.55	36.61	47.31	14.53					1.38	.89		Hanging-wall seam, top bench. Coke; good, but dense. Sample from face 200 ft from portal.
					12	3	M	A	1.56	37.25	49.41	11.78					.56	.72		Hanging-wall seam, lower top bench. Coke; good. Sample from face 200 ft from portal.
25	Timberline No. 6 mine.	do	do		4	4	M	A	1.35	30.45	43.22	24.98					.45	.73		Hanging-wall seam, upper middle bench. Coke; rather poor. Sample from face 200 ft from portal.
					5	5	M	A	1.46	39.15	47.26	12.13					.57	.73		Hanging-wall seam, middle bench. Coke; good, but dense. Sample from face 200 ft from portal.
					4	6	M	A	1.09	39.11	43.79	16.01					.55	.74		Hanging-wall seam, lower middle bench. Coke; good. Sample from face 200 ft from portal.
				47	4	7	M	A	1.98	36.47	48.94	12.61					.91	.96		Hanging-wall seam, bottom bench. Coke; good. Sample from face 200 ft from portal.
					4	8	M	A	1.54	39.89	49.92	8.65					.67	.64		Footwall seam, top bench. Coke; good. Sample from face 200 ft from portal.
					7½	9	M	A	1.68	39.98	48.78	9.56					.84	.87		Footwall seam, upper middle bench. Coke; good. Sample from face 200 ft from portal.
					8	10	M	A	1.87	36.60	47.96	14.17					.62	.93		Footwall seam, lower middle bench. Coke; good, but dense. Sample from face 200 ft from portal.
					14	11	M	A	1.92	38.45	50.11	9.52					.64	1.92		Footwall seam, bottom bench. Sample from face 200 ft from portal.
								A	4.85	29.98	36.45	28.72					.51			
								B	1.91	30.91	37.57	29.61					.53	3.0		
			Belden and others; Calvert.	40	60	166-D	M	C		31.51	38.30	30.19					.54			Sample from face 4,600 ft from portal.
	Washoe Coal Co. No. 3 mine.	Cokedale						D		45.2	54.8						.80			
								A	4.01	34.54	45.48	15.97					.51		11,860	
			Beldon and others; USBM.	41	73	167-D	M	B	2.05	35.24	46.41	16.30					.52	2.0		Sample from face 4,000 ft from portal.
26								C		35.98	47.38	16.64					.53		12,355	
								D		43.16	56.84						.64		14,821	
								A	5.8	33.1	50.5	10.57	5.38	69.23	1.01	13.31	.50		12,280	
	Hodson mine	do	Calvert	42	37	6597	M	B	2.0	34.5	52.5	10.99	5.16	71.96	1.05	10.32	.52	3.8	12,770	Sample from pillar between rooms 1 and 2.
								C		35.2	53.6	11.22	5.03	73.47	1.07	8.68	.53		13,030	
								D		39.6	60.4		5.67	82.75	1.21	9.77	.60		14,680	
								A	6.25	32.41	45.65	15.69	5.20	63.35	.91	14.41	.44	4.5	11,455	
35	Washoe Coal Co. No. 1 mine.	Paddy Miles	USBM			3691	M	C		34.57	48.69	16.74	4.81	67.58	.97	9.43	.47		12,218	Sample location unknown.
								D		41.52	58.48		5.78	81.16	1.16	11.34	.56		14,675	

See footnotes at end of table.

TABLE 2.—*Chemical analyses of coals from the Livingston coal field, Montana*—Continued

Location (sec.)	Mine or prospect	Coal bed	Source of data	Measured coal section No. on plate 1	Thickness of coal analyzed (in.)	Laboratory No.	Kind of sample	Form of analysis	Analyses, in percent: Proximate: Moisture	Volatile matter	Fixed carbon	Ash	Ultimate: Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Air-drying loss (percent)	Heating value (Btu)	Remarks
T. 2 S., R. 8 E.																				
21	Unnamed prospect	Cokedale	[1]	24		[6]	M	A	2.4	38.0	50.0	9.6								Sample location unknown.
	Hubbard mine	Middle	[1]			[6]	M	A	2.5	40.0	42.0	9.5								Do.
22	Cokedale No. 2 mines	Cokedale	Eldridge	26	50	[6]	S	A	21.21	34.43	30.80	13.56					0.34	7.28		
22	Cokedale No. 2 mines	Cokedale	Eldridge	26	4	1	M	A	11.76	35.69	36.32	16.23					.47	6.27		Upper bench.
22	Cokedale No. 2 mines	Cokedale	Eldridge	26	19½	2	S	A	9.24	35.85	49.34	5.57					.37	4.85		Upper middle bench.
22	Cokedale No. 2 mines	Cokedale	Eldridge	26	6	3	S	A	10.85	37.17	44.50	7.48					.39	5.82		Middle bench.
22	Cokedale No. 2 mines	Cokedale	Eldridge	26	6	4	S	A	8.34	37.94	38.74	14.98					.36	4.75		Lower middle bench.
22	Cokedale No. 2 mines	Cokedale	Eldridge	26	14	6	S	A	11.33	35.24	47.67	5.76					.45	4.27		Lower bench.
22	Cokedale No. 2 mines—Sugar Loaf entry.	Paddy Miles	do	27	80½	15	M	A	3.50	34.86	53.17	8.67					.52	1.52		4 benches, aggregating. Sample from face 38 ft from portal.
22	Cokedale No. 3 mine.	Middle	do	29		[6]	S	A	12.51	37.63	32.83	17.03					.47	4.34		
24	Unnamed prospect	Cokedale(?)	Calvert		31	6596	S	A	6.2	30.6	36.9	26.26	4.77	53.79	0.86	34.64	.68		9,790	Sample from working face. Prospect 500 ft west of Northern Pacific Coal Co. mine.
								B	1.7	32.1	38.7	27.53	4.47	56.38	.90	10.01	.71	4.6	10,260	
								C		32.6	39.4	28.01	4.34	57.38	.92	8.62	.73		10,450	
								D		45.3	54.7		6.03	79.71	1.28	11.97	1.01		14,510	
24	Northern Pacific Coal Co. mine.	Cokedale	Eldridge	56		[6]	M	A	2.56	38.81	43.04	15.59					1.94	1.10		Coke; good. Sample from face 53 ft from portal.
				57			M	A	2.73	34.34	38.85	24.08					.86	.64		Coke; good. Sample from face 60 ft from portal.
				59	8	1	M	A	1.40	34.78	51.54	12.28					.52	.96		Upper bench. Coke; good. Sample from face 80 ft from portal.
				59	12	2	M	A	1.36	38.47	44.51	15.66					.54	1.06		Middle bench. Coke; good. Sample from face 80 ft from portal.
				59	43	3	M	A	1.52	35.93	39.81	22.74					.69	.71		Lower bench. Coke; good. Sample from face 80 ft from portal.
				60	7	1	M	A	.97	30.90	42.80	25.33					.47	.76		Top bench. Coke; poor. Sample from face 148 ft from portal.
				60	11	2	M	A	1.10	32.81	40.87	25.22					.50	.59		Upper middle bench. Coke; good. Sample from face 148 ft from portal.
				60	27	3	M	A	1.46	34.65	37.57	26.92					.59	.52		Lower middle bench. Coke; good. Sample from face 148 ft from portal.
				60	6	4	M	A	1.23	40.74	42.53	15.50					.79	.67		Lower bench. Coke; good. Sample from face 148 ft from portal.
				61	42	5	M	A	.93	39.05	45.94	14.08					.68	.85		Middle bench. Coke; good. Sample from face 200 ft from portal.
				61	48	6	M	A	1.13	41.18	53.91	3.78					.59	.97		Lower bench. Coke; good. Sample from face 200 ft from portal.
				61	54	16	M	A	1.31	34.66	42.01	22.02					.57	.66		Middle bench. Coal; good. Sample from face 280 ft from portal.
26	Cokedale No. 1 mines.	do	do	55		[6]	M	A	2.03	35.07	35.62	27.28					.57	.77		Coke; good. Sampled at portal.
26	Unnamed prospect	do	do	63		[6]	M	A	2.47	27.88	25.89	43.76					1.24	1.20		Coke; poor.
							M		5.70	6.00	78.09	10.21					.67	1.88		Analysis of the coke.
32	Small mine, unnamed.	do	do	72		[6]	M	A	6.69	32.39	39.50	21.43					.49	1.96		
				72	5½	1	M	A	9.98	35.93	44.35	9.74					.50	6.26		Top bench.
				72	12	2	M	A	4.55	33.12	52.45	9.88					.53	2.72		Upper middle bench.
				72	12	3	M	A	2.90	35.45	54.94	6.71					.57	1.39		Lower middle bench. Coke; poor, dense.
				72	8	4	M	A	2.89	36.20	50.08	10.83					.60	1.37		Bottom bench. Coke; poor, dense.
				73	16	12	M	A	4.81	33.90	36.49	24.80					.50	2.61		Top bench. Sample from face 71 ft from portal.
				73	33½	11	M	A	2.49	35.37	48.74	13.40					.66	1.93		3 benches, aggregating. Sample from face 71 ft from portal.

T. 2 S., R. 9 E.																				
28	Kangley mine	Cokedale	([2,3])	66	--	([6])	M	A	1.92	37.12	50.85	10.11	--	--	--	--	--	--	--	
T. 3 S., R. 8 E.																				
18	Unnamed prospect.	Storrs No. 3	([2,3])	79	--	([6])	M	A	9.02	36.99	47.76	6.23	--	--	--	--	--	--	--	Sample from a prospect drift.
	Sheep Corral mine.	do	([2,3])	80	--	([6])	M	A	8.60	34.39	52.34	4.67	--	--	--	--	--	--	--	Sample from a branch gangway, location unknown. Mine operated as a part of the Mountain House mine.
	Mountain House mine.	do	Calvert	81	98	3813	M	A	12.5	31.0	39.6	16.9	--	--	--	--	0.50	--	--	Sample from third entry 800 ft west of foot of slope.
								B	9.4	32.1	41.0	17.5	--	--	--	--	.52	3.4	--	
								C	--	35.5	45.2	19.3	--	--	--	--	.57	--	--	
								D	--	44.0	56.0	--	--	--	--	--	.70	--	--	
					62	3818	M	A	12.4	36.8	42.3	8.51	5.64	62.53	0.93	21.78	.67	--	10,950	Sample from head of west entry, 1,200 ft north of slope.
								B	9.8	37.9	43.5	8.77	5.48	64.40	.95	19.77	.63	2.9	11,280	
								C	--	42.1	48.2	9.72	4.86	71.38	1.06	12.28	.70	--	12,500	
								D	--	46.6	53.4	--	5.39	79.06	1.18	13.60	.77	--	13,840	
		Paddy Miles	USBM	82	--	3821	M	A	13.18	33.44	36.91	16.47	5.34	52.63	.86	24.07	.63	3.0	9,518	Sample location unknown.
								C	--	38.52	42.51	18.97	4.47	60.62	.99	14.22	.73	--	10,964	
								D	--	47.53	52.47	--	5.52	74.81	1.22	17.55	.90	--	13,531	
		Storrs No. 3	USBM	83	--	3814	M	A	10.42	28.64	30.00	30.94	--	--	--	--	.44	2.1	--	Sample from face 325 ft from No. 3 entry.
								C	--	31.97	33.49	34.54	--	--	--	--	.49	--	--	
								D	--	48.84	51.16	--	--	--	--	--	.75	--	--	
			([2,4])	86	--	([6])	M	A	9.31	34.75	47.34	8.60	--	--	--	--	--	--	--	Sample from southeast slope gangway.
							M	A	8.87	33.08	49.48	8.57	--	--	--	--	--	--	--	Do.
20	Kountz mine	Paddy Miles(?)	Calvert	87	--	3725	M	A	11.7	36.4	41.4	10.52	5.40	61.17	.87	21.65	.39	--	10,760	Sample location unknown.
								B	8.4	37.8	42.9	10.92	5.18	63.52	.90	19.07	.41	3.7	11,170	
								C	--	41.2	46.9	11.92	4.63	69.31	.99	12.71	.44	--	12,190	
								D	--	46.8	53.2	--	5.26	78.70	1.12	14.42	.50	--	13,840	
	Maxey Bros. No. 2 mine.	Maxey	do	88	108	6607	M	A	16.3	30.1	40.1	13.50	5.15	53.48	.82	26.64	.41	--	9,250	Sample from face 825 ft from portal.
								B	7.6	33.3	44.2	14.90	4.54	59.03	.90	20.18	.45	--	10,210	
								C	--	36.0	47.9	16.13	3.99	63.92	.98	14.49	.49	9.4	11,050	
								D	--	42.9	57.1	--	4.70	76.21	1.17	17.28	.58	--	13,180	
			([2,3])	--	--	3	M	A	16.67	32.12	44.78	6.43	--	--	--	--	--	--	--	Sample location unknown.
						4	M	A	13.21	36.89	43.71	6.19	--	--	--	--	--	--	10,619	Do.
						5	M	A	8.60	32.00	51.70	7.70	--	--	--	--	--	--	--	Do.
						6	M	A	9.20	31.80	49.90	9.19	--	--	--	--	--	--	10,225	Do.
28	Maxey Bros. Prospect.	Middle	([5])	89	--	B-22766	M	A	20.4	30.3	38.5	10.8	5.9	51.9	.9	30.1	.4	--	8,920	Sample from face 135 ft from portal.
								B	14.1	32.7	41.5	11.7	5.5	56.0	1.0	25.4	.4	7.3	9,630	
								C	--	38.1	48.3	13.6	4.6	65.2	1.1	15.0	.5	--	11,210	
								D	--	44.1	55.9	--	5.3	75.5	1.3	17.3	.6	--	12,980	
						B-22767	M	A	18.1	29.5	38.3	14.1	5.6	51.3	.8	27.8	.4	--	8,810	Sample from face 110 ft from portal.
								B	12.7	31.4	40.9	15.0	5.2	54.7	.9	23.8	.4	6.2	9,390	
								C	--	36.0	46.8	17.2	4.3	62.6	1.0	14.4	.5	--	10,760	
								D	--	43.5	56.5	--	5.2	75.7	1.2	17.3	.6	--	12,990	
						B-22768	M	A	19.2	30.0	38.2	12.6	5.8	51.7	.9	28.6	.4	--	8,860	Composite of samples B-22766 and B-22767.
								B	13.3	32.2	41.0	13.5	5.4	55.4	.9	24.4	.4	6.8	9,500	
								C	--	37.1	47.4	15.5	4.5	64.0	1.1	14.4	.5	--	10,960	
								D	--	43.9	56.1	--	5.3	75.7	1.3	17.1	.6	--	12,980	

[1] Analysis courtesy of Am. Smelting & Refining Co.; date of analysis, 1925.
[2] Analysis courtesy of Northern Pacific Ry. Co.
[3] Date of analysis: 1912.
[4] Date of analysis: 1907.
[5] U.S. Bur. Mines; date of analysis, 1937.
[6] No number assigned by laboratory.

