GEOLOGY OF THE HOUND CREEK DISTRICT OF THE GREAT FALLS COAL FIELD, CASCADE COUNTY, MONTANA.

By V. H. Barnett.

INTRODUCTION.

This paper is based on field work done during the month of September, 1909, by W. R. Calvert and the writer, assisted by J. R. Hoats. Its objects are to give information regarding the coal resources of the Hound Creek district of the Great Falls coal field and to describe the geologic formations and the structure relating to the occurrence or absence of the coal-bearing rocks. As the work was done primarily

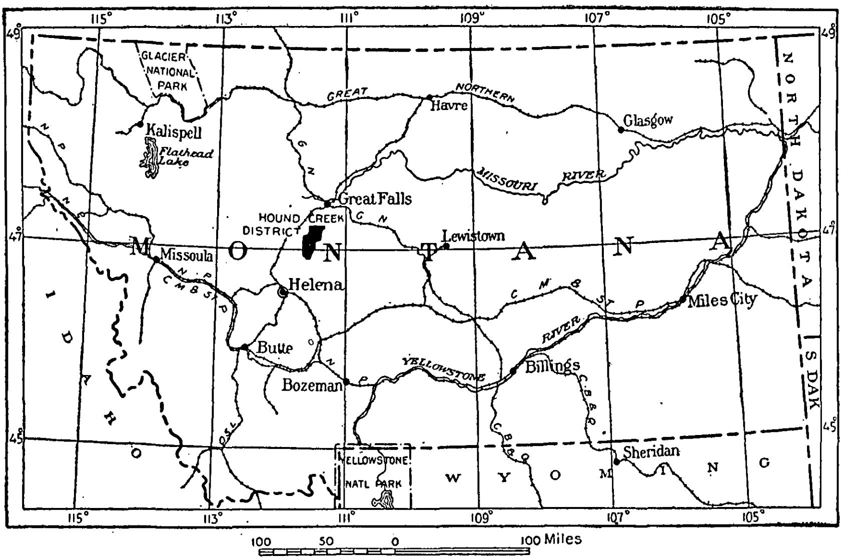


Figure 15.—Key map showing location of Hound Creek district, Mont.

for land classification, the determination of the presence or absence of the coal was one main purpose.

The Hound Creek district is the southwestern extension of the Great Falls coal field, on which a detailed report[1] has been published. It comprises 180 square miles in Cascade County, Mont., and extends

[1] Fisher, C. A., Geology of the Great Falls coal field, Mont.: U. S. Geol. Survey Bull. 356, 1909.

along both sides of Hound Creek from a point near its mouth on Smith River (Deep Creek) to the head of Elk Creek in the foothills of the Big Belt Mountains. (See Pl. XXII and fig. 15.)

In the course of the field work section corners were found with very little difficulty. Plane-table triangulation and mapping with telescopic alidade and stadia rod were also employed, so that a fair degree of accuracy was attained. Altitudes were obtained by aneroid-barometer readings based on the assumed altitude of Hound Creek bridge, in sec. 24, T. 17 N., R. 2 E.

SURFACE FEATURES.

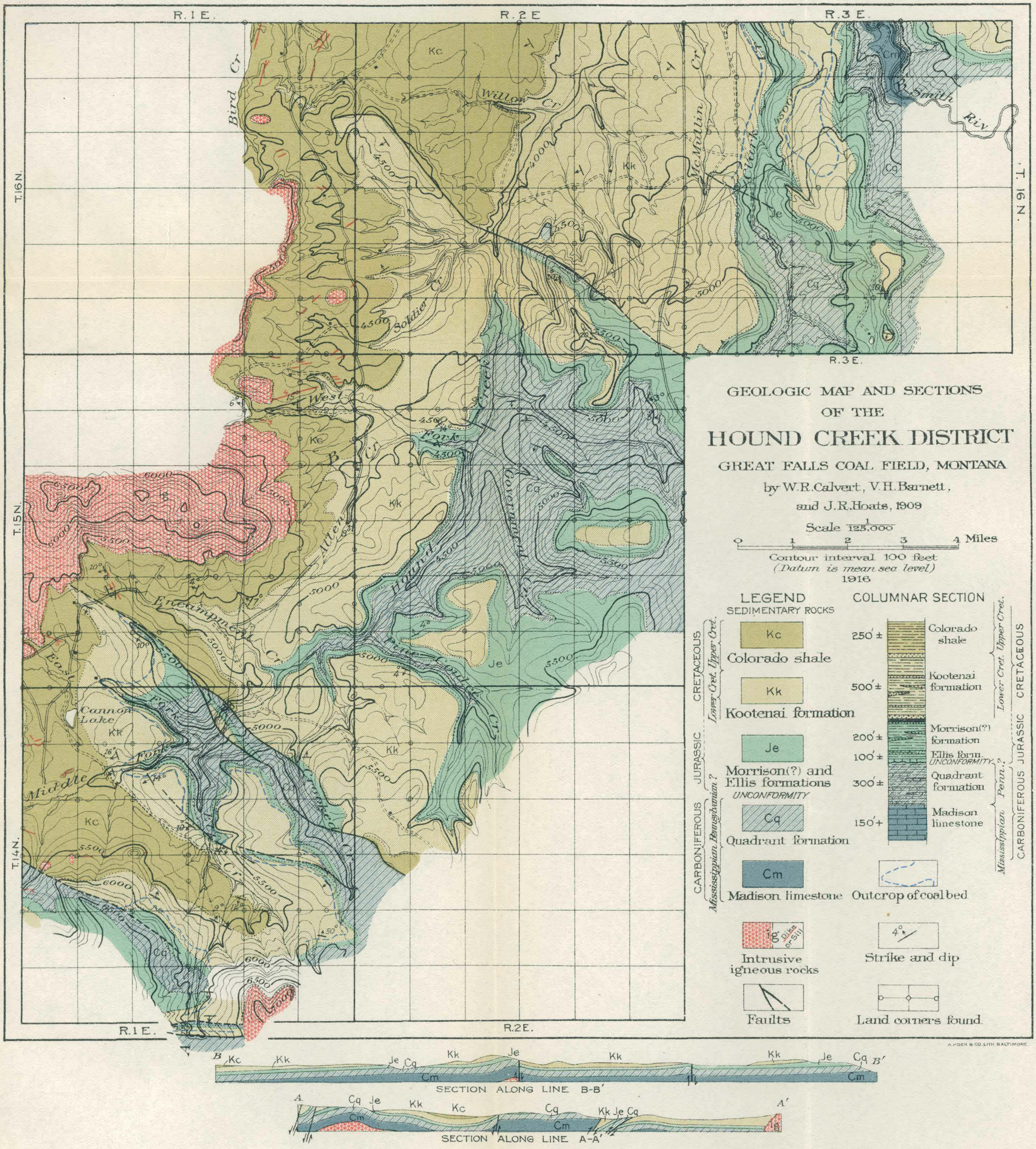
RELIEF.

