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GEOLOGY AND COAL RESOURCES OF NORTH PARK, COLORADO

BY

A. L. BEEKLY

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GEOLOGY AND COAL RESOURCES OF NORTH PARK, COLORADO.

By A. L. Beekly.

INTRODUCTION.

LOCATION AND AREA.

North Park is a great natural depression in the Rocky Mountains of northern Colorado. Its remoteness from much frequented routes of travel, amounting until recent years almost to isolation, has resulted in its geology remaining but very little known until the pres-

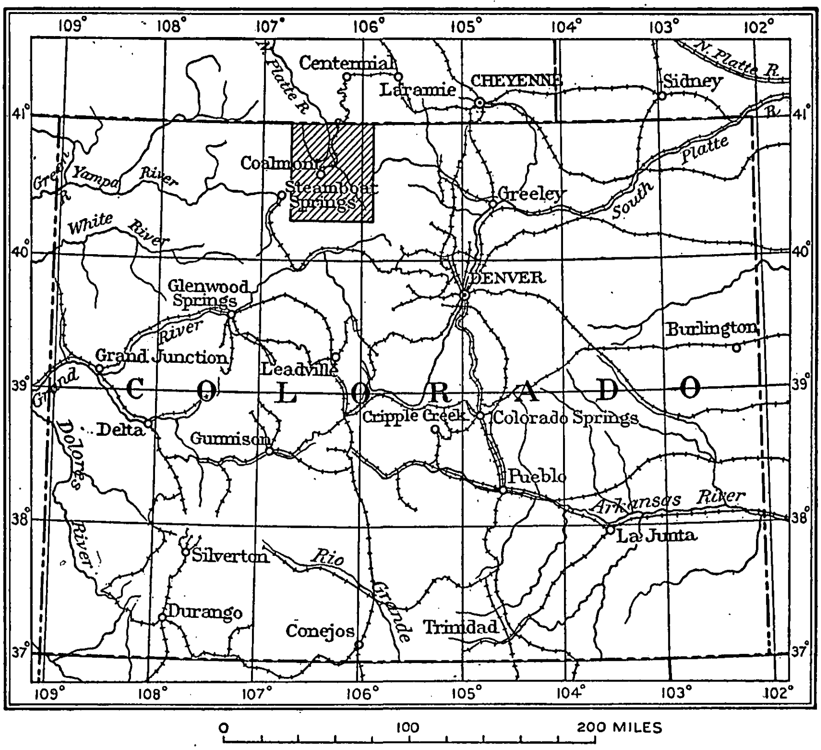

FIGURE 1.—Index map of Colorado, showing location of North Park.

ent time. It covers about 1,400 square miles, including practically all of Jackson County. (See fig. 1.) Its northern boundary is within a few miles of the Colorado-Wyoming State line, which is approximately coincident with the forty-first parallel. On the south the Continental Divide, which here runs approximately east and west near parallel 40° 20′, separates it from Middle Park. The Continental Divide also forms its western boundary, extending northward from Rabbit Ears Peak along the top of the Park Range, near and roughly parallel to meridian 106° 40′. Its eastern boundary lies along the crest of Medicine Bow Range, which extends from the southeast corner of the park, in longitude 106°, northward halfway to the Wyoming line and thence somewhat west of north to the northern boundary.

ACCESSIBILITY.

The Laramie, Hahns Peak & Pacific Railway was extended southward from Laramie as far as Coalmont, in North Park, in November, 1911, and is now in operation, placing the most remote parts of the field within 20 miles of a railroad. In 1914 the name of this line was changed to the Colorado, Wyoming & Eastern Railway. It is about 40 miles long and affords a convenient route to the park by way of the Union Pacific Railroad at Laramie, Wyo.

The Denver, Northwestern & Pacific Railway (Moffat road) crosses Middle Park about 20 miles south of Willow Creek, Arapaho, and Muddy passes, on the Continental Divide (see map, Pl. XII, in pocket at end of bulletin) and turns northward to Steamboat Springs, about 10 miles west of the middle of the western boundary of the area. At the time of the field examination a stage line was in regular operation from Granby, on the Moffat road, by way of Willow Creek Pass to Rand, in the southwest quarter of the park. The field is also accessible from the Moffat road by means of good wagon roads from Kremmling over Arapaho and Muddy passes and by steep but passable roads from Steamboat Springs over Rabbit Ears and Buffalo passes.

The Saratoga & Encampment Railway extends from Walcott, Wyo., on the Union Pacific Railroad, to Encampment, Wyo., which is about 24 miles north of the park and from which a stage line runs to Pearl, Colo., in the park.

Good wagon roads lead eastward across the Medicine Bow Range through Ute and Cameron passes from North Park to Fort Collins and to Greeley.

EXPLORATIONS IN THE REGION.

Coal was mined in North Park for domestic use by a few settlers as long as 30 years ago, but on account of the inaccessibility of the region and the lack of systematic prospecting its amount and quality were little known. Recently, however, prospecting and the development of mines has shown the necessity for a detailed examination of the field for the purpose of classification and valuation of the public coal land, and in consequence the field work upon which this report is based was undertaken.

A. R. Marvine, geologist of the Hayden Survey, in 1873, reported the occurrence of thin beds of lignite in his so-called "Lignite series" of Middle Park[1] and stated that "the Lignitic series crosses the divide and is probably present throughout a considerable portion of North Park." In a discussion of a paper by Whitman Cross,[2] R. C. Hills refers to "the presence in North Park of four thick seams of coal." So far as known to the writer, this was the first published statement pointing to North Park as a coal field of probable importance.

The geologic maps published as a result of the surveys of this area by Hayden[3] and King[4] in the seventies were very generalized. Marvine examined the field in 1874, after finishing his work in Middle Park, but died as a result of hardship and exposure soon after the completion of the field work, and all that was ever published of the geologic data collected by him was that which was included in generalized form in the Hayden geologic atlas. The report on North Park by Arnold Hague[5] of the King Survey is very brief and is based on field work which was admittedly of a hasty reconnaissance nature. It is, however, a very creditable description of the larger geologic features of the field. Allowing for the necessarily hurried character of this early geologic work and for the adverse conditions under which it was accomplished, the field geologist of the present, working under greatly improved field conditions and by greatly improved methods, can not but be impressed with the pioneer geologist's remarkable grasp of the leading geologic features.

Since the adoption of the present subdivision and nomenclature of the Cretaceous and younger strata no geologic work has been done in North Park and no attempt made to correlate the strata there with those of better-known adjoining fields. The location of the park between the two large granitic mountain masses that separate the Denver Basin on the east from the Routt County coal fields on the west makes it an area of considerable importance in the geologic correlation of the rocks flanking the east slope of the Rocky Mountain uplift with those on the west slope.

In the present report are presented the results of an examination of North Park made during the summer of 1911 with the twofold object of obtaining all available facts concerning the coal resources

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[1] Marvine, A. R., Geology of Middle Park: U. S. Geol. and Geog. Survey Terr. Seventh Ann. Rept., pp. 154–192, 1874.

[2] Cross, Whitman, The post-Laramie beds of Middle Park: Colorado Sci. Soc. Proc. for 1891–1893, vol. 4, p. 214, 1892.

[3] Hayden, F. V., Atlas of Colorado: U. S. Geol. and Geog. Survey Terr., 1877.

[4] King, Clarence, Atlas: U. S. Geol. Expl. 40th Par., 1876.

[5] Hague, Arnold, and Emmons, S. F., U. S. Geol. Expl. 40th Par. Final Rept., vol. 2, pp. 112–129, 1877.

and of making as thorough a study of the general geology of the region as might be possible in the time available.

PREPARATION OF THE MAP.

Base map.—The base for horizontal control in the construction of the geologic map (Pl. XII, in pocket) is a land net established by surveys made for the United States Land Office from 1878 to 1883. This base map was used instead of geographic control by triangulation only because of the necessity for mapping all coal beds in their correct relation to legal land subdivisions. Of the section corners established by the Land Office survey only a comparatively small number were found. Stadia traverses were carried continuously and served to check the locations of the corners found. North of the correction line between Tps. 8 and 9 N. the corners located gave no evidence of irregularity or discrepancy in the Land Office net. South of the correction line, and particularly in the southeast quarter of the field, few section corners were found, and those that were found are separated by long distances. It was reported that in certain areas in this part of the field many of the original corners had been moved or destroyed and that many of the corners now existing could not be relied upon. Allowing for the possibilities of error in long stadia traverses, there is still reason to believe that a few of the corners found are somewhat at variance with the locations shown on the base map, which, for the most part, is an exact representation of the assembled Land Office plats. These discrepancies are so slight that they were considered negligible except in Rs. 77 and 78 W., south of the base line, where a modification of the land net was necessary. Corners found along the correction line in the vicinity of Marrs ranch and farther west were considerably at variance with the record of the Land Office plats. The distance measured in the field between the southeast corner of sec. 31, T. 9 N., R. 77 W., and the northeast corner of sec. 6, T. 8 N., R. 77 W., is 20.6 chains less, and the distance from the southwest corner of T. 9 N., R. 78 W., to the northwest corner of T. 8 N., R. 78 W., is 6.5 chains less than the measurements recorded on the Land Office plats. The original corners may have been obliterated and some of those enumerated above may have been set by local surveyors in an attempt to reestablish the original land net. No definite information to this effect was obtained, however, and the land net of the area was constructed to fit the corners now existing along the correction line, a procedure additionally supported by the fact that the northwest and southwest corners of sec. 20, T. 8 N., R. 78 W., seemingly in error, were brought into agreement by the readjustment.

Field work.—Coal outcrops, mines, and prospects were mapped by stadia traverse tied to section corners. (See traverse lines on map, Pl. XII, in pocket.) The major portion of the geology and culture was mapped either by stadia traverse or by intersection of sights to prominent points along traverse lines.

The topographic mapping of the east slope of the Park Range between parallels 40° 30′ and 40° 40′ and west of meridian 106° 30′ was completed by the United States Geological Survey early in the season and was used as a base for mapping part of the geology of that area. Approximate levels were carried in conjunction with the traverses and a number of altitudes sufficient to indicate the amount of relief in the field are shown on the map. For vertical control one Geological Survey bench mark was available in addition to the Colorado, Wyoming & Eastern Railway profile, which is based on sea level as a datum plane through its connection with the Union Pacific at Laramie, Wyo. The mapping of culture was treated as of comparatively minor importance, and in areas of considerable size, mainly in the central and southeastern parts of the field, many of the ranches and some of the roads are not mapped, and the roads mapped are only approximately located. The time allotted to the work was insufficient for instrumental mapping of any areas except those containing coal outcrops or important geologic exposures.

Office work.—In the office the land net of the base map was constructed over a polyconic projection of 10′ quadrangles, the relation of which to the land lines was obtained from the recently completed map of the Hahns Peak quadrangle, the eastern boundary of which lies in North Park along meridian 106° 30′. On this base map all traverse lines and data contained on the plane-table field sheets were assembled and all geologic localities recorded in notebooks by compass sights were plotted.

Certain data available as a result of contemporary or earlier field work by other parties has been added to the map. The drainage and culture west of meridian 106° 30′ is taken from the topographic map of the Hahns Peak quadrangle. The geology of the Continental Divide in the vicinity of Rabbit Ears Peak and for several miles to the east is taken in part from a geologic map prepared by the Geological Survey of Colorado. The location of the Continental Divide, the locations and altitudes of several mountain peaks, and the dotted geologic boundaries in the extreme southeast corner of the map are for the most part taken from Hayden's topographic and geologic atlas of Colorado. It should be noted that the dotted lines are rough approximations and are based on reconnaissance observations by the writer combined with data from the Hayden atlas.

ACKNOWLEDGMENTS.

The field work upon which this report is based was done by G. I. Finlay, Harvey Bassler, C. B. Barnett, E. H. Finch, and the writer.

Mr. Finlay assisted mainly with the stratigraphic and structural geology. Messrs. Bassler and Barnett carried the greater part of the control traverse and level line throughout the field and added materially to the geologic data in the course of that work. Mr. Finch assisted with the instrument work during the month of July. The author wishes to publicly express to the members of the field party his appreciation of their valuable assistance and hearty cooperation, to which is due much of whatever value this report may have. Acknowledgments are due to M. R. Campbell, who exercised general supervision, and to E. G. Woodruff for many helpful suggestions relating to both field and office work. The writer is also indebted to R. D. George, State geologist of Colorado, for geologic data relating to the vicinity of Rabbit Ears Peak; to R. D. Stewart, chief engineer of the Colorado, Wyoming & Eastern Railway, for railroad maps and profiles; and Stewart Kennedy, manager of the Northern Colorado Coal Co., for information relating to the coal. For valuable information and many courtesies rendered in the field grateful acknowledgments are made to Neal Sudduth, William Marr, C. A. Brand, C. W. Winscom, A. E. Dwinell, and many other citizens of North Park.

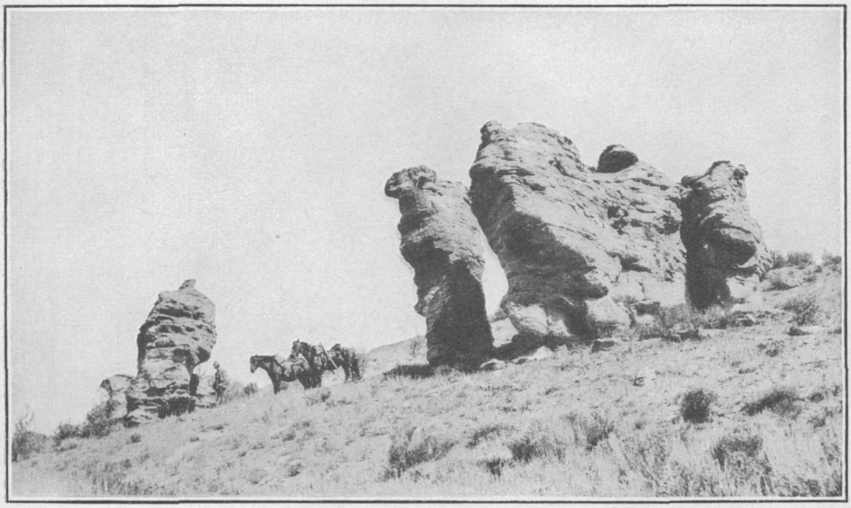
GEOGRAPHY.

RELIEF.

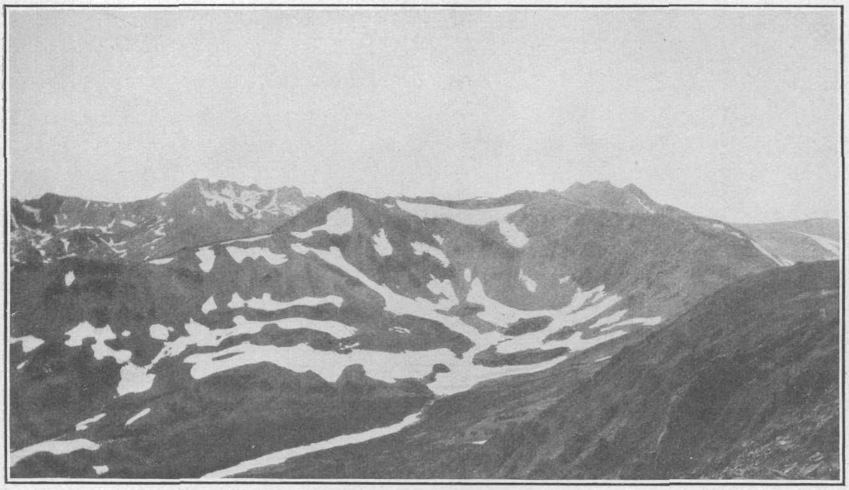
North Park is an immense roughly quadrangular topographic basin, whose comparatively level floor of about 1,000 square miles is surrounded, except on the north, by mountain walls that rise to heights of 2,000 to 5,000 feet above the bottom of the basin. It is sharply defined as a topographic unit by its prominent, picturesque, and practically continuous rim of mountain crests.

MAJOR FEATURES.

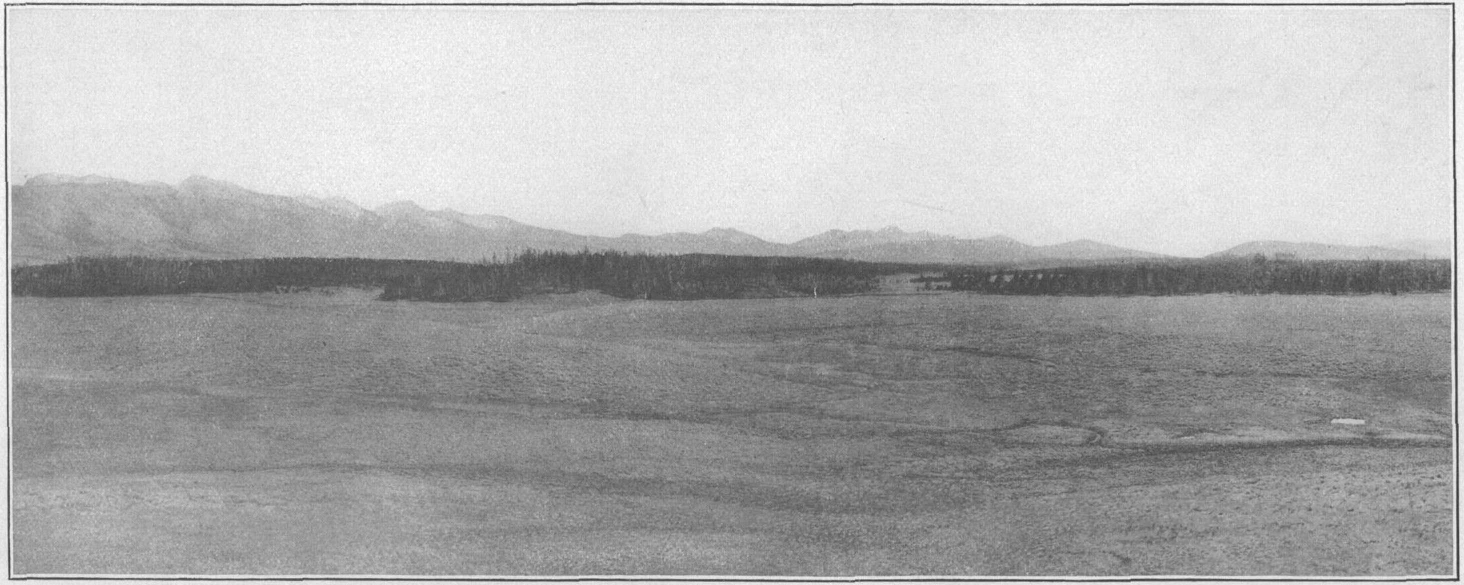
Medicine Bow Range.—The Medicine Bow Range, which lies on the east side of the field, is a huge ridge whose crest is marked by a series of sharp, ragged peaks, 11,000 to 13,000 feet in altitude, extending from the southeast end of the field to a point a few miles north of Clarks Peak. (See map, Pl. XII.) This section of the mountains has been appropriately called the "Sawtooth Range." North of Clarks Peak the crest of the range slopes gradually downward and broadens into a round-topped, timber-covered ridge. The upper west slope of the range is very steep—in many places near the top it is precipitous—but farther down it drops gradually 2,500 to 3,500 feet in a horizontal distance of 3½ to 6 miles. In the northeastern part of the field this slope is broken into small ridges and gulches, and from a distance appears smooth, but in the vicinity of Clarks Peak and farther south it is made up of sharp canyons, ridges,



A. ERODED SANDSTONE OF COALMONT FORMATION.



B. CREST OF ZIRKEL MOUNTAIN.



FLOOR AND RIM IN SOUTHEAST PART OF NORTH PARK.

and glacially rounded valleys that reach down to the headwaters of Canadian and Michigan rivers.