TABLE 3.—*Chemical analyses of coal from the Storrs No. 3 coal bed, NW¼ sec. 35, T. 2 S., R. 7 E., Meadow Creek district of the Livingston coal field, Montana*

[From Belden, Delamater, and Groves (1909, p. 28). All data reduced to a dry basis for better comparison]

Test No.	Raw coal				Washed coal								Refuse			
	Volatile matter	Fixed carbon	Ash	Sulfur	Volatile matter	Fixed carbon	Ash			Sulfur			Volatile matter	Fixed carbon	Ash	Sulfur
							Percent	Reduction (percent)	Removed (percent)	Percent	Reduction (percent)	Removed (percent)				
207	30.90	36.91	32.19	0.54	35.53	44.31	20.16	37	61	0.61	------	30	23.34	26.43	50.23	0.58
211	30.90	36.91	32.19	.54	35.18	44.47	20.35	37	60	.64	------	24	22.53	23.11	54.36	.65
212	30.90	36.91	32.19	.54	34.84	44.97	20.19	37	66	.58	------	41	22.70	21.71	55.59	.61
212[1]	30.90	36.91	32.19	.54	36.83	47.82	15.35	52	77	.60	------	46	27.63	42.18	30.19	.58

[1] Rewashed coal from test 212.

TABLE 4.—*Coking tests of coal from the Storrs No. 3 coal bed, NW¼ sec. 35, T. 2 S., R. 7 E., Meadow Creek district of the Livingston coal field, Montana*

[From Belden, Delamater, and Groves (1909, p. 40). r. o.m., run of mine; w., washed; f.c., finely crushed; n.c., not crushed]

	Test 207	Test 208	Test 212	Test 213
Date	Jan. 10, 1908	Jan. 12, 1908	Jan. 27, 1908	Jan. 29, 1908
Duration ... hours	55	34	37	50
Size:				
As shipped	r.o.m.	r.o.m.	r.o.m.	r.o.m.
As used	w., f.c.	w., f.c.	w., f.c.	w., n.c.
Coal charged:				
Wet ... pounds	10,560	8,660	8,230	4,950
Dry ... do	9,611	7,903	7,591	4,474
Coke produced:				
Wet ... pounds	5,780	3,900	4,437	2,100
Wet ... percent	54.73	45.04	53.91	42.42
Dry ... pounds	5,750	3,893	4,417	2,042
Dry ... percent	59.83	49.26	58.19	45.64
Breeze produced:				
Wet ... pounds	1,412	1,170	720	944
Wet ... percent	13.37	13.51	8.75	19.07
Dry ... pounds	1,405	1,168	717	918
Dry ... percent	14.62	14.78	9.44	20.52
Total yield:				
Wet ... do	68.10	58.55	62.66	61.49
Dry ... do	74.45	64.04	67.63	66.16
Physical properties of coke:				
Specific gravity:				
Apparent	.92	.92	.85	1.03
Real	1.88	1.87	1.87	1.89
Volume:				
Coke ... percent	49.00	49.00	45.00	54.00
Cells ... do	51.00	51.00	55.00	46.00
Weight per cubic foot:				
Wet ... pounds	88.89	89.08	87.06	91.14
Dry ... do	57.07	57.26	52.77	62.45
6-ft drop test over 2-in. mesh:				
1 ... percent	85.00	86.00	95.50	80.50
2 ... do	73.00	74.00	90.00	61.00
3 ... do	62.00	61.50	83.00	48.50
4 ... do	54.50	53.50	76.00	35.50
5 ... do	74.00	65.50	80.50	47.50

REMARKS

Test 207: Dull-gray color. No apparent cell structure. Not coked down to bottom. Large amount of breeze and high volatile in coke probably due to this. Soft, punky, dense coke. Impossible to wash coal enough to reduce ash of coke within allowed limits.

Test 208: Same as 207.

Test 212: Rewashing of washed coal reduced ash content of coke to 22.07 percent and reduced percentage of breeze, but did not materially better coke.

Test 213: Attempt to improve rewashed charge of 212 by not crushing. Breeze very much increased and cross fracture of coke more highly pronounced.

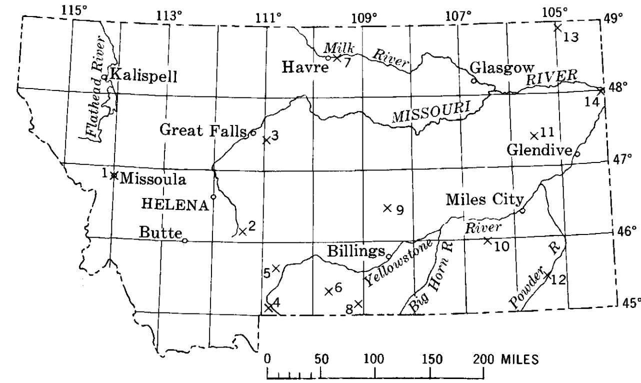
Most production from the Timberline and Meadow Creek districts was consumed in the operations of the Northern Pacific Railway. Production from mines in the Cokedale district went primarily into the manufacture of coke which was used in the copper smelters of western Montana. Mines of the Trail Creek district produced for the domestic heating market, mostly in Bozeman, Livingston, and Helena.

COKE PRODUCTION

The Cokedale district of the Livingston coal field began coke production in the 1880's during the early development of the silver and copper mines in western Montana and furnished coke to these mines and to smelters at Anaconda, Butte, and East Helena. Maximum coke production was attained in the 1890's; thereafter, production declined gradually, and by 1896 it had stopped at Cokedale. The Electric coal field near Gardiner was then the principal producer in Park County. The small production reported from Gallatin County consisted of tests at Chestnut and Storrs, and neither of these localities became commercial producers of coke. A small amount of coke was produced at Cokedale in the early 1900's, but the mines there were abandoned in 1906. Coke production stopped in the Electric coal field in 1911 (U.S. Bur. Mines, 1932, p. 20). Recorded production of coke in Gallatin and Park Counties during 1889–1910 is given in table 7. Before 1889, coke production was not recorded, and little is known regarding production in the Livingston coal field before that time. A total of 19,450 short tons of coke was manufactured in Montana during 1883–88 (U.S. Geol. Survey, 1901, p. 585), of which approximately half was produced at Cokedale. The yield of coke from coal was approximately 50 percent (U.S. Geol. Survey, 1901, p. 585).

Coke was manufactured at Cokedale and Storrs in beehive ovens. Cokedale had 115 ovens, and Storrs had 100 finished ovens and 100 unfinished ovens (Rowe, 1906, p. 77). The average charge of coal to each oven was 3.4 tons. The coke yield was 1 ton from 1.6 tons of coal.

Era and period		Series	Formation and member	Missoula (1)	Lombard (2)	Belt (3)	Electric (4)	Livingston (5)	Stillwater (6)	Milk River (7)	Red Lodge (8)	Roundup (9)	Colstrip (10)	McCone Co (11)	Broadus (12)	Sheridan Co (13)	Girard (14)
				FIELD OR AREA													
Cenozoic	Tertiary	Miocene or Oligocene	Kishenehn(?) Formation of Daly (1913)	X													
		Eocene	Wasatch Formation														
		Paleo-cene	Fort Union Formation: Tongue River Member								X	X	X	X	X		X
			Fort Union Formation: Lebo Shale Member														
			Fort Union Formation: Tullock Member														
Mesozoic	Cretaceous	Upper	Hell Creek Formation (Lance Fm)													X	
			Lennep Sandstone (Fox Hills Sandstone)														
			Bearpaw Shale														
			Judith River Formation							X							
			Claggett Shale														
			Eagle Sandstone				X	X	X								
			Telegraph Creek Formation														
			Colorado Shale														
		Lower	Kootenai Formation														
	Jurassic	Upper	Morrison Formation		X	X											



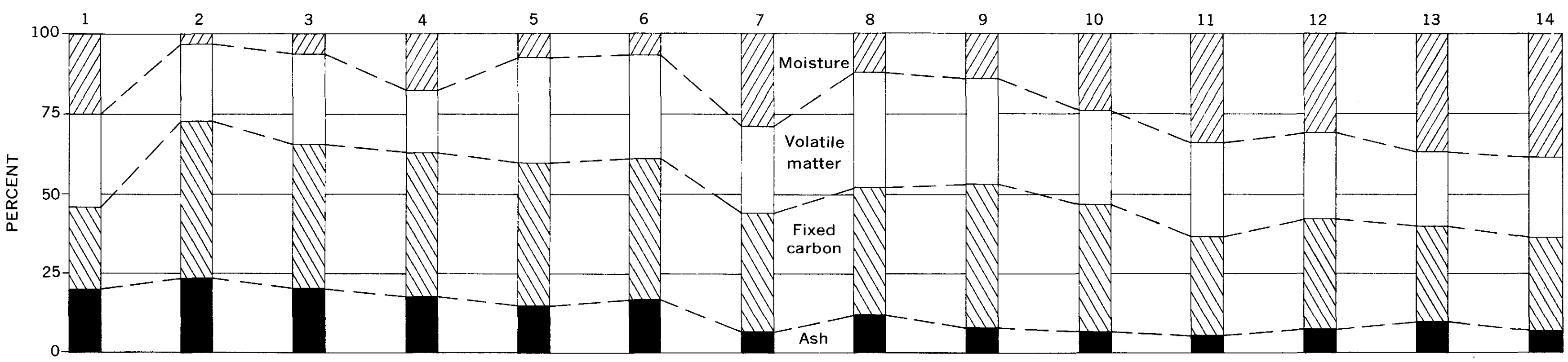


FIGURE 7.—Average proximate analysis of coal from major coal beds in selected coal fields of Montana, "as received" basis.

TABLE 5.—*Chemical analyses of coke from the Storrs No. 3 coal bed, NW¼ sec. 35, T. 2 S., R. 7 E., Meadow Creek district of the Livingston coal field, Montana*

[From Belden, Delamater, and Groves (1909, p. 41)]

Test No.	Laboratory No.			Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Phosphorus
207	229-D	Coal	Wet	8.99	32.33	40.34	18.34	0.55	
			Dry		35.53	44.31	20.16	.61	
	235-D	Coke	Wet	.52	1.42	71.94	26.12	.56	0.0177
			Dry		1.43	72.31	26.26	.56	
208	234-D	Coal	Wet	8.74	32.11	40.58	18.57	.59	
			Dry		35.18	44.47	20.35	.64	
	236-D	Coke	Wet	.18	1.26	70.60	27.96	.51	.0175
			Dry		1.26	70.73	28.01	.51	
212	253-D	Coal	Wet	7.76	33.97	44.11	14.16	.55	
			Dry		36.83	47.82	15.35	.60	
	265-D	Coke	Wet	.46	2.00	75.47	22.07	.55	.0100
			Dry		2.01	75.82	22.17	.55	
213	263-D	Coal	Wet	9.61	33.00	42.34	15.05	.46	
			Dry		36.50	46.85	16.65	.51	
	266-D	Coke	Wet	2.78	2.03	74.13	21.06	.58	.0125
			Dry		2.09	76.25	21.66	.60	

HISTORY OF MINING

Coal was mined on a small scale for local use at many localities in Montana during the 1860's and 1870's; however, it was not mined industrially until the early 1880's. In 1865 a coal mine was opened in the Big Hole Valley, about 60 miles northeast of Bannack, and another opened near Argenta (McDonald and Burlingame, 1956, p. 24). About the same time, a mine was opened near Virginia City; and in 1866 a mine was opened on Mullen Pass, about 15 miles west of Helena. Coal was discovered in the Livingston coal field in 1867. The coal deposits at Belt were prospected in 1876. About this same time a mine was opened 6 miles north of Miles City, and the Bull Mountain coal field was prospected. The Red Lodge coal field was opened in 1882, and the upper Yellowstone Valley coal deposits near Gardiner were opened in 1883.

The Federal Government and the Northern Pacific Railway Co. made many reconnaissance surveys across the Pacific Northwest before the final transcontinental route was established. Areal distribution and quality of coal deposits in Montana influenced the location of the Northern Pacific Railway route across Montana. The Livingston coal field was investigated, and considerable coal-bearing land was acquired or leased by the Northern Pacific Railway Co. or by one of its subsidiaries. Within a year after completion of the transcontinental route, the mines at Timberline and Chestnut were supplying fuel for locomotives and shops throughout the Pacific Northwest, as well as to local domestic consumers.

The coal industry in the Livingston coal field grew steadily until the end of the 19th century. Then it declined very rapidly because (1) the best and most readily mined coal had been exploited, and better mining methods and machinery were required to mine the remaining coal; (2) an improved method for smelting copper was developed that required less coke; (3) technological advances made the price of lower rank coals in the eastern part of the State more competitive, for these coals could be strip mined at much less cost; and (4) coal was replaced by oil as a fuel.

Use of coal as a domestic fuel renewed mining activity in the Livingston coal field on a very small scale in the early 1930's. Several prospects were developed into small mines, and older mines were reopened; but little is known of these mines because only a few, scattered records were kept. As the general economy of the area improved during the 1930's, commercial production ceased.

In the early 1880's the Northern Pacific Railway Co. established the Northern Pacific Coal Co. to develop its mines in the Pacific Northwest. This subsidiary company developed a small mine at Cokedale; however, its first large operation in the Livingston coal field was the Timberline mines. About 1895 the Northern Pacific Railway Co. acquired the Rocky Canyon (Chestnut) and Mountain Side mines, and these mines then were operated by the Northern Pacific Coal Co. In 1902 the Northern Pacific Coal Co. was incorporated in the Northwestern Improvement Co., also a subsidiary of the Northern Pacific Railway Co.