The surface of the district is made up of high, rounded hills and broad slopes cut by streams into steep-sided valleys. For the most part the area borders a zone of mountain topography, but on the north it is adjacent to a more level country. The range of altitide is from 3,800 feet near the mouth of Hound Creek to about 7,200 feet in the southern part of the district. The average altitude of the field is about 5,000 feet, and the greatest difference in any one locality is 1,200 feet in three-fourths of a mile in sec. 22, T. 15 N., R. 1 E. Most of the streams have cut deep channels into the soft shale, and the more resistant limestones and sandstones make the valley sides steep and precipitous. The deeper valleys are from 300 to 500 feet below the level of the bordering plains. Smith River is locally known as Deep Creek because it flows through a deep, narrow gorge in this part of its course. It crosses the northeast corner of the district and empties into Missouri River about 16 miles to the northwest. Hound Creek drains the larger part of the area, and its numerous mountain tributaries are fed by perennial springs.

CULTURE.

There are few settlements in the Hound Creek district, the population averaging about six families to the township. Adel, the only post office, is maintained at a ranch house in the southwestern part of the district. The location of ranches is determined by the position of readily irrigable land or by proximity of range for stock. There is an abundance of water almost everywhere, so that except on the higher areas it is not very difficult to procure sufficient water for irrigating small tracts.

Wagon roads generally are poor, but two regularly traveled roads cross the district from north to south. One is the stage road from Great Falls to Milligan post office and the other the main line of travel between Adel and Cascade, on Missouri River, 15 miles to the north. Other roads connect with these main roads but are difficult to travel over even with a light wagon.



R.1 E.
R.2 E.
R.3 E.
T.16 N.
T.15 N.
T.14 N.
GEOLOGIC MAP AND SECTIONS OF THE
HOUND CREEK DISTRICT
GREAT FALLS COAL FIELD, MONTANA
by W.R.Calvert, V.H.Barnett, and J.R.Hoats, 1909
Scale 1/125,000
0 1 2 3 4 Miles
Contour interval 100 feet
(Datum is mean sea level)
1916
LEGEND
SEDIMENTARY ROCKS
COLUMNAR SECTION
Kc Colorado shale
Kk Kootenai formation
Je Morrison(?) and Ellis formations
UNCONFORMITY
Cq Quadrant formation
Cm Madison limestone
Outcrop of coal bed
Intrusive igneous rocks
Dike
Sill
Strike and dip
Faults
Land corners found
CRETACEOUS
Upper Cret.
Lower Cret.
JURASSIC
CARBONIFEROUS
Mississippian
Pennsylvanian?
250'± Colorado shale
500'± Kootenai formation
200'± Morrison(?) formation
100'± Ellis form.
UNCONFORMITY
300'± Quadrant formation
150'+ Madison limestone
Bird Cr.
Willow Cr.
McMillan Cr.
Smith Riv.
Soldier Cr.
West Fork
Allen Cr.
Hound Cr.
Encampment Cr.
Pine Coulee Cr.
Cannon Lake
Middle Fork
East Fork
SECTION ALONG LINE B-B'
SECTION ALONG LINE A-A'
A.HOEN & CO.LITH.BALTIMORE

An electric power line from Great Falls to Butte has been constructed across this region for the purpose of transmitting power from the falls of the Missouri.

GENERAL GEOLOGY.

SEDIMENTARY ROCKS.

The rocks that crop out in the Hound Creek district belong to the Carboniferous, Jurassic, and Cretaceous systems, but detailed study was confined to the coal-bearing Kootenai formation (Lower Cretaceous). The stratigraphic position, characteristic features, age, thickness, and economic importance of the formations are given in the accompanying table:

Geologic formations in the Hound Creek district.