On the north side of the field the Park and Medicine Bow ranges are connected by Independence Mountain, which lies west of North Platte River, and by a series of picturesque granite ridges and small closely huddled peaks which extend eastward from the North Platte to the main ridge of the Medicine Bow Range. Independence Mountain is a large, more or less ridge-shaped granite mass of irregular contour, probably 11,000 feet in altitude at its highest point, which is in the northeast quarter of T. 11 N., R. 81 W. The northwest spur of the mountain slopes downward to the valley of Big Creek, where it meets the eastern slopes of the Park Range.

Park Range.—The crest of the Park Range on the west side of North Park presents a very even and regular sky line when viewed from the east. It has the appearance of a much dissected high plateau or remnant of a peneplain, particularly from Flattop Mountain southward. The average altitude of the flat-topped and more rounded portions of the range is approximately 10,800 feet. Above this a number of more or less prominent peaks rise to elevations ranging from 11,000 to over 12,000 feet. The top of Mount Zirkel (see Pl. I, *B*), the highest point on the range, stands 12,220 feet above sea level. In the vicinity of Rabbit Ears Peak at the southwest corner of the park the crest is narrower, more ridgelike, and considerably lower than from Buffalo Pass northward. The east front of the range is made up of a series of high sharp ridges separated by steep canyons, many of which were the channels of glaciers that left considerable areas of débris, which is molded into typically glacial hummocks, hollows, and ridges at the canyon mouths and in the valleys below. (See Pl. XII.)

Continental Divide.—The Continental Divide on the south side of the park is a large rounded swell separating the North Park and Middle Park basins. The eastern half of the divide, especially near its junction with the Medicine Bow Range, is marked by sharp, rugged peaks rising to altitudes of 11,500 to 12,400 feet. This section of the divide has an average elevation about 2,000 feet higher than that of the flat portion of North Park. West of these mountains the divide is much less prominent, having an altitude of about 8,875 feet at Muddy Pass, which is less than 1,000 feet above the park floor. The main features of this section of the divide are a series of lava-capped, mesa-like hills and a number of more or less prominent buttes and small peaks.

Floor of the park.—When viewed from any of the prominent high points around the park, its floor appears remarkably flat, much more so than it is shown to be by level lines carried from one stream valley to the next. (See Pl. II.) The elevation of the surface varies from approximately 7,900 feet above sea level in the valley bottoms and lowest depressions to 8,100 feet at the town of Walden, which is probably very near the average altitude of the greater part of the park floor. Many local areas in the north-central and south-central parts of the park are extremely flat, but few such areas are more than 20 to 30 square miles in extent and most of them are surrounded by somewhat rolling areas that have long even slopes, in which abrupt changes in altitude occur only where the benches or uplands drop off suddenly into the stream valleys.

MINOR FEATURES.

The prevailing flatness of the park floor is locally broken by ridges, hills, and small mesas, which appear prominent when viewed from the lower level areas, but which become insignificant when viewed from the summits of the Park or Medicine Bow ranges. The most prominent of these minor features is the long hogback-like ridge which rises 1,000 to 1,500 feet above the park floor and extends from the northwest corner of the park south-southeastward about halfway to the southern boundary, terminating abruptly at the south end of Delanos Butte. This ridge runs approximately parallel to the east base of the Park Range and is separated from it by the valley of North Fork of Platte River. The valley is about 3 miles wide west of Delanos Butte and Sheep Mountain but is much narrower farther north, where it is partly filled by the moraines from Zirkel Mountain. The ridge is broken by two gaps. One of them lies east of the Boetcher ranch, separating Sheep Mountain from the main ridge on the north; the other is a gap cut by North Platte River between Sheep Mountain and Delanos Butte on the south. The ridge is formed by immense wedges of granite, most of them sharp along the crest. In many places along the west side they present almost sheer walls for 300 to 800 feet that farther down give way to steep slopes which end in the valley of North Fork. On the east the ridge presents a less precipitous front with more uniform slopes, ending throughout most of its length in a V-shaped trough between the main ridge and a smaller ridge that practically parallels it. This smaller ridge is of unequal prominence, ranging from a scarcely discernible roll in some places to a hogback 400 to 700 feet high in others.

A large timber-covered ridge known as Owl Mountain joins the Medicine Bow Range near the abandoned mining camp of Teller in the southeast corner of the park. This mountain extends from the main range slightly north of west for about 5 miles to a point where it breaks abruptly on the west but continues northward and northwestward as a gradually diminishing ridge. The highest part of Owl Mountain separates the upper valleys of Michigan River and Illinois Creek, above which it rises to a height of 1,500 to 2,000 feet. The south and west slopes of the mountain are very steep, particularly near the top, where they become almost perpendicular cliffs 300 to 500 feet high. The north slope is less steep and is heavily timbered and very uniform from the top of the mountain down to the border of the valley of Michigan River. The ridge extending northwestward from the western extremity of Owl Mountain gradually decreases in height toward the west from about 1,800 feet near the mountain to about 400 feet near the center of the park, where it is cut through by Illinois Creek. Beyond Illinois Creek it is less regular in contour and has an average elevation of 300 to 500 feet above the park floor to a point within a few miles of Delanos Butte, where it ends abruptly near the junction of Grizzly Creek and Roaring Fork. The position of this ridge is outlined in a general way on the map (Pl. XII) by the belt occupied by the North Park formation, which extends from Owl Mountain almost to the foot of Delanos Butte.

Sentinel Mountain, in the northeast corner of North Park, is cut off from the main body of the Medicine Bow Range by the canyon of Pinkham Creek on the north and by the upper valley of Government Creek on the south and east. This mountain is somewhat ridge shaped, and its long axis extends southeastward. Although considerably rounded, it is the most conspicuous topographic feature in the northeast corner of the park, rising to an elevation of 1,200 to 1,500 feet above the valleys which almost entirely surround it. The mountain was no doubt named Sentinel because it overlooks the entire park and because it is conspicuous from the most used entrance, Upper Pinkham Creek valley, known to the inhabitants as the "Neck of the Park."

In the southwestern part of the field the flat or gently rolling surface gives way to a comparatively rugged area, the principal features of which are Crones Hill and Pole Mountain. Crones Hill, which stands in the area bounded by Grizzly, Mexican, and Colorado creeks, rises 900 to 1,200 feet above the creek valleys. Its longer axis extends northwestward, and though somewhat rounded its contour is more or less irregular. On the south and west its slopes are very steep, and at its southeast extremity, on the north side of Grizzly Creek, they are almost precipitous. On the north the slopes are more gradual and the mountain side is heavily timbered. A long, dissected ridge or plateau extending northward from the northwest extremity of Crones Hill stands 500 to 800 feet above the upper valley of Little Grizzly Creek, to which it is approximately parallel. The northern extremity of this much dissected upland is in sec. 35, T. 7 N., R. 82 W., at an altitude of 8,955 feet. (See Pl. XII.)

Pole Mountain, which stands a few miles southwest of the town of Coalmont, between Mexican and Little Grizzly creeks, is a prominent isolated hill, the summit of which is approximately 1,000 feet above the larger stream valleys. This hill breaks abruptly on the west and south, with steep and locally precipitous walls, which are 200 to 400 feet high near the top and give way to gradual slopes below. On the north and east several more or less pronounced ridgelike spurs descend gradually from the summit of the hill to the flat lowland.

DRAINAGE.

North Platte River drains the entire field. It has its source in a network of clear rapid streams, which rise in the mountain walls of North Park and unite near the entrance to Platte Canyon, through which the river flows northward into Wyoming. The canyons of these streams are cut in the various formations, and in the exposures thus revealed most of the data shown on the geologic map (Pl. XII) were collected.

The North Platte is a rapidly flowing stream, having at the north side of the field an average width estimated at more than 100 feet and an average depth of about 3 feet. The name "North Platte" is applied to the stream as far south as the junction of Grizzly Creek and Roaring Fork in the west-central part of the field. A considerable quantity of the river water is used in irrigating the large hay meadows along its valley.

Canadian River, on the east side of the field, rises in the vicinity of Clarks Peak. Considerable quantities of snow lie in the cirques and on the protected slopes in the high altitudes of the region practically throughout the year and are a constant source of water supply. Canadian River flows generally northwestward to its junction with the North Platte near North Gate. Its eastern tributaries are mainly creeks of small but constant flow, the sources of which are on the timbered upper slopes of the Medicine Bow Range. The drainage ways entering the Canadian Valley from the west are dry channels, through which water flows only during the rainy periods. During the summer months the Canadian furnishes an abundance of water for irrigating the large areas of hay land along its broad valley.

Michigan River, the largest of the secondary streams, rises on the timbered slopes of the Medicine Bow Range, near the southeast corner of the park. It receives a number of small but rapid and constant tributaries, some of which are shown on the map (Pl. XII). These streams issue from the canyons in the vicinity of Cameron Pass, from which Michigan River flows northwestward almost across the park to its junction with the North Platte, about 2 miles northwest of Cowdrey. Throughout this distance the river supplies an abundance of water for the stock on the ranches along the valley and for the irrigation of a large acreage of hay land.

Illinois Creek has its source in the small streams emanating from the densely timbered slopes of the Continental Divide, in the southeast corner of the park. Although these streams are small, their flow is rapid and constant, so that the volume of the Illinois remains practically the same throughout the year. This stream is very similar to the Michigan, and supplies the same needs along its valley from its source to its confluence with the Michigan near Walden.

Grizzly Creek, the main stream of the southwestern part of the field, is made up of the combined waters of Colorado and Arapaho creeks, which head along the Continental Divide in the vicinity of Rabbit Ears Peak and to the east. Buffalo Creek is a small stream which rises in the more rugged portion of the divide on the south side of the park and flows into Grizzly Creek, about 3 miles southeast of Coalmont. Little Grizzly Creek, made up by the junction of small streams flowing from the east slope of the Park Range north of Rabbit Ears Peak, and Chedsey Creek, which rises near Buffalo Pass, together form a stream of considerable volume, which enters Grizzly Creek in the southwest quarter of T. 8 N., R. 80 W.

Norris Creek and Roaring Fork have their sources in the upper canyons of the Park Range near Mount Ethel and north of that peak. Norris Creek flows into Roaring Fork about 3 miles west of the locality where the latter stream empties into the North Platte. The northwest corner of the field is drained by North Fork, which rises near the divide southeast of Big Creek Lake, and flows southward through the valley between the Park Range and the large ridge on the east. At the south end of Sheep Mountain the stream turns eastward and joins the North Platte about 6 miles west of Walden. (See Pl. XII.) The numerous tributaries of North Fork issue from canyons in the vicinity of Bear, Flattop, and Zirkel mountains. This part of the range is heavily timbered and very rugged, and the immense quantities of snow which lodge in the cirques and canyons in winter furnish a constant supply of water throughout the year.

The surface water of a large area east of Sheep Mountain and the long ridge on the north has no outlet and settles into depressions, forming lakes, the largest of which are Lakes John and Boetcher. Although numerous channels leading to streams drain by far the greater part of the field, some rather large areas in different parts of the park are isolated from the drainage system.

The erosive action of the streams of North Park has undoubtedly greatly hastened the development of the coal resources by removing the cover which otherwise would have left the beds inaccessible and probably undiscovered for an indefinite length of time. The larger streams are available as sources of water power, and practically all parts of the field in which mines may be developed are within reach of streams large enough to furnish abundant water for operation.

Of greater importance, however, than their bearing on the development of the coal field is the value of the streams to the growing of beef cattle, which is the chief industry of the region. In addition to furnishing excellent water for the range stock, these streams supply an abundance of water for irrigating the pastures and hay meadows which occupy the greater portion of all the stream valleys. The abundance of good water furnished by the streams of the region and the consequent excellent forage have been prime factors in the shipment from North Park of some of the finest range cattle ever produced. Owing to the high altitude of the park floor and the consequent shortness of the growing season, agriculture, aside from the production of hay, has not been successful and but small inroads have been made by the farmer on the range lands of the field. Although a large part of the park is irrigable, the irrigation now practiced is confined to the stream valleys and to a few tracts of bench land. Several irrigation projects of considerable size, however, are at present in process of development in an effort to enlarge the acreage of productive hay land.

SETTLEMENT.

North Park has a population of slightly more than 1,000 people, nearly half of whom live in the towns of Walden, Coalmont, and Rand. The remainder live on ranches scattered along the stream valleys. The ranchers have settled in the park within the last 30 years and have taken up practically all the most valuable land in the valleys. The recent advent of the railroad and the possible development of coal mines will no doubt give a new impetus to settlement, and the population will probably double within a few years as a result of the demand for mine laborers and the extension of irrigation that is likely to follow the increased shipping facilities.

Walden, which stands a few miles northeast of the center of the park, is the county seat of Jackson County and the principal town of the region. It has a population of about 400, and in addition to having the county offices and many reliable business enterprises it is the distributing center for practically all of Jackson County. In the fall of 1911 several new buildings were in process of construction, and to all appearance the town was flourishing.

Coalmont is a comparatively new mining settlement whose population varies with the activity of the Northern Colorado Coal Co.'s mine. It is in the southwestern part of the park, about 15 miles southwest of Walden. In November, 1911, about 20 men were employed in preparation for operation of the mine on a commercial basis, and although the total population of the camp was not over 50 at that time, the indications pointed to a considerable growth after the completion of the railroad then constructed to within a few miles of the town.

North Gate, in the northeast corner of the park, is a railroad station consisting of a depot and stockyards. Cowdrey, about 2 miles south of North Gate, consists of a store and post office. Rand, in the southeastern part of the field, has a post office, store, and hotel, and a total population of about 35. Hebron is a combination store and post office about 3 miles northeast of Coalmont. Owl, Spicer, and Higho are country post offices.

The Colorado, Wyoming & Eastern Railway is completed and in operation between Laramie, Wyo., on the Union Pacific Railroad, and Coalmont, in North Park, giving a daily train service from the stations at North Gate, Walden, and Coalmont. This road was constructed primarily as a coal road but places shipping facilities within comparatively easy access of all parts of the park.

Before the construction of the railroad the entire North Park region was dependent on stage lines for the transportation of mail, freight, and passengers, and as a result good roads were maintained from Walden to Laramie by way of Cowdrey and Pinkhampton stage station, to Rand by way of Owl post office, to Spicer and Butler post offices by way of Hebron and Coalmont, and to Higho post office. In addition to the stage roads the field is traversed by roads that connect the ranches with each other and with the post offices and county seat. The main roads and many of those that are less traveled are shown on the map (Pl. XII, in pocket). Most of these roads were sketched from stadia traverses, but others were sketched across areas in which the absence of geologic exposures rendered instrumental work unnecessary, and the locations of these are but roughly approximate.

STRATIGRAPHY.

SEDIMENTARY ROCKS.

AGE AND CORRELATION.

The sedimentary formations of North Park range in age from late Carboniferous or Triassic to Quaternary. The older formations, whose age, owing to the lack of fossils, can not be fixed with certainty, are tentatively referred to the Carboniferous and Triassic by correlation with rocks provisionally so designated along the Front Range and in the Laramie-Sherman district, on the north. This correlation is based on lithologic similarity and corresponding position in geologic columns which are for the most part similar. None of the formations is exposed in entirety, and the details of the general section and of the descriptions which follow are based on a study of the composite section produced by fitting together as accurately as possible notes on all available exposures, whether patchy or of considerable extent. As this report considers primarily the coal of North Park, which is of late Cretaceous or early Tertiary age, the stratigraphy of the younger rocks, which are more closely associated with the coal measures, was studied in somewhat greater detail than that of the older rocks.

GEOLOGIC SECTION.

A general geologic section, showing the formations exposed in the park, is given below:

General geologic section in North Park, Colo.

System.	Series.	Group.	Formation.	Character.	Thickness.
					Feet.
Quaternary.				Alluvium. Dune sand.	0-30 0-50
				Terrace gravel.	0-6
				Glacial material (silt, sand, and bowlders).	0-hundreds.
Tertiary.			North Park formation.	Shale, sandstone, volcanic ash, tuff, and conglomerate.	600
		Unconformity (?)			
Cretaceous or Tertiary.			Coalmont formation.	Sandstone, conglomerate, shale, and coal beds.	4,000-6,000
		Unconformity			
Cretaceous.	Upper Cretaceous.	Montana.	Pierre shale.	Dark shale and thin beds of sandstone.	4,500
		Colorado.	Niobrara formation.	Calcareous gray and dark shale; thin beds of limestone.	800
			Benton shale.	Shale and sandstone.	165
			Dakota sandstone.	Sandstone, conglomerate, shale (?).	300
Jurassic or Cretaceous.			Morrison formation.	Maroon, greenish, and dove-colored marl and shale, with some interbedded limestone and sandstone beds.	260
Triassic (?).			Chugwater formation.	Brick-red sandstone and shale, with some interbedded clay and limestone beds.	1,350
Carboniferous (?).				Limestone.	20-30
Pre-Cambrian.				Granite, gneiss, and schist.	

CARBONIFEROUS (?) SYSTEM.

PENNSYLVANIAN OR PERMIAN (?) SERIES.

DISTRIBUTION AND CHARACTER.

In the northwest quarter of T. 10 N., R. 78 W., a mass of limestone underlies the red sandstone and shale of the Chugwater formation and rests directly upon the crystalline rocks of the Medicine Bow Range. The limestone was examined in only one locality, in sec. 8 of this township, and the data obtained are not sufficient to furnish a basis for definite conclusions as to age and correlation.

The limestone is made up of thin beds of light bluish-gray limestone, which weathers lighter gray with a brownish tinge. Considerable jointing was observed, particularly in the thinner layers, which appear to be made up largely of crystalline calcite. The beds range in thickness from a few inches to 5 or 6 feet and aggregate about 30 feet.

The outcrop of the limestone probably does not extend more than a mile or two on either side of the locality examined. (See Pl. XII.) As the strata dip west at practically the angle of surface slope the outcrop is here of considerable width. No very thick limestones were found between the Chugwater formation and the crystalline rocks, either in the vicinity of Sentinel Mountain on the northwest or near Ute Pass on the southeast. The place at which these beds should outcrop, however, is almost entirely covered with material slumped down from the higher slopes of the Medicine Bow Range, and the limits of outcrop as mapped are necessarily hypothetical.

STRATIGRAPHIC RELATIONS.

The limestone beds rest directly upon the crystalline complex of the Medicine Bow Range, and no evidence of unconformity between them and the overlying Chugwater formation was observed. Through lack of paleontologic evidence the age of the limestone can not be given with certainty. Its tentative reference to the Permian or Pennsylvanian series of the Carboniferous is based mainly on the fact that it underlies red beds, which are thought to be of Triassic age, and that the red beds (Chugwater formation) of the section in the adjoining Laramie region are underlain by Carboniferous limestone.

The occurrence of this limestone below the red beds on the North Park side of the Medicine Bow Range is similar to the occurrence of a limestone of nearly the same thickness (the Forelle limestone of Darton and Siebenthal),[1] about 15 miles to the northeast. Through-

[1] Darton, N. H., Blackwelder, Eliot, and Siebenthal, C. E., U. S. Geol. Survey Geol. Atlas, Laramie-Sherman folio (No. 173), p. 7, 1910.

out the southern part of the Laramie district this limestone lies immediately beneath the Chugwater formation, with which the red sandstones and shales of North Park are correlated because of the very similar lithologic character of the two and because each is overlain with apparent conformity by rocks of determined Morrison age. Fossils found in the Forelle limestone of the Laramie region were studied by G. H. Girty and are regarded by him as of late Pennsylvanian age or as possibly equivalent to those of the lowest so-called Permian limestones of Kansas. Opposed to the correlation of the Forelle limestone with the limestone below the red beds of North Park is the fact that the Forelle is fossiliferous and that the other limestone is, in one locality at least, apparently barren of organic remains. Owing to the very small extent of the outcrop examined, however, this evidence is not conclusive, and it is offset in some degree by the fact that the thickness of limestone exposed on the North Park side of the Medicine Bow Range is considerably greater than that of any limestone member of the Chugwater formation exposed elsewhere in North Park or in the Laramie district. That this limestone was regarded as Carboniferous by the geologists of the King Survey is shown in the report on North Park by Arnold Hague, who says:[1]

> Carboniferous limestones were recognized at only one locality, and that upon the northeast side, where they lie up against the Medicine Bow Range, inclined at a low angle. They occupy but a comparatively small area and derive their chief interest from being the single instance observed of Paleozoic strata within the parks. No fossils were found, but there can be no doubt that the beds belong to the Carboniferous series, inasmuch as they underlie a very considerable development of Red Beds, and measure at least 200 or 300 feet in thickness, which is far too heavy to represent one of the limestone strata included within the Triassic. Moreover, in their bedding and texture they resemble the upper members of the Coal-Measure limestone wherever seen below the red sandstones.