DESCRIPTION OF MINES

COKEDALE DISTRICT

The Cokedale No. 1 mines were developed concurrently with the early Timberline mines and the Rocky Canyon mine at Chestnut. The community of Cokedale, in the western part of Park County—sec. 26, T. 2 S., R. 8 E., 9 miles west of Livingston—grew rapidly,

TABLE 6.—*Total recorded coal production, in short tons, and value in Gallatin and Park Counties, Mont.*

[Reference: MIM, Montana Inspector of Mines; USGS, U.S. Geol. Survey; USBM, U.S. Bur. Mines]

Year	Gallatin County[1]		Park County		Total		Reference
	Production	Value	Production	Value	Production	Value	
1883[2]	19,695		([1])		19,695		USGS (1886, p. 39).
1884	63,670		([1])		63,670		Do.
1885	83,865		([1])		83,865		Do.
1886	45,446		([1])		45,446		USGS (1888, p. 276).
1887	7,802		([1])		7,802		Do.
1888	24,867		([1])		24,867		USGS (1890, p. 291).
1889	43,838	$104,377	147,300	$421,950	191,138	$526,327	USGS (1892, p. 228).
1890	51,452	119,084	252,737	690,870	304,189	809,954	Do.
1891	56,981	135,893	285,745	692,570	342,726	828,463	USGS (1893, p. 269).
1892	61,198	152,496	258,991	684,473	320,189	836,969	USGS (1893, p. 436).
1893	63,163	148,021	306,526	691,816	369,689	839,837	USGS (1894, p. 321).
1894	69,257	168,431	214,253	463,394	283,510	631,825	USGS (1896, p. 147).
1895	98,398	204,122	503,200	1,099,075	601,598	1,303,197	USGS (1897, p. 552).
1896	108,460	214,535	93,132	147,875	201,592	362,410	Do.
1897	132,413	223,024	122,889	294,072	255,302	517,096	USGS (1899, p. 441).
1898	63,626	102,712	147,154	284,970	210,780	387,682	Do.
1899	56,671	84,961	128,850	262,062	185,521	347,023	USGS (1901, p. 469–470).
1900	51,671	84,472	86,025	255,700	137,696	340,172	USGS (1901, p. 407).
1901	24,583		77,981	144,254	102,564	144,254	USGS (1904, 396–398).
1902	88,000		89,640	189,080	177,640	189,080	Do.
1903	58,696		86,044	258,132	144,740	258,132	USGS (1905, p. 514–515).
1904	109,556		78,646	227,226	188,202	227,226	Do.
1905	123,006		81,807	241,463	204,813	241,463	USGS (1907, p. 696).
1906	97,926		102,339	287,520	200,265	287,520	Do.
1907	79,106		102,555	381,940	181,661	381,940	MIM (1909, p. 27); USGS (1909 p. 140).
1908	29,653		106,942	343,760	136,595	343,760	MIM (1909, p. 32); USGS (1909, p. 140).
1909	16,771		139,464	282,517	156,235	282,517	USGS (1911, p. 156–157).
1910	22,465		98,434	211,655	120,899	211,655	Do.
1911	8,515		46,333		54,848		USGS (1913, p. 160).
1912	1,406		44,626		46,032		Do.
1913	([3])		21,126		21,126		USGS (1916, p. 699).
1914	([3])		21,472		21,472		Do.
1915	([3])		([3])				USBM (written commun., 1958).
1916	([3])		4,000		4,000		Do.
1917	([3])		([3])				Do.
1918	([3])		([3])				Do.
1919	3,000		([3])		3,000		Do.
1920	8,000		240		8,240		Do.
1921	807		228		1,035		Do.
1922	115		([3])		115		Do.
1923	29		([3])		29		Do.
1924	4,000		([3])		4,000		Do.
1925	4,000		([3])		4,000		Do.
1926–31	([3])		([3])				Do.
1932	([3])		1,991	4,002	1,991	4,002	Do.
1933	([3])		([3])				Do.
1934	1,000	3,000	800	2,000	1,800	5,000	Do.
1935	([3])		([3])				Do.
1936	210	298	104	499	314	797	Do.
1937	([3])		([3])				Do.
1938	2,693		1,502		4,195		Do.
1939	1,217	3,651	3,019	8,695	4,236	12,346	Do.
1940	([3])		2,327	7,516	2,327	7,516	Do.
1941	1,206	3,485	1,988	7,137	3,194	10,622	Do.
1942	([3])		1,338	2,713	1,338	2,713	Do.
1943–64	([3])		([3])				Do.
Total	1,788,433		3,661,748		5,450,181		

[1] Gallatin County, Mont., established in 1865, was divided into Gallatin and Park Counties in 1887. Coal production from mines at Cokedale and Timberline was listed under Gallatin County prior to 1889. Production figures for mines near Gardiner, Mont., are included in, and could not be separated from, Park County statistics.

[2] Prior to 1882 mining activity was limited to development of mines and to mining small amounts of coal for local domestic use. Rocky Canyon Coal mine produced 224 tons in 1880 and a small amount in 1882 for use during construction of railroad tunnel at Bozeman Pass.

[3] No recorded production.

TABLE 7.—*Total recorded coke production, in short tons, in Gallatin and Park Counties, Mont., during 1889–1910*

[See table 6 for source of data for individual year]

Year	*Gallatin County*	*Park County*	*Total*
1889	----------	30, 576	30, 576
1890	----------	24, 000	24, 000
1891	858	27, 667	28, 525
1892	----------	36, 412	36, 412
1893	----------	57, 770	57, 770
1894	----------	36, 000	36, 000
1895	----------	19, 700	19, 700
1896	----------	79, 632	79, 632
1897	----------	100, 000	100, 000
1898	----------	128, 632	128, 632
1899	----------	83, 000	83, 000
1900	----------	74, 475	74, 475
1901	----------	65, 137	65, 137
1902	----------	60, 740	60, 740
1903	----------	62, 134	62, 134
1904	7, 000	47, 500	54, 500
1905	5, 000	68, 777	73, 777
1906	----------	69, 045	69, 045
1907	14, 074	60, 239	74, 313
1908	----------	59, 268	59, 268
1909	----------	82, 973	82, 973
1910	----------	37, 519	37, 519
Total	26, 932	1, 311, 196	1, 338, 128

FIGURE 8.—First coke oven in Montana, built in 1881 by W. H. Williams in the SE¼SW¼ sec. 24, T. 2 S., R. 8 E., Livingston coal field. The oven is made of blocks of sandstone from the Cokedale and Eagle Formations.

and in the 1890's rivaled Livingston in population. But the mines were short lived and by the turn of the century were abandoned. The town of Cokedale was deserted soon after.

The Cokedale Nos. 1 and 2 mines, secs. 21, 22, and 26, T. 2 S., R. 8 E., were the largest producers in the district. The Cokedale No. 1 mines were also among the largest in the Livingston coal field and were the largest producers of coke.

A pilot coke oven was built in 1881 by W. H. Williams in the SE¼SW¼ sec. 24, T. 2 S., R. 8 E., to test the coking qualities of the coal (fig. 8). Later, 40 beehive coke ovens were constructed at Cokedale, and by the time the mines were at maximum production, 115 ovens were in operation. A good grade of coke was produced from the Cokedale coal bed (table 2) until the Cokedale No. 1 mines closed about 1896.

COKEDALE NO. 1 MINES

Mining operations at the Cokedale No. 1 mines were started by W. H. Williams in about 1881, and commercial production began in 1883. In 1885 Williams sold his interest to V. E. Tull, who, in turn, sold the property to Samuel Hauser in 1888. The Livingston Coal and Coke Co., formed by Hauser, operated the mines until about 1896, when the failure of of the First National Bank of Helena caused the company to close the mines. The arrangement of the mines, coal-car tramway, tipple, washing plant, and coke ovens at Cokedale is shown in figure 9.

The mines were first opened with a horizontal drift 1,500 feet east of the NW cor. sec. 26, T. 2 S., R. 8 E. (pl. 1). The tunnel was only 600–700 feet long when the Livingston Coal and Coke Co. began an inclined shaft about 300 feet west of the portal. This shaft. which is adjacent to measured coal section 54 (pl. 1), was driven down the 40° northward dip of the Cokedale coal bed. Rooms or chutes were mined adjacent to the shaft from the first level to a depth of about 300 feet, at which point the shaft entered sec. 23.

The second level was started westward at a depth of 226 feet and was developed into sec. 22; an eastern extension of the level did not progress far before broken and faulted coal was penetrated, and further work in that direction was abandoned. After the second level had been driven a considerable distance westward, the incline was extended an additional 362 feet in depth, and the third level was driven westward through sec. 23 and a considerable distance into sec. 22. The fourth level was 286 feet below the third, and the fifth level was 386 feet below the fourth. The first through fourth levels were mined out for a distance of 5,555 feet west of the incline and for about 800 feet east of the incline. The fifth level, at a depth of 1,260 feet, was not developed.

The dip of the rocks at the surface is 40°, but it decreases gradually downward to 34° at the No. 1 level; the average dip between the Nos. 1 and 2 levels is 34°; between the Nos. 2 and 3 levels, 42°; between the Nos. 3 and 4 levels, 42°; and between the Nos. 4 and 5 levels, 40°. At the No. 5 level the dip flattens and averages 20°.

In the two lower levels west of the incline, several faults were discovered whose effects, in the form of rolls, were noticeable in the upper levels. The displacements were small and caused no trouble in mining. East of the incline, very little development was done at any level, as the coal had been badly broken by faulting.

Widely spaced crosscut tunnels on several levels west of the incline were developed southward to penetrate the Paddy Miles bed and the underlying Storrs No. 3 bed. The coal in these beds would coke, but the beds were not thick enough to be mined profitably.

The Andrew Miller prospect, in the NE¼ sec. 26, T. 2 S., R. 8 E., is a horizontal drift driven westward along the strike of the Cokedale bed to connect with the workings of the Cokedale No. 1 mines; however, the prospect was abandoned because the coal was thin, had many partings, and had been broken by faulting.

In 1889 the Cokedale No. 1 mines produced 49,400 tons of coal; 78 ovens produced 50 tons of coke per day, and 18 additional ovens were being repaired (Weed, 1891, p. 362). By 1892, mining at Cokedale was limited almost entirely to the Cokedale bed in three levels west of the main shaft at the Cokedale No. 1 mines, developed to a depth of 650 feet (Weed, 1892, p. 522).

Many pillars were mined from the lower levels during the middle 1890's in expectation of an end to mining operations. Then, about 1896, mining was discontinued, pumps were removed, and the workings became flooded.

During 1898–1900, Oscar James, of Spokane, Wash., leased the Cokedale No. 1 mines from the Livingston Coal and Coke Co. (or its creditors) and reopened the mines through the original incline. The water was pumped out, and the upper levels west of the incline were worked, mostly by pulling the remaining pillars. The coal was shipped, but no attempt was made to renew the coking operations. About 1902 the property was acquired by the Anaconda Copper Co., who dewatered the mines and made several developments, including a sixth level 300 feet below the No. 5 level (Montana Inspector of Mines, 1904, p. 24). The output in 1904 was 5,000–7,000 tons, all of which was used at Cokedale (Rowe, 1905, p. 247). The mine was abandoned in 1906 (Montana Inspector of Mines, 1906, p. 47).

The Cokedale bed was sampled at localities 54 and 55 (pl. 1) at the Cokedale No. 1 mines. Its stratigraphic relations and correlation are shown on plate 3, and analysis of a sample (No. 55) is given in table 2.

COKEDALE NO. 2 MINES

The Livingston Coal and Coke Co. developed several entries, known as the Cokedale No. 2 mines, west of and in conjunction with their Cokedale No. 1 mines. The No. 2 mines were used primarily for ventilation and safety exits for the No. 1 mines. Eldridge (1886, p. 781, 782) sampled the No. 2 mines in 1882.

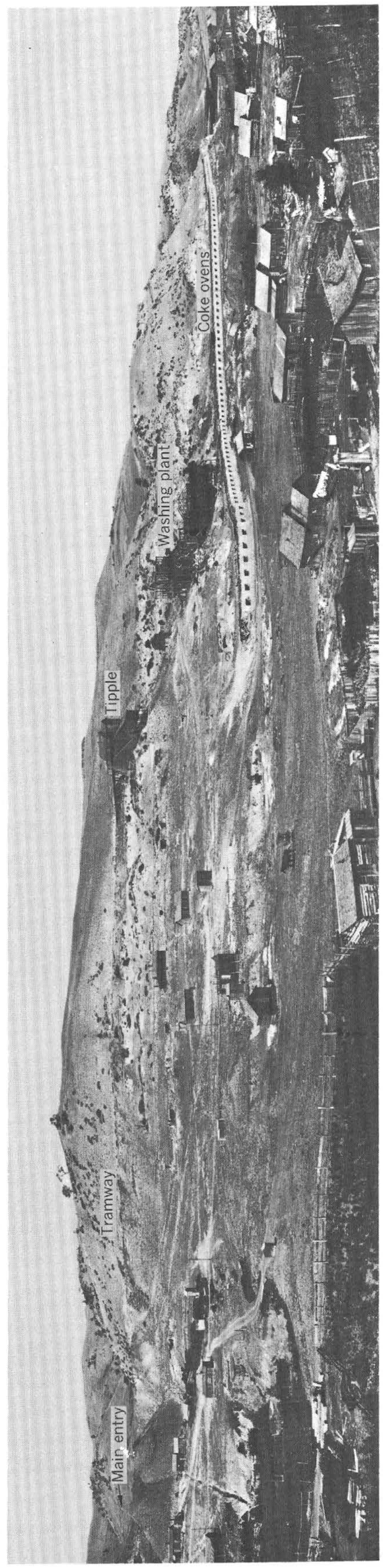


FIGURE 9.—Cokedale No. 1 mines, Livingston coal field. The main inclined shaft was immediately behind the mine dump (left side of photo.). The coal-car tramway from the shaft can be traced to the right to the tipple. Just below the tipple to the right is the washing plant, and below the washing plant are the coke ovens. Cokedale Spur of the Northern Pacific Railway Co. was adjacent to the coke ovens. Community of Cokedale was to the right of the area photographed. View north in sec. 26, T. 2 S., R. 8 E. Photographed by W. R. Calvert in 1908.

After removing the pillars from the Cokedale No. 1 mines, the Oscar James Co. made several new openings near those made by the Livingston Coal and Coke Co. The Oscar James Co.'s main development was a short horizontal drift driven eastward in the SW¼ sec. 22, T. 2 S., R. 8 E., to connect with the upper part of the rooms driven from the first level westward from the Cokedale No. 1 incline. Below the first level were the flooded old workings, so no attempt was made to develop the workings deeper.

Later the Oscar James Co. moved its operations farther west and drove a 280-foot inclined shaft on the Cokedale coal bed—about 300 feet west of the east line of sec. 21 and 900 feet north of the southeast corner of the section (pl. 6). This mine, known as the James entry, developed levels at depths of 80 and 280 feet; it extended eastward and intersected the upraises from the eastern works of the Cokedale No. 2 mines. A few hundred feet west of this new incline, small faults were discovered, and mining was discontinued.

The Cokedale No. 2 mines were worked by the Oscar James Co. for about 1 year, during which time all easily obtained coal, including the pillars, was removed to a depth of 280 feet, from the James entry eastward to the workings of the main Cokedale No. 1 mine. Output of about 20 tons per day was shipped to Spokane, Wash., where it was used by the Spokane Gas and Fuel Co. in the manufacture of gas. After the Oscar James Co. ceased work at these mines, the Northern Pacific Railway Co. removed its rails from the Cokedale spur.

The Cokedale bed was sampled at localities 25, 26, and 27 (pl. 1) at the Cokedale No. 2 mines. The bed's stratigraphic relations and correlation are shown on plate 3, and the analyses of two samples (Nos. 26, 27) are given in table 2.

NORTHERN PACIFIC COAL CO. MINE

An inclined shaft in the SW¼ sec. 24, T. 2 S., R. 8 E. (pl. 1), was begun in 1882 by the Northern Pacific Coal Co. Eldridge sampled this mine during 1882–83 at several levels and later (1886, p. 749, 782) very briefly described the coal bed's thickness in the mine. The incline was developed to a depth of 534 feet on the Cokedale bed, which dipped 37°–40°.

During a period of labor trouble in 1890, the portal was destroyed, and the mine was never reopened. Calvert (1912a, p. 393) visited the mine in 1908 and mentioned that there was an attempt at that time to reopen the mine with a new entry 500 feet westward along the strike; however, this entry was not completed. Calvert's (1912a, p. 402) location for his sample 6596 from this second entry is incorrect; it should be in the SW¼SW¼ sec. 24, T. 2 S., R. 8 E. The 31-inch coal bed which he sampled at the face 100 feet from the new portal was probably the Paddy Miles bed. The 2-foot coal bed above the sampled bed (Calvert, 1912a, p. 393) would then be the Cokedale; and the third bed, 30 feet above the Cokedale, would be a coal in the lower part of the Cokedale Formation (pl. 3).