System.	Series.	Formation.	Lithologic character.	Thickness (feet).	Economic features.
Quaternary.		Alluvium.[a]	Silt, clay, and gravel.	2–25	Forms irrigable fertile tracts.
Cretaceous.	Upper Cretaceous.	Colorado shale.	Shale, dark, with beds of tough gray sandstone.	[b] 250	Contains sandstone which is resistant to weather and covers fields with loose slabs.
	Lower Cretaceous.	Kootenai formation.	Sandstone, gray, and shale and clay, red, sandy, with local beds of white limestone. The sandstone predominates in the lower part, but the red shale and clay constitute most of the upper part. Coal or shale bed 60 feet above base.	400–500	Contains locally a bed of coal.
Cretaceous (?).		Morrison (?) formation.	Shale, variegated, and clay, containing sandstone and limestone layers.	200±	Contains limestone suitable for building stone.
Jurassic.		Ellis formation.	Sandstone, tough, drab colored, conglomeratic in upper part, with some limestone underlying it.	100±	Contains sandstone and limestone probably suitable for building stone.
		Unconformity			
Carboniferous.	Pennsylvanian (?).	Quadrant formation.	Limestone, red, bluish, and greenish calcareous shales and clay, and a bed of white sandstone near top.	300±	Contains limestone probably suitable for a flux or for a building stone.
	Mississippian.	Madison limestone.	Limestone, massive, white to gray.	[b] 150+	Contains abundance of limestone probably suitable for building stone.

[a] Alluvial deposits in the Hound Creek district occupy small tracts in valleys.
[b] Exposed.

CARBONIFEROUS SYSTEM.

MISSISSIPPIAN SERIES.

Madison limestone.—Only the upper 150 feet of the Madison limestone is exposed in this field. It crops out in the gorge of Smith River, in the northeastern part of the district, and is the gorge-forming rock along that river for a number of miles above this area. It is also the most prominent sedimentary rock along the west slope of the Little Belt Mountains.

Weed [1] ascribes a thickness of 1,000 feet to the Madison and divides it into three members—at the bottom the Paine shale, consisting of gray thin-bedded shaly limestones; in the middle the light-colored Woodhurst limestone, whose beds are separated by thin argillaceous layers; and at the top the massive Castle limestone.

No special study was made of the Madison in connection with the work in the Hound Creek district, and no fossils were obtained from it, but collections made by Fisher [2] in 1906 in the Great Falls field, and by Calvert [3] in 1907 in the Lewistown coal field were determined by George H. Girty to be of Mississippian age.

PENNSYLVANIAN (?) SERIES.

Quadrant formation.—The Madison limestone is overlain by the Quadrant formation. The lower two-thirds of this formation consists principally of red, bluish, and greenish calcareous or dolomitic shale with irregular bands of limestone. This shale rests upon the Madison limestone, and the change in lithology is so abrupt, from the Madison beds, laid down in a deep quiet sea, to the Quadrant beds, laid down in shallow water, that an unconformity is suggested, but no stratigraphic evidence regarding it has been obtained. The upper part of the Quadrant consists mainly of bluish compact massive or thin-bedded limestone. The formation received its name from Quadrant Mountain, in the Yellowstone Park, where it is well developed.

The thickness of the Quadrant formation, according to Weed, ranges from 230 feet on Sixteenmile Creek, in the southwestern part of the Little Belt Mountains quadrangle, to 1,400 feet on Judith River, in the northeastern part of the quadrangle. Calvert [4] found it ranging in thickness from 425 feet to about 750 feet in the Lewistown coal field, and Fisher [5] noted its absence from the section at a few localities in the southern part of the Great Falls field, where, according to his statement, the Ellis formation lies unconformably upon the Madison limestone. At one locality in the Great Falls

[1] Weed, W. H., U. S. Geol. Survey Geol. Atlas, Little Belt Mountains folio (No. 56), 1899.

[2] Fisher, C. A., Geology of the Great Falls coal field, Mont.: U. S. Geol. Survey Bull. 356, 1909.

[3] Calvert, W. R., Geology of the Lewistown coal field, Mont.: U. S. Geol. Survey Bull. 390, 1909.

[4] Idem, pp. 15-17.

[5] Fisher, C. A., op. cit., p. 25.

field (in sec. 34, T. 17 N., R. 3 E.) W. R. Calvert and the writer found about 190 feet of the Quadrant formation exposed. At this place a section was measured through the Quadrant formation, and fossils were found near the top and in the overlying Ellis formation. The fossils from bed 1 of the section (see below) were determined by T. W. Stanton to be *Ostrea strigilecula* White and Camptonectes sp., both Jurassic forms, whereas those from bed 3 of the section were found by George H. Girty to contain a single species which he determined to be *Myalina arkansana* and which he assigns to the Quadrant. The Quadrant-Ellis contact therefore must be concealed in bed 2 of the section, so that the thickness of the Quadrant formation at this place can not be more than 196 feet and may be 25 or 30 feet less.

Section of Quadrant formation on Smith River, in sec. 34, T. 17 N., R. 3 E.

	Feet.
1. Limestone, massive, irregular bedded (Ellis).	
2. Covered (Quadrant-Ellis contact)	36
3. Limestone, thin bedded, and shale, with few fossils	15
4. Limestone, bedded and massive, argillaceous, with irregular layers of chert	11
5. Shale, greenish, and thin beds of limestone	103
6. Sandstone, white, saccharoidal	4
7. Partly covered; red shale where exposed elsewhere	27
	196

The quadrant formation is variable not only in thickness but also in character. Generally the lower half is more shaly than the upper half, but red, blue, and green shales and clays occur at many levels and are replaced laterally by limestone beds.

No especial study was made of the Quadrant in the Hound Creek district, so that but few fossils were collected. Those obtained from the upper part of the formation are listed below as determined by George H. Girty.

Schizophoria? sp.
Derbya kaskaskiensis.
Myalina arkansana.
Productus semireticulatus.
Productus pileiformis.
Productus sp.