The thickness of strata recorded by Hague is much in excess of that existing in the field, a fact probably due, in the opinion of the present writer, to the common difficulty of estimating the thickness of strata exposed on a dip slope. Notwithstanding the possibility that the limestone may represent a local limy phase of the Chugwater formation, it seems more probable from the small amount of data in hand that the two formations should be differentiated and the limestone tentatively assigned to the Carboniferous.

FOSSILS.

A thorough search of the limestone beds revealed only a few indistinct casts which may have been made by either very small shells or pebbles. These, however, were not of determinable value.

[1] Hague, Arnold, and Emmons, S. F., U. S. Geol. Expl. 40th Par. Final Rept., vol. 2, p. 114, 1877.

TRIASSIC (?) SYSTEM.

CHUGWATER FORMATION.

DISTRIBUTION, CHARACTER, AND THICKNESS.

The red shale and sandstone beds of the Chugwater formation rest directly upon the crystalline mountain masses on the east and west sides of North Park, except in the northwest quarter of T. 10 N., R. 78 W. (see p. 21), where they are separated by limestone, probably of Carboniferous age. Because of its position near the foot of the mountain slopes the Chugwater outcrop is for the most part obscured by débris, and for this reason localities in which there is opportunity to study the character of the rocks are few and scattered.

The Chugwater formation is made up of a series of brick-red sandstone and shale beds, which, in most of the localities exposed, constitutes more than 95 per cent of the formation. In the more extensive exposures a few thin white or cream-colored sandstones and light limestone bands commonly less than a foot in thickness are interbedded at various horizons with the heavier red sandstone and shale. The constituent material of the formation is somewhat variable, however, and a complete section of the formation, if any were exposed at one locality, would be typical of the formation as a whole only in showing the predominance and homogeneity of the red sandstone and shale and not in its minor details. The red sandstone is of medium hardness, is massive, fine grained to conglomeratic in texture, and is composed chiefly of quartz grains with a ferruginous cement. Although the sandstone is predominantly fine to medium grained, in a few localities it is coarse or finely conglomeratic. The formation as a whole is, however, notably free from the coarse conglomerate which is prominent in what is supposed to be the same formation in the fields adjoining North Park. The shale beds are mainly sandy but are clayey in streaks and are of varying thickness.

At the northern extremity of the Chugwater outcrop, near the Pearl Road in the northwest corner of the field, the formation contains a number of thin varicolored shale beds, limestone bands, and several thin beds of gray conglomeratic sandstone. Near the northwest corner of T. 10 N., R. 81 W., an exposure of the Chugwater reveals two friable red sandstones separated by 20 feet of tough black clay containing an abundance of gypsum crystals. In the northeast corner of the field several thin layers of cream-colored nonferruginous sandstone occur near the stratigraphic center of the formation. The thickness of the formation ranges in various localities from 300 to over 1,500 feet. The 300-foot measurement, however, is known to represent a very local condition and the average thickness of the formation is estimated at approximately 1,350 feet. This great variation in thickness is probably due to unconformable relationship with the underlying pre-Cambrian rocks, as a result of which in many localities the lower strata of the Chugwater formation do not reach the surface.

The Chugwater formation outcrops in a narrow band near the foot of the slope of the Medicine Bow Range on the east side of the park and along the base of the Park Range on the west and presumably underlies all of the intervening area. These outcrops pass over the Continental Divide into Middle Park on the south, and on the north they are bounded by the faults which bring up the crystalline rocks. The upthrust granite of Sheep Mountain and the long ridge extending northward toward Pearl is bounded on the east by a comparatively wide outcrop of Chugwater strata, which dip east and rest with sedimentary contact directly upon the granite. The outcrop here occupies the valley between the main ridge and the secondary or Dakota sandstone ridge on the east, and its width is due to the downward cutting of the stream in the direction of dip. In the area north of Boetcher Gap the red sandstone and shale beds outcrop in a narrow strip along the west side of the ridge, but here their contact with the granite is a result of faulting. A small exposure of the Chugwater occurs east of the fault between Sheep Mountain and Delanos Butte. The outcrop of the formation is prominent in King Canyon in the northeast corner of the park, where it is duplicated by the fault on the east of Sentinel Mountain. The formation also comes to the surface along the axis of the anticline in the southwest corner of T. 9 N., R. 77 W. Small masses of red sandstone were observed on top of the fault block of crystalline rocks in the vicinity of Watson Mountain and in the col between Flattop and Zirkel mountains. In the last-named locality a wedge of red sandstone, 100 feet thick, surrounded on all sides by gneiss, was undoubtedly faulted into position.

STRATIGRAPHIC RELATIONS.

On the evidence afforded by their lithologic character and stratigraphic position the red shale and sandstone beds of North Park are correlated with the strata described by Darton and Siebenthal as the Chugwater formation,[1] the exposures of which nearest to North Park are on the opposite side of the Medicine Bow Range, about 15 miles to the northeast. In North Park this formation rests directly on crystalline rocks, except in one locality in T. 10 N., R. 78 W., in which they are separated by about 30 feet of Carboniferous (?) limestone, and in the several localities in which the Chugwater is faulted into contact with formations which normally overlie

[1] Darton, N. H., Blackwelder, Eliot, and Siebenthal, C. E., U. S. Geol. Survey Geol. Atlas, Laramie-Sherman folio (No. 173), p. 7, 1910.

it. The formation here, as in the Laramie field, bears a close resemblance to the Lykins formation, which may be its stratigraphic equivalent in the Boulder district[1] and other localities east of the Front Range. The sandstone and shale of the Chugwater formation closely resembles that of the Lykins, and both formations are conformably overlain by the well-recognized Morrison formation. One notable difference, however, is the presence of thick gypsum beds in the Lykins of the Boulder district and in the Chugwater near Laramie and their apparent absence in the Chugwater in North Park. The Chugwater formation, like the lithologically similar formations which occupy the same stratigraphic position in many parts of the Rocky Mountain region, is provisionally considered Triassic because it in many localities conformably underlies the fossiliferous Morrison formation (presumably Jurassic) and overlies fossil-bearing limestone of the Carboniferous. The formation is apparently barren of organic remains in North Park, and it is notable that the discovery of fossils in the presumably equivalent formations of the general region has been extremely rare. Careful search was made in this field for the Saurian limestone conglomerate which forms the basal part of the Dolores formation (Triassic) of the San Juan region in southwestern Colorado and which is reported to occur in Middle Park, but it could not be found and is probably not present. Concerning the position of the "Upper Wyoming" formation, later named the Lykins, of the Denver Basin, Eldridge[2] concludes:

> As there seems to be reasonable ground for the assumption that a portion, at least, of the Red Beds horizon of the Rocky Mountain region is Triassic in age, and since the beds treated in this report occur immediately beneath well-defined Jurassic strata and very probably represent the upper part of the great series of Red Beds, it seems proper to designate them, provisionally at least, Triassic.

The occurrence of remnants of the "Red Beds" sandstone on top of the granite fault block northwest of Sentinel Mountain and on the very summit of the Park Range near Mount Zirkel is of great interest in its bearing on the geologic history of the region. In the former locality small areas of reddish disintegrated rocks very similar to the shale and sandstone of the "Red Beds," where weathered, were observed, but their relation to those rocks is not beyond question. In the Mount Zirkel locality, however, the remnant of red sandstone is sharply defined and well preserved, and is identical in character to the sandstone outcropping a few miles southeast at the foot of the Park Range. In the opinion of the writer, the position of these sandstone remnants is strongly suggestive if not conclusive evi-

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[1] Fenneman, N. M., Geology of the Boulder district, Colo., U. S. Geol. Survey Bull. 265, p. 24, 1905.

[2] 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.

dence that the "Red Beds" of North Park were at one time continuous with those of the Hahns Peak district, a few miles to the west, and probably also with the Chugwater formation of the Laramie district. Could such a connection be established with certainty it would strongly suggest that this region was once covered by a still more extensive continuous formation and that the present Rocky Mountain region was in late Carboniferous or Triassic time occupied by a broad shallow sea or, as indicated by the character of the sediment, by a great flat area well covered with lakes or shallow basins.

FOSSILS.

The exposures of the Chugwater formation were examined with especial care in the hope of finding fossils that would afford paleontologic evidence both of their age and of the age of the so-called "Red Beds" in surrounding fields. The search was not rewarded, however, and, so far as could be ascertained, the beds are as barren of fossils in North Park as they commonly are in other western fields.

JURASSIC OR CRETACEOUS SYSTEM.

MORRISON FORMATION.

CHARACTER, THICKNESS, AND DISTRIBUTION.

The Morrison formation, though partly exposed at many places in North Park, is in general very much concealed. Its position immediately below the Dakota sandstone, which forms a ridge along the lower mountain slopes, places its outcrop throughout much of the field in the bottom of a trough which serves as a receptacle for talus from the Dakota sandstone ridge on one side and from the mountain wall on the other.

The Morrison formation is made up mainly of maroon, greenish, and dove-colored shale and marl, interbedded with a few thin lenticular layers of limestone and sandstone, which differ greatly in different localities. The marl beds, which predominate, are mainly soft and friable but include several layers that contain a much higher proportion of lime and are much more resistant. The shale members of the formation are bluish drab to dove-colored and are calcareous throughout, the differentiation between shale and marl depending on the predominance of shale or lime in the bed. The formation contains several thin purple limestones in the exposures north of the Hill ranch in T. 11 N., R. 81 W.

In the gap east of the Boetcher ranch, in the next township south, the marl beds contain near the base a white sugary sandstone, 10 to 15 feet thick. In the canyons and gulches along the west side of the park the Morrison formation contains limestone layers 3 feet or more thick and a white sandstone about 5 feet thick. In the King Canyon section the lowest member of the Morrison is a coarse white sandstone 40 to 50 feet thick. This sandstone is composed mainly of grains of quartz, is friable, and is heavily bedded. The thickness of the formation is known to vary from about 150 feet east of the Boetcher ranch to approximately 350 feet in the northeast corner of the field. The average thickness is estimated to be about 260 feet.

The Morrison outcrops near the foot of the mountain slopes along the east and west sides of the park and is probably present at considerable depth everywhere between these outcrops. On the south the formation passes across the Continental Divide into Middle Park, and on the north it is limited by the faults which bring up the granite on that side. The uplifted granite core of Sheep Mountain and the large ridge extending northward a few miles east of the main range causes a duplication of outcrop of the entire series in that part of the field. The Morrison formation outcrops in a narrow band along the west slope of the Dakota sandstone ridge, which lies east of Sheep Mountain and extends northward with more or less prominence to its contact with the granite of Independence Mountain.

The Morrison outcrop is also duplicated by the fault on the east side of Sentinel Mountain, in which locality broader exposures of the formation occur than at any other place in the field. North of Pinkhampton, along the railroad in Pinkham Creek valley, the marls of the Morrison formation are exposed in many places along the creek banks and railroad cuts. The beds outcrop on both sides of the anticline, in the southern part of T. 9 N., R. 77 W., and also on the east side of the fault which separates the anticline from the Medicine Bow Range.

STRATIGRAPHIC RELATIONS.

The deposits in North Park are referred to the Morrison because of their resemblance to the typical Morrison formation exposed near Morrison, Colo., about 15 miles west of Denver. The correlation is made on paleontologic evidence, which, though not abundant, is of determinative value. It is supported by the stratigraphic position and lithologic character of the formation, which in many fields of the Rocky Mountain region bears the same relation to the widely recognized Dakota and to the nearly nonfossiliferous "Red Beds" that it does in North Park. The highly colored limestone and marl beds which constitute so large a part of the formation in this field are characteristic of the Morrison wherever it occurs in the West. The Morrison formation is present in the Laramie and Sherman districts of Wyoming, which lie northeast of this field on the opposite side of the Medicine Bow Range. In the Laramie area the Morrison is somewhat thinner and contains more clay and shale than in North Park, but otherwise it has practically the same characteristics. Although there is no marked evidence of unconformity between the Morrison and underlying Chugwater formation ("Red Beds") in North Park, the line between them is thought to represent a time break because the same formations are separated in the Sherman district on the east by the marine Sundance formation of the Jurassic, which was not found in the Laramie or North Park fields.

Evidence of unconformity at either the top or base of the Morrison is lacking in North Park, but because of the scarcity and small extent of the contact exposures this is not conclusive proof that it is conformable with the underlying and overlying formations. Although the Dakota-Morrison contact is nowhere sharply defined it is probable that the base of the lowermost conglomerate or conglomeratic sandstone of the Dakota marks the top of the Morrison. The base of the formation is not so well marked but is drawn as nearly as possible at the horizon at which the red sandstone of the Chugwater formation gives place to the marly beds of the Morrison. This horizon is not marked by the occurrence of gypsum beds, as is commonly the case along the Front Range in central Colorado.

The unsatisfactory character of the North Park exposures and the somewhat hurried nature of the field work render it unsafe to state with finality that marine Jurassic beds are absent from that section, but on the basis of the fossils found and the thickness of the strata between the red beds and the Dakota it seems most probable that only the Morrison is represented. Henderson,[1] of the Colorado Geological Survey, reports marine Jurassic fossils but no Morrison from the Hahns Peak region west of Mount Zirkel and correlates the formation with the Sundance of the Sherman district. The Sundance outcrops below the Morrison along the east side of the Sherman Hills and is reported by Darton[2] as occupying that position to a few miles south of the Colorado-Wyoming line, where the marine beds pinch out. This formation is apparently not represented in the Front Range section farther south in Colorado, however, and the facts concerning its disappearance are still to be determined. The presence of the marine Jurassic in the Sherman and Hahns Peak districts and its absence in the Laramie region and also in North Park indicate that the Laramie and North Park portion of the present Rocky Mountain belt was uplifted and was not the scene of deposition while the marine Jurassic sediments were being laid down both on the east and west.

[1] Colorado Geol. Survey Rept., 1908, p. 205, 1909.

[2] Darton, N. H., Geology and underground waters of the Arkansas Valley in eastern Colorado: U. S. Geol. Survey Prof. Paper 52, p. 96, 1906.

The similarity of the Morrison formation of North Park to that of the type locality, both as to character and stratigraphic relations, is shown by Eldridge,[1] who says:

Throughout the Denver field and for much of the distance along the eastern base of the Rocky Mountains in Colorado the Jura is essentially a formation of fresh-water marls, of an average thickness of about 200 feet. Its upper limit is sharply defined by the Dakota sandstone, while the brown and pink sandstone closing the Trias as clearly marks its lower limit. To this formation has been assigned the name "Morrison," from the town near which it is typically developed.

The marls are green, drab, or gray, and carry in the lower two-thirds numerous lenticular bodies of limestone of a characteristic drab color and a texture compact and even throughout. A small but persistent band of sandstone and limestone in thin alternating layers occurs about 20 feet above the base. * * * The clays of the lower two-thirds of the Jura are remarkable for their reptilian remains and from the predominating form have been designated "Atlantosaurus clays."

FOSSILS.

The Morrison is very scantily fossil bearing in North Park and furnished collections from but two localities, located very near each other, in the south side of T. 10 N., R. 81 W. The following invertebrates, identified by T. W. Stanton, were found at locality 45, on the east side of the ridge, near the center of sec. 33, T. 10 N., R. 81 W.: Unio sp., *Valvata scabrida* M. and H., *Planorbis veternus* M. and H., *Viviparus gilli* M. and H.?.

Near the southeast corner of sec. 33, on the west slope of the ridge, just below the crest (locality 48), a collection of reptilian remains was obtained. A large amount of the material consisted of bone fragments which could not be determined. C. W. Gilmore identified the base of a dermal spine as that of Stegosaurus. He reported as follows on the remainder of the material:

Tooth of a crocodile, probably representing the genus Goniopholis. Fragments of large limb bones which, from their great size, may pertain to one of the sauropodous dinosaurs. Many other fragments which are indeterminable.

At locality 68, in the SW. ¼ sec. 11, T. 8 N., R. 82 W., a single much-worn vertebra of a dinosaur was found in the talus from a limestone ledge which outcrops near the top of the Morrison in the steep wall of a canyon.

Stegosaurus is found only in the Morrison and, with the invertebrate fossils identified, establishes the Morrison age of the formation beyond question.

[1] Emmons, S. F., Cross, Whitman, and Eldridge, G. H., Geology of the Denver Basin in Colorado: U. S. Geol. Survey Mon. 27, pp. 60–61, 1896.

CRETACEOUS SYSTEM (UPPER CRETACEOUS SERIES).

DAKOTA SANDSTONE.

CORRELATION.

As used in this report, the name Dakota sandstone is applied to the strata which occupy the stratigraphic position between the Morrison formation and the base of the Benton shale. Until recently a series of hard fine-grained sandstone at the top separated by a shaly member from coarser sandstone and conglomerate at the base was collectively treated as Dakota in the Rocky Mountain region. In the course of subsequent detailed work, however, evidence was obtained that only the upper fresh-water sandstone belonged to the Upper Cretaceous or true Dakota[1] and that the remaining beds were distinct from them and of Lower Cretaceous age. In and south of Colorado, for instance, marine fossils found in the intermediate shaly member determined its age to be Lower Cretaceous (Comanche), and in the Black Hills and northern areas fossil flora found in the lower part (the Lakota sandstone and Fuson shale) proved its age to be Lower Cretaceous.

In North Park the formation is made up almost entirely of sandstone and conglomerate. The upper strata are lithologically like the true Dakota and yielded a few poorly preserved plant remains which leave little doubt as to their age. The lower coarse sandstone and conglomerate may be of Comanche age, but the absence of a well-defined and persistent shale member and the failure to find Lower Cretaceous fossils anywhere in the formation make it unsafe to attempt to differentiate it at this time.

CHARACTER AND THICKNESS.

The Dakota of North Park is made up of sandstone and conglomerate interbedded with thin shale, clay, and clayey sandstone layers. The sandstone and conglomerate constitute 90 per cent or more of the formation, which has an average thickness of approximately 300 feet. Near the Ute Pass road in the southeastern part of T. 10 N., R. 78 W., there is evidence of a tripartite character of these beds similar to that of the formation in eastern Colorado and New Mexico, where only the upper sandstone belongs to the true Dakota and the lower conglomeratic sandstone and the intermediate shale member are of Comanche (Lower Cretaceous) age. In the Ute Pass locality the upper sandstone, which has all the characteristics of the true Dakota, is separated from the lower coarse sandstone and conglomerate by 30 to 40 feet of beds, which are predomi-

[1] Stanton, T. W., Jour. Geology, vol. 13, p. 662, 1905.

nantly shale with sandy layers. It is highly probable, however, that this thickness of shale in the section near Ute Pass represents only a local shaly phase in the base of the upper member. In general, the lower sandstone member consists of coarse, gritty, and in many places pebbly layers, interbedded with thin sandy shale or clay beds. The rock is bedded in variable thicknesses, is white or cream-colored in most localities (though buff in many others), and on weathering yields a clean, almost white quartz sand. Toward the base the sandstone is cross-bedded and coarse and grades into the basal conglomerate, which is made up of material ranging from coarse sand to well-rounded quartz and chert pebbles up to 2 inches in diameter. This conglomerate varies in hardness, and though in some localities friable and less resistant than the upper sandstone, is in others the most resistant stratum of the series and forms the crest of the Dakota sandstone ridge. The thickness of the lower member varies from less than 100 to nearly 200 feet.