The Cokedale bed was sampled at localities 56, 56a, and 57–62 (pl. 1) at (or in) the Northern Pacific Coal Co. mine. The bed's stratigraphic relations and correlation are shown on plate 3, and the analyses of five samples (Nos. 56, 57, 59–61) are given in table 2.

DALY PROSPECT

In 1892 Marcus Daly sank an inclined shaft on the Cokedale bed in the NE¼ sec. 30, T. 2 S., R. 9 E. (pl. 1). The incline was developed to a depth of 150 feet before being abandoned the same year. The coal from the top to the bottom of this incline was uniform and was similar to that in the bed at Cokedale; however, it was less suitable for coking.

SULPHUR FLATS MINE AND FRANK AND HILSON PROSPECTS

In sec. 29, T. 2 S., R. 9 E., coal is indicated in many places by abandoned mine or prospect dumps; however, little information is available regarding them. The Sulphur Flats mine in the center of sec. 29 (pl. 1) was reported by L. E. Williams (oral commun., 1957) to produce about 6–8 tons of coal per day, which was sold for domestic use in Livingston. G. Bowers developed the mine about 1906. The Frank prospect in the NW¼ was an inclined shaft on the Cokedale bed (pl. 1). This shaft was developed by H. L. Frank to a depth of about 100 feet and was abandoned prior to 1901. In 1912 Cleveland Hilson made an incline, which he named the Peacock mine, on the Cokedale bed in the NE¼ sec. 29, T. 2 S., R. 9 E. (pl. 1). The prospect was abandoned at a depth of 60 feet the same year. Hilson reported the Cokedale bed to be 4–5½ feet thick, including two partings, and to contain about 2½ feet of merchantable coal.

SPANGLER AND KANGLEY MINES

Very little is known about these mines, which are in sec. 29, T. 2 S., R. 9 E. (pl. 1). They were small producers for domestic trade. The Spangler mine was an inclined shaft developed by Joe Spangler in 1883 on the Cokedale bed, and the Kangley mine was a horizontal drift that trended westward along the strike of the Cokedale bed.

The Cokedale bed was sampled at locality 66 (pl. 1) at the Kangley mine; the bed's stratigraphic relations and correlation are shown on plate 3, and the analysis of a sampler (No. 66) is given in table 2.

WILLIAMS MINE

The Williams mine, in the NE¼ sec. 27, T. 2 S., R. 9 E., is the easternmost mine in the Cokedale district (pl. 1). This mine, developed by W. H. and Thomas Williams, was a small producer of domestic coal sold in Livingston during the 1930's. The mine was a horizontal drift developed westward on the strike of the Big Dirty bed, which, at that locality, dips 35° NW. The bed contained many partings (see measured section 2) and the coal was badly broken.

The stratigraphic relations and correlations of the Big Dirty bed at the portal of the Williams mine at locality 67 (pl. 1) are shown on plate 3.

HUBBARD MINE

In 1920–21 the Hubbard mine, in the SE¼ sec. 21, T. 2 S., R. 8 E. (pl. 1), was developed in the Middle bed, known locally as the Cokedale No. 3 bed (pl. 3). The main haulageway extended 930 feet along the strike of this bed (pl. 6). Near the west end of the level and 850 feet in from the portal, a crosscut rock tunnel was started northward in 1924 in an effort to reach the thicker Cokedale bed; however, after only 35 feet of sandstone had been cut, work was discontinued.

Approximately 3,000 tons of coal was mined before the operation was abandoned in 1925. A considerable part of this total was left on the dump.

An analysis of the coal bed at the Hubbard mine is given in table 2.

COKEDALE NO. 3 MINE

In 1934 Llewellyn and Thomas Williams, sons of the W. H. Williams who started mining at Cokedale, developed the Cokedale No. 3 mine in the SW¼ sec. 22, T. 2 S., R. 8 E. (pl. 1). The mine was entered by a 20-foot rock tunnel and was developed from an inclined shaft on the Middle bed—known locally as the Cokedale No. 3 bed—on a combination of stall and room-and-pillar systems with no specific spacing. The mine produced small amounts of coal for domestic use for approximately 2 years before it was closed.

The stratigraphic relations and correlations of the Middle bed in the Cokedale No. 3 mine, locality 8 (pl. 1), are shown on plate 3, and the analysis of a sample (No. 29) is given in table 2.

BUCKSKIN AND JOHNSON MINES

These two small mines at the west end of the Cokedale district, in the SW¼ and NW¼ sec. 28, T. 2 S., R. 8 E. (pl. 1), were horizontal drifts southward along the strike of the Cokedale bed. Production, which was small, was for domestic use in Livingston. The Buckskin mine was developed in 1888 by Joseph McKeown and was sold in 1889 to the Livingston Coal and Coke Co. Gus Johnson opened the Johnson mine about 1906.

The stratigraphic relations and correlations of the Cokedale bed in the Buckskin and Johnson mines, localities 52 and 53 (pl. 1), are shown on plate 3.

McCORMICK PROSPECT

One of the latest efforts to revive coal mining in the Livingston coal field was by E. B. McCormick in 1955. He drove a horizontal drift eastward along the strike of the Middle bed in the SW¼ sec. 22, T. 2 S., R. 8 E. The prospect was abandoned in 1956.

The stratigraphic relations and correlations of the Middle bed at the McCormick prospect, locality 28 (pl. 1), are shown on plate 3.

TIMBERLINE DISTRICT

C. W. Thompson began development in this district in 1881 for the Northern Pacific Coal Co. A narrow-gage railroad between Timberline and West End was completed in 1883, and during that year coal shipments totaled 10,489 tons. The coal was used exclusively for locomotive fuel by the Northern Pacific Railway Co. on the run from Glendive, Mont., to Sprague, Wash. Production totaled 55,664 tons in 1884, 83,156 tons in 1885, 45,446 tons in 1886 (although the mines were idled by labor strikes during much of 1886), 7,802 tons in 1887, 24,867 tons in 1888, and 43,838 tons in 1889 (U.S. Geol. Survey, 1887, p. 275; Weed, 1891, p. 362). During 1882–83 Eldridge (1886, p. 781–782) took samples from many of these mines and prospects.

C. W. Hoffman leased the Timberline mines in 1888 and operated them through 1895. During 1891–95 the Timberline Nos. 3, 5, and 6 mines employed about 125 men, who mined about 5,000 tons of coal per month (Montana Inspector of Mines, 1891, 1895).

In 1895, after the readily available coal had been removed, the Timberline mines were closed because the continuation of mining would have required many expensive improvements. Hoffman then moved from Timberline to Trail Creek and purchased the Mountain House mine.

During the first brief period of mining in this district, a sizable community known as Timberline was established along Timberline Creek in secs. 23–25. At peak production of the Timberline No. 3 mine, more than 300 miners and their families lived in this small valley. Calamity Jane, one of the more enterprising residents during the growth of this community, maintained a strategically located log cabin near Craig's Cut, just west of the Timberline No. 3 mine.

The Q and H Nos. 1 and 2 mines and the Hyer, Dunn, Thompson, Brady, and Palmer and Ryan prospects were all closed by the time the Timberline mines suspended operations in 1895. The miners and their families moved to other districts, and the community of Timberline was abandoned. Activity was resumed in the 1930's with the development of the Woodland, Ross, Pendleton, DiLulo, and Number Thirty mines and the reopening of the Timberline No. 6 mine; however, production was small and mining activities were short lived.

TIMBERLINE NO. 1 MINE

The Timberline No. 1 mine was a horizontal drift driven westward on the Cokedale bed by the Northwest Improvement Co. about 1881. The portal was 1,600 feet west and 800 feet north from the SE cor. sec. 24, T. 2 S., R. 7 E. (pl. 1). The coal bed dips 52° NE.; and, according to Eldridge (1886, p. 749), it had fewer and smaller partings than did the bed at prospects and mines to the south. The workings extended approximately 600 feet westward, and the last recorded depth was 232 feet (Eldridge, 1886, p. 749). An inclined shaft was also developed immediately east of the water-level entry.

The Cokedale bed was sampled at localities 15–19 (pl. 1) in the Timberline No. 1 mine. The bed's stratigraphic relations and correlation are shown on plate 3, and analyses of five samples (Nos. 15–19) are given in table 2.

TIMBERLINE NO. 2 MINE

The Timberline No. 2 mine, in the SE¼ sec. 24, T. 2 S., R. 7 E. (pl. 1), was a horizontal drift driven eastward on the Cokedale bed. The portal was 200 feet east of the No. 1 portal. The workings extended 500 feet east and dipped 53°. The coal in this mine contained very few partings (pl. 3).

The stratigraphic relations and correlations of the Cokedale bed in the Timberline No. 2 mine, locality 20 (pl. 1), are shown on plate 3.

TIMBERLINE NO. 3 MINE

The Timberline No. 3 mine, in the central part of the S½ sec. 23, T. 2 S., R. 7 E. (pl. 1), was by far the largest producer in the Timberline district and was one of the largest in the Livingston coal field. The mine was started with a horizontal entry on the Cokedale bed 2,650 feet east and 1,175 feet north of the SW cor. sec. 23. This tunnel extended eastward into the NE¼ sec. 23, and a 30° incline was developed near the portal. By 1891 the first level was down 280 feet, and work was continuing on a second level 250 feet below the first (Montana Inspector of Mines, 1891). The main incline was 900 feet deep by 1895 (Montana Inspector of Mines, 1895). During this development a small amount of coal was produced from the Paddy Miles bed.

Daily production from this mine during 1885–95 averaged 300 tons; however, it declined to 200 tons near the end of this period (Montana Inspector of Mines, 1895). The mine closed in 1895.

Warm sulfur-bearing springs are present in this mine. The pungent odor of the water caused local residents to call the mine the Stinking Water mine, and it is thus designated on the U.S. Geological Survey topographic map of the Bozeman Pass quadrangle, published in 1957. This water now flows from the former air tunnel of the No. 3 mine.

In 1940 Henry Merrick tried to reopen the No. 3 mine by opening the old portal. He mined a few pillars and then abandoned his venture.

The stratigraphic relations and correlations of the Cokedale bed in the Timberline No. 3 mine, locality 11 (pl. 1), are shown on plate 3.

TIMBERLINE NO. 4 MINE

The Timberline No. 4 was a rock tunnel 50 feet south and 1,775 feet west of the SE cor. sec. 25, T. 2 S., R. 7 E. (pl. 1). The tunnel was dug about 1894 and extended north 850 feet to a point where it joined the lower workings of the Timberline No. 1 and 2 mines. It was then used as a haulageway for these mines.

TIMBERLINE NO. 5 MINE

The Timberline No. 5 was a rock tunnel 1,975 feet east and 350 feet north of the SW cor. sec. 24, T. 2 S., R. 7 E. (pl. 1). This tunnel extended 1,800 feet north to intersect the Cokedale bed and was intended as a haulageway for the Timberline No. 3 mine workings when this point was reached; however, the mines were closed before the haulageway was completed. During the 1930's Frank Woodland and Ray Ross reopened 1,300 feet of the tunnel in a second unsuccessful attempt to develop the No. 5 mine.

TIMBERLINE NO. 6 MINE

The Timberline No. 6 mine was opened by the Northern Pacific Coal Co. about 1881 in the NE¼ sec. 25, T. 2 S., R. 7 E., and the NW¼ sec. 30, T. 2 S., R. 8 E. (pl. 1). Eldridge (1886, p. 781–782) sampled this mine during 1882–83. The mine was developed by a rock tunnel that had horizontal entries on the Cokedale bed, normal to the tunnel (pl. 7). The coal bed dips 79° E. The mine was worked to a depth of 300 feet by the Northern Pacific Coal Co. before being closed. The Cokedale bed at this locality contains many partings, and the coal required washing. Three levels were mined by use of a room-and-pillar system for about 500 feet along the strike and to a depth of 40 feet. Production was small and was recorded along with that from the company's other mines at Timberline.

Tom Coulston reopened the Timberline No. 6 mine in 1933. During the next 3 years he developed a fourth level, at a depth of 60 feet, and also mined many of the pillars in the older workings. Since 1933 the mine has been known as the Coulston mine. The coal was sold for local domestic use.

The Cokedale bed was sampled at localities 45–48 (pl. 1) in the Timberline No. 6 mine. The bed's stratigraphic relations and correlation are shown on plate 3, and the analyses of three samples (Nos. 45–47) are given in table 2.

Q AND H NOS. 1 AND 2 MINES

During the 1880's P. J. Quealy and C. W. Hoffman operated the Q and H Nos. 1 and 2 mines at Timberline in the SW¼ sec. 23, T. 2 S., R. 7 E. (pl. 1). These were horizontal drifts driven southward along the strike of the Cokedale bed. The Q and H No. 2 mine was 300 feet above the Q and H No. 1 mine. It was reached by a double-track incline railroad 440 feet long, up which the empty cars were hauled by the weight of the loaded ones going down (Avant Courier, Feb. 19, 1885). The No. 2 mine was 800 feet long, and the rooms from which the coal was mined were 250 feet high. The No. 1 mine was about 900 feet long. The entire output of the mines was sold to the Northern Pacific Railway Co. Mining was suspended in July 1888, when C. W. Hoffman leased the Timberline mines (Avant Courier, July 12, 1888).

WOODLAND MINE

The Woodland mine was a horizontal drift driven eastward 800 feet on the Cokedale bed. The entry, 1,450 feet north and 3,500 feet west of the SE cor. sec. 24, T. 2 S., R. 7 E. (pl. 1), was opened in 1935 by Frank Woodland. In 1938 a slope was made near the portal, and a second level 50 feet below the first was developed (pl. 7); the second level had been extended 300 feet eastward before the mine was closed in 1943.

The Cokedale bed was 8 feet thick in the mine and was very similar in many respects to the bed in the Ross mine (pl. 3). Only the upper 2½ feet of the bed could be marketed, because there was no washing plant. The beds dipped 43°–59° N. Mining was done by the room-and-pillar system with no specific spacing. Production was small and was sold for domestic use.

ROSS MINE

The Ross mine was a 150-foot inclined shaft from which three levels were driven eastward on the Cokedale bed. The portal, 1,465 feet north and 2,700 feet west from the SE cor. sec. 24, T. 2 S., R. 7 E. (pl. 1), was opened by Ray Ross in 1934. The first and second levels extended 750 feet eastward and were mined to the surface (pl. 7). The third level had been mined 220 feet eastward before the mine was closed in 1941.

The Cokedale bed was 8 feet thick, had many partings (pl. 3), and dipped 49°–56° NE. Mining was done by the room-and-pillar system with no specific spacing. Production was small and was sold in Bozeman for domestic fuel.

The stratigraphic relations and correlation of the Cokedale bed in the Ross mine, locality 12 (pl. 1), are shown on plate 3.

PENDLETON MINE

The Pendleton mine was a horizontal drift driven northward on the Cokedale bed. The portal was 975 feet north and 1,650 feet west from the SE cor. sec. 24, T. 2 S., R. 7 E., just north of the Timberline No. 1 mine (pl. 1). The mine was opened in 1943 by H. D. Pendleton and was developed 390 feet into the hill before it was closed in 1947 (pl. 7). The mine workings were a modified room-and-pillar system with 45-foot centers. Production was very small.

The stratigraphic relations and correlation of the Cokedale bed in the Pendleton mine, localities 13 and 14 (pl. 1), are shown on plate 3.