Mr. Girty states that the above forms "would not of themselves afford very satisfactory evidence for exact age determinations, but they seem to agree with more extensive collections from the same formation made by W. R. Calvert and me, which show that the fauna is very closely related to that of the interval of the Moorefield, Batesville, and Fayetteville formations of the Arkansas section, which have generally been regarded as upper Mississippian." He says, however, that there is a possibility that the rocks may prove to be of early Pennsylvanian (Pottsville) age. In areas to the south and southwest the Quadrant formation has yielded Pennsylvanian fossils. In the absence of conclusive fossil evidence, the beds belonging to the Quadrant formation in this area are doubtfully assigned to the Pennsylvanian series.

JURASSIC SYSTEM.

Ellis formation.—Resting unconformably upon the Quadrant is the Ellis formation, made up of compact impure limestone and dull-colored sandstone. It has been described by Weed,[1] Fisher,[2] and Calvert.[3]

The formation crops out in a narrow zone over a large part of the east side of the district and along the slopes bordering many of the streams, where the resistant beds of the formation have formed escarpments in many places. The Ellis, wherever observed in this area, lies unconformably on the Quadrant formation.

The Ellis formation is almost as variable in thickness and lithology as the Quadrant. Where the full section is present the lowest part usually consists of compact limestone from 15 to 25 feet thick, and in places is separated from the upper part by a bed of calcareous shale. The upper member is usually a sandstone from 50 to 75 feet thick which is compact and locally conglomeratic in the lower part, but thin-bedded or even shaly toward the top.

The fossils collected from this formation, a list of which follows, have been determined by T. W Stanton to belong to the Ellis formation (Jurassic):

Astarte sp.
Camptonectes sp.
Cyprina? sp.
Gervillia? sp.
Mytilus sp.
Ostrea strigilecula White.
Rhynchonella gnathophora Meek?
Trigonia sp.
Undetermined small pelecypods.

CRETACEOUS (?) SYSTEM.

Morrison (?) formation.—The strata here tentatively assigned to the Morrison formation (named by Eldridge [4] from the town of Morrison, near Denver, Colo.), consist of alternating beds of shale, sandstone, and argillaceous limestone. They rest conformably on the underlying Ellis formation and are overlain with apparent conformity by the Kootenai, though the line of contact between the two formations is not well defined, and the similarity of their beds, both in color and in lithology, makes it difficult to define the limits. In the Hound

[1] Weed, W. H., and Pirsson, L. V., Geology and mineral resources of the Judith Mountains of Montana: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 3, pp. 476-480, 1898. Weed, W. H., U. S. Geol. Survey Geol. Atlas, Little Belt Mountains folio (No. 56), 1899.

[2] Fisher, C. A., op. cit., pp. 27-28.

[3] Calvert, W. R., op. cit., pp. 19-22.

[4] Emmons, S. F., Cross, Whitman, and Eldridge, G. H., Geology of the Denver Basin in Colorado: U. S. Geol. Survey Mon. 27, p. 60, 1896.

Creek district few good exposures of the Morrison (?) formation occur. The following section was measured in this district:

Section of Morrison (?) formation in the NE. ¼ sec. 34, T. 16 N., R. 3 E.

	Feet.
Kootenai formation.	
Sandstone, hard, drab, shaly	12
Clay, soft, green; contains some sandstone concretions	17
Sandstone, hard, brown to pink, calcareous	6
Shale, soft, pink to red, alternating with bands of sandy and calcareous shale from 2 inches to 24 inches thick	115
Ellis formation.	
	150

Fisher[1] mapped the beds overlying the Ellis formation as Morrison because of their similarity to that formation in Colorado and Wyoming and also because they contain vertebrate fossils. This was the first recognition of the Morrison in Montana, although Weed and Pirsson,[2] in speaking of the beds above the Ellis formation say that "it is possible they may be equivalent to the Upper Jurassic[3] (Morrison formation) recognized in Colorado." Vertebrate fossils found in them by Fisher were provisionally identified by C. W. Gilmore as being of Jurassic age. Calvert[4] has also mapped the Morrison in the Lewistown coal field, and the meager fossil evidence obtained in that field seems to point toward the Jurassic age of the beds, but until more evidence is at hand the age of the Morrison can not be known with certainty. Although search was made at every opportunity, no fossils were obtained during the present work, and so this paper can add nothing toward the solution of the problem.

CRETACEOUS SYSTEM.

LOWER CRETACEOUS SERIES.

Kootenai formation.—The term Kootenai, derived from the name of a tribe of Indians in the Canadian Rockies, was proposed by Dawson[5] in 1885 for beds that occur in that part of Canada, consisting of sandstone interbedded with shale and shaly sandstone, in which there are in places layers of conglomerate and a zone of coal beds.

Two years later Newberry[6] correlated the coal-bearing beds of the Great Falls region with Dawson's Kootenai formation of the Canadian Rockies. The question of the age of the Kootenai and the application of the term in the Great Falls and Lewistown coal fields is fully discussed in the bulletins by Fisher and Calvert, already cited.

[1] Fisher, C. A., op. cit., pp. 28–30.
[2] Weed, W. H., and Pirsson, L. V., op. cit., p. 480.
[3] The Morrison formation is now classed by the United States Geological Survey as Cretaceous (?).
[4] Calvert, W. R., op. cit., pp. 22–24.
[5] Dawson, G. M., Roy. Soc. Canada Trans., vol. 3, sec. 4, p. 2, 1885.
[6] Newberry, J. S., School of Mines Quart., vol. 8, No. 4, p. 327, 1887.

The Kootenai of this area overlies the Morrison (?) formation with apparent conformity, and the beds of the two are lithologically similar. There is, however, a predominance of red shale in the Kootenai and fewer beds of limestone than in the underlying formation. Measurement of the thickness of the Kootenai was rendered impracticable by the fact that the full section is not exposed in any one locality in the area. It is believed, however, that there is little variation in thickness from about 500 feet as measured by Fisher in the Great Falls field.