The upper sandstone, which is definitely assigned to the Dakota, is fine grained and is made up chiefly of white quartz, though it contains darker mineral grains in variable proportions. This sandstone has a characteristic buff color, which, where the rocks are weathered, is in many places iron stained to shades of brown, red, and pink. It is much less porous than the lower conglomeratic sandstone and throughout most of the field is much harder, its upturned edges in most localities forming the crest of the ridge or hogback, which is more or less conspicuous wherever these rocks appear at the surface. The sandstone occurs in layers ranging from thin regular laminæ to beds 8 to 10 feet in thickness. In many places joints are so well developed that the débris weathered down from them contains many roughly rectangular blocks. Ripple marks are common on the exposed bedding planes of the Dakota, indicating that the sediments were laid down in shallow water. The shallow fresh-water origin of these sandstones, considered in connection with their wide distribution over the western interior and Rocky Mountain sections of the United States, furnishes opportunity for unlimited speculation as to the source of the tremendous quantity of fine white quartz grains which they contain.

DISTRIBUTION.

The Dakota sandstone outcrops along the base of the Medicine Bow and Park ranges on the east and west sides of North Park and underlies all of the intervening plains area. The outcrop of the formation is cut off on the north by the Independence Mountain fault, but on the south it passes over the Continental Divide into Middle Park. Notwithstanding the comparative thinness of the formation, its outcrop is more conspicuous than that of any other sedimentary formation in the field because of the resistant, ridge-forming character of its sandstones. On the east side of the park the upturned edges of the Dakota form a large, well-defined ridge, continuous, except where numerous stream canyons cut it, from Sentinel Mountain, at the northeast corner of the field, to the vicinity of the Clear Creek and Kelly Canyon moraines, which obscure the formation. The eastern limit of the formation south of these moraines is marked by an inconspicuous roll or bench along the débris and timber covered lower slopes of the Medicine Bow Range as far as the Cameron Pass road, near which is the southernmost exposure of Dakota sandstone observed in this part of the field. In the south half of T. 9 N., R. 77 W., the formation outcrops widely around an eroded anticline and in the trough of the supplementary faulted syncline on the east. In the northeast corner of the field the Dakota sandstone outcrop is duplicated by the Sentinel Mountain fault. To the east of the fault the greater part of the formation is exposed along the King Canyon railroad cut and to the west the uppermost hard sandstone outcrops prominently at the summit of Sentinel Mountain and on the upper part of its western slope, which conforms to the dip slope of the strata. Northwest of Sentinel Mountain the sandstones come to the surface but are poorly exposed in the small anticlinal fold cut off by the major fault on the north.

The Dakota outcrop is less conspicuous along the foot of the mountain slopes on the west side of the park than it is along the base of the Medicine Bow Range on the east side, being largely hidden beneath the numerous moraines and widespread detrital material which cover much of the older sedimentary outcrops from Rabbit Ears Peak to the northwest corner of the field. Throughout this distance the Dakota is partly exposed in many of the canyons cut by streams rising in the Park Range. It does not form a chain of prominent hogbacks, however, and its influence on the topographic forms is noticeable only in the vicinity of Norris Creek, where the steeply dipping sandstone forms a prominent wall, and in a few localities to the south, where a scarcely discernible ridge marks the outcrop. The Dakota sandstone appears at the surface of a considerable area between Norris Creek and Roaring Fork, because of minor folds in the strata in that locality. The elevation of the granitic masses of Delanos Butte, Sheep Mountain, and the long ridge to the north causes a duplication of the Dakota outcrop in the northwestern part of the field. The formation is exposed on a dip slope on the east side of Delanos Butte and forms a more or less prominent ridge extending from the south end of Sheep Mountain along the east side of the granite northward to the Independence Mountain fault in the north side of T. 11 N., R. 81 W. As indicated on the map (Pl. XII), several isolated masses of Dakota sandstone outcrop in the vicinity of Boetcher Gap, where they are cut off by faults from the main body of the formation.

STRATIGRAPHIC RELATIONS.

The lithologic character of the upper division of the formation and a single collection of poorly preserved fossil plants obtained from that division show that it belongs to the true Dakota. The constituent material and general character of the Dakota sandstone are so persistently uniform throughout the Rocky Mountain region as to have much weight in correlation.

The marked difference in character of the upper and lower divisions of the formation in North Park and the resemblance of the basal conglomeratic beds to the Comanche (Lower Cretaceous) sandstones of southeastern Colorado and New Mexico strongly suggest that these lower beds are of Comanche age. In all localities known to the writer, however, in which both Dakota and Lower Cretaceous rocks have been recognized, the sandstones of the Dakota are separated by an intermediate shale member from the conglomerate. This shale, which contains marine fossils in many localities in southeastern Colorado, is apparently not present in North Park, except possibly in Ute Pass (see p. 30), where the conglomerate is overlain by a considerable thickness of shale, which may be assumed to represent the intermediate shale found in other fields, though its lack of persistency and its barrenness of fossils throw doubt on this assumption.

Lithologically the sandstone members of the Dakota formation of North Park are very similar to the upper and lower sandstones of the "Cloverly" formation of the Laramie-Sherman district, in which the "Cloverly" consists of two sandstone members separated by a considerable thickness of shale. Darton[1] provisionally correlates the upper sandstone with the true Dakota, the shale member with the Fuson, and the lower sandstone with the Lakota of the Black Hills. This correlation is not supported by paleontologic evidence, however, and the suggested correlation of the shale member with the plant-bearing Fuson of the Lower Cretaceous is rendered somewhat doubtful by the discovery of marine shells in the northern Front Range section of Colorado in shale beds which are continuous with the medial shale member of the "Cloverly" in the Laramie-Sherman field.

Concerning the formation which in the foothills of northern Colorado occupies a stratigraphic position corresponding to that of the

[1] Darton, N. H., Blackwelder, Eliot, and Siebenthal, C. E., U. S. Geol. Survey Geol. Atlas, Laramie-Sherman folio (No. 173), p. 9, 1910.

Dakota of North Park and the "Cloverly" of the Laramie-Sherman area, Prof. Henderson says:[1]

> The uniformity of the tripartite character of the formation along the foothills of the Front Range and the discovery of Comanche fossils in the medial member at Canon City and elsewhere southward strongly suggest that at least part of the medial shales and the lower sandstone member in the Boulder district and northward may be the time equivalent of the Comanche.

As there is no evidence of the Lower Cretaceous age of any part of this formation in North Park except in the lithologic character of the basal conglomerate, the name Dakota sandstone is applied to this entire series of strata, but as this nomenclature is based on lack of evidence rather than on negative evidence there is a distinct possibility that the lower beds may eventually be identified as Comanche.

FOSSILS.

The Dakota was carefully examined at many localities and was found to be very scantily fossiliferous. Fragments of wood and impressions of stems were frequently observed, but determinable fossils were found in one locality only (No. 17, in King Canyon), and the ones found there were but poorly preserved. F. H. Knowlton reported as follows on a collection from this locality:

Gleichenia kurriana? Heer.	Brachyphyllum sp.
Sequoia sp. cf. S. condita Lesq. (cone).	Laurophyllum reticulatum? Lesq.

> This material is exceedingly fragmentary and so poorly preserved that essential characters are almost wholly lacking. So far as can be made out, however, it appears to be Dakota and may be regarded as of this age.

COLORADO GROUP.

GENERAL FEATURES.

In the Colorado group are included all the strata between the top of the Dakota sandstone and the base of the Pierre shale. Two formations are represented—the Benton shale, which rests directly upon the Dakota and is well marked at the top by a persistent sandy layer, and the Niobrara formation, which overlies the Benton but which apparently grades into the overlying Pierre shale imperceptibly, so that the dividing line between this group and the Montana group above has been arbitrarily drawn between the stratigraphic horizons at which the highest Niobrara and the lowest Pierre fossils have been found.

BENTON SHALE.

Character and thickness.—The Benton shale consists of three more or less distinct divisions—about 50 feet of very dark shale at the

[1] Colorado Geol. Survey Rept., 1908, p. 175, 1909.

base, 75 feet or more of gray and light shales containing thin limestone in the middle, and 35 to 50 feet of gray sandy shale and sandstone at the top. The top and bottom of the Benton shale are very well defined, the top by the uppermost sandstone, which appears at the surface in many places, and the bottom by the cap sandstone of the Dakota, upon the dip slope of which the lowest shale beds of the Benton are exposed in various localities throughout the field. The formation is in general very poorly exposed, because a large part of its outcrop along the base of the hogback is covered by talus of the Dakota sandstone and because the shales of its middle and lower members offer slight resistance to erosion and weathering.

The lowest division of the Benton is made up of bluish-black thinly laminated shale, which lies in direct contact with the Dakota sandstone. The laminæ range from one-fourth inch to 3 inches in thickness and weather out in thin slabs or sheets which soon crumble, forming a flaky gray shale talus. In the north bank of Norris Creek (locality 57, T. 8 N., R. 82 W.) the exposed bedding planes of the black shale show innumerable jet-black glossy fish scales and fragments of fine fishbones, which give the shale a mottled appearance. In this locality the black fissile shale gives way to dark-gray and drab shale beds, which are included in the lowest dark-colored member of the formation and which vary from place to place in color and in thickness. The middle division of the Benton consists of light-gray and yellowish shale containing limy streaks and at several horizons bluish-gray slabby limestones 2 to 12 inches thick. The light-colored shale is very soft, weathering to a fine light-colored homogeneous mass, which is broken in places by slight ridges of lighter color formed by the weathered outcrop of the more resistant bands of limestone. The upper division of the formation is made up mainly of medium-grained gray shaly sandstone, which is rendered calcareous in its upper layers by abundant fossil shells. The sandstone is thin bedded, is generally less than 2 feet thick, and is separated by thin layers of sandy shale. The freshly broken sandstone is gray but weathers to brownish gray and buff, giving the outcrop a characteristic light-tawny color. This sandstone is very persistent and is easily recognizable by its characteristic color and by the fossil shells which it nearly everywhere contains. It is more resistant than the shales above and below it, and appears at the surface in many localities, in some as a more or less pronounced ridge.

Each of the three members of the Benton varies considerably in thickness from place to place, and the formation as a whole ranges in thickness from less than 100 to about 200 feet, probably averaging about 165 feet.

Distribution.—The Benton shale outcrop extends along the east and west sides of the park in two narrow bands extending from the

Independence Mountain fault at the north end of the field southward to the Continental Divide, across which it passes into Middle Park. All of the park floor is underlain by this formation, which in the central part of the field is probably 8,000 to 10,000 feet below the surface. On the east side of the field the lower part of the Benton is almost concealed by talus from the Dakota sandstone ridge, along the base of which it outcrops. Small and more or less obscure exposures of the lower black shale occur along several of the stream channels which are cut through the Dakota on that side, and in several localities the top sandstone member appears at the surface. The exposures are sufficient, however, to prove that the Benton is present on this side of the field. Its outcrop follows that of the Dakota but is not duplicated by the Sentinel Mountain fault in the northeast corner of the park, for its beds have been removed by erosion east of the fault. The Benton occurs in its normal relation to the Dakota in the small anticline northwest of Sentinel Mountain and in the faulted anticline in T. 9 N., R. 77 W. On the west side of the field the best exposures of the Benton occur in T. 11 N., R. 81 W., where the lower beds outcrop in several localities along the east slope of the ridge of Dakota sandstone. The upper sandstone member is also exposed in places along the strike, and its outcrop is duplicated in this township by a strike fault that extends from the Independence Mountain fault southward across the township, about half a mile east of the Dakota sandstone ridge and roughly parallel to it. The black fissile shale at the base of the formation is well exposed in the north bank of Norris Creek, where that stream cuts across the upturned edges of the Dakota and Benton in sec. 13, T. 8 N., R. 82 W. Throughout the remainder of the west side of the field the Benton is present but is concealed except for inconspicuous outcrops of the shell-bearing sandstone, which occur near the Dakota outcrop in places along the east side of Delanos Butte and Sheep Mountain and between the moraines along the base of the Park Range.

Stratigraphic relations.—The Benton shale rests directly upon the uppermost part of the Dakota sandstone, and no evidence of unconformity between the two was observed. The shell-bearing sandstone, which outcrops more persistently than the rest of the formation, is the highest stratum in which fossils of undoubted Benton age were found, and for this reason it is mapped as the top of the formation, although it is possible that a greater or less thickness of the overlying shale is of Benton age. The only fossils yielded by the shale are fish scales, which are not distinctive, for they are characteristic of certain beds both in the Benton and Niobrara. The close resemblance of the sandstone of the Benton of this field, however, to a sandstone that marks the top of the same formation in adjoining fields, strongly indicates that this member is at or only a few feet below the Benton-Niobrara contact. The formation is assigned to the Benton on evidence afforded by fossils, which though not abundant are of determinative value, and the determination is borne out by the lithologic character of the beds and by their stratigraphic position between the Dakota and the Niobrara, which is the same here as in many fields on both the east and west sides of the Rocky Mountains.

The total thickness of the Benton in North Park, where it averages approximately 165 feet, is much less than that of the same formation in the Laramie-Sherman, Denver Basin, or Pueblo districts, where its thickness is 800, 350 to 600, and 400 feet, respectively. Notwithstanding the comparative thinness of the formation in North Park it retains the tripartite character that it shows along the Front Range and in the Laramie-Sherman field.

In describing the Pueblo region[1] Gilbert treated the Benton as a group and divided it into three formations, the lower composed of shale, the middle of shale with thin limestone beds, and the upper of argillaceous to sandy shale, with a persistent sandstone near the top. These he named, respectively, the Graneros shale, the Greenhorn limestone, and the Carlile shale, after creeks along which the different formations are best exposed in or near the Pueblo quadrangle. In the northern foothills of Colorado[2] and in the Laramie-Sherman[3] and Black Hills[4] regions, divisions of the Benton have been recognized, which, though differing somewhat in detail, are essentially similar to and are believed to represent the three divisions of the Benton in the Pueblo field. In North Park the shale which constitutes approximately the lower 50 feet of the formation is probably the equivalent of the Graneros shale. The black laminated shale at the base of this division bears a close resemblance in character and abundance of fish remains to the Mowry shale member, near the base of the Benton in the vicinity of Laramie and in northern Wyoming and in Montana. The shale and limestone beds of the middle division of the Benton in North Park are believed to represent the Greenhorn limestone of the Pueblo field. In North Park this division, like the upper and lower ones, is thinner than the corresponding division elsewhere exposed, approximately in proportion to the total thicknesses of the formation here and in other fields. The character of the beds and the proportion of limestone and shale are much the same here as in the type locality of the Greenhorn, where the shale beds predominate, the name Greenhorn "limestone" probably having been applied because the limestone bands are more

[1] Gilbert, G. K., U. S. Geol. Survey Geol. Atlas, Pueblo folio (No. 36), p. 3, 1897.
[2] Colorado Geol. Survey Rept., 1908, p. 176, 1909.
[3] U. S. Geol. Survey Geol. Atlas, Laramie-Sherman folio (No. 173), 1910.
[4] Idem, Sundance folio (No. 127), 1905. Idem, Belle Fourche folio (No. 164), 1909.

resistant and outcrop more conspicuously than the shale beds. *Inoceramus labiatus*, which, though not confined to the Greenhorn, is almost invariably contained in abundance in that formation, was found in but one locality in North Park, and in that one is believed to have come from beds higher than those correlated with the Greenhorn limestone. This part of the formation was not examined in as great detail as the better-exposed beds above and below, and it is probable that a more extended search would prove that this species is present. That the sandy shale and calcareous shell-bearing sandstone at the top of the Benton in this field represents the Carlile shale of the Pueblo, Front Range, and Black Hills sections is practically beyond doubt. It has the lithologic character of the Carlile and contains great numbers of Inoceramus, Scaphites, and *Prionocyclus wyomingensis*, all of which are common to the Carlile shale.

Fossils.—The upper part of the Benton yielded practically all of the identifiable fossils found in the formation. A great many scales and fragmentary bones of fishes are contained in the lower shale beds, but these, though common in the Benton and indicative of lower Benton age, are not sufficient for definite age determination.

Dr. T. W. Stanton examined and reported as follows on fossils collected from the localities indicated on Plate XII:

Locality 30. SE. ¼ sec. 32, T. 11 N., R. 81 W., 1¾ miles southeast of Hill ranch:
Inoceramus fragilis H. & M.
Inoceramus dimidius White.
Scaphites warreni M. & H.
Prionocyclus wyomingensis Meek.
Fish vertebræ.

Locality 33. SW. ¼ SE. ¼ sec. 34, T. 10 N., R. 81 W., north of Lake John:
Inoceramus fragilis H. & M.
Inoceramus dimidius White.
Prionocyclus wyomingensis Meek.
Scaphites warreni M. & H.

Locality 36. NE. ¼ SW. ¼ sec. 32, T. 10 N., R. 81 W., 1 mile south of Boetcher ranch:
Inoceramus dimidius White.
Inoceramus fragilis H. & M.

Locality 42. NE. ¼ SE. ¼ sec. 20, T. 11 N., R. 81 W., northeast of Hill ranch:
Inoceramus fragilis H. & M.
Inoceramus labiatus Schlotheim.
Scaphites warreni M. & H.
Prionocyclus wyomingensis Meek.

Locality 43. NW. ¼ SW. ¼ sec. 16, T. 11 N., R. 81 W.:
Inoceramus fragilis H. & M.
Scaphites warreni M. & H.
Prionocyclus wyomingensis Meek.

Locality 47. SW. ¼ sec. NW. ¼ sec. 16, T. 11 N., R. 81 W.:
Inoceramus sp.
Inoceramus fragilis H. & M.
Inoceramus dimidius White.
Prionocyclus wyomingensis Meek.

Locality 57. NE. ¼ SW. ¼ sec. 13, T. 8 N., R. 82 W., north of bank of Norris Creek, about 200 yards north of Norris house, and 12 to 14 miles southwest of Walden:
Scales and fragmentary bones of fishes.

Locality 65. SW. ¼ SW. ¼ sec. 34, T. 7 N., R. 82 W., about 4¼ miles southwest of Royalty ranch:

Ostrea sp.
Inoceramus fragilis H. & M.
Prionocyclus wyomingensis Meek.

Locality 91. NW. ¼ sec. 20, T. 9 N., R. 77 W., one-half mile northwest of Kerr's ranch house:

Inoceramus fragilis H. & M.
Scaphites warreni M. & H.
Fish scales.

NIOBRARA FORMATION.

Distribution, character, and thickness.—All the rocks between the top of the Benton and the base of the Pierre shale are included in the Niobrara. The bottom of this formation is well marked by the top of the sandstone member of the Benton, but the top shows no change in character sufficiently well marked to permit any horizon to be safely mapped as a definite contact line. Although the rocks at this horizon are nowhere well exposed the absence of a sharp change in color, hardness, or texture of the beds indicates a gradual transition from Niobrara to Pierre, and the dividing line as mapped is arbitrarily drawn between the stratigraphic horizons at which the highest Niobrara and the lowest Pierre fossils were found.

The Niobrara formation is made up of limestone and shale and has an aggregate thickness ranging from a probable minimum of 500 feet in the northern part of the field to more than 1,000 feet near Rabbit Ears Peak in the southwest corner. The thickness of beds believed to be representative of most localities in the field is estimated at approximately 800 feet. The lower part of the formation is composed of highly fissile bluish-gray and brownish limestone, which occurs in layers ranging in thickness from almost papery laminæ to bands 2 inches or more in thickness and which weathers light gray to chalky white. Although the chief constituent of these beds is lime, they are very impure and in many places contain so much shale as to resemble calcareous shale more closely than limestone. Fish scales and bones are almost invariably present in the lower limestone layers of the Niobrara, and were it not for the somewhat lighter color of these beds it would be difficult to distinguish them from the calcareous fissile shale of the Benton.