HYER PROSPECT

The Hyer prospect was an inclined shaft on the Cokedale bed in the NE¼ sec. 25, T. 2 S., R. 7 E. (pl. 1). Eldridge (1886, p. 782) sampled this incline in 1883. No production is reported from this prospect.

The Cokedale bed was sampled at localities 43 and 44 (pl. 1) in the Hyer prospect. Its stratigraphic relations and correlation are shown on plate 3, and the analysis of a sample is given in table 2.

DUNN AND THOMPSON PROSPECTS

The Dunn and Thompson prospects, in the NW¼ sec. 30, T. 2 S., R. 8 E. (pl. 1), were opened on the Cokedale bed in the early 1880's. No production is reported from these prospects.

The stratigraphic relations and correlation of the Cokedale bed at the Dunn and Thompson prospects, localities 49 and 50 (pl. 1), are shown on plate 3.

NUMBER THIRTY MINE

The Northern Pacific Coal Co. opened the Number Thirty mine by means of a horizontal drift driven southeast along the strike of the Cokedale bed in the SW¼ sec. 30, T. 2 S., R. 8 E. (pl. 1). The tunnel had been extended about 500 feet from the portal before the mine was abandoned. The date of this period of development is not known. Production was small and was incorporated with the company's production from other mines at Timberline. The mine was named for the section in which it was located.

Frank Woodland and Ray Ross reopened the mine in 1932. Three shafts were driven from the original tunnel, and a second level was developed 25 feet below the original tunnel. The second level was driven 600 feet southward before the mine was closed in 1934. The coal bed was thick at this locality (pl. 3), but it contained many partings that were difficult to separate without a washing plant. Mining was done by the room-and-pillar system with 50-foot centers. The coal bed dips 86° E.

The stratigraphic relations and correlation of the Cokedale bed in the Number Thirty mine, locality 50 (pl. 1), are shown on plate 3.

DiLULO MINE

In 1933 Mike DiLulo opened a horizontal drift on the Cokedale bed in the NE¼ sec. 31, T. 2 S., R. 8 E. (pl. 1). The mine was developed 480 feet northward along the strike of the coal bed, which dips 55°–85° E., by the room-and-pillar system with 25-foot centers. The mine operated until 1937, and the production, which was small, was sold locally for domestic use. Coal from this mine was of coking quality.

The stratigraphic relations and correlation of the Cokedale bed in the DiLulo mine, locality 68 (pl. 1), are shown on plate 3.

BRADY NO. 1 AND 2 PROSPECTS AND PALMER AND RYAN PROSPECT

Very little information is available regarding the coal prospects in sec. 32, T. 2 S., R. 8 E. (pl. 1). Eldridge (1886, p. 781–782) sampled them during 1882 and 1883, but no production is reported from these workings.

The stratigraphic relations and correlation of the Cokedale bed at the Brady Nos. 1 and 2 prospects and at the Palmer and Ryan prospect, localities 70, 71, and 75 (pl. 1), are shown on plate 3.

MEADOW CREEK DISTRICT

Many mines were developed in the Meadow Creek district, including the Rocky Canyon and the Mountain Side mines, which became two of the largest producers in the Livingston coal field. The Rocky Canyon mine was the first commercial mine in Montana (McDonald and Burlingame, 1956, p. 24); its development stimulated growth of the nearby community of Chestnut. The later development of the Mountain Side mine extended the growth of Chestnut for an additional decade. Most of the production was consumed as locomotive fuel by the Northern Pacific Railway Co.

ROCKY CANYON (CHESTNUT) MINE

Coal was discovered in the Livingston coal field in 1867 by two blacksmiths from Bozeman. Col. James D. Chesnut, hearing of the discovery, offered to furnish provisions to men who would work the coal bed, if the men would give him a share of the property. This scheme was so successful that, later, Colonel Chesnut became the sole owner of the claim (A. C. Peale, in Hayden, 1873, p. 113), which he developed as the Rocky Canyon coal mine. Colonel Chesnut's colorful career and his influence on the young community of Bozeman was presented in detail and documented by McDonald and Burlingame (1956).

Colonel Chesnut drove a horizontal drift, which by 1871 was 180 feet long (Hayden, 1872, p. 46) and by 1872 was 250 feet long (A. C. Peale, in Hayden, 1873, p. 113). Through 1879 the mine had produced 1,344 tons of coal, which was sold at Fort Ellis and Bozeman for domestic use. Production during 1880 was 224 tons (U.S. Dept. Interior, 1886, p. 899).

By 1881 Colonel Chesnut had developed two parallel horizontal drifts driven northwestward 150 and 500 feet along the strike of the Cokedale coal bed (known locally as the Chestnut bed). The bed dipped 60°–86° NE. The portals were in the NW¼SW¼ sec. 21, T. 2 S., R. 7 E. (pl. 1).

The Rocky Canyon mine was worked by Col. James Muir during the fall and winter of 1882–83 to supply coal for the operation of the large steam engines used in constructing the Northern Pacific Railway Co. tunnel through Bozeman Pass.

In 1882 F. D. Pease and C. W. Hoffman filed claims to land adjacent to the Rocky Canyon coal mine, and went into partnership with Colonel Chesnut. D. F. Sherman, C. H. Cobb, and Frank Esler bought Colonel Chesnut's one-third interest in the mine and property in 1883, and, with Pease and Hoffman, formed the Bozeman Coal Co. and contracted to furnish to the Northern Pacific Railway Co. the entire output of coal for the next 5 years (Avant Courier, June 28, 1883). Within a few months, however, the Northern Pacific Railway Co. got the Timberline mines into production, and little coal was taken out of the Rocky Canyon mine in 1883 compared with that taken from the Timberline mines.

By September 1883 the two main drifts had been developed 900 and 1,100 feet along the strike of the Cokedale bed. Sixty to seventy-five men were employed, and the output was 80–100 tons per day. The Bozeman Coal Co. made a new entry on the Cokedale bed in the center of the N½N½ sec. 20, T. 2 S., R. 7 E., in November 1883 and built a tramway from this entry southward one-half mile to the railroad (pl. 8).

The contract with the Northern Pacific Railway Co. was voided in 1884 when the Bozeman Coal Co. sold its property to the Union Pacific Railroad Co. At that time the Union Pacific Railroad Co. contemplated building a branch line from Bozeman to Butte and coking the coal of the Rocky Canyon mine for use in the smelters at Butte. The Union Pacific Railroad Co. had previously purchased the Maxey mine, and both mines were taken out of production while the coking quality of the coal was being tested. The tests proved the coal to be only partly coking in character, and the proposed branch line was not built.

Production from the Rocky Canyon mine in 1883 was 8,970 tons; in 1884, 7,612 tons; and in 1885, 100 tons (U.S. Geol. Survey, 1885, p. 38). The mine was closed in 1885.

Frank Esler reopened the mine in 1887 under a lease from the Union Pacific Railroad Co. He operated the mine for several years, employing about 40 miners, until the Northern Pacific Railway Co. acquired the property about 1891. The Northern Pacific Railway Co. leased the mine to J. C. McCarthy and J. A. Johnson, who operated it until 1902. The property was then transferred to the Northwestern Improvement Co., a subsidiary of the Northern Pacific Railway Co. The mine was operated by this company until about 1906, when it was again closed (Calvert, 1912a, p. 398) and never reopened for commercial production. Plate 8 shows the extent of these underground workings. The mine became best known during this time as the Chestnut mine, and the name Rocky Canyon has all but been forgotten.

With the development of prospects and mines near the Rocky Canyon mine, a community grew in the center of sec. 20, T. 2. S., R. 7 E. Colonel Chesnut spelled his name as written here; but the name on the post office in this community was misspelled as Chestnut, and the misspelled name prevailed. Eldridge (1886, p. 781) and Calvert (1912a, p. 397) referred to the mine as the Chestnut mine. During the period when the mines were owned by the Bozeman Coal Co., the mines were known as the Bozeman mines.

By 1895 the main tunnel extended 2,000 feet from the portal, and the mine employed 80 men (Montana Inspector of Mines, 1895). The mine produced 240 tons of coal daily. By 1897 the mine was being developed through two tunnels: No. 1, 5,500 feet long; and No. 2, 4,500 feet long (Montana Inspector of Mines, 1897). The mine employed 150 men underground and 15 men on the surface at that time and production averaged 350 tons per day. The length of the main drift by 1900 was 10,000 feet, but the mine employed only 75 men (Montana Inspector of Mines, 1900). By 1901 the workings of the Rocky Canyon coal mine included all of the Cokedale bed above the main water-level drift through secs. 17, 18, 20, and 21, T. 2 S., R. 7 E. (pl. 8), and at this time the operators began sinking a shaft to develop a lower level.

In 1902 the Northwestern Improvement Co. assumed operation of the Chestnut mine and also acquired the Mountain Side mine (Montana Inspector of Mines, 1904). Operations of the two mines were then combined, and a horizontal drift was cut to connect their main workings (pl. 8).

The total production of the Rocky Canyon (Chestnut) mine from 1882 through 1902 was 565,000 tons. During 1903–7 production was recorded with that of the Mountain Side mine. An analysis of the coal is given in table 2.

The Cokedale bed was sampled at localities 5 and 6 (pl. 1) at the Rocky Canyon (Chestnut) mine. The bed's stratigraphic relations and correlation are shown on plate 4.

MAXEY MINE

In 1881, Daniel Maxey, a western Montana pioneer, opened the Maxey mine—a horizontal drift driven southward on the strike of the Cokedale bed—on the south side of Rocky Canyon in the SW¼ sec. 21, T. 2 S., R. 7 E. (pl. 8), and by 1882 the mine was supplying coal for domestic needs in Bozeman (Avant Courier, Dec. 1, 1881; Nov. 30, 1882). Production was 236 tons in 1883 and 394 tons in 1884; no coal was produced in 1885 (U.S. Geol. Survey, 1885, p. 39).

In 1884 the Utah and Northern Railroad Co., a subsidiary of the Union Pacific Railroad Co., purchased the Maxey mine. The Utah and Northern Railroad carried large quantities of coke from Utah to the copper smelters in Butte, and the officials of the railroad company decided to manufacture coke at this closer locality. Experiments on the coking qualities of coal from this mine and from the Rocky Canyon mine, which they had also acquired, were carried on for about 1 year. The results of the coking tests were discouraging, and the mine was closed in 1885.

MOUNTAIN SIDE MINE

The Maxey mine and its property were leased from the Union Pacific Railroad Co. in the late 1890's by the Mountain Side Coal Co. This company, under the direction of M. J. Johnson, began a new horizontal drift on the Cokedale bed from a portal just north of the older Maxey portal in the NE¼SW¼ sec. 21, T. 2 S., R. 7 E. (pls. 1, 8). The coal bed dipped 23°–60° NE. By 1900 the drift was 1,800 feet long southward and the mine employed 70 men (Montana Inspector of Mines, 1900). During 1901 the drift was extended an additional 1,200 feet southward, and areas to be mined were blocked out.

The Mountain Side mine was purchased by the Northern Pacific Railway Co. in 1902, and operations of the mine were combined with those of the Chestnut mine, under the supervision of the Northwestern Improvement Co. (Montana Inspector of Mines, 1905). A horizontal drift, connecting the main workings of the Chestnut and Mountain Side mines, was completed in 1903. An inclined shaft was then driven to a depth of 500 feet in the Mountain Side mine (Montana Inspector of Mines, 1904).

In the Mountain Side mine there were areas in sec. 21, T. 2 S., R. 7 E., where Tertiary diabase dikes intruded the coal-bearing rocks, and the Cokedale bed adjacent to the intrusives had been transformed to coke (pl. 8).

The exterior workings of the Mountain Side mine were up to date, and the mine was one of the best equipped in the Livingston coal field. The mine had an excellent tipple, a washing plant with a daily capacity of 600 tons of coal (fig. 10), hand-picking tables for removing the bone, and four large hoists (Rowe, 1908a, p. 15).

The following production data were taken from reports by the Montana Inspector of Mines (1906, 1909, 1910):

	Year	*Tons produced*	*Men employed*
Mountain Side and Rocky Canyon (Chestnut) mines combined	1903	43, 224	200 (approx)
	1904	60, 000–70, 000	200 (approx)
	1905	124, 380	161
	1906	86, 175	125
	1907	64, 128	162
Mountain Side mine	1908	29, 191	174
	1909	8, 117	17
	1910	15, 672	32

All production from this mine was used by the Northern Pacific Railway Co. for locomotive fuel.

The stratigraphic relations and correlation of the Cokedale bed at locality 8 (pl. 1) in the Mountain Side mine are shown on plate 4, and an analysis of the coal is given in table 2.

THOMPSON NOS. 1 AND 2 PROSPECTS

The Thompson Nos. 1 and 2 open-pit prospects on the Cokedale bed in the NE¼ sec. 20, T. 2 S., R. 7 E. (pl. 1), were made in 1880 by C. W. Thompson. These prospects were dug to evaluate Colonel Chesnut's property for possible purchase by the Northern Pacific Railway Co. Eldridge (1886, pl. 63, secs. 1 and 2) sampled and described the coal in these pits in the early 1880's.

The Cokedale bed was sampled at localities 1 and 3 (pl. 1) at the Thompson Nos. 1 and 2 prospects. The bed's stratigraphic relations and correlation are shown on plate 4, and the analysis of a sample is given in table 2.

BAILEY AND BEADLE MINE

The Bailey and Beadle mine, in the SW¼ sec. 13, T. 2 S., R. 6 E. (pl. 1), was opened in the early 1900's by John Bailey and Joseph Beadle. The mine was a horizontal drift driven about 450 feet northeastward along the strike of the Cokedale bed, which at that locality dips 40°–50° NW. (pl. 6). The coal bed is 2½–3 feet thick where it is least disturbed and includes three distinct partings of bone 2–6 inches thick. Much of the coal is bony and badly broken. Many small faults cut the coal bed, and many minor irregularities are present in its roof and floor (Calvert, 1912a, p. 398). The mine produced only a small amount of coal, which

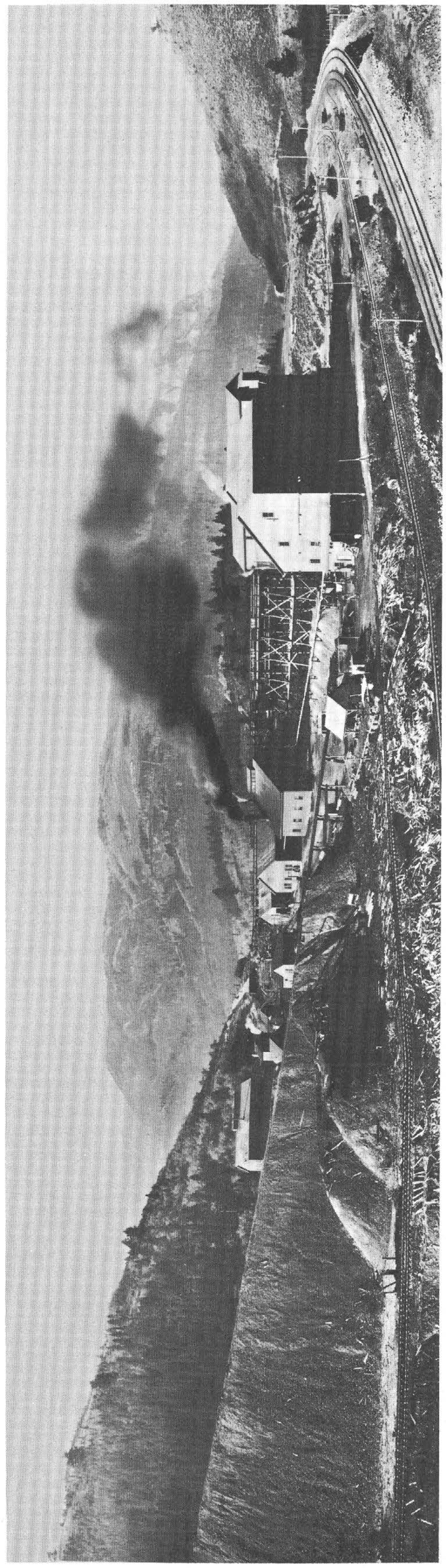


FIGURE 10.—Mountain Side mine, Livingston coal field. Main entry was just to the left of the three buildings shown in the center of the photograph. The largest building was the washing plant and tipple. Double tracks at right are those of the Northern Pacific Railway Co. The community of Chestnut was just behind the hill shown at the right side of the photograph. View toward the west; Chestnut Mountain is in background. Photographed by W. R. Calvert in 1908.

was sold to the ranchers in the nearby valley. The mine was closed in 1910.