The formation is composed of red, blue, and gray shales and clays alternating with beds of sandstone and in the lower portion with thin beds of impure limestone. A coal bed is also present locally. The most prominent of the sandstone beds occurs about 60 feet above the base of the formation and is about 20 feet thick. This is the thickest bed of sandstone in the formation, and to its hardness is due much of the bench land as well as many of the loose rock slabs scattered over the surface. The coal bed, wherever present, occurs either immediately below or within 6 or 8 feet of the base of this sandstone. The beds below the coal zone consist of about 60 feet of alternating red and blue shales and thin beds of sandstone and impure limestone. The beds above the massive sandstone overlying the coal zone are composed of red, blue, and gray shales and clays alternating with gray sandstone. The red color predominates in the upper part of the formation and continues up to the base of the overlying Colorado shale. No discordance of dips at the top of the Kootenai was observed. The Kootenai occupies a broad bench in the north-central part of the district and borders Hound Creek on the west, extending to the southwestern part of the area. It is also present in isolated areas in the eastern part of the district. In the mountains bordering the district on the southwest the Kootenai formation is present, but it is complexly faulted and occupies only a small portion of the surface.

With the exception of one small collection of ferns which were too fragile to bear transportation and which were obtained from a carbonaceous shale near the coal, no fossils were found in the Kootenai of this district, but in the Great Falls field an abundant flora of Lower Cretaceous age was found by Newberry,[1] who used the fossil plants in correlating the Kootenai of this field with that of the Canadian area, and also by Fisher.[2] In the Lewistown field, farther east, Calvert[3] observed that fossils in the Kootenai are not abundant, and the same thing is true of the area under discussion.

UPPER CRETACEOUS SERIES.

Colorado shale.—The Colorado shale, the highest formation present in the Hound Creek district, overlies the Kootenai formation and is

[1] Newberry, J. S., op. cit., p. 327.
[2] Fisher, C. A., op. cit., pp. 33-35.
[3] Calvert, W. R., op. cit., pp. 28-29.

300 or 400 feet thick. It is composed of alternating beds of dark clay and shale with interbedded pale-yellow shaly sandstone. The base of the Colorado is marked by a heavy sandstone from 15 to 30 feet thick that is distinguishable from the sandstone of the Kootenai formation by its pale-yellowish color and finer texture; in fact, this color is fairly constant for all the sandstones of the Colorado in the region. The Colorado shale probably represents part of the beds originally described by Meek and Hayden as the Fort Benton shale. That term was derived from the name of a town on Missouri River about 40 miles below Great Falls, but the stratigraphic limits of the formation (now called Benton shale) are based largely on a section along Missouri River in northern Nebraska, where the Benton shale rests upon the Dakota sandstone and is overlain by theNiobrara limestone. The Niobrara is not separable in this region, and consequently the group term Colorado is used, Benton not being appropriate.

The exposures of the Colorado shale in this district are so poor that fossils were obtained at but one locality, in the bed of West Hound Creek, in the NW. ¼ sec. 11, T. 15 N., R. 1 E. These fossils as determined by T. W. Stanton are Anchura sp., *Inoceramus labiatus* Schlotheim, and Lingula sp., all referred by him to the Benton.

QUATERNARY SYSTEM.

No attempt was made in the Hound Creek district to map Quaternary deposits, for they are confined entirely to narrow beds of gravel along the streams and to very small alluvial deposits.

IGNEOUS ROCKS.

There are no crystalline rocks in the Hound Creek area except along the west and southwest sides. The high ridges bordering the area for nearly its entire length along the west side are hills of igneous rocks. Radiating from this igneous mass are numerous dikes and sills, most of which are small and composed of basic rocks. Little time was given to the study of these rocks, however, for they lie mostly outside of the area occupied by the coal-bearing formation.

The Colorado shale, through which the dikes cut, is not extensively altered. Alteration is confined usually to a few inches on each side of the dikes and is noticeable along a zone a few feet thick in contact with some of the igneous masses.

Specimens were collected from a few of the dikes and sills, and examined by E. S. Larsen, who describes them below.

Specimen 5, trachydolerite.—From a dike cutting the Colorado shale in sec. 31, T. 15 N., R. 1 E. The dike is about 2½ feet thick and is traceable for about half a mile.

In the hand specimen this rock is dense and dark green. The numerous dark-green augite crystals, some of which are a centimeter in length, break out cleanly from the matrix. Small lenses of white fibrous natrolite occur. Analcite is present in rounded grains. The groundmass is finely crystalline and shows numerous cleavage faces of feldspar. The thin section reveals rather abundant phenocrysts of augite, feldspar, and analcite in a holocrystalline groundmass. This groundmass consists of feldspar laths, biotite, augite, and altered olivine. Accessory apatite and iron ore and secondary natrolite, calcite, and chlorite are present. The feldspar phenocrysts are labradorite and bytownite, and nearly all of them have a rather broad border of orthoclase; those of the groundmass are mainly orthoclase, though they likewise have a core of labradorite. The plagioclase core of the feldspar is always much altered, but the border is fresh. The analcite is probably primary and occurs as poorly developed crystals, many of which are pierced by orthoclase laths. The olivine is altered to a green pleochroic mineral with the optical properties of iddingsite. The rock is of rather basic character and is rich in the femic minerals and the alkalies. It belongs to the trachydolerites of Rosenbusch.

Specimen 3.—From a dike about 5 feet wide in the bed of West Hound Creek, in sec. 11, T. 15 N., R. 1 E.