In the northwestern part of the field, near the Hill ranch, an exposure of dark shale was observed underlying the upper chalky beds of the formation and presumably overlying the thin limestone layers at the base. Although both top and bottom of this bed were concealed approximately 20 feet of dark homogeneous shale not unlike the olive-colored shale of the Pierre formation was exposed. At some distance from this locality lighter-colored beds somewhat higher in the section were exposed. Because of the patchy nature of the Niobrara exposures, however, and the necessity for estimating the relative stratigraphic positions of the rocks exposed, the sequence of beds as described is probably only approximate and the thicknesses of covered strata between exposed zones are not definitely known.

The light-colored beds of the middle and upper part of the formation are made up of light-gray and yellowish calcareous shale, interbedded with chalky limestone layers from a few inches to a foot or more in thickness. These limestones, which are grayish to dirty white when unweathered, change to cream-colored chalk on exposure to the air, and their comparatively resistant character causes them to form very slight ridges at places along the strike and makes them conspicuous in the Niobrara outcrop. Large numbers of oyster shells (*Ostrea congesta*) are contained in the chalky beds, in some places forming a solid shelly layer 2 or 3 inches thick. Above this chalky member the formation consists of shale grading from yellowish gray, more or less calcareous beds upward into dark-gray and brownish shale which can not be definitely distinguished from the Pierre. Along Colorado Creek in the southwest corner of the park, where the greatest thickness of Niobrara in the field is developed, the limestone beds are thicker and more massive than in the areas farther north. Approximately a mile northwest of the Clover Valley ranch a considerable thickness of gray limestone in layers several inches to a foot thick is exposed in the creek bank. This limestone is very impure, weathers to a dull white, and contains an abundance of the characteristic Niobrara oyster shells.

The outcrop of the Niobrara formation borders that of the Benton along the east and west sides of the park, and in general the distribution of the two formations is practically the same. The extent of the outcrop of the Niobrara, except at a few places, is influenced by the various structural features of the field, very much like that of the Benton. (See p. 36.) Along the west side of Sheep Mountain a fault block of Niobrara rocks, dipping toward the granite, is exposed for several miles. In the vicinity of Rabbit Ears Peak, at the southwest corner of the field, the outcrop of the formation is several miles in width, probably owing both to the unusual thickness of the formation at this locality and to a local uplift near the Continental Divide, which flattened the Niobrara rocks from dips of 20° to 30° near the base to almost zero in the upper part. The exposures in this vicinity are not sufficient to permit a satisfactory determination of the structure, but, though no westerly dips were observed, it seems probable that so great an increase in the width of outcrop is the result of uplift and possibly of slight wrinkling of the strata. A small exposure of very chalky shale containing scales and fragmentary bones of fishes was found in the upper valley of Buffalo

Creek in the central southern part of the field. (See Pl. XII.) These fossils, though not of determinable value, are similar to fish remains found in the Niobrara in many localities throughout the field, and the chalky matrix is so typically Niobrara in appearance as to leave little doubt concerning the age of the beds. In this single poor exposure no opportunity was offered for determining the dip and strike of the beds, and the boundary of the outcrop as drawn is based on the topography and what appeared to be chalky beds showing at the surface in several places. Sandstone ledges near the top of the bluff on the east side of the creek indicate that the Niobrara is here brought in contact with the much younger rocks of the Tertiary, but the débris from the bluff and from the mountain wall on the west obscures the bedrock so completely that the nature of the structural disturbance which brought the Niobrara rocks to the surface could not be determined.

Stratigraphic relations.—Exposures are rare along the upper and lower limits of the Niobrara in North Park, and neither contact line is fixed with certainty. No evidence was obtained which indicates other than a conformable relationship between this formation and the Pierre shale which overlies it, and the character of the shale along the contact zone strongly suggests a gradual transition. At the base of the formation the contact with the Benton is assumed to be at the top of the comparatively prominent shell-bearing sandstone, and no evidence of unconformity between the two was noted. The Niobrara is widely distributed throughout the Rocky Mountain and western interior regions and is invariably a chalky limestone formation whose outcrop is marked by white and cream-colored chalky ridges. The formation in North Park has the general characteristics of the Niobrara rocks exposed along the Front Range and in the Laramie-Sherman field in Wyoming and is easily recognizable by its characteristic outcrops.

The Niobrara age of the beds, which is established by fossils, is thus corroborated by the lithologic character of the rocks. The invertebrates collected, though representing only a few species, are distinctive Niobrara types. The absence in this field of the purer and more massive limestones which are found near the base of the formation in eastern Colorado, and the failure to find clearly recognizable *Inoceramus deformis*, which in most localities is abundant in those limestones, indicates a possibility that the Niobrara of North Park represents only the upper portion of the formation as it is developed east and northeast of this field. This possibility is strengthened by the fact that the beds in North Park bear a closer lithologic resemblance to the upper part of the Niobrara in the Front Range section than to the formation as a whole. The greater thickness of the formation in North Park, however, leads rather to the belief that the deposition of the beds occupied no less time here than in the fields to the east but was affected by dissimilar conditions.

Fossils.—The Niobrara is highly fossiliferous at various horizons, and wherever these are exposed a few minutes' search is likely to reveal the presence of shells or fish scales. The latter are very common and were observed in many localities of which no record was kept. The following collections of fossils obtained from the Niobrara at the localities given (see Pl. XII) were examined and identified by T. W. Stanton:

Locality 20. SE. ¼ NW. ¼ sec. 19, T. 11 N., R. 79 W.:
Ostrea congesta Conrad.
Inoceramus deformis Meek? Fragments of thick shell of this species or one closely related to it.

Locality 22. SW. ¼ SE. ¼ sec. 11, T. 9 N., R. 81 W.:
Ostrea congesta Conrad.
Inoceramus sp.; thick shelled.
Fish scales and bones.

Locality 24. SE. ¼ SE. ¼ sec. 16, T. 9 N., R. 81 W.:
Ostrea congesta Conrad.
Inoceramus sp.; thick shelled.
Fish scales and bones.

Locality 28. SE. ¼ SE. ¼ sec. 34, T. 10 N., R. 81 W.:
Ostrea congesta Conrad.

Locality 39. NE. ¼ SE. ¼ sec. 29, T. 11 N., R. 81 W.:
Globigerina and other Foraminifera.
Echinoid spines.
Ostrea congesta Conrad.
Fish scales.

Locality 41. SE. ¼ SE. ¼ sec. 20, T. 11 N., R. 81 W.:
Globigerina and other Foraminifera.
Ostrea congesta Conrad.
Fish scales and bones.

Locality 59. NE. ¼ SE. ¼ sec. 34, T. 7 N., R. 82 W.:
Inoceramus sp.
Fragmentary fish bones.
Ostrea congesta Conrad.

Locality 63. 200 feet east of road one-fourth to one-half mile south of Muddy Pass (between North and Middle Park), 15 miles southwest of Coalmont:
Ostrea congesta Conrad?
Scales and fragmentary bones of fishes.

Locality 74. SE. ¼ NE. ¼ sec. 27, T. 6 N., R. 82 W.:
Ostrea congesta Conrad.
Inoceramus sp.; fragments of large flat form.
Fisn scales.

Locality 85. NE. ¼ NE. ¼ sec. 9, T. 8 N., R. 77 W.:
Ostrea congesta Conrad.
Inoceramus sp.; fragments of thick shell.

At localities 16, 19, 26, 29, 35, 37, 40, 44, 60, 64, 81, and 92 fossils were found which were not determined but which from their stratigraphic relations to the collections identified must belong to the Niobrara. These collections consist mainly of scales and fragmentary bones of fishes, though several of them include shells which were identified but could not be assigned to definite horizons because of their wide range.

MONTANA GROUP.

GENERAL FEATURES.

The Montana group is represented in North Park by approximately 4,500 feet of shale, having several layers of sandstone at the top, unconformably overlain by coal-bearing rocks. The fossils collected from these rocks, except a few species obtained from the sandstone layers on the east side of the field, are undoubted Pierre forms. The occurrence in these upper sandstones of fossils that range from the Pierre up into the Fox Hills and the lithologic resemblance of the sandstone to the Fox Hills in several localities suggest the possibility that in this part of the field the Fox Hills was present and was not entirely removed by erosion before the younger coal-bearing beds were deposited. As the evidence, however, points as strongly to the Pierre as to the Fox Hills, and as the thickness of possible Fox Hills strata is slight, the sandstones in question are mapped as Pierre and will be discussed with that formation.

PIERRE SHALE.

Character and thickness.—The Pierre shale, as its name indicates, is made up mainly of beds of shale, which near the top of the formation are interbedded with thin layers of sandstone. The shale is prevailingly dark, usually olive, brownish, or dark gray, though somewhat lighter colored drab clayey beds were observed at two or three horizons. The shale is for the most part thin bedded and is practically homogeneous from the top to the bottom of the formation except for a few thin sandy beds and more numerous bands of concretions which occur at several horizons. The comparatively nonresistant dark shale, however, constitutes at least 90 per cent of the formation and contains no beds hard enough to form ridges or otherwise give definite character to the topography of the outcrop. On weathering the shale yields a characteristic drab adobe wash, through which is usually disseminated a considerable number of selenite crystals, though these are less abundant here than in the Pierre shale of other fields. Where erosion has cut into the beds to any considerable extent it generally exposes fossiliferous concretions of black calcareous material cemented together by many calcite veins, the whole usually incased in a thin gray adobe crust. The concretions most commonly occur in zones or layers in the shale, are ellipsoidal in shape, and range from a few inches to more than 3 feet in diameter.

Most of the sandstones of the Pierre are near the top of the formation, although several thin bands were observed in the lower part. The horizons of these lower sandstones could not be accurately determined because of the cover which obscures so large a part of the formation. The sandstone beds range from 1 foot to 10 feet or more in thickness but are not prominent as ridge makers, with the exception of the uppermost bed on the east side of the field, which is light gray, weathers buff, and forms a more or less distinct ridge which marks the contact between the marine Cretaceous and the fresh-water coal-bearing rocks throughout a considerable area. In many localities this ridge has a striking brownish-red color due to the disintegration of small iron concretions which are embedded more or less abundantly in the sandstone.

The following section of the upper sandy zone of the Pierre was measured near the fault in T. 9 N., R. 78 W.:

Section of beds near top of Pierre shale, locality 3, sec. 8, T. 9 N., R. 78 W.

	Feet.
Covered.	
Sandstone, gray, coarse, containing concretions	10
Sand, yellow, unconsolidated, shaly	10
Sandstone, yellowish gray, coarse	6
Sandstone, gray, coarse, containing fossiliferous concretions	6
Shales, alternating yellow and dark, sandy	60
Sandstone, buff, thin bedded, fine grained	2
Shale, drab, sandy	75
Sandstone and concretions, fossiliferous	6
Shales, drab and dark	100+
Covered.	
	275+

This section was measured in a region of somewhat complex structure where the beds are badly covered, and though its exact stratigraphic position is not known it is believed to be very near the top of the formation. Sandstone beds thought to represent part of the same section are exposed near the coal outcrop in sec. 26, where the following section was measured:

Section at location 6, sec. 26, T. 9 N., R. 78 W.

	Feet.
Covered.	
Sandstone, gray, coarse, thin bedded	5
Covered	6
Sandstone, brown, medium grained, bedded, fossiliferous	10
Covered	3
Sandstone, brown, shaly	3
Sand, yellow, shaly, unconsolidated	8
Sandstone, gray, coarse, cross bedded	1½
Covered	13
Sandstone, brown, concretionary	3
	52½

The upper sandy part of the Pierre is present, though very poorly exposed, along the east side of the field, but on the west side it is covered by the overlap of the coal-bearing rocks and does not outcrop.

Distribution.—The Pierre shale outcrops near the base of the Medicine Bow Range along the east side of the field and also along the west border, where its outcrop varies greatly in width and in several localities is covered by the coal measures, which overlap its entire thickness as well as the upper members of the Niobrara. The formation is present at various depths below the surface in all the area between these outcrops, extending from the Independence Mountain fault southward across the field and across the Continental Divide into Middle Park. It outcrops most extensively along the broad Canadian Valley and in the large flat area traversed by Government and Pinkham creeks, south and west of Sentinel Mountain. Southward along the Canadian from locality 8, sec. 25, T. 9 N., R. 78 W., where the strata are sharply folded and stand practically on edge, the Pierre outcrop is much narrower, owing in part to steeper dips and in part to the overlap of the coal-bearing formation. Practically the entire thickness of the Pierre is exposed by erosion in the McCallum anticline, T. 9 N., R. 78 W. The outcrop of the shale covers 7 or 8 square miles along the axis of this anticline and is separated from the Pierre outcrop in the Canadian Valley by a sharp synclinal trough occupied by the younger coal-bearing rocks.

On the west side of the field the Pierre outcrops widely along the North Fork Valley between the main range and the upthrust granite ridges extending from Delanos Butte northward to Pearl post office. The uplift of these ridges, together with faulting and subsequent erosion, duplicated the Pierre outcrop along their east flank from the Independence Mountain fault in T. 11 N., R. 81 W., to the south side of Delanos Butte, causing the outcrop to vary in width from a few hundred feet to more than 2 miles. The Pierre is entirely covered by coal-bearing sandstones along Roaring Fork, and from that locality southward its outcrop varies in width from less than 100 feet to more than 1 mile. The position of the base of the Pierre is doubtful in this part of the field, however, as fossils collected from a zone of considerable width contained forms which may be either Niobrara or Pierre, and the lithologic evidence along this zone is not adequate for differentiation.

Stratigraphic relations.—The Pierre shale rests conformably upon the Niobrara formation and is the uppermost recognized formation of the known Cretaceous in North Park. It is separated from the coal measures above by an unconformity, which if the coal-bearing rocks prove to be Tertiary represents the geologic time in which were deposited the Laramie and possibly the Lewis shale of Carbon County, Wyo., and the Laramie and Fox Hills of the Denver Basin and other Front Range sections. With the exception of the slightly ridge-making marine sandstone immediately underlying the coal measures on the east side of the field the age of the beds mapped as Pierre is established by an abundance of well-preserved fossils collected at various localities and is confirmed by the lithology of the beds, which have many of the characteristics common to the Pierre from eastern Colorado to the type locality of the formation in South Dakota. The uppermost marine sandstone contains impressions of a seaweed (Halymenites) and several species of fossil shells which are found in the Fox Hills sandstone, though not confined to that formation, and this, as well as the occurrence of small ironstone and larger sandstone concretions, sometimes called "nigger heads," in the thin cross-bedded buff sandstone, is suggestive of the Fox Hills. However, in view of the facts that no fossils distinctively younger than Pierre were found in the sandstones, and that their lithologic character is not greatly unlike that of the upper sandstones of the Pierre of other fields, it is believed that the balance of evidence favors the Pierre age, and they are provisionally included with that formation in this report.

The Pierre of North Park closely resembles the Steele shale of the Laramie district[1] on the north, and as the formations have very similar faunas and both conformably overlie the Niobrara they are believed without doubt to be stratigraphic equivalents. The Steele shale was named from Fort Fred Steele, about 70 miles down Platte River from North Park, in Carbon County, Wyo., where it has been examined by Veatch[2] and others and has been recognized as of Pierre age. The shale beds at Fort Fred Steele, however, represent only the lower part of the Pierre of the fields east of the Front Range, and the Mesaverde and possibly the Lewis, of Carbon County, were also deposited during Pierre time. The possibility suggests itself that the marine sandstones underlying the main coal on the east side of North Park may represent the lowest sandstones of the Mesaverde of the Hanna field, particularly in view of the close relationship said by T. W. Stanton to exist between the fossil fauna from these sandstones at locality 12, sec. 24, T. 10 N., R. 79 W., in North Park, and that which occurs beneath the Mesaverde coal on the Laramie Plains near Harper station, Wyo. If the age of the coal-measures flora of North Park, however, has been correctly interpreted, it is plain that the coal-bearing Mesaverde of the Hanna field and the Lewis shale and "Lower Laramie" as applied by Veatch in that locality are represented in North Park either by the upper portion of the Pierre shale or by the unconformity at the base of the coal-bearing rocks. There is little doubt, therefore, that the Pierre shale of North Park is equivalent to that formation east of the Front Range, but it seems probable that in the former locality the

[1] U. S. Geol. Survey Geol. Atlas, Laramie-Sherman folio (No. 173), p. 10, 1910.
[2] Veatch, A. C., U. S. Geol. Survey Bull. 316, p. 246, 1907.

rocks representing the later portion of Pierre time may have been removed during the period of erosion recorded by the unconformity.

Fossils.—The upper sandstones of the Pierre and the calcareous concretions which occur at many horizons in the shale beds are abundantly fossiliferous, and but little search is required to make very satisfactory collections of fossils in most localities where the beds are exposed. A comparatively large amount of well-preserved material, collected from various localities in the field (see Pl. XII), was examined by T. W. Stanton, who furnishes the report given below. Most of the collections were obtained from the upper third of the formation, but several of them came from the lower part, and altogether they are representative of the formation from top to bottom. Several specimens of *Halymenites major* Lesq., collected at locality 5, NW. ¼ NW. ¼ sec. 25, T. 9 N., R. 78 W., were examined and identified by F. H. Knowlton. The horizons from which collections were obtained could not be accurately determined because of the badly covered condition of the field, but the approximate horizons are given.

Locality 3. SW. ¼ SE. ¼ sec. 8, T. 9 N., R. 78 W.; within 100 feet of the top of the formation:

Avicula nebrascana E. & S.
Tellina sp.
Cardium speciosum M. & H.
Leptosolen sp.
Corbula sp.
Corbulamella gregaria M. & H.?
Liopistha undata M. & H.
Dentalium sp.
Lunatia sp.
Anchura sp.
Haminea? sp.

Locality 4. SE. ¼ SW. ¼ sec. 14, T. 9 N., R. 78 W.; 100 to 300 feet below top of formation:

Chætetes? dimissus White.
Ostrea sp.
Anomia sp.
Avicula linguiformis E. & S.
Inoceramus sp.
Syncyclonema rigida H. & M.
Corbula sp.
Cuspidaria sp.
Margarita nebrascensis M. & H.
Vanikoro ambigua M. & H.
Haminea occidentalis M. & H.

Locality 6. SW. ¼ NW. ¼ sec. 26, T. 9 N., R. 78 W.; 300 to 500 feet below top of formation:

Chætetes? dimissus White.
Ostrea sp.
Avicula linguiformis E. & S.
Inoceramus cripsi var. barabini Morton.
Inoceramus sp.
Pinna sp.
Margarita nebrascensis M. & H.
Baculites sp.
Heteroceras? sp.
Helicoceras? sp.

Locality 7. SW. ¼ NW. ¼ sec. 27, T. 9 N., R. 78 W.; 700 to 1,000 feet below top of formation:

Syncyclonema rigida H. & M.
Ostrea sp.
Avicula nebrascana E. & S.
Avicula linguiformis E. & S.
Liopistha undata M. & H.
Baculites compressus Say.
Placenticeras intercalare M. & H.
Heteroceras sp.

Locality 8. NE. ¼ NE. ¼ sec. 25, T. 9 N., R. 78 W.; 800 to 1,100 feet below top of formation:

Inoceramus cripsi var. barabini Morton.
Baculites ovatus Say.
Baculites sp.
Fish scales.

Locality 10. Near quarter corner west side sec. 32, T. 10 N., R. 78 W.; 50 to 100 feet below top of formation:

Liopistha undata M. & H.

Locality 12. SW. ¼ NE. ¼ sec. 24, T. 10 N., R. 79 W.; within 100 feet below top of formation:

Ostrea sp. related to O. inornata M. & H.
Syncyclonema rigida (H. & M.).
Avicula linguiformis E. & S.
Avicula nebrascana E. & S.
Inoceramus barabini Morton.
Crenella elegantula M. & H.
Trigonarca (Breviarca) exigua M. & H.
Trigonia sp.
Eriphyla gregaria M. & H.
Anatina sp.
Lunatia? sp.
Vanikoro ambigua M. & H.
Anchura americana (E. & S.).
Fusus? sp.
Odontobasis? sp.
Haminea sp.
Actæon sp.
Placenticeras intercalare M. & H.