Bailey and Beadle also opened several prospects in sec. 13. They drove a horizontal drift about 50 feet long 350 feet northeast of the mine portal, and another about 250 feet long 250 feet farther northeast.

An unnamed bed crops out near the mine and prospects, 40 feet stratigraphically above the Cokedale bed. The bed is 6 feet thick, including partings, but the abundant impurities preclude economic mining (Calvert, 1912a, p. 398).

The area was prospected again during 1929–31, and a small amount of coal was mined by D. Whitehead and B. Storey for domestic use.

An analysis of the coal bed at the Bailey and Beadle mine is given in table 2.

LASICH PROSPECT AND MINE

The Lasich prospect, in the NE¼NW¼ sec. 20, T. 2 S., R. 7 E. (pl. 1), was a horizontal drift driven north 682 feet on the strike of an unnamed bed by Steve Lasich during 1921–22. The bed contained 14–16 inches of clean coal and dipped almost vertically.

In 1924 Steve Lasich began development of the Lasich mine, in the N½SE¼ sec. 18, T. 2 S., R. 7 E. (pl. 1). The mine was a horizontal drift driven southeast on the strike of the Cokedale bed. The coal bed was thin and contained many partings. The mine, producing for the domestic trade in Bozeman, was operated on a small scale until 1934.

In the early 1930's, N. L. Rouse sank a prospect shaft on the Cokedale bed between the southern limits of the Lasich mine and the northern limits of the Rocky Canyon (Chestnut) mine. The coal bed dipped 83° NE. and was too thin to be mined.

During 1930–33 a prospect horizontal drift was driven southward 525 feet on the strike of an unnamed coal bed in the NE¼NW¼ sec. 20, T. 2 S., R. 7 E. (pl. 1), just southeast of the Lasich prospect. The bed was the same one that was found at the Lasich prospect.

MEADOW CREEK COAL CO. MINES

Daniel Maxey, after selling the Maxey mine in Rocky Creek Canyon in 1884, began development of a mine in sec. 28, T. 2 S., R. 7 E., which was later known as the Meadow Creek No. 3 mine (pls. 1, 5). It was developed on the Storrs No. 3 bed by two horizontal drifts, the longer of which was about 600 feet in length. Production was small and was sold for domestic use in Bozeman. Maxey operated this mine for only a few years and then moved to the Trail Creek coal district.

In 1918 the Maxey Bros. began a horizontal drift on the Storrs No. 3 bed a few hundred feet east of the Meadow Creek No. 3 mine. This tunnel was later known as the Meadow Creek No. 2 mine. Production by the Maxey Bros. was about 50 tons per day for about 1 year. The mine was taken over by the Meadow Creek Coal Co. and was their main producer for 3 years before it was abandoned in 1924.

In 1922 the Meadow Creek Coal Co. opened the Meadow Creek No. 1 mine, a small mine in the NW¼ sec. 27, T. 2 S., R. 7 E. (pl. 5), on the Cokedale bed. It was abandoned the same year because a large diabase dike (pl. 1) nearby limited the amount of accessible coal.

In the early 1930's, several mines were developed in the vicinity of the Meadow Creek mines. These included the Whitehead-Robinson, Harris-Murphy, Harris-Murphy-Rouse, and Miller Nos. 1, 2, and 3 mines. The Whitehead-Robinson mine (pl. 5) was the largest, and it operated from 1931 through 1942 for domestic trade. The Harris-Murphy mine (pl. 5) was a small lower level development in the Meadow Creek Coal Co. No. 2 mine. The Harris-Murphy-Rouse mine was opened in 1931 in an unsuccessful attempt to intersect the Storrs No. 3 coal bed. The Miller No. 1 mine (pl. 5) was developed by Carl and Edward Miller in 1926 on the Storrs No. 3 bed to supply the local domestic trade; it produced about 30 tons per day for about 5 months per year through 1933. The Miller No. 2 mine on the Cokedale bed and the Miller No. 3 mine on an unnamed bed stratigraphically beneath the Storrs No. 3 bed produced small quantities of coal which were sold for domestic use locally.

The stratigraphic relations and correlation of the Cokedale and Storrs No. 3 beds in the Meadow Creek Coal Co. mines, localities 37 and 38 (pl. 1), are shown on plate 4.

HODSON MINE

Enoch Hodson opened the Hodson mine, in the NW¼ sec. 35, T. 2 S., R. 7 E., in 1883 (pls. 1, 5). The mine was first opened by an inclined shaft, which was superseded in 1888 by a rock tunnel driven 650 feet across the strike to intercept the Cokedale bed 350 feet below the previous workings. Development was confined to the area northwest of the entry because a fault cuts the coal on the opposite side. The entry from the slope extended 900 feet along the strike, and rooms were opened above the entry. The bed here dips 35° NE.

The mine was operated intermittently by Hodson, who generally employed less than 10 miners. Production was small and for local trade. By 1902 the property had been acquired by the Washoe Coal Co.; however, this company did not continue development of the mine.

In 1908 the property was under lease to J. D. Evans; and at the time of examination by Calvert (1912a,

p. 395), the mine had been put in operating condition. Nine men mined 6,950 tons of coal in 1909, and 12 men mined 6,073 tons of coal in 1910 (Montana Inspector of Mines, 1910). A section of the coal bed was described by Calvert (1912a, p. 395), who incorrectly identified this mine as the Washoe No. 1. According to Calvert (1912a, p. 396), the mine was abandoned in 1910.

The Cokedale bed was sampled at locality 42 (pl. 1) in the Hodson mine. The bed's stratigraphic relation and correlation are shown on plate 4, and the analysis of a sample is given in table 2.

WASHOE COAL CO. NOS. 1, 2, 3, AND 4 MINES

A Northern Pacific Railway Co. field party, under the direction of L. S. Storrs, prospected the coal-bearing rocks in the valley of Meadow Creek in 1901. This work was done for the Anaconda Copper Co. for the purpose of developing mines to produce coking-quality coal. In 1902 Anaconda—through a subsidiary, the Washoe Coal Co.—acquired the property and began development of the mines and construction of a large and elaborate washing plant, coke ovens, Goose Creek reservoir, and the community of Storrs (fig. 11) (Montana Inspector of Mines, 1904).

During this period of development, prospecting was concentrated on the Paddy Miles and the Storrs No. 3 beds. These beds were thicker and had larger coal reserves above the valley floor than did the Cokedale bed. The Washoe Coal Co. Nos. 1, 2, 3, and 4 mines were developed (pl. 1). The largest mine was the Washoe Coal Co. No. 3 on the Storrs No. 3 bed (Calvert, 1912a, p. 394).

The Washoe Coal Co. No. 4 mine was a horizontal drift driven 860 feet northward on the Big Dirty Bed in the NE¼ sec. 35, T. 2 S., R. 7 E. (pl. 5). The bed ranged in width from 10 to 25 feet, but none of the coal was of commercial value.

The Washoe Coal Co. mines were situated in much the same way as the Meadow Creek mines—along the strike of coal beds in a tightly folded syncline. The coal was generally crushed or broken and admixed with clastic partings, many of which could not be separated from the coal either in the mining or by washing. Sufficient tonnage of clean coking coal to supply the company's elaborate facilities was never found, and in 1907, after spending nearly $1 million, the Washoe Coal Co. closed its operations at Storrs (Parsons, 1907, p. 1074). Most of the 100 coke ovens were never fired.

In 1905, production by the Washoe Coal Co. was 500 tons, and 16 men were employed. In 1906 there was no recorded production (Montana Inspector of Mines, 1906). In 1907, the production by 98 men was 14,978 tons, of which 14,074 tons was made into coke (Rowe, 1908b, p. 718).

In 1915 the Maxey Bros. took over the Washoe Coal Co. property at Storrs. Under the name of Chestnut Hill Coal Co., they mined some coal for the domestic trade in Bozeman.

Late in 1921 W. D. Gibson consolidated the more promising leases, including the Meadow Creek mines, Washoe Coal Co. mines, and the Maxey Bros. developments, in secs. 23, 26–28, 34, and 35, T. 2 S., R. 7 E. (pl. 5), to form the Meadow Creek Coal Co. This company did not reopen the Washoe Coal Co. mines.

The Cokedale bed was sampled in the Washoe Coal Co. No. 3 mine (locs. 40, 41, pl. 1). The bed's stratigraphic relations and correlation are shown on plate 4. Analyses of samples from the Cokedale and Paddy Miles beds are given in table 2. Analyses of coal from the Storrs No. 3 bed are given in table 3, coking tests of this coal are given in table 4, and analyses of the coke from this coal are given in table 5.

PAYNE MINE

This small mine, opened by Oscar Payne in about 1938 in the SW¼ sec. 35, T. 2 S., R. 7 E. (pl. 1), was a horizontal drift on the Storrs No. 3 bed. The small amount of coal produced was for domestic use.

MONROE MINE

The Monroe mine, developed in the early 1900's by William Monroe in the NW¼ sec. 2, T. 3 S., R. 7 E. (pl. 1), was a horizontal drift on the Maxey bed. A small amount of coal was mined for domestic use. Calvert (1912a, p. 396) briefly described the coal bed after visiting this mine in 1908.

The stratigraphic relations and correlation of the Maxey bed in the Monroe mine, locality 77 (pl. 1), are shown on plate 4.

PLANISHEK MINE

The Planishek mine, developed in the early 1930's by Joe Planishek and his sons in the NE¼ sec. 2, T. 3 S., R. 7 E. (pl. 1), was a horizontal drift that extended about 250 feet on the strike of the Maxey bed. The production was small and for domestic use; the mine was closed in 1933.

HARRISON MINE

This small mine, in the NE¼ sec. 2, T. 3 S., R. 7 E. (pl. 1), was developed by Henry Harrison in the early 1900's. The entry was a horizontal drift on the Maxey bed and extended 700 feet north of the portal. Calvert (1912a, p. 396–397) visited this mine in 1908 and briefly described it.

The coal is fairly clean and hard, irregular in thickness, and usually slickensided. The bed's location in a tightly folded syncline (pl. 1) considerably influenced the character of the coal.

Production was chiefly during the winter months and for a small domestic trade. During 1908 four men mined 462 tons of coal; during 1909 three men mined 491 tons (Montana Inspector of Mines, 1909, 1910). The mine was closed in 1910.

The stratigraphic relations and correlation of the Maxey bed in the Harrison mine, locality 78 (pl. 1), are shown on plate 4.

MORAN MINE

The Moran mine, a horizontal drift on the Big Dirty bed in the NE¼ sec. 2, T. 3 S., R. 7 E. (pl. 1), was developed in the early 1930's by Ernest Moran. Production was small and limited to domestic use.

TRAIL CREEK DISTRICT

The Trail Creek district was developed later than other districts of the Livingston coal field, primarily because of the difficulty in transporting coal to shippers at Brisbin and Chestnut. The Yellowstone Park Railway—an 11-mile private road completed in about 1899 by the Turner Bros. and leased to the Northern Pacific Railway Co.—began at Mountain Siding (near Chestnut) and ended at the Maxey Bros. mines. The railroad was first built to Hoffman; later it was extended to Chimney Rock. After the first closing of the Maxey Bros. mines in 1917, the tracks were removed.

The Mountain House and the Maxey Bros. mines became large producers in the Trail Creek district. As these mines grew, the communities of Hoffman and Chimney Rock—near the Mountain House and Maxey Bros. mines respectively—grew apace (pl. 1).

MOUNTAIN HOUSE MINE

In 1878 W. H. Randall and N. M. Black began development of the Mountain House mine, near the top of the divide between Trail and Meadow Creeks, in the NW¼SE¼ sec. 18, T. 3 S., R. 8 E. (pl. 1). It was named for Mountain House, a stage stop half a mile southeast of the mine on the road from Bozeman to Yellowstone Park.

In 1883 W. F. Sloan, E. D. Ferguson, and W. McIntyre bought Randall's interest in the mine. A horizontal drift extended 175 feet from the entry by the end of 1883, and during the next 2 years, 1,200 feet of workings was developed. Production in 1885 was 609 tons (U.S. Geol. Survey, 1885, p. 38).