This specimen is a dense dark-green rock with abundant large euhedral crystals of pyroxene and some small crystals of feldspar in an aphanitic groundmass. Microscopic examination shows that the rock is porphyritic and contains numerous large crystals of pyroxene, now replaced by calcite and chlorite, and about an equal amount of labradorite in a fine-textured altered groundmass, which consists of minute feldspar laths with nearly parallel extinction, abundant grains of iron ore, and secondary calcite, chlorite, etc. The groundmass probably consisted originally in the main of alkali feldspar, augite, iron ore, and glass. The rock is very similar to that represented by specimen No. 5, although it is finer textured and more altered. It should probably also be called a trachydolerite.

Specimen 4, soda syenite porphyry.—From the largest dike in the Hound Creek area. The dike occurs in sec. 2, T. 15 N., R. 1 E., and is about 60 feet thick. It forms a prominent ridge wall about three-fourths of a mile long and from 20 to 60 feet high.

This is a dense, rather light gray rock, which has scattered phenocrysts of hornblende and feldspar in a very fine textured groundmass. The thin section shows a few phenocrysts of oligoclase-albite and still fewer of a greenish amphibole in a groundmass which consists largely of stout prisms of albite and oligoclase with some orthoclase and pyroxene and a very little interstitial quartz. Apatite and iron occur as accessory minerals. The amphibole has an extinction angle (approximately $Z \wedge c$) on the cleavage face of 18° and a maximum index of refraction of about 1.70. It is probably an alkali variety. The pyroxene occurs in small grains. It is pale green and faintly pleochroic. The extinction angle could be measured only approximately, but the measurement gave as a maximum value $Z \wedge c=28°$. The texture of the groundmass might be called coarsely trachytic. The rock is fairly fresh, though the feldspars are dusted with alteration products and large parts of the femic minerals are changed to a brown chloritic material. The texture is rather coarsely porphyritic and the rock is a soda syenite porphyry.

Specimen 6, syenite.—From a sill a few feet thick that crops out in the east bank of Hound Creek in sec. 19, T. 14 N., R. 1 E.:

This specimen is a rather light green fine even-grained rock. It consists largely of orthoclase, but there is considerable altered augite and biotite, some plagioclase, and a little quartz. Long needles of apatite are prominent; titanite and iron ore are sparingly present; secondary calcite, chlorite, and uralite are rather abundant. The plagioclase occurs as the core of the orthoclase crystals. The orthoclase is probably a variety rich in soda, as it has a maximum index of refraction of about 1.53. The texture is hypidiomorphic granular and the composition is that of a syenite.

STRUCTURE.

MAJOR FEATURES.

The availability and extent of coal in any field are directly related to the structure. Since the period when the coal-bearing beds were deposited in this region there has been, first, the deposition of several hundred feet of Upper Cretaceous strata, then an epoch of mountain building which resulted in the uplift of the Little Belt and Big Belt mountains and elevated the area above the sea. During or after this epoch intrusions of igneous rocks occurred, and possibly at the same time the faulting and folding of the Hound Creek district was begun. Then followed the degradation of the land to the present surface. All these factors have contributed to produce the present structure of the rocks.

The area considered in this report lies between the north ends of the Big Belt and Little Belt mountains and extends from the flanks of the latter range on the east to the base of the former on the west. The strata lie in a low monocline dipping away from the mountains toward the northwest. This monocline is broken in many places by faults and folds, and though the beds dip locally in almost any direction, the average dip is about 4° or 5° NW., but as the plains country is approached the dips flatten.

The Little Belt Mountains constitute a broad, flat-topped anticline of sedimentary rocks cut up into smaller ridges by subsequent erosion. The steeply dipping sides of this anticline form the slopes of the mountain range, and the more gently dipping beds extending out from it toward the west are the bench lands of the Hound Creek district. There are few faults and local folds associated with the Little Belt Mountains anticline.

From the complexity of the structure along the northeast border of the Big Belt Mountains, where faults are very numerous and where igneous rocks have in many places been thrust up through Paleozoic beds, the formation of these mountains was apparently accompanied by more complex disturbances than in the Little Belt Mountains. The beds of the Hound Creek area, though more faulted, also dip away from the Big Belt Mountains. The number and magnitude of faults increase toward the mountains, which suggests that the faults are directly related to the disturbances connected with mountain building.

FOLDS.

In the Hound Creek district there are several small folds of the strata which are parallel to one another and to the faults of the field, and which strike northwest. Perhaps the most prominent anticline is in the extreme southwestern part of the district. Here the folding was so sharp that a thrust fault resulted, in which the beds on each side dip away from the fault zone. Although the fault line was not actually observed, it is known to be present because the Kootenai formation and the Colorado shale are almost in contact with the Quadrant formation. In the valley of Elk Creek, in sec. 34, T. 14 N., R. 1 E., the anticline is less sharp and seems to pitch and die out, but from this place eastward the beds are covered, so that it was impossible to decipher the structure in detail. North of the fault above referred to and forming a rather broad valley is a syncline, the axis of which enters this district in the SE. ¼ NE. ¼ sec. 25, T. 14 N., R. 1 E., and extends westward through secs. 25 and 26, where it bends toward the northwest and trends in a nearly direct line to the boundary of the district near the SW. ¼ sec. 6, T. 14 N., R. 1 E. At the east side of the district this syncline is very narrow and pitches westward. It becomes broader toward the west until it is about 4 miles across at the west side of the field. The greater part of the surface rock included in this syncline is the Colorado shale, which is bordered on either side by the Kootenai. The beds dip irregularly toward the axis of the syncline at angles varying from a very slight amount to 50° or 60°.