Locality 18. NE. ¼ NE. ¼ sec. 26, T. 11 N., R. 80 W.; about 150 feet below top of formation:

Mactra holmesii (Meek)?
Baculites sp.; young shells, including fine examples of the initial coiled portion.
Fish scales.

Locality 23. NE. ¼ NE. ¼ sec. 29, T. 9 N., R. 81 W.; probably near middle of formation:

Inoceramus altus Meek.
Inoceramus sagensis Owen?

Locality 27. NE. ¼ SW. ¼ sec. 21, T. 9 N., R. 81 W.; 1,000 to 1,500 feet below top of formation:

Inoceramus sp.
Baculites sp.

Locality 32. SW. ¼ SE. ¼ sec. 6, T. 9 N., R. 81 W.; about 3,000 to 3,500 feet above base of formation:

Ostrea sp.
Inoceramus sp.; fragmentary imprint.
Mactra? holmesii Meek?
Baculites sp.

Locality 34. NW. ¼ SE. ¼ sec. 12, T. 9 N., R. 81 W.; about 1,000 to 1,200 feet above base of formation:

Inoceramus sp.
Lucina occidentalis (Morton).
Baculites sp.

Locality 49. NE. ¼ SW. ¼ sec. 12, T. 9 N., R. 81 W.; about 700 to 1,000 feet above base of formation:

Ostrea sp.
Baculites sp.
Inoceramus barabini Morton.

Locality 61. NW. ¼ SW. ¼ sec. 18, T. 5 N., R. 81 W., near dike in bank of creek; 1,000 to 1,500 feet above base of formation:

Baculites sp.; fragments of small specimens.

Locality 62. SW. ¼ SW. ¼ sec. 7, T. 5 N., R. 81 W., small gully about one-fourth mile above main creek; about 300 feet higher than that of locality 61:

Baculites sp.

Locality 64. NE. ¼ sec. 10, T. 5 N., R. 82 W., cut bank of creek, at intersection of sights S. 75° E. from Rabbit Ears, and S. 79° W. from Spicer Peak (Arapaho); probably between 50 and 200 feet above base of formation:

Inoceramus sp. | Baculites sp.
Mactra sp.

Locality 71. Platte River in NE. ¼ NE. ¼ sec. 26, T. 11 N., R. 80 W.; about 150 feet below top of formation:

Lucina occidentalis Morton.
Baculites compressus Say; young specimens showing initial whorl.

Locality 87. N. 85° E. from coal trench north of Winscom's ranch in N. ½ sec. 15, T. 8 N., R. 77 W.; 50 to 100 feet above base of formation:

Thracia sp. | Baculites sp.; fragments.

Locality 88. SE. ¼ sec. 6, T. 8 N., R. 77 W.; near top of formation:

Inoceramus barabini Morton. | Baculites sp.

Locality 90. SE. ¼ SW. ¼ sec. 4, T. 8 N., R. 77 W.; 500 to 700 feet above base of formation:

Inoceramus barabini Morton. | Mactra sp.
Astarte sp. | Baculites ovatus Say.

Locality 92. NW. ¼ sec. 17, T. 9 N., R. 77 W., 2 miles north of Kerr's ranch house; base of Pierre or top of Niobrara:

Inoceramus sp. | Baculites sp.

CRETACEOUS OR TERTIARY SYSTEM.

COALMONT FORMATION.

GENERAL FEATURES.

By the evidence now available the 4,000 to 5,000 feet of fresh-water beds lying between the marine Cretaceous and the North Park formation (Tertiary) can be no more definitely assigned than to the Cretaceous or Tertiary. Lithologic differences in these rocks indicate that they are made up of two more or less distinct formations. The 3,000 to 4,000 feet of dark-colored coal-bearing beds that immediately overlie the marine Cretaceous on the east side of the field and outcrop in various localities in the western and southwestern portions appear to be the older and to be unconformably overlain by about 2,000 feet of lighter-colored sandstone and conglomerate, which outcrop over a large part of the park floor and in many localities appear to overlap the lower beds. No definite line of demarcation between the coal-bearing and sandy members can be drawn, for no unmistakable contact between them is exposed at any locality in the field. The impression that these two members are separate and distinct is therefore based mainly on more or less indistinct stratigraphic evidence and on the fact that the rocks observed in all the scattered exposures from the upper limit of the Pierre shale on the east side of the field westward almost to the Michigan River valley are strikingly different in character from those observed farther west at many localities along Michigan and

North Platte rivers and Illinois Creek. A heavy yellow sandstone overlying a rather thick dull-gray shale is thought to mark the contact at an exposure about three-fourths of a mile northeast of Walden, and an attempt has been made to draw an arbitrary boundary from this locality to the northwest and the southeast on the basis of scattered exposures, in such manner as to represent approximately the zone of change from the dark-colored coal-bearing rocks to the yellow sandstone above. The dark-colored beds are exposed in several localities on the west side of the field, but in none of these is there evidence for more than an approximate delimitation of their outcrop. The dividing line thus drawn at first seemed entirely defensible and in a general way it may yet prove to be well founded, although later and closer study of the rocks and complete reports on the fossil evidence strongly tend to break down the distinction.

The evidence collected is capable of two interpretations: (1) That the sandy member constitutes a separate and distinct formation, resting unconformably on the dark-colored coal-bearing rocks; and (2) that the two sets of beds belong to an unbroken formation, and that the lithologic differences are to be explained as representing varying phases of contemporaneous deposition. Meanwhile, in default of a decisive solution of the problem, all the strata which rest unconformably upon the marine Cretaceous and are overlain by the North Park (Tertiary) formation (p. 66) are here treated as a single formation, to which the name Coalmont is applied. The formation is much better exposed along North Platte River than in the vicinity of Coalmont (see Pl. I, *A*, p. 12), but the name Coalmont is used as the most acceptable name not preoccupied or otherwise unsuitable.

CHARACTER AND THICKNESS.

The coal-bearing portion of the Coalmont formation outcrops mainly on the east side of the field southeast of the Dwinnell ranch, between Canadian and Michigan rivers. Similar coal-bearing strata outcrop within a radius of about 4 miles from Coalmont in the southwestern part of the field, in the vicinity of the Mitchell mine and northward to Roaring Fork in the western part, and along the west flank of Sheep Mountain north and south of the Monahan mine in the northwestern part. Elsewhere, within the boundaries of this formation, the rocks are of very different lithologic character. To avoid confusion of localities and for facility of description the two general lithologic divisions of the Coalmont formation will be described separately.

The slightly resistant character of the coal-bearing strata causes them to yield very readily to weathering, and in consequence the exposures are very small and patchy. The areas in which they outcrop are characterized mainly by large flats and well-rounded hills, practically all of which are thickly covered with a persistent mantle of gray to buff clay soil, on which sagebrush grows abundantly. These areas are trenched to a considerable extent by stream channels, but even along these the soft bedrock weathers down rapidly and covers the slopes with rock débris and soil. The outcrops are widely scattered, and most of them extend for less than 50 feet and few for more than 100 feet. In the absence of persistent horizon markers by which the position of the exposed beds might be determined, the succession of beds must necessarily be determined by the location, altitude, and dip of the rocks exposed. Notwithstanding the fact that considerable portions of the coal-bearing strata are covered and that the locations and altitudes of many of the exposures could be only approximately established, it is believed that by arranging the various groups of exposed strata as accurately as possible in a composite section a good idea of the formation as a whole may be gained.

The thickness of the coal-bearing rocks east of Walden is approximately 3,500 feet, and this is the maximum thickness of these beds in the field. The main coal bed of the region occurs very near the base of the formation in the eastern part of the park, and at the Marr mine, sec. 35, T. 9 N., R. 78 W., it is separated from the uppermost marine Cretaceous sandstone by 30 to 40 feet of white sugary sandstone. This sandstone is medium to fine grained and is nonresistant and, though composed mainly of grains of white quartz, contains a great many black cherty siliceous grains, which are evenly disseminated through it.

The large coal bed is overlain by 15 feet or more of thin beds of slate-colored clay and shale alternating with white and buff-colored sandstone bands 2 to 8 inches in thickness. These thin sandstones are leaf bearing, though not abundantly so, and several small collections were obtained from them. Above the shale and sandstone there are about 2,000 feet of strata very poorly exposed. Scattered outcrops along this zone indicate that the upper and lower parts of it consist of light-yellow and drab shale containing many layers of light-gray and buff sandstone 1 foot to 5 feet thick. A mass of dark clay and chocolate-colored shale containing several highly carbonaceous streaks occupies the central part of the zone. The dark clay beds could not be distinguished readily from some layers in the Pierre except for the impressions of fossil leaves which they contain. The brownish shales are largely homogeneous except for the black layers, which in several localities are so highly carbonaceous that they have been mistaken for coal beds and opened up by prospectors. The principal exposures of these beds were found in the vicinity of the Dwinell ranch and southward between that locality and the north end of the Kerr-McCallum anticline.

On the west side of the field dark shale beds containing carbonaceous layers are exposed for a considerable distance along Chedsey Creek, about 1½ miles northwest of Coalmont, and are believed to be equivalent to the dark shale along the coal zone east of Walden. The outcrop of the strata between the dark shale and the main coal bed is characterized by the appearance at the surface of thin light-gray and buff-colored sandstone. This sandstone is coarse and friable and has influenced the topography so little that some doubt exists as to the proportion of sandy beds in this part of the section. The presence of several thin coal beds or highly carbonaceous layers 100 to 300 feet stratigraphically above the main coal bed is indicated by streaks of coaly material at several localities. Above the dark shale zone coarse, thin-bedded, buff sandstone shows at intervals through the covering of dark-gray to yellowish-gray soil. The character and color of the surface cover along this zone indicate a large proportion of similarly colored shale in the bedrock below.

On the east side of the park the upper coal zone is about 2,000 feet stratigraphically above the main coal bed. The two coal beds exposed in this zone are separated by 100 feet or more of thin buff and gray sandstones alternating with more or less carbonaceous gray to black shaly layers. The sandstone that predominates in this mass is medium grained and thin bedded and is somewhat more resistant than that lower in the section. It is composed mainly of quartz but contains many reddish and dark mineral grains and flakes of mica. The rocks that outcrop between these upper coal beds and the massive yellow sandstone exposed three-fourths of a mile northeast of Walden consist of gray and yellowish shale and light-colored sandy layers too soft to be of value as horizon markers.

The coal-bearing strata exposed in the vicinity of Coalmont and along Grizzly and Chedsey creeks, in the southwestern part of the field, are in general much like those which outcrop east of Walden, though they show notable differences in the character of some of the sandstones and in the number and distribution of the coal beds. The presence of a thick bed of brown, locally carbonaceous shale and black clay and the proportion of shale and sandstone in the beds above and below it are points of resemblance between the coal-bearing rocks near Coalmont and those on the east side of the field. The section at Coalmont contains five coal beds, which are distributed at fairly regular distances through approximately 2,000 feet of strata. Although the number and distribution of these beds discourage any attempt at correlation with the coal beds on the east side of the field, it is believed that the rocks exposed near Coalmont occupy the stratigraphic position of the lower coal-bearing strata, and that the Pole Mountain uplift brings the top of the Pierre shale very close to the surface at that locality. The sandstone associated with the upper coal beds in this vicinity is coarse, gray, and friable and contains strikingly large amounts of white mica. It is more shaly and friable and contains much larger proportions of mica and black chertlike grains than any sandstone observed in the district east of Walden. At Coalmont, as in the eastern part of the field, all but the more resistant sandstones of the section are concealed by surface wash, which makes it impossible to trace the coal beds or sandstones more than a few hundred feet from the actual exposures. The absence of coal beds and sandstones along Chedsey Creek, where, according to the strike of the rocks, the Coalmont formation should outcrop, may be considered strong evidence that both sandstone and coal beds were deposited under local and variable conditions and are lenticular in character. In view of the covered condition of the intervening area, however, the disappearance of the coal beds might be attributed to concealed faults or other local structures.

The remnant of coal-bearing rocks along North Fork west of Sheep Mountain is made up of dense hard thin-bedded buff sandstone interbedded with gray clay and shale. The sandstone is fine grained, mainly quartz flecked with mica and black chert grains, and is much harder than the sandstone of the coal-bearing rocks on the east side of the park or in the Coalmont region. A 4½-foot bed of coal outcrops several hundred feet above the base of the strata, and a coal bloom exposed on the hillside 40 to 50 feet higher stratigraphically indicates the presence of a second bed of possible commercial value. About 1¼ miles south of the Monahan mine a bed of coarse conglomerate, mainly composed of granitic material, is exposed a short distance above the horizon of the coal, which is concealed. The hardness, density, and general appearance of the sandstone associated with these coal beds are more characteristic of Cretaceous or older rocks than of other coal-bearing strata of North Park.

The part of the Coalmont formation that is typically exposed along North Platte River and its tributaries in the central part of the field is composed mainly of sandstone and conglomerate with intercalated beds of shale. Nearly 2,000 feet of strata were measured along the North Platte, near the mouth of Michigan River and a few miles to the south, and of this thickness sandstone and conglomerate constitute more than nine-tenths. The maximum thickness of these beds is estimated at a little more than 2,000 feet, but unequal erosion of the outcrop of the formation, which constitutes the surface rock of a large portion of the park floor, has in all probability left various thicknesses of the strata ranging from the maximum down to only a few hundred feet. The predominating constituents of the formation are coarse grayish sandstone, which occurs in more or less massive beds that weather to a characteristic yellow, and greenish conglomerate containing bands of pebbles which vary greatly in size. The sandstone is made up mainly of quartz grains but contains varying proportions of feldspar and mica and at many horizons consists of gritty layers of quartz pebbles that are one-eighth to one-half inch in diameter. It is strikingly cross-bedded in many localities and is found in all stages of induration from very friable to hard ridge-making beds. Two or three horizons in this sandstone member are marked by well-rounded masses of hard iron-stained sandstone 1 to 2 feet in diameter. These are round to oval in shape, ocher-yellow to reddish brown in color, and bear a close resemblance to the "niggerheads" of the Fox Hills sandstone east of the Front Range.

Beds of fine-grained shaly sandstone 1 foot to 4 feet thick occur at intervals in the section, and thin beds of brown carbonaceous shale, containing plant remains and traces of coal, were observed at several horizons. The conglomerate of the Coalmont formation occurs in layers rarely more than a few feet thick and is made up for the most part of granite, gneiss, and quartz pebbles 1 to 4 inches in diameter. In some places along the North Platte, at the north side of the park, the conglomerate contains bowlders 1 to 3 feet in diameter, and these, like the smaller pebbles, are angular and appear to have been transported only a short distance. Schist, limestone, and chert pebbles are also present in the conglomerate in proportions varying with the different localities. The following section of the sandy and conglomeratic portion of the formation was measured along North Platte River northwest of Cowdrey. The upper part of the section is almost perfectly exposed along the river and the lower rocks are sufficiently well exposed to leave no doubt as to their character.

Detailed section of upper portion of Coalmont formation exposed at top of bluff northwest of bridge, on North Platte River near Cowdrey.

	Ft.	in.
Sandstone, yellow, coarse, conglomeratic; contains bowlders of conglomerate	16	0
Sandstone, brown, coarse, pebbly, friable	12	0
Sandstone, gray, micaceous; contains brownish bowlders or concretions	6	0
Sandstone, soft brownish yellow; carbonaceous streak at top	10	0
Sandstone, yellow and coarse at top, dark and fine grained at bottom	10	0
Sandstone, alternating yellow and dark, friable; coarse at base	8	0
Sandstone, dark colored, shaly	4	0
Sandstone, medium grained; weathers white	6	0
Sandstone, drab and brown, shaly, and pebbly, banded	4	0

Detailed section of upper portion of Coalmont formation, etc.—Continued.

	Ft.	in.
Sandstone, yellow, coarse	8	0
Shale, dark brown, sandy	5	0
Sandstone, light and dark, thin bedded, banded	6	0
Sandstone, buff, massive; coarse at top; brownish yellow at base	18	0
Shale, bluish, sandy	4	0
Sandstone, yellowish gray; carbonaceous near base	14	0
Shale, dark brown, very sandy; contains charcoal and plant stems	4	0
Sandstone, buff, coarse	5	0
Shale, sandy and carbonaceous	2	0
Sandstone and shale, in alternating layers, banded dark and light; dark beds contain tree trunks, charcoal, and plant stems	10	0
Covered	40	0
Sandstone, brownish yellow, concretionary	2	0
Covered	34	0
Sandstone and conglomerate alternating; pebbles up to 3 inches in diameter; banded yellow, gray, and brown; cross-bedded; contains concretions	24	0
Shale, sandy carbonaceous; contains stems and plant remains		6
Sandstone, yellow, coarse	6	0
Sandstone, gray, coarse	2	0
Local unconformity (?).		
Sandstone, banded brown, yellow, and gray, thin bedded, indurated	6	0
Shale, carbonaceous and sandy; contains poorly preserved leaves		6
Sandstone, pinkish gray, coarse, streaked with brown	2	0
Sandstone, gray, coarse, cross-bedded; dark streaks	2	6
Sandstone; carbonaceous layer at top and bottom; contains leaves		6–10
Sandstone, gray, brown, and yellow banded	10	0
Shale, drab, sandy; contains plant remains	1	6
Sandstone, yellow, soft, coarse; upper 6 inches hard	6	0
Shale, carbonaceous, leaf bearing		3
Sandstone, yellow, coarse; contains gray bands	24	0
Sandstone; alternating yellow and gray bands	8	0
Sandstone, gray, slightly carbonaceous, leaf bearing	1	0
Sandstone, yellow, coarse	2	0
Sandstone and shale; yellow, dark-brown, and gray bands, alternating in thin beds, carbonaceous	30	0
Covered	35	0
Sandstone, yellowish gray, coarse; pebbly in streaks	4	0
Sandstone, mostly covered	6	0
Covered	40	0
Sandstone, coarse, yellow and gray, locally indurated	50	0
Sandstone and shale; thin beds alternating	15	0
Conglomerate, pebbles up to 3 inches in diameter; quartz, granite, limestone, chert, and schist	14	0

Detailed section of upper portion of Coalmont formation, etc.—Continued.

	Ft.	in.
Sandstone, dark, shaly, thin bedded	8	0
Sandstone, coarse; conglomeratic in streaks; contains pebbles up to 1 inch	6	0
Sandstone, shaly, thin bedded	6	0
Sandstone, yellow, massive	14	0
Sandstone and shale; dark and light bands and thin bedded	10	0
Covered	27	0
Shale, buff, sandy	4	0
Shale, coaly, some pieces of coal and petrified wood		6
Sandstone, alternating with carbonaceous shale; sandstone yellow and gray, shale dark	22	0
Sandstone and shale; alternating beds 1 to 5 feet thick, banded brown, dark yellow, light tan	50	0
Sandstone and sandy shale, banded drab, yellow and buff	32	0
Shale, buff and drab, brown, sandy; sandstone concretions at base	18	0
Shale, brown, carbonaceous, leaf bearing		8
Conglomerate, coarse; sand grains to 2-inch pebbles	12	0
Shale and sandstone, alternating; shale buff to drab, sandstone yellow	15	0
Shale, carbonaceous, and sandstone, thin bedded, alternating; banded light grayish yellow and dark gray	20	0
Sandstone, yellow, coarse; dark carbonaceous streak	25	0
Shale, sandy to pebbly, dark	6	0
Sandstone, yellow, coarse	3	0
Shale, carbonaceous		6
Shale, dark, sandy	3	0
Sandstone, gray to buff, coarse	6	0
Shale, banded dark and brown, sandy; carbonaceous in streaks	18	0
Sandstone, gray, hard, fine grained	2	0
Sandstone, yellow, coarse	6	0
Shale and sandstone in thin beds; banded dark gray and brown	8	0
Shale, drab, sandy	10	0
Sandstone, dark gray, hard, leaf bearing		8
Sandstone, yellow, coarse, friable	4	0
Shale, olive, thin bedded, sandy	3	0
Shale and sandstone, alternating; shale predominates, banded brown, olive, drab, and dark	18	0
Sandstone, yellow at top and bottom, hard, gray, concretionary near middle; cross-bedded, coarse	10	0
Shale, sandy, drab to olive, hard, thin bedded	14	0
Sandstone, brown and gray; contains hard concretions	2	0
Sandstone, yellow, coarse; conglomeratic at base, pebbles up to 1 inch in diameter; contains dark-gray shale streaks	26	0

Detailed section of upper portion of Coalmont formation, etc.—Continued.