C. W. Hoffman acquired the mine about 1896 after closing his operations at Timberline. He renamed the mine after himself but operated as the Mountain House Coal Co. In 1897 the No. 1 slope (pl. 6), which was an inclined shaft oblique to the 45° dip, was started on the lower split of the Storrs No. 3 bed (pl. 4). This slope

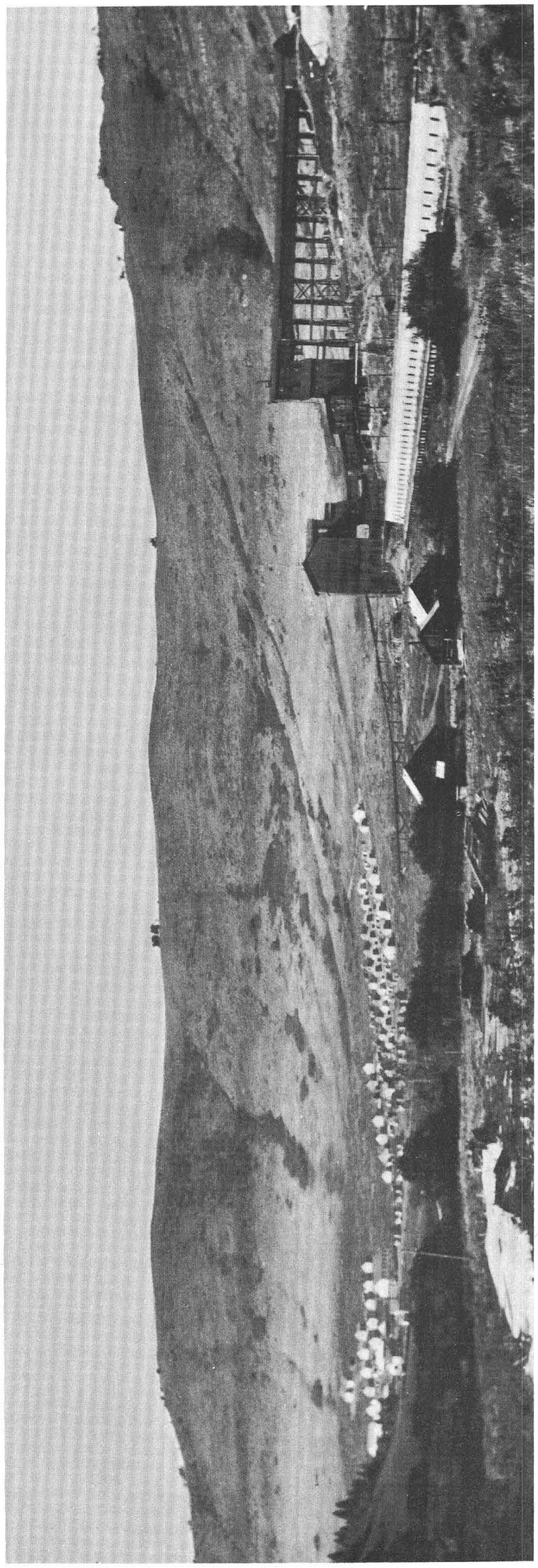


FIGURE 11.—The tipple, washing plant, and coke ovens of the Washoe Coal Co. in the Livingston coal field. Community of Storrs is in background. The view is north; Washoe Coal Co. mines were to the right of the area shown. Photographed by W. R. Calvert in 1908.

was extended down 200 feet, and the coal was removed from entries to the right (Montana Inspector of Mines, 1900). On the northwest side of the slope, the workings eventually extended to 2,700 feet (pl. 6); on the southeast side, to 530 feet.

J. W. Anderson and T. J. Evans leased the Mountain House Coal Co. property in 1905 and began development of the No. 2 slope. This inclined shaft was driven on the 45° dip of the Storrs No. 3 coal bed. By 1908 the No. 2 slope had been driven 320 feet; the workings extended 1,675 feet northwest and 1,495 feet southeast from the bottom of the slope (pl. 6). In the southeastern workings the Storrs No. 3 bed and the lower, unnamed bed were mined for nearly 1,200 feet—almost to the surface or to the contact with the older Hoffman workings above. In 1907 a fire broke out in the northwestern workings and the entries had to be sealed about 700 feet from the No. 2 slope. Between the sealed entries and the slope, both beds were mined up to the older Hoffman workings.

Although production data for the Mountain House mine are incomplete, the Montana Inspector of Mines (1900, 1906, 1909, 1910) reported a daily output of 125 tons by 1900, and reported data for other years as follows:

Year	*Tons of coal produced*	*Men employed*
1905	2, 610	19
1906	12, 022	30
1907	18, 908	34
1908	21, 639	45
1909	18, 906	50
1910	25, 452	54

The coal was shipped throughout the State for domestic use. The mine was closed in 1912.

The Sheep Corral mine, in the NW¼ sec. 18, T. 3 S., R. 8 E. (pl. 1), was a horizontal drift developed by the Mountain House Coal Co. that connected with the main workings of the Mountain House mine and extended those workings to the northwest. The tunnel was on the Storrs No. 3 bed, which dipped 41° NE. at the portal, and it extended at least 1,000 feet to the northwest. Production for this mine was recorded with that of the Mountain House mine.

The coal beds were sampled at localities 81–86 in the Mountain House mine and at localities 79 and 80 (pl. 1) in the Sheep Corral workings. The beds' stratigraphic relations and correlation are shown on plate 4, and the analyses of five samples are given in table 2.

STEVENSON MINE

The Stevenson mine, in the SW¼SW¼ sec. 17, T. 3 S., R. 8 E. (pl. 1) was reportedly started by Sy Mounts in 1884. The mine began as a horizontal drift driven southward along the strike of the Storrs No. 3 coal bed and continued as a slope driven northeastward 150 feet. Mounts' work was limited to development; no production was reported. The mine was closed in 1889 owning to difficulty in transporting the coal to the railroad and to the low price of coal at that time.

The tunnel was reopened by A. Stevenson in 1907, and the workings were extended 600 feet southeastward (pl. 7). Production was small and was sold in Bozeman for domestic use. The mine was closed in 1909.

In 1934 J. W. Anderson reopened the mine by driving a crosscut rock tunnel and a slope (pl. 7). Again, production was small; it was trucked to Bozeman for domestic use. The mine was abandoned in 1940.

KOUNTZ MINE

J. J. Kountz and George Cox, who operated as the Park County Coal Co., developed the Kountz mine, in the NW¼ sec. 20, T. 3 S., R. 8 E. (pl. 1), during the late 1890's by driving an inclined shaft on the lower split of the Storrs No. 3 bed. By 1907 the incline was 600 feet deep and followed the coal, which dipped 42° NE. The coal was mined to a depth of 200 feet. About 1907 J. W. Anderson and T. J. Evans acquired the mine. During their operation the incline was advanced to a depth of 700 feet, and the workings, which were terminated at faults, were extended 750 feet northwestward and 550 feet southeastward. The mine was closed in 1910 because of fire (Calvert, 1912a, p. 399).

Coal production was 3,000 tons in 1905 and 5,580 tons in 1906; it was shipped to Bozeman and other nearby towns for domestic trade (Montana Inspector of Mines, 1906). During those years the mine employed 10–15 men. In 1907, mining by 45 men yielded 8,366 tons, and in 1908, mining by 35 men yielded 5,728 tons (Montana Inspector of Mines, 1909). Production during 1909 was recorded with that of the Mountain House mine, which was operated by Anderson and Evans.

The lower split of the Storrs No. 3 bed was sampled at locality 87 (pl. 1) at the Kountz mine. The split's stratigraphic relations and correlation are shown on plate 4, and the analysis of a sample (No. 87) is given in table 2.

GASAWAY MINE

In 1908 D. E. Gasaway drove a 300-foot rock tunnel from Trail Creek northeast to intersect four coal beds (pl. 2) in the NW¼SE¼ sec. 20, T. 3 S., R. 8 E. (pl. 1). The coal beds dip 64° SW. and have been badly broken by faulting. A small amount of coal was produced for domestic use.

FEATHERSTONE MINE

B. Featherstone opened this small mine, in the SW¼SE¼ sec. 21, T. 3 S., R. 8 E. (pl. 1), in the early

1900's by means of a 55-foot-long shaft inclined northeastward on the Big Dirty bed. The coal at the surface is overturned and dips 45° NE., but, at the bottom of the slope, the dip reversed to 60° SW. Many small faults were discovered in the mine, and the coal was soft. A short horizontal drift was driven southeastward, but it intersected a fault and was abandoned. The mine was operated for about 1 year, and a small amount of coal was produced for domestic use.

HEDGES BROS. MINE

In 1884 the Hedges brothers drove a horizontal drift into the Maxey bed in the NW¼NW¼ sec. 28, T. 3 S., R. 8 E. (pl. 1). A small amount of coal was produced for the Anaconda Copper Co. smelters at Butte. Operations of the Hedges Bros. and the Byam Bros. mines were merged by G. V. Moroford in 1885. The Hedges Bros. mine was closed at the end of 1885.

BYAM BROS. MINE

By 1884 H. C. and O. O. Byam—sons of the famed judge, Dr. D. L. Byam of the Vigilante Miners Court in Virginia City, Mont.—had developed a 170-foot-long horizontal drift on the Maxey bed in the NE¼NW¼ sec. 28, T. 3 S., R. 8 E. (pl. 1). G. V. Moroford merged operations of the Byam Bros. and the Hedges Bros. mines in 1885 following the death of O. O. Byam by an accident in the Byam Bros. mine. The combined operations were suspended after only 1 year. From 1887 to 1892 H. C. Byam worked the mine intermittently. In 1889 about 20 tons per day was produced for use by the Dodson lime kiln, a few miles south of Livingston. Production for 1890 was approximately 1,000 tons.

MAXEY BROS. NOS. 1, 2, AND 3 MINES

Daniel Maxey in 1889 drove an inclined shaft to a depth of 40 feet on the Maxey bed in the SE¼NE¼ sec. 28, T. 3 S., R. 8 E., just west of Trail Creek, near what later became the community of Chimney Rock (pl. 1). Development was intermittent, and about 1895 A. B. Cook acquired the property and operated as the Trail Creek Coal Co. (Montana Inspector of Mines, 1900). A 260-foot slope was driven southwestward from the No. 1 tunnel and entries are northwestward and southeastward. The dip of the coal increased from 34° to nearly vertical (Calvert, 1912a, p. 399), several faults were struck, and the mine was abandoned. Daniel Maxey reacquired the mine in 1903 and with his sons, John, William, David, and George, operated as the Maxey Coal Co. The company developed the largest producing mine in the Trail Creek district. The mine was best known as the Maxey Bros. coal mine (fig. 12), although it has been referred to as the Byam, Cook, Maxey, and the Chimney Rock mines.

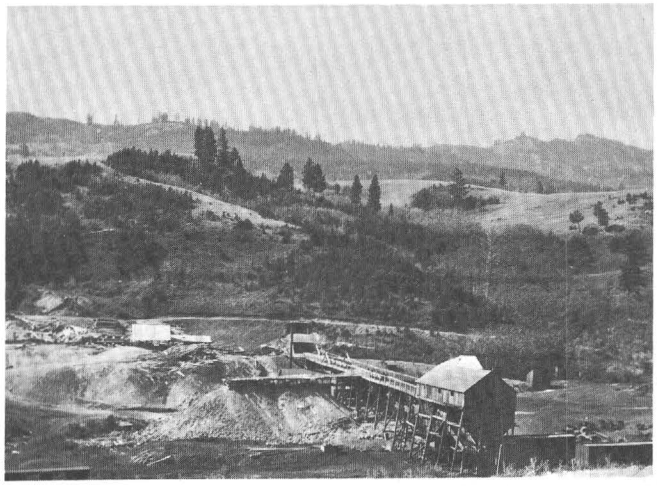


FIGURE 12.—The Maxey Bros. No. 1 mine portal and tipple, Livingston coal field. Wooded hills in background are underlain by Eocene conglomerate and volcanic breccia. Chimney Rock shows on skyline on right side of photograph. View is to the west. Photographed by W. R. Calvert in 1908.

In 1903 the Maxey Bros. reopened the mine, drove southward through the fault, and resumed production (Calvert, 1912a, p. 399). When they found that the dip of the coal bed lessened southward, they made a new entry, Maxey Bros. No. 2 mine (pl. 6), and all the coal mined during 1908–10 came from these workings. In 1910 a third entry, Maxey Bros. No. 3 mine (pl. 6), was developed as the main haulageway and connected with the workings of the No. 2 mine. Midway between these workings, driven from the No. 2 water-level tunnel, was a 1,100-foot incline that trended 45° SW. (pl. 6). This incline was driven on the dip of the coal. Near the hoist the dip was 18° SW.; 600 feet farther down the incline the dip had gradually flattened to 14° NW.; and at the bounding fault that terminated the mine to the west (pl. 6), the dip had flattened to 10° NW.

The main workings of the Maxey Bros. mines lie between two northwest-trending faults; the north fault offset the coal 100 feet; the south fault, more than 150 feet (pl. 1). After the main slope reached the south fault, a crosscut was made that passed through the fault and into the stratigraphically higher beds of the Eagle Sandstone. During this exploration a small coal bed was opened—probably the Bottamy bed—about 150 feet stratigraphically above the Maxey bed. No further exploration was made along this fault, and by about 1915 the blocked-out reserves had all been mined.

The Maxey bed was unusually thick in this part of the Livingston coal field. The bed in the Maxey Bros. mines was 9 feet thick; it had a sandstone roof, a shale floor, and a prominent 2- to 4-inch sandstone parting 66 inches from the base (pl. 4). This parting was left as a roof during the early mining; but later, when the pillars were mined, the coal above the parting was removed.

The Maxey Bros. mined less than 500 tons in 1906. In 1907, however, they mined 7,629 tons, employing 53 men; in 1908, 15,520 tons, employing 52 men; in 1909, 15,564 tons, employing 28 men; and in 1910, 32,308 tons, employing 47 men (Montana Inspector of Mines, 1909, 1910). Production in 1911 was 31,402 tons. Mining continued through 1914, but production figures are not available.

During 1915–18 the mine was virtually idle while the operators attempted unsuccessfully to locate the Maxey bed in secs. 27 and 34, T. 3 S., R. 8 E., and sec. 3, T. 4 S., R. 8 E. The pillars were mined during 1930–31 and generally produced 50–60 tons per day; at times they yielded as much as 100 tons of coal. The mine was abandoned in 1931.

Approximately 200,000 tons of coal was produced from 22 acres of underground workings while the mines were in operation. The coal was an excellent fuel for domestic purposes because it left no clinkers, and most of the output was shipped to many parts of the State.

The stratigraphic relations and correlation of the Maxey bed in the Maxey Bros. No. 2 mine, locality 88 (pl. 1), and of the Middle bed at the Maxey Bros. prospect, locality 89 (pl. 1), are shown on plate 4, and the analyses of a sample from each locality are given in table 2.

KEARNS PROSPECT

In the late 1890's W. M. Kearns sank a prospect shaft on a steeply dipping unnamed bed (this bed may correlate with a part of the Big Dirty bed) in the NE¼ sec. 34, T. 3 S., R. 8 E. (pl. 1). The coal bed was too thin and impure to be of commercial value, and development stopped in about 1900.

BOTTAMY NOS. 1 AND 2 MINES

Many prospects were made along the north slope of Pine Creek valley in secs. 3 and 4, T. 4 S., R. 8 E. The Avant Courier (Feb. 19, 1885) briefly referred to the Pine Creek mines—owned by Wilber and Co.—which were developed by about 600 feet of tunnels. H. Kohler, J. W. Ponsford, L. Swan, F. D. Pease, and C. Daly also prospected in this area during the 1880's and 1890's. The greatest mining efforts in the Pine Creek area were those of H. Bottamy during 1907–34, and those of his son, G. H. Bottamy, during 1914–57.

The Bottamy prospect, in the SW¼NE¼ sec. 4, T. 4 S., R. 8 E. (pl. 1), was a slope driven in 1907 by H. Bottamy, 150 feet northeastward on the Bottamy bed, which dipped 15° NE. at this location. Section 95 (pl. 4) of the coal bed was measured 50 feet from the portal. The prospect was abandoned in 1909.

The Bottamy No. 1 mine, in the NE¼NW¼ sec. 4, T. 4 S., R. 8 E. (pl. 1), was started in 1909 by H. Bottamy with a horizontal drift on the Bottamy bed. By 1934, when the mine was abandoned, the workings had three horizontal drifts driven northwestward, each about 250 feet long. Coal section 94 (pl. 4) was measured near the main portal.

The Bottamy No. 2 mine, in the NE¼NW¼ sec. 4, T. 4 S., R. 8 E., was opened by G. H. Bottamy in 1936 (pl. 1). The mine operated as the Pine Creek Coal Co. and was developed from two horizontal drifts driven about 300 feet northwestward on the strike of the Bottamy bed (No. 93, pl. 4). The mine was worked intermittently through 1957 and was the last one active in the Livingston coal field.