At the east edge of the district, in the NE. ¼ sec. 34, T. 16 N., R. 3 E., an anticline is exposed where it crosses a north-south ridge. The fold could not be traced beyond the ridge, but rather strong local dips toward the north were observed in the NW. ¼ sec. 34, and the beds to the south, in sec. 5, T. 15 N., R. 3 E., dip 15°–35° S., so that the broad valley of Clark Creek in secs. 28, 29, 32, and 33 is believed to be in part at least an anticlinal valley.

In secs. 11 and 12, T. 16 N., R. 1 E., there is an anticline which seems to replace a fault from the southeast. This anticline is observable for less than a mile in a northwesterly direction. It brings the Kootenai formation to the surface in an outcrop which is entirely surrounded by the Colorado shale in such a way that an elongated dome is suggested. The exposures are so incomplete that the structure could not be determined with certainty.

A syncline on the south side of the fault in T. 16 N., R. 2 E., extends from the SE. ¼ sec. 35 to Hound Creek in sec. 27. It pitches northwestward parallel to the fault and not more than a mile distant. The dips on the two sides of the syncline range from nearly horizontal to 20° or 30.°

FAULTS.

The Hound Creek district is much faulted, particularly in the southwestern part. The principal faults are of the overthrust type, normal faults being confined principally to those of lesser throw. Faulting has brought the hard rocks of the Quadrant and Ellis formations to the surface in places, and from their greater resistance to weathering escarpments have been formed.

Carter ranch fault.—A fault enters T. 16 N., R. 2 E., in sec. 36 and leaves it in sec. 7. It crosses Hound Creek near Carter ranch, in sec. 21, and for this reason is termed the Carter ranch fault. The fault curves to the west and dies out near the township line, on the west side of sec. 7. This fault displaces the beds about 700 feet at the place of its maximum throw, in secs. 26 and 27, where the Quadrant is brought up against the Kootenai along the south side of the fault line. Partly on account of the westerly dip and partly because of the difference in amount of throw, which has produced a stronger westerly dip on the south side, the fault has offset the Kootenai-Colorado contact about 3 miles. On the north side of the fault this contact is in the valley wall on the west side of Hound Creek in sec. 21, T. 16 N., R. 2 E., but on the south side it is in sec. 12, T. 16 N., R. 1 E., over 4 miles farther west. The strata dip in general away from the fault at angles of 70° to 90° on the upthrown side but less steeply on the downthrown side. This fault, like the other great faults farther southwest, is probably of the thrust type, although the evidence along the fault plane is not conclusive. However, as it is parallel to others which are known to be thrusts, and as it also seems to have resulted from a broken fold, it is believed to be a thrust fault.

Green ranch faults.—Two faults cross East Fork of Hound Creek just above the Green ranch. They are best exposed in the valley walls, where they are about a quarter of a mile apart, but they converge on the hill about half a mile northwest of Hound Creek. They continue roughly parallel in a southeasterly direction. The northern one dies out in Crooked Creek valley near the west side of sec. 12, T. 14 N., R. 1 E., and the other extends to the southeast border of the district in sec. 19, T. 14 N., R. 2 E. Although the fault line is not exposed farther northwest than the top of the hill near the township line, the fault continues in this direction as much as 2 miles and forms the escarpment south of Adel. These are thrust faults, in which the fault plane dips southwest, toward the upthrow. In the hillside on the north bank of Hound Creek limestone of the Quadrant formation is thrust up over sandstone of the Colorado. The succession of beds as exposed here is Kootenai and Colorado below (downstream from the east fault); Quadrant, Ellis, Morrison (?), and Kootenai between the two faults; and Quadrant, Ellis, Morrison (?), Kootenai, and Colorado west of the upper fault. Between the two faults Quadrant, Ellis, Morrison(?), and Kootenai occur in narrow zones and dip southwest at an angle of about 40°. The maximum displacement of beds by these faults occurs in sec. 3, T. 14 N., R. 1 E., and is probably about 1,000 feet. The offset of the Kootenai-Colorado contact is nearly 4 miles from sec. 3, T. 14 N., R. 1 E., to sec. 30, T. 15 N., R. 1 E. The dips on both sides of these faults are southwest and range from 5° or 6° to 40° or 50°.

Crooked Creek fault.—The Crooked Creek fault is best developed in sec. 24, T. 14 N., R. 1 E. It enters the Hound Creek area at the east side of the section on Crooked Creek, strikes in a northwesterly direction, and dies out gradually within about 2 miles. It is apparently a thrust fault, as the Quadrant-Ellis contact on its south side is brought up against the Kootenai. The maximum throw is about 400 feet, and the base of the Kootenai formation is offset about 2 miles.

Faults near Elk Creek.—Fault near the Northern Pacific coal prospect, in sec. 15, strikes in a northwesterly direction. For about half a mile on each side of Elk Creek this fault is very prominent, but beyond this stretch it can not be made out. The beds on the north side of the break dip at a low angle southward into the fault; those on the south side dip 40°–74° S. The fault plane dips at a high angle to the south. The fault is normal and has a downthrow of about 150 feet to the south, which brings the base of the Morrison(?) against the Quadrant.

Near the head of Elk Creek, in secs. 3 and 4, T. 13 N., R. 1 E., are two parallel faults about a quarter of a mile apart. These are both thrust faults which strike in an easterly direction and dip about 60° S. The fault planes are parallel to the bedding planes and the throw on both planes has brought the Quadrant against the Kootenai. These faults extend about half a mile on each side of Elk Creek, being terminated by an igneous mass on the east and merging into more complex faults on the west.

ECONOMIC GEOLOGY.

RESOURCES.

Coal is present locally in the area under discussion, and there is an abundance of sandstone in the Ellis, Kootenai, and Colorado formations and of limestone in the Quadrant and Madison formations, which might be used for building. It is probable that calcareous shale, with the proper proportions of lime and clay to make Portland cement, could be found in the Quadrant. No metallic minerals are known to occur in the Hound Creek district.