	Ft.	in.
Shale and sandstone, alternating beds 2 to 5 feet thick; shale, sandy, dark and brown; sandstone, gray and yellow, coarse, friable; 6-inch carbonaceous shale streaks at base	30	0
Sandstone, gray at top, yellow and friable at base, coarse and conglomeratic in streaks; hard, thin bedded; contains shale streaks	13	0
Covered, except for some thin sandstone ledges	102	0
Coal, shaly, soft	2	0
Covered	20	0
Sandstone, gray, hard, leaf bearing	2	0
Covered	260	0
Conglomerate capped by hard gray sandstone	8	0
	1,366	3
Sandstone and conglomerate, greenish colored	500	0
Pierre shale.		
	1,866	3

The remarkable diversity in the color and character of constituent materials of the Coalmont formation in areas very near each other indicates abrupt changes in its deposition. The diversity is particularly marked in the vicinity of the Dwinell ranch, in the northeastern part of the field, and at the Mitchell mine, in the western part. A coal bed and a considerable thickness of chocolate-colored shale containing highly carbonaceous and coaly streaks are the principal rocks exposed east, south, and southwest of the Dwinell ranch buildings, which stand in an area largely covered by surface wash. Within a mile to the north and northeast of the ranch, however, no trace of coal or dark shale beds is seen and only greenish-yellow conglomeratic sandstone, similar to that exposed on the lower North Platte, can be observed in the scattered outcrops along the stream channels. Near the Mitchell mine the dark shale associated with the coal bed apparently gives way within a very short distance to the south to coarse yellow sandstone very much like that outcropping along the North Platte. Lithologic evidence, however, in a region of possibly pronounced local structure and unsatisfactory rock exposures can not be considered conclusive.

The striking dissimilarity between the lower beds of the Coalmont formation in the area east of Walden and in that near the lower North Platte River a few miles to the northwest indicates that in the former locality coal was probably formed simultaneously with the formation of sandstone and conglomerate in the latter. The distribution and apparent lenticularity of the coal beds and the inconstant lithologic character of the rocks of this formation are in all probability the result of local oscillations of the rock surface, causing inconstant lake and marsh areas and of diversity in the sources from which the sediment was derived.

DISTRIBUTION.

The strata comprising the Coalmont formation occupy more than three-fourths of the park floor. (See Pl. XII.) In the south half of the field they extend from near the base of the Park Range almost to the lower slopes of the Medicine Bow Range, outcropping throughout all this area except in a long, narrow strip of light-colored younger rocks that extend from Owl Mountain slightly north of west to the junction of Grizzly Creek and Roaring Fork. In the north half of the field the outcrop is much narrower, the broad Pierre shale occupying large areas of the park floor along the mountain ranges on either side of the field. The outcrop widens from about 7 miles along the south face of Independence Mountain to more than 15 miles in the central part of the field. The rocks strike directly into the upthrust granite of Independence Mountain on the north and disappear beneath the lava sheets and débris along the Continental Divide on the south. It is believed that they are continuous southward and are present in at least the northern part of Middle Park, although no fossils and very little lithologic data in support of this supposition are available.

STRATIGRAPHIC RELATIONS.

The evidence obtained in North Park bearing on the age of the Coalmont formation indicates its Tertiary age. This evidence, however, consisting of a supposed Tertiary flora and a markedly unconformable relationship to the underlying marine Cretaceous, very strongly indicates the equivalence of the Coalmont formation to the "Upper Laramie" of Carbon County, Wyo., in which the evidence as interpreted is divided between Cretaceous and Tertiary. This leaves the age of the Coalmont formation open to question as Upper Cretaceous or early Tertiary. The grouping of all the strata between the base of the North Park formation and the top of the Pierre shale in a single formation, though favored by the weight of evidence, is made in the face of more or less conflicting evidence, and certain conditions are somewhat difficult to explain.

The earliest field work done by the writer in North Park led to the belief that the yellow sandstone beds outcropping along North Platte and Michigan rivers are of lacustrine origin and are separated from the shaly coal-bearing strata on the east side of the field by an unconformity. This conclusion was based on the friable pebbly character of the sandy beds and on their seeming overlap on the coal-bearing rocks which, though no actual contact was found, was indicated by the geographic distribution of the two lithologically different groups of strata. It was supported, furthermore, by a report on fossil plants collected early in the season, which seemed to establish a stratigraphic break between the sandy and shaly beds. As the field work progressed it was expected that more positive evidence if not absolute proof of unconformable relations would be found, but on the contrary the evidence became less and less as the data accumulated. No persistent conglomerate, abrupt change of dip, nor irregular contact line was found; in fact, but one exposure showing a possible contact line was observed, and this one showed no suggestion of unconformity. These facts, together with later reports on all the fossils collected and the more or less obscure evidence of the interfingering of the yellow sandstone and the shaly coal-bearing beds in the northeastern, west-central, and southwestern parts of the field, have in a large degree discredited the separation and unconformable relations of the two sets of beds and strongly indicate that they are conformable and are members of a single formation.

The fossils available to determine the relations of these beds consist of several collections of poorly preserved fish remains and invertebrates and of plant collections from 25 localities, each represented by from 1 to 10 species, some of which are well preserved and others so indistinct as to have little determinative value. Although certain species of these plants appear to range from near the base of the shaly coal measures almost to the top of the yellow sandstone beds, and although several collections from the sandy beds are made up wholly of species which commonly belong to the coal-bearing rocks, in general the material falls into two more or less distinct classes. This indication of two generally distinct floras, supported as it is by a general lithologic division, strongly suggests that the two sets of beds under discussion may ultimately be recognized as two closely associated formations with a gradual transition from one to the other. The name Coalmont formation is therefore applied to these rocks and will serve to designate them until such time as further evidence may be obtained sufficient to permit their correlation with recognized formations in adjoining fields.

The unconformity between the Coalmont formation and the Pierre shale is plainly evident in the vicinity of the Mitchell mine, near the east line of T. 8 N., R. 82 W., where a considerable thickness of strata having the main characteristics of the coal measures overlaps all but the very lowest part of the Pierre shale. About 3 miles north of this locality, along Roaring Fork, these beds, which here cover the Pierre and rest upon the upper members of the Niobrara, are much sandier and lighter colored, resembling to some extent the rocks of the lower North Platte River section.

The sandstones exposed in the bluff along the east side of Beaver Creek and at locality 66, about 2 miles southwest of the Mitchell mine, are lithologically very much like those exposed northwest of Cowdrey along North Platte River. They are strikingly different, however, from the rocks associated with the Mitchell coal bed, and although the rocks in the area directly south of the Mitchell mine are concealed and no direct connection could be traced between the two outcrops above named, the presence of light-colored friable sandstone in the two localities and the folding in the shaly beds which could not be detected in the obscurely exposed sandstone suggest that the sandstone overlaps the shaly coal measures and extends over the Pierre shale almost to the top of the Niobrara. It is believed that the coal-bearing strata exposed in the Coalmont district are near the base of the Coalmont formation, and that the top of the Pierre is brought close to the surface by an uplift, the center of which is approximately marked by the summit of Pole Mountain. The structure is more or less obscure in this locality, however, and the stratigraphic position of the coal beds here exposed is not beyond question. In general, the rocks exposed near Coalmont resemble the shaly coal measures on the east side of the field, except that several sandstone layers near Coalmont are much more friable and micaceous than those on the east side, and that the character of the coal in the two localities differs considerably. On the east side of the field only three coal beds of considerable value were found, and of these the thickest is almost at the base of the coal-bearing formation. The Coalmont section, on the other hand, shows five coal beds, with the thickest at the top, distributed through a stratigraphic distance about equal to the thickness of the coal-bearing zone in the former locality. The absence of coal in the exposures along Chedsey Creek about 2 miles northwest of Coalmont, where under normal conditions the Coalmont coals might be expected to outcrop, is probably due to the lenticularity of the beds. This supposition, together with the failure of the coal beds in the Coalmont section to agree with those on the east side of the field in number, thickness, or distance between beds, tends to make the coal beds a general rather than a definite basis for correlation.

On the east side of the field the 3,000 to 4,000 feet of rocks immediately above the Pierre is characterized by a predominance of dull-gray to dark shale, alternating with light-gray and buff sandstone, by the absence of conglomerate, and by the presence of coal beds in the lower half of the group. Along the North Platte, near the mouth of the Michigan, the shaly coal-bearing strata are apparently either absent or are represented by non coal-bearing sandstone containing numerous layers of coarse conglomerate at the base and resting directly upon the Pierre shale. The same appears to be true to the north and northwest of this locality, and to some extent along the eastern boundary of the Pierre west of North Platte River from the Independence Mountain fault southward to Roaring Fork. These conditions were first thought to be due to an unconformity in the Coalmont formation, but with the balance of evidence opposed to this unconformity three possible explanations remain: (1) That the marked difference in character of the strata immediately above the Pierre contact in the localities named is the result of contemporaneous deposition, under different conditions, of materials whose probably various sources of derivation might well account for the different color and composition of the rocks laid down; (2) that the shaly coal measures are wholly or in large part unrepresented near the northern end of the field because of inequalities of the land surface at the close of Montana time, which left that portion of the region a land area long after the beginning of Coalmont sedimentation in areas of depression farther south; (3) that the contemporaneous deposition of different materials and the inequalities in the ancient land surface affected the deposition of the beds about equally and were jointly instrumental in creating the existing geologic record. The writer is inclined to favor the third explanation.

FOSSILS.

Invertebrate fossils are very scarce in the Coalmont formation, and those found are so poorly preserved that they have no decisive value for the determination of the age of the beds. T. W. Stanton examined and reported on small lots from localities 1, 50, 54, 70–A, and 72 (Pl. XII). C. W. Gilmore and J. W. Gidley, of the National Museum, identified fish scales and bones collected at locality 95, 4 miles southeast of Walden, as remains of Lepisosteus and state that they are probably of Wasatch age but may be Fort Union.

The fossil plants were examined and reported on by F. H. Knowlton, as follows:

In the light of all materials now available I am convinced that the coal-measures plants are not Laramie, as I at first thought, but are undoubtedly the same as the flora associated with the coal at Carbon, Wyo., and vicinity and are post-Laramie, or "Upper Laramie," as Veatch called it. This places them above the major unconformity as defined by Veatch.

The question that naturally presents itself is that of the age of this so-called "Upper Laramie." In a general way this has been more or less closely identified with the Fort Union, but some years ago, in discussing the Carbon area, I wrote:[1] "It seems probable to the writer that the lower portion may belong to the recently established Shoshone group of Cross and the upper portion only to the Fort Union." Subsequently plants were obtained from the vicinity of Hanna, Wyo., which did not appear to sustain this view, since certain species common at Carbon were there found in association with undoubted Fort Union types. That the former was, however, probably the correct view is shown by what was found in 1909 by Peale and myself on the North Platte, just above the mouth of Medicine Bow River, which is about 30 miles northwest of Carbon. Here

[1] Washington Acad. Sci. Proc., vol. 6, p. 216, 1909.

we found Triceratops in the basal portion (lower 300 feet) of the "Upper Laramie," and demonstrated stratigraphically, lithologically, and paleontologically that this portion of the section is to be identified with the Lance formation ("Ceratops beds") of Converse County and other areas to the east and north. Now, as the Carbon area is directly connected stratigraphically with the locality above the Medicine Bow, it follows that the lower portion of the section at this place is in all reasonable probability to be referred to the Lance formation, and, further, as the so-called "'coal-measures" portion of the column in North Park is indubitably the same as the Carbon area, it likewise follows that the basal portion of the beds in North Park is referable to the Lance formation, or, at least, to its stratigraphic equivalent. Just what thickness of the "Upper Laramie" in the Medicine Bow and Carbon sections and North Park section is to be referred to the Lance is not at present known, for here, as in all other areas, we are without a satisfactory criterion to delimit the Lance from the overlying more typical Fort Union. * * * It may include the whole of the "coal-measures."

The above reference furnishes an explanation of a number of things in the North Park problem. Thus (1) the overlap of the "coal-measures" beds on Pierre, as observed on the west side of the park, shows that they are unconformable on all underlying beds, and accounts for the absence in whole or greater part of the Laramie. This demonstrates the unconformity. (2) The remarkably poor quality of the North Park coals is explained, since they correspond closely with the equally poor coal of the Carbon area.

It now remains to consider the so-called "lake beds" (light sandy member of Coalmont formation). In my first report I stated that they seemed to be distinct from the underlying "coal measures," as no species had then been found common to the two sets of beds. In general this distinction still holds, though the difference is less marked than then appeared, for two or three of the species undoubtedly pass from one to the other, and if it could be positively ascertained that the stratigraphic position assigned certain of the lots is correct it would almost break down the apparent distinctness. Thus lot No. 76 has species of the upper beds, yet is presumed to have come from the upper part of the "coal measures." This is also true of lot 83, while lot 67 comes from near the main coal, yet has Fort Union species, but the trouble with this is that the forms are very obscurely preserved and may not be correctly determined.

The stratigraphic equivalence and possible correlation of the Coalmont formation of North Park with the "Upper Laramie" of the Hanna field, as indicated by the similar floras of the two formations, is upheld by the facts that each formation is markedly unconformable on unquestioned Upper Cretaceous rocks and that a general similarity exists between the coals of the two regions. No final correlation or age assignment of the "Upper Laramie" of the Hanna field has as yet been generally agreed upon. Veatch reports these rocks as unconformable on the Cretaceous and states that the unconformity cuts out 20,000 feet or more of Cretaceous and older beds.[1] The remains of Triceratops and the fossil plants of the lower 500 feet or more of the "Upper Laramie" section point strongly to the ultimate correlation of these beds with the Lance formation, typically exposed on Lance Creek, in Converse County, Wyo. Although no satisfac-

[1] Veatch, A. C., On the origin and definition of the geologic term Laramie: Jour. Geology, vol. 15, No. 6, pp. 526–527, 1907.

tory delimitation of the probable Lance formation can be made at this time, the Fort Union affinities of the flora found higher in the "Upper Laramie" section indicate that by far the greater thickness of these beds is of Fort Union age.

The apparent absence of fossil remains of the characteristic Lance dinosaur Triceratops in the coal-bearing formation of North Park is a notable and perhaps important difference between these beds and the lower beds of the "Upper Laramie."

The Fort Union affiliations of the floras in the upper beds of both the Coalmont and the "Upper Laramie" formation and the similarity in the stratigraphic position, fossil floras, and coal of their lower members present a distinct possibility that the "Upper Laramie" of the Hanna field, Wyoming, may serve as a connecting link between the shaly and sandy members of the Coalmont formation of North Park and the Lance and Fort Union formations of eastern Wyoming and Montana.

Following are the lists of fossils collected from the Coalmont formation at several localities. (See Pl. XII.) With few exceptions the horizons from which collections were obtained are approximate, close determination being impossible because of the great amount of surficial material covering the bedrock.

Invertebrates.

Locality 1. SW. ¼ sec. 29, T. 9 N., R. 79 W.; near top of sandy member:

Viviparus ? sp. Fish scales.

Locality 50. SE. ¼ NW. ¼ sec. 28, T. 9 N., R. 80 W.; estimated horizon near middle of sandy member about 2,000 feet above base of formation:

Viviparus ? sp.

A number of gastropods too badly crushed for generic determination.

Locality 70. NW. ¼ NE. ¼ sec. 2, T. 5 N., R. 81 W., 2 miles southeast of Spicer on east bank of Grizzly Creek; estimated about 2,000 feet above base of formation:

Viviparus sp. Campeloma ? sp.

Locality 70–A. NE. ¼ SW. ¼ sec. 14, T. 6 N., R. 81 W.; estimated about 2,000 feet above base of formation:

Viviparus sp.; specimens are all of one species.

Locality 72. SW. ¼ SE. ¼ sec. 11, T. 7 N., R. 81 W.; estimated horizon 1,500 to 2,000 feet above base of formation:

Unio sp., casts of a simple type.

Vertebrates.

Locality 54. NE. ¼ NE. ¼ sec. 7, T. 9 N., R. 80 W.; about 1,000 feet above base of formation:

Fish scales and bones.

Locality 95. SW. ¼ sec. 36, T. 9 N., R. 79 W.; near base of sandy member, about 3,500 to 4,000 feet above base of formation:

Lepisosteus sp.

Plants.

Locality 9. SW. ¼ SW. ¼ sec. 32, T. 10 N., R. 78 W.; 50 to 100 feet above base of formation:

Laurus sp.?
Ficus sp.?

Locality 11. NE. ¼ NE. ¼ sec. 25, T. 10 N., R. 79 W.; horizon of locality 9:

Platanus raynoldsii integrifolia? Lesq.

Locality 13. SE. ¼ SE. ¼ sec. 29, T. 9 N., R. 78 W.; about 2,500 feet above base of formation:

Two specimens only, a piece of bark and a leaf without margin.

Locality 14. SE. ¼ SE. ¼ sec. 35, T. 11 N., R. 80 W.; 700 to 1,000 feet above base of formation:

Aralia notata Lesq.
Sapindus affinis? Newb.

Locality 15. SW. ¼ NW. ¼ sec. 2, T. 10 N., R. 80 W.; 1,200 to 1,500 feet above base of formation:

Rhamnus cleburni? Lesq.
Tetranthera præcursoria Lesq.
Populus balsamoides var.
Laurus sp., cf. L. princeps.
Populus sp.? Much broken.
Platanus sp.? Broken.
Quercus platanea? Heer.
Quercus straminea Lesq.
Fragmentary leaves.

Locality 21. SW. ¼ SE. ¼ sec. 27, T. 11 N., R. 80 W.; about 1,000 feet above base of formation:

Aralia notata Lesq.

Locality 25. SE. ¼ SE. ¼ sec. 31, T. 10 N., R. 82 W.; 300 to 500 feet above base of formation:

Carpites sp.
Sequoia longifolia? Lesq.
Fragments of a dicotyledon.

Locality 31. SE. ¼ SE. ¼ sec. 6, T. 9 N., R. 81 W.; horizon same as at locality 25:

Minute vegetable fragments, pieces of bark, scraps of grasslike leaves, and detached leaves of conifers, but nothing diagnostic.

Locality 46. SE. ¼ SE. ¼ sec. 31, T. 10 N., R. 82 W.; horizon same as at locality 25:

Carpites sp.
Sequoia reichenbachi (Gein.) Heer.

Locality 51. NW. ¼ SE. ¼ sec. 21, T. 9 N., R. 80 W.; about 2,000 to 2,500 feet above base of formation:

Taxodium distichum miocenum Heer.
Fragmentary dicotyledon.

Locality 53. NW. ¼ SE. ¼ sec. 21, T. 9 N., R. 80 W.; horizon same as at locality 51:

Fragments of several dicotyledonous leaves, but nothing determinable.

Locality 54. NE. ¼ NE. ¼ sec. 7, T. 9 N., R. 80 W.; 700 to 1,000 feet above base of formation:

Stems, a minute fragment apparently of a conifer, and scraps of two dicotyledons.

Locality 55. NE. ¼ SW. ¼ sec. 29, T. 9 N., R. 80 W.; 1,500 to 2,000 feet above base of formation:

Carpites sp.
Sapindus? sp.