Production from these mines was small owing to the difficulty in transporting the coal to rail facilities. The output was hauled to Livingston for domestic use.

The stratigraphic relations and correlation of the Bottamy bed in the Bottamy Nos. 1 and 2 mines, localities 94 and 93 (pl. 1), and at the Bottamy prospect, locality 95 (pl. 1), are shown on plate 4.

BRIDGER CANYON DISTRICT

In the Bridger Canyon district, two coal beds were prospected. The relation of these beds to those in the nearby Meadow Creek district is unknown; however, they are in the lower coal zone and are perhaps equivalent to the Big Dirty and Maxey beds. The 4-foot-thick lower bed and the 6-foot-thick upper bed are separated by 25 feet of massive sandstone. Both beds contain many partings of shale, bone, and impure coal. No mines were developed on these beds.

In the SE¼ sec. 34 is an abandoned stone quarry (pl. 1) where sandstone was once quarried for building stone used largely in Bozeman. During the operation of this quarry, both coal beds were exposed for a distance of 200 feet and to a depth of nearly 50 feet. Neither the thickness nor the quality of these beds warranted further development.

Two prospect tunnels—one, 200 feet long—were driven in sec. 26, T. 1 S., R. 6 E. The coal beds had the same characteristics as those described from secs. 34 and 35 and may be the same beds.

METHODS OF MINING

Structural and topographic conditions as well as the character of each coal bed influenced the methods of mining in the Livingston coal field. Three large anticlines and related structural features (pl. 1) affect the dip and strike of the coal. The coal beds are generally broken by many small faults where the coal-bearing rocks curve around the plunge of these folds. Faults of large displacement generally occur along the flanks of the major folds. In many places near the large faults, the coal beds are crumpled and shattered, and the offset of the beds is too great to permit economical mining operations.

The poor structural location of most mines in the Livingston coal field has been a major cause of the past mine failures and the resultant poor reputation of the field. Most mine entries were located in ravines for easy access to the coal and were generally developed on a slight grade along the strike of the coal bed for easy drainage and hauling. Most headings were double timbered and lagged. As mining progressed along the strike in the first level, inclined shafts were developed for expansion at depth. Mining was by the room-and-pillar or the chute-and-pillar method. Rooms or chutes were developed at right angles to the haulageways. The rooms were worked on the longwall plan, as there were no pillars between them. (See pl. 8.) Under some conditions, generally as the dip of the bed increased, the chutes were driven across the dip at an angle, so that the grade on which coal was moved to the haulageway was not as great. The width of the room chutes varied in proportion to the dip of the coal. In the larger operations the chutes were propped on both sides, and the space between the chutes was filled with coal. Generally the dip of the coal bed was steep enough that explosives were not required, and the coal was undercut and allowed to slide down into the chute. Coal was loaded into cars by gravity from the chutes, and the loaded cars were pulled up the inclined shafts to the tipple by steam-driven winches.

All the coal beds of the Livingston coal field have one or more partings; hence, all the coal requires washing in order to yield a product having an acceptably low ash content. The partings, which are heavier than the coal, usually can be removed in a washing plant. Generally the coal was screened before shipment. At Cokedale the finer size material generally went to the coke ovens, and the larger size material was shipped for industrial use; however, when the market for this commercial size declined, the larger size material was crushed at the washing plant and sent to the coke ovens.

The size distribution of a mine-run sample of the Middle bed from the Cokedale No. 3 mine was described by Smith [2] as follows: Larger than 1½ inches, 2.04 percent; 1½–¾ inches, 6.67 percent; ¾–⅜ inch, 16.82 percent; ⅜–3/16 inch, 21.35 percent; 3/16 inch–20 mesh per inch, 39.92 percent; and smaller than 20 mesh per inch, 13.20 percent.

[2] Smith, G. R., 1954, Carbonization of Montana coal: Bozeman, Montana State College unpub. M.S. thesis, p. 40.

Mining methods in the Livingston coal field were also influenced by the need for good ventilation. The Rocky Canyon mine and the Timberline No. 3 mine contained explosive gases (Montana Inspector of Mines, 1896, p. 43). The Mountain Side mine was fairly well ventilated, but some lower workings contained gas (Rowe, 1908b, p. 675). Gas was also reported to be in the Mountain House mine (Montana Inspector of Mines, 1906, p. 78).

COAL RESERVES

The estimated coal reserves in the Eagle Sandstone in the Livingston coal field as of January 1, 1965, totaled more than 300 million short tons. These reserves are in beds that are 14 inches or more thick and are within 3,000 feet of the surface. The distribution of reserves in individual coal beds and townships and by categories according to thickness of the bed, amount of overburden, and classes (measured and indicated, and inferred reserves) is shown in table 8.

The coal-reserve estimates given in this report for the Livingston coal field were calculated for individual beds by use of 7½-minute quadrangles enlarged to a scale of 1:15,840 as aerial units. On the map of each bed, the outcrop of the coal, location of all measured sections, and subsurface information were compiled. The boundaries between overburden thicknesses, coal-thickness categories, and reserve classes (measured, indicated, and inferred) were plotted on the maps of the beds in accordance with standard procedures of the U.S. Geological Survey (Averitt, 1961).

The weight of bituminous coal in the ground is most affected by the coal's ash content and, to a lesser extent, by its content of fixed carbon, moisture, and volatile matter. Precise data on the weight of coal in the Livingston coal field were not available, and the average of 1,800 tons per acre-foot (Averitt, 1961, p. 18) was used in all calculations of reserves.

Partings more than three-eighths inch thick were omitted in determining the thickness of an individual bed. Beds or parts of beds made up of alternating layers of thin coal and partings were excluded if the partings made up more than half the total thickness.

Only a small amount of coal in the Livingston coal field could be classed as measured, inasmuch as the points of observation for measured coal should be no greater than half a mile apart and at least three in number. Large amounts of coal could be classed as indicated, because many of the points of observation were within the interval of 1½ miles, and projection of visible data on geologic evidence was reasonable for this distance. In reporting reserves for the Livingston coal field, therefore, these two classes are combined as "measured and indicated." The reserve table shows that approximately 85 percent of the total estimated reserves is included in this class. Inferred reserves are quantitative estimates, primarily based on knowledge of the geologic character of the coal beds and on the assumption that the continuity of the beds extends as much as 2 miles from the nearest observation point. Areas mined out or destroyed in mining were measured and subtracted from the original reserves because of the paucity of accurate production records.

The percentages of coal recovered and lost in mining vary in different beds and areas; they are related to thickness and quality of the coal, nature of the roof and floor, amount of overburden, mining methods employed, and other factors. The lack of complete production or mining records for the Livingston coal field precludes an accurate estimate of the percentage of coal recovered in mining. In a few of the larger mines more than 50 percent of the coal was recovered, and in most of the small mines recovery probably was less; however, in the larger mines for which records were available, the average recoverability seems to have been approximately 50 percent, which is similar to the nationwide average (Averitt, 1961, p. 25). Statistically, then, the recoverable reserves for the Livingston coal field would be half of the remaining reserves listed in table 8.

The future of the Livingston coal field is in the development of the coal in areas where large-scale mining could be economic. These areas include the coal at depth in the Cokedale and Timberline districts, the Eldridge Creek synclinal area between these two

TABLE 8.—*Estimated coal reserves in the Eagle Sandstone, Livingston coal field, Montana, January 1, 1965*

[In thousands of short tons]

Coal bed	Overburden (ft)	Measured and indicated				Inferred				Total all categories			Grand total
		14–28 in.	28–42 in.	>42 in.	Total	14–28 in.	28–42 in.	>42 in.	Total	14–28 in.	28–42 in.	>42 in.	
T. 2 S., R. 7 E.													
Cokedale	0–1,000	------	1,459	7,016	8,475	------	795	------	795	------	2,254	7,016	9,270
	1,000–2,000	------	1,417	9,930	11,347	------	933	------	933	------	2,350	9,930	12,280
	2,000–3,000	------	1,115	8,686	9,801	------	1,106	------	1,106	------	2,221	8,686	10,907
	Total	------	3,991	25,632	29,623	------	2,834	------	2,834	------	6,825	25,632	32,457
Paddy Miles	0–1,000	763	1,766	4,663	7,192	------	1,313	------	1,313	763	3,079	4,663	8,505
	1,000–2,000	899	2,029	3,286	6,214	------	1,382	------	1,382	899	3,411	3,286	7,596
	2,000–3,000	------	3,321	2,494	5,815	------	1,624	------	1,624	------	4,945	2,494	7,439
	Total	1,662	7,116	10,443	19,221	------	4,319	------	4,319	1,662	11,435	10,443	23,540
Storrs No. 3	0–1,000	------	69	8,893	8,962	760	------	------	760	760	69	8,893	9,722
	1,000–2,000	------	------	7,476	7,476	829	------	------	829	829	------	7,476	8,305
	2,000–3,000	------	------	6,705	6,705	991	------	------	991	991	------	6,705	7,696
	Total	------	69	23,074	23,143	2,580	------	------	2,580	2,580	69	23,074	25,723
Unnamed bed at base of upper coal zone	0–1,000	847	355	------	1,202	------	------	------	------	847	355	------	1,202
	1,000–2,000	786	258	------	1,044	------	------	------	------	786	258	------	1,044
	2,000–3,000	772	161	------	933	------	------	------	------	772	161	------	933
	Total	2,405	774	------	3,179	------	------	------	------	2,405	774	------	3,179
Total, 4 beds	------	4,067	11,950	59,149	75,166	2,580	7,153	------	9,733	6,647	19,103	59,149	84,899
T. 2 S., R. 8 E.													
Cokedale	0–1,000	138	553	9,009	9,700	------	2,212	------	2,212	138	2,765	9,009	11,912
	1,000–2,000	------	311	10,243	10,554	------	2,281	------	2,281	------	2,592	10,243	12,835
	2,000–3,000	------	------	11,146	11,146	------	2,316	------	2,316	------	2,316	11,146	13,462
	Total	138	864	30,398	31,400	------	6,809	------	6,809	138	7,673	30,398	38,209
Paddy Miles	0–1,000	------	3,316	3,456	6,772	------	------	2,580	2,580	------	3,316	6,036	9,352
	1,000–2,000	8	3,137	2,915	6,060	------	------	2,765	2,765	8	3,137	5,680	8,825
	2,000–3,000	71	3,587	2,984	6,642	------	------	2,949	2,949	71	3,587	5,933	9,591
	Total	79	10,040	9,355	19,474	------	------	8,294	8,294	79	10,040	17,649	27,768
Storrs No. 3	0–1,000	------	968	46	1,014	1,797	------	------	1,797	1,797	968	46	2,811
	1,000–2,000	------	795	138	933	1,313	------	------	1,313	1,313	795	138	2,246
	2,000–3,000	------	864	438	1,302	1,290	------	------	1,290	1,290	864	438	2,592
	Total	------	2,627	622	3,249	4,400	------	------	4,400	4,400	2,627	622	7,649
Middle	0–1,000	46	4,285	------	4,331	968	760	------	1,728	1,014	5,045	------	6,059
	1,000–2,000	------	4,044	------	4,044	691	760	------	1,451	691	4,804	------	5,495
	2,000–3,000	------	4,562	------	4,562	760	864	------	1,624	760	5,426	------	6,186
	Total	46	12,891	------	12,937	2,419	2,384	------	4,803	2,465	15,275	------	17,740
Total, 4 beds	------	263	26,422	40,375	67,060	6,819	9,193	8,294	24,306	7,082	35,615	48,669	91,366

TABLE 8.—*Estimated coal reserves in the Eagle Sandstone, Livingston coal field, Montana, January 1, 1965*—Continued

Coal bed	Overburden (ft)	Measured and indicated				Inferred				Total all categories			Grand total
		14–28 in.	28–42 in.	>42 in.	Total	14–28 in.	28–42 in.	>42 in.	Total	14–28 in.	28–42 in.	>42 in.	
T. 2 S., R. 9 E.													
Middle	0–1,000			9,562	9,562		4,147		4,147		4,147	9,562	13,709
	1,000–2,000			8,640	8,640		4,458		4,458		4,458	8,640	13,098
	2,000–3,000			7,718	7,718		5,288		5,288		5,288	7,718	13,006
	Total			25,920	25,920		13,893		13,893		13,893	25,920	39,813
Total				25,920	25,920		13,893		13,893		13,893	25,920	39,813
T. 3 S., R. 7 E.													
Storrs No. 3	0–1,000	35		46	81					35		46	81
	1,000–2,000												
	2,000–3,000												
	Total	35		46	81					35		46	81
Total		35		46	81					35		46	81
T. 3 S., R. 8 E.													
Paddy Miles	0–1,000			922	922							922	922
	1,000–2,000												
	2,000–3,000												
	Total			922	922							922	922
Storrs No. 3	0–1,000	138	242	852	1,232					138	242	852	1,232
	1,000–2,000												
	2,000–3,000												
	Total	138	242	852	1,232					138	242	852	1,232
Unnamed bed (or lower split of the Storrs No. 3)	0–1,000	23	35	4,044	4,102					23	35	4,044	4,102
	1,000–2,000												
	2,000–3,000												
	Total	23	35	4,044	4,102					23	35	4,044	4,102
Middle	0–1,000			15,552	15,552			58	58			15,610	15,610
	1,000–2,000			5,760	5,760							5,760	5,760
	2,000–3,000												
	Total			21,312	21,312			58	58			21,370	21,370
Bottamy	0–1,000		14	9,298	9,312						14	9,298	9,312
	1,000–2,000			597	597							597	597
	2,000–3,000												
	Total		14	9,895	9,909						14	9,895	9,909
Maxey	0–1,000			24,618	24,618			2,822	2,822			27,440	27,440
	1,000–2,000			3,629	3,629							3,629	3,629
	2,000–3,000												
	Total			28,247	28,247			2,822	2,822			31,069	31,069
Total, 6 beds		161	291	65,272	65,724			2,880	2,880	161	291	68,152	68,604
T. 4 S., R. 8 E.													
Bottamy	0–1,000		94	3,602	3,696						94	3,602	3,696
	1,000–2,000												
	2,000–3,000												
	Total		94	3,602	3,696						94	3,602	3,696
Maxey	0–1,000			7,344	7,344			4,884	4,884			12,228	12,228
	1,000–2,000			98	98							98	98
	2,000–3,000												
	Total			7,442	7,442			4,884	4,884			12,326	12,326
Total, 2 beds			94	11,044	11,138			4,884	4,884		94	15,928	16,022
Grand total		4,526	38,757	201,806	245,089	9,399	30,239	16,058	55,696	13,925	68,996	217,864	300,785

districts, the Meadow Creek synclinal area in the Meadow Creek district, and the Pine Creek synclinal area in the Trail Creek district (pl. 1). Development of any of these areas should be preceded by a systematic drilling program to determine whether the coal beds are thick enough and whether the quality of the coal is high enough to justify the expense of opening a mine. The high cost of mining the relatively thin and structurally complicated coals in the Livingston coal field may be offset by future demands—such as the needs of the expanding chemical industry—for these higher rank coals. Future mining in this field could be successful only if the mine operations are planned for the specific geological conditions.

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