THE COAL.

OCCURRENCE.

Coal occurs locally in this district in a zone about 60 feet above the base of the Kootenai formation in close association with a thick bed of sandstone. The work of the United States Geological Survey in the Great Falls coal field in 1906 and in the Lewistown field in 1907 has shown that coal does not occur regularly throughout the region, the coal zone being in places either occupied by a very thin seam embedded in carbonaceous shale or entirely replaced by shale. This irregularity was found also in the Hound Creek district.

Just north of the Hound Creek district, on both sides of Hound Creek, in T. 17 N., R. 2 E., and along McMullin Creek, in T. 17 N., R. 3 E., there is a coal bed averaging about 4 feet in thickness, and two mines are in operation in sec. 24, T. 17 N., R. 2 E., where about 2,000 tons is taken out annually for local consumption. These mines are described by Fisher[1] under the heading "Smith River mines." It is believed that the coal pinches out within a short distance south of these mines, for in a prospect along McMullin Creek, in the SW. ¼ sec. 31, T. 17 N., R. 3 E., the coal changes from a bed 3 feet thick at the entrance of the prospect to a thin film in the face of the entry, and in the NW. ¼ sec. 6, T. 16 N., R. 3 E., the sandstone immediately above the coal zone shows prominent cross-bedding, giving evidence of shore conditions and strong currents. Only carbonaceous shale could be found at the coal horizon along the west side of Hound Creek in T. 15 N., R. 2 E., and in the southern part of T. 16 N., R. 2 E. The only coal observed more than 6 or 8 inches in thickness occurs in two prospects on Elk Creek.

In the area along Elk Creek the Northern Pacific Railway Co. prospected for coal in 1905, but most of the openings have since caved. That this company found no coal which it considered of economic value is indicated by the fact that the land was offered for sale as agricultural land. There are two prospects which were open at the time the field examination was made, however, one in sec. 15, T. 14 N., R. 1 E., and the other in sec. 3, T. 13 N., R. 1 E. The one in sec. 15 was open 40 feet down a dip of 47° S. The following section was measured here:

Section of coal bed in sec. 1⅝, T. 14 N., R. 1 E.

	Ft.	in.
Shale	2	4
Coal, fair quality	1	9
Shale, carbonaceous	2	8
Coal, very impure	6	10
Shale, carbonaceous.		
	13	7

[1] Fisher, C. A., op. cit., pp. 66–67.

East of this prospect the coal bed approaches a fault and increases in dip until an angle of 74° is reached. Then for a short distance the coal bed is cut out, but it reappears and the heavy sandstone above it is traceable around the synclinal trough in sec. 25.

Near the head of Elk Creek, in sec. 3, T. 13 N., R. 1 E., there are two prospects, one on each side of the stream. The one on the west side was full of water at the time of visit and so could not be entered, but the one on the east side was open for a distance of about 60 feet, and the coal was found to be 7 feet 6 inches thick with roof and floor not exposed. The coal is much crushed, however, and dips 61° S. The coal undoubtedly terminates on the east at the igneous mass in sec. 2. West of the prospect the structure is very complex and the rocks are largely covered to the foot of a mesa of igneous rock. Whether the coal is present south and west of this place the writer was not able to learn, but the heavy sandstone that comes near the coal horizon was observed at two or three places high in the hills.

CHARACTER.

No samples for analysis were taken in the Hound Creek district, because only weathered coal could be obtained. However, a sample was taken by the writer from the Gibson mine, on Hound Creek, just north of the area, and according to the Pishel mortar test [1] some of it possesses coking properties but other pieces do not.

The mortar test was worked out by Pishel while engaged in the study of the physical properties of coal in the United States Geological Survey. He found that coals known to possess coking qualities adhered to the sides of the mortar and to the pestle on being pulverized, whereas noncoking coals adhered very slightly or not at all. Sufficient experiments have not yet been made to prove that this test is absolutely reliable, yet it is probably more certain than the ordinary field method of testing in a pit.

Fisher [2] states that "Certain benches of the coal of the Great Falls field possess coking properties. Formerly a number of coke ovens were operated by the Anaconda Copper Mining Co. at Belt. The separation of coking from noncoking coal, however, was too expensive to render the work profitable, and they were abandoned."

As the sample above referred to was obtained in the ordinary manner, by making a cut entirely across the bed, the fact that some pieces of this sample show coking properties and other pieces do not would indicate that the coal bed here, as in the Belt district, contains benches which might be coked. Samples collected by Fisher [3] in 1906 from

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[1] Pishel, M. A., A practical test for coking coals: Econ. Geology, vol. 3, No. 4, pp. 265-275, June-July, 1908.
[2] Fisher, C. A., op. cit., pp. 80-81.
[3] Idem, p. 80.

mines near the mouth of Hound Creek show the coal to average about 10,500 British thermal units, and from the analysis and physical properties he states that the coal is medium-grade bituminous.

FUTURE DEVELOPMENT.

It is highly improbable that the Hound Creek district will ever be an important coal-mining center because the coal probably does not occur in sufficient quantity and is too impure to justify the establishment of a plant to mine coal for shipment, even if transportation facilities were available. At present the nearest railroad is the Helena-Great Falls branch of the Great Northern Railway, which is about 20 miles to the northwest. The known amount of coal will certainly not warrant the extension of the Great Northern Railway into the Hound Creek district on that account alone, and the other resources of the district are too meager to bring about in the near future a betterment of transportation facilities. Development of the coal, therefore, will probably be dependent on purely local demand.