Locality 56. NW. ¼ NW. ¼ sec. 19, T. 9 N., R. 80 W.; about 500 feet above base of formation:

Glyptostrobus europæus Brongn.
Carpites sp.
Viburnum sp.

Locality 66. NW. ¼ SW. ¼ sec. 26, T. 8 N., R. 82 W.; 100 to 200 feet above base of formation:

Carpites sp., bark, and very fragmentary dicotyledons, but nothing determinable.

Locality 67. NW. ¼ SE. ¼ sec. 24, T. 8 N., R. 82 W.; 300 to 500 feet above base of formation:

Glyptostrobus europæus Brongn.
Thuya interrupta? Newb.
Sapindus sp.

Locality 69. SE. ¼ NW. ¼ sec. 2, T. 5 N., R. 81 W.; 1,500 to 2,000 feet above base of formation:

Glyptostrobus europæus Brongn.
Fish scales and bones.

Locality 73. NE. ¼ SE. ¼ sec. 9, T. 7 N., R. 81 W.; about 1,000 feet above base of formation:

Glyptostrobus europæus Brongn.
Fragments of dicotyledons, but none perfect.

Locality 75. NW. ¼ sec. 25, T. 7 N., R. 81 W.; 1,500 to 2,500 feet above base of formation:

Aralia? sp.
Fragments of dicotyledonous leaves, but nothing determinable.

Locality 76. SW. ¼ NE. ¼ sec. 13, T. 6 N., R. 81 W.; 2,000 to 2,500 feet above base of formation:

Aralia notata? Lesq.
Aralia sp., probably new.
Carpites.
Fragmentary leaves.

Locality 77. SE. ¼ NE. ¼ sec. 30, T. 6 N., R. 80 W.; 3,500 to 4,000 feet above base of formation:

Glyptostrobus europæus Brongn.
Aralia notata Lesq.
Tetranthera præcursoria? Lesq.
Laurus sp.
Platanus? sp.
Sapindus affinis? Newb.

Locality 78. NE. ¼ NE. ¼ sec. 19, T. 6 N., R. 79 W.; probably in upper portion of sandy member 5,000 feet or more above base of formation:

Aralia notata Lesq.
Aralia sp., probably new.
Fragments of several other dicotyledons.

Locality 79. SE. ¼ NW. ¼ sec. 20, T. 6 N., R. 79 W.; horizon same as at locality 78:

A single leaf, apparently a Quercus but not definitely recognized.

Locality 80. NE. ¼ sec. 25, T. 7 N., R. 80 W.; probably near top of formation in upper sandy member:

Lygodium kaulfussi Heer.
Lastræa fischeri Heer.
Pteris pseudopinnæformis? Lesq.
Fern, gen.? New and very fine.
Glyptostrobus europæus Brongn.
Cinnamomum cf. C. affine Lesq.
Sapindus sp. New?
Ficus ungeri? Heer.

Locality 82. NE. ¼ NW. ¼ sec. 12, T. 10 N., R. 81 W.; 1,000 to 1,500 feet above base of formation:

Populus sp.
Diospyros? sp.
Rhamnus? sp.

Locality 83. SW. ¼ NE. ¼ sec. 36, T. 8 N., R. 78 W.; 3,000 to 3,500 feet above base of formation:

Aralia notata Lesq.
Populus amblyrhyncha Ward.
Sapindus, like S. affinis Newb.

Locality 84. (SW. ¼?) sec. 28, T. 8 N., R. 77 W.; about 1,500 feet above base of formation:

Populus meekii (Lesq.) Kn.
Rhamnus cleburni? Lesq.
Corylus macquarri? (Forbes) Heer.
Fragmentary dicotyledons.

Locality 93. SE. ¼ SE. ¼ sec. 29, T. 9 N., R. 78 W.; about 2,500 feet above base of formation:

Carpites cocculoides? Heer.
Corylus macquarri (Forbes) Heer.
Populus decipiens Lesq.
Populus meekii (Lesq.) Kn.

Locality 94. NW. ¼ SE. ¼ sec. 19, T. 9 N., R. 78 W., 4½ miles east of Walden; horizon same as at locality 93:

Carpites sp.
One dicotyledon too imperfect to be positively identified.

TERTIARY SYSTEM.

NORTH PARK FORMATION.

DESIGNATION.

The uppermost stratified rocks of North Park constitute the North Park formation, which outcrops in a long, comparatively narrow area in the south-central part of the field. The geologists of the King Survey[1] applied the name North Park group to all of the strata overlying the marine Cretaceous of the North Park field, but they particularly described the appearance and character of the uppermost white calcareous and ashy beds. In 1906 Veatch[2] used the name North Park to designate a similar white calcareous and ashy formation in east-central Carbon County, Wyo., which, though considerably thicker, is apparently the stratigraphic equivalent of the upper white beds of the North Park group of King. He used the name in a much more restricted sense in Wyoming than it was originally applied in North Park, for he made a distinction between the white ashy beds and the underlying formation, which now appears to be equivalent to the Coalmont formation or the lower part of the North Park group as defined by King. The name North Park is therefore restricted in this report to the topmost formation in North Park, which is characterized by white calcareous sandstone and ash beds. The relation of the North Park formation to the underlying rocks, though very much obscured, is believed to be one of unconformity, and the Tertiary age of the formation is unquestioned.

CHARACTER AND THICKNESS.

The North Park formation is made up of alternating shale and sandstone, with intercalated beds of various volcanic materials. The most conspicuous members of the formation are several hard white

[1] King, Clarence, Systematic geology: U. S. Geol. Expl. 40th Par., vol. 1, pp. 431–434, 1878.

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

calcareous sandstone and marly layers, which form more or less prominent ridges along the base of the formation. These sandstones are distinctly bedded and are for the most part fine-grained, though in places they are much coarser, consisting of smooth elongated particles resembling rice grains. Patches of white calcareous material having the characteristic appearance of spring deposit and containing tubelike veins and small irregular cavities filled with bluish-white calcite were also observed. Above the white sandstone, which occurs in the lower 100 feet, the formation is largely obscured by surface cover, and what is known of its character is obtained from small scattered exposures. Gray and drab shale containing a few light-gray and buff sandstone layers and several dark bands of conglomerate make up the major portion of the upper part of the formation. The shale is not unlike some of that in the Coalmont formation, except that it contains pinkish and gray ashy streaks and thin laminæ of black cinder. So far as could be ascertained the thin gray and buff sandstone beds are separated by considerable distances and constitute only a small part of the formation. These thin sandstone beds are medium to coarse grained, grayish yellow to buff, and are so friable that they are exposed in few places other than stream channels. The conglomerate, which is irregularly distributed through the upper part of the formation, is made up mainly of imperfectly rounded basalt pebbles varying from 1 inch to 6 inches in diameter. Small rhyolite pebbles are found sparingly and andesite pebbles somewhat more abundantly, though together they make up less than 10 per cent of the conglomerate. In the vicinity of Owl Mountain and northward many layers of ashy tuffaceous material and beds of pink and bluish-gray vesicular lava are intercalated in the upper part of the formation. The volcanic materials contained in this part and the white calcareous beds near the base are the chief characteristics of the formation as a whole. The thickness of the North Park formation is estimated at approximately 500 feet near the west end of the syncline and is believed to range upward to 1,000 feet or more east of Illinois Creek.

DISTRIBUTION.

The North Park formation outcrops in a long narrow syncline that extends from Owl Mountain on the east slightly north of west to the junction of Roaring Fork and Grizzly Creek, on the west side of the park. The area of outcrop is approximately 20 miles long and ranges in width from less than a mile at the west end to about 5 miles near Owl Mountain. The formation constitutes the surface rock of about 60 square miles and is best exposed where the syncline is cut by Grizzly and Illinois creeks and along the west face of the ridge extending northwest from Owl Mountain.

STRATIGRAPHIC RELATIONS.

The North Park formation is believed to be younger than Eocene, but its age can not be definitely established by the evidence in hand. No fossils were found in it, and its contact with the Coalmont formation is not sufficiently well exposed to prove the relationship, although evidence observed outside of the park leaves little doubt that it is one of unconformity. In several localities along what was believed to be the contact the white calcareous sandstone of the North Park formation was observed alternating with greenish-colored sandy beds similar to those of the upper part of the Coalmont, thus indicating a possible transition of one into the other. This evidence is not conclusive, however, as the location of the contact could not be definitely ascertained. On the other hand, the presence of an unconformity between the North Park and Coalmont formations is very strongly indicated by the probable correlation of the Coalmont with the "Upper Laramie" of the Hanna field, Wyo. (see p. 62), and the apparent equivalence of the North Park formation to the North Park Tertiary of Veatch, which overlaps the "Upper Laramie" in the Hanna field. It is confirmed, moreover, by the presence of white calcareous and ashy beds, apparently belonging to the North Park formation, resting horizontally on the crystalline rocks north of Independence Mountain. As the strata of the Coalmont formation are faulted into contact with the granite it seems probable that the upthrust of these crystalline rocks took place in an erosion period following the deposition of the Coalmont sediments.

The correlation of the North Park formation with the grayish-white horizontal beds north of Independence Mountain and along the North Platte Valley for a long distance northward in Wyoming, is based on lithologic similarity and on the stratigraphic position of these rocks immediately above presumably equivalent formations in two widely separated localities. Buff marly beds and grayish white sandstone apparently identical in character with rocks exposed along the North Park syncline were observed by the writer resting horizontally upon the pre-Cambrian rocks, which connect the Medicine Bow and Park ranges from Independence Mountain northwestward for 25 miles or more to the Encampment district in Wyoming. Northward from Encampment these beds are continuous, lying horizontally on the sedimentary rocks of the North Platte Valley to a point northwest of Saratoga, beyond which they extend northward over the flat area east of the river, overlapping the steeply tilted Cretaceous rocks along the Union Pacific Railroad near Walcott and resting on the eroded edges of the "Upper Laramie" about 5 miles southwest of Hanna.

Although the development of white calcareous beds is considerably less in North Park than in the North Platte Valley north of the park, it seems highly probable that these beds are remnants of what was once a continuous formation. Concerning these beds Hague[1] wrote as follows:

Overlying the uppermost Cretaceous strata represented within the park occur the beds of approximately horizontal Tertiary deposits, to which allusion has already frequently been made. They were rarely observed inclined at a higher angle than 4°. They lie unconformably upon the older rocks, resting in places against every formation from Archean to the top of the Colorado group and are seen in an undisturbed condition resting against the basalts. They extend over the entire park basin, giving it the level prairie-like aspect which it presents from all the higher elevations. Through these beds the many streams of the Platte drainage have worn their present channels, leaving everywhere long benchlike ridges with steep sides, which, although offering numerous good exposures, appear in no case to have cut deeply into underlying strata, making any determination of their thickness uncertain. Within the park they probably do not exceed a few hundred feet. Lithologically these deposits possess a somewhat local character, the material of which the uppermost beds are formed being derived exclusively from the relatively narrow limits hemmed in by the park walls, rendering any comparison with other basins almost impossible, although they present certain features like the Niobrara Pliocene beds east of the Laramie Hills.

So far as known to us, neither vertebrate nor invertebrate forms have as yet been obtained from these deposits, so that paleontological evidence, so desirable in determining the age of Tertiary basins, is still wanting for the North Park deposits. It is quite probable that there may be found included within the park two distinct Tertiary series. Some observations were made at the time of our explorations which would tend in this direction, showing a lower set of unconformable beds, which, however, only reach the surface in a few localities, the greater part of the area being covered with more recent deposits. From the difficulty of sharply defining the two horizons of these beds they have been given a local name, the North Park Tertiary, and a distinct designation upon the geological map. Partly from the general appearance of the strata and in part from their relation to the basaltic rocks they have been regarded provisionally as of late Pliocene age.

Lithologically, as already stated, these deposits within the park develop a local character, the uppermost beds being invariably loose friable sandstones, formed from the comminuted detritus mixed with the rearranged sands of the Colorado beds. Where the old crystalline rocks prevail the sandstone is generally coarse and of a gray color, while in the other beds yellowish-brown shades prevail. Beneath these overlying sands are finer beds, with interstratified layers of impalpable grayish-white and cream-colored marls, which can not be told from similar beds east of the Laramie Hills, in the neighborhood of Horse Creek and Shelter Bluffs. Many of these cream-colored beds are exceedingly friable and rich in lime, and upon being treated with dilute acid give off a brisk effervescence. Under the microscope the mass seems made up of exceedingly minute angular crystalline grains; other beds consist largely of trachytic and rhyolitic material. On the south side of Bruin Peak occur beds which differ somewhat from those found in other parts of the park, being made up of loose coarse crystalline detritus mixed with gravel and fine sand.

[1] Hague, Arnold, U. S. Geol. Expl. 40th Par., vol. 2, pp. 127–128, 1877.

Beyond the park the North Park Tertiary deposits extend down the Platte Valley and may be traced northward between the two great ranges, along the Medicine Bow Range as far as Elk Mountains, and around the northern end of the Park Range.

In his report on the systematic geology of the Fortieth Parallel Survey, King says:[1]

West of the western base of Medicine Bow Range the depression of the North Park * * * was occupied by a lake which we have every reason to believe was of Pliocene date. The entire valley of North Park, except where the Cretaceous and volcanic rocks rise above its surface, is occupied by a nearly horizontal set of lacustrine strata, which in places overlap the secondary beds and come directly in contact with the Archean bodies. * * * The entire middle portion of the park, however, is covered with horizontal beds of extremely white, fine, marly, and sandy deposits. The various affluents of Platte River have eroded shallow valleys through these soft beds, displaying along their banks many excellent sections. There seem to be not over 300 feet of these materials.

Made up as they are of local débris from the surrounding hills, and devoid, so far as our observations go, of fossils, it is difficult to correlate these beds with other formations. They appear to occupy, nevertheless, positions entirely similar to the Niobrara Pliocene to the east, and may hereafter be proved by fossil remains to be the equivalent of those beds. In the absence of proper evidence we have simply made of them a special group, calling it, after the locality of the basin, the North Park group. That they are Tertiary is clear from their position unconformably over the Cretaceous. That they are Pliocene is rendered highly probable by their abutting horizontally against the post-Cretaceous basaltic hills which line the park at the southwest. * * *

A continuation of this lacustrine Pliocene occupies the whole valley of the North Platte up to the latitude of 41° 30′. Throughout that distance it rests directly upon the Archean rocks on both sides of the valley, wrapping around the northern end of the Grand Encampment Mountains and extending out unconformably upon the Laramie Cretaceous to the west of Savory Plateau. * * *

It has sometimes seemed possible that this great thickness of North Park Tertiary might possibly be an eastward extension of the Eocene basin, whose limits approach it so nearly in the region of Savory Plateau; but if, as we have supposed, the basalts of the southern end of North Park are coeval with those of the Elkhead Mountains, it is clear that the two Tertiaries sustain different relations to their eruption. The wonderful dike which rises above the Vermilion Creek strata west of the Elkhead Mountains, to which Mr. Emmons has given the name of the Rampart, clearly cuts through the soft Eocene beds, while it is equally certain that the Tertiaries of the northwest [probably southwest] corner of North Park abut unconformably upon the flanks of the basaltic hills.

There are some slight indications, especially near the three forks of the Platte, at the north end of the depression of North Park, of a disturbed Tertiary, which is possibly unconformable beneath the light beds that cover the main surface of the Park.

It is evident that King included all of the rocks above the marine Cretaceous of North Park in his North Park group and that only the upper "not over 300 feet" of extremely white, fine, marly, and

[1] King, Clarence, Systematic geology: U. S. Geol. Expl. 40th Par., vol. 1, pp. 431–434, 1878.

sandy deposits belongs to the North Park formation of this report. The description of these upper white beds is apparently based on exposures along Grizzly and Illinois creeks, where these streams have cut into the formation, and the fact that the Park floor was generally covered with débris no doubt misled the early geologists as to the extent of the formation. King's words give the impression that the upper white strata in North Park are continuous or nearly continuous with those which occupy the North Platte Valley farther north, in Wyoming, whereas it is about 20 miles from the north boundary of these beds in the park to the nearest white calcareous rocks exposed along the Encampment road northeast of Independence Mountain. The fact that the Independence Mountain fault breaks the strata of the Coalmont formation indicates that the crystalline barrier now separating the white beds of the North Park formation from those of the North Platte Valley in Wyoming may have arisen subsequent to their deposition, and that these sediments may have been laid down in a single lake covering both areas.

The presence of volcanic material throughout all but the lower beds of the North Park formation shows that the earliest volcanic action in the region a few miles to the south took place soon after the deposition of these beds began, and the apparent absence of fossils is doubly unfortunate, as determinable material from these beds would have indicated not only the age of the formation but also the time when the volcanic action took place.

QUATERNARY SYSTEM.

GENERAL FEATURES.

To the Quaternary system belong the alluvium of the broader stream valleys, some of the terrace gravel and drifted sand of the east-central and northeastern parts of the park, and the glacial moraines along the lower slopes of the Park Range, of the Continental Divide on the south side of the park, and of the Medicine Bow Range south of Clear Creek. The observation of these recent deposits was mainly incidental to other work, and no attempt was made to map alluvium or terrace gravel. Many of the moraines were not mapped and others were outlined only approximately.

ALLUVIUM.

The steep gradient and high velocity of the streams in North Park and the nearness of their source prevent, in general, the extensive filling of the valleys. In places where the valleys broaden out, however, and receive the drainage from large areas of hilly or bench land considerable areas are covered by a thin deposit of alluvium washed down from the surrounding country. The principal alluvium-covered areas in the field are along the lower valleys of Canadian, Michigan, and North Platte rivers, although local areas of alluvium are common along practically all the streams. The alluvium is of variable thickness. In most places it is thin, but at some localities it reaches a thickness of 30 feet.

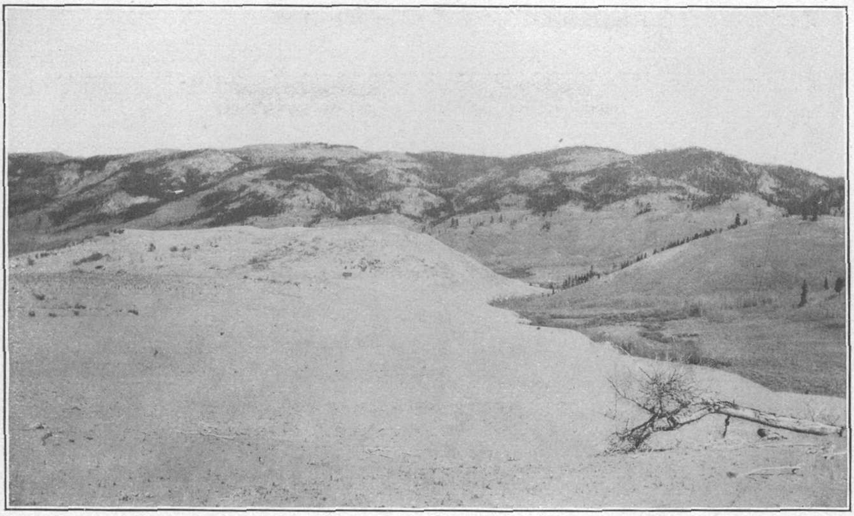
TERRACE GRAVEL.

In the east-central part of the field fluviatile gravel caps several flat-topped hills which rise approximately 400 feet above the general level of the park floor and caps also the more or less extensive benches which apparently represent a somewhat lower level of erosion. No attempt was made to map the boundaries of these gravel beds, and they were noted mainly along the routes of traverse. The greatest thickness of gravel observed is about 6 feet, and it is probable that the maximum thickness in the field is not much in excess of this. The gravel ranges from small pebbles to cobblestones 5 inches in diameter, and its lithology at once indicates its source in the crystalline core of the Medicine Bow Range. The material is mainly made up of granite and gneiss pebbles 1 inch to 3 inches in diameter, although quartz and chert pebbles are not uncommon. The pebbles are very imperfectly rounded and in some localities, particularly on the bench east of the McCallum mine, are quite firmly cemented by calcareous material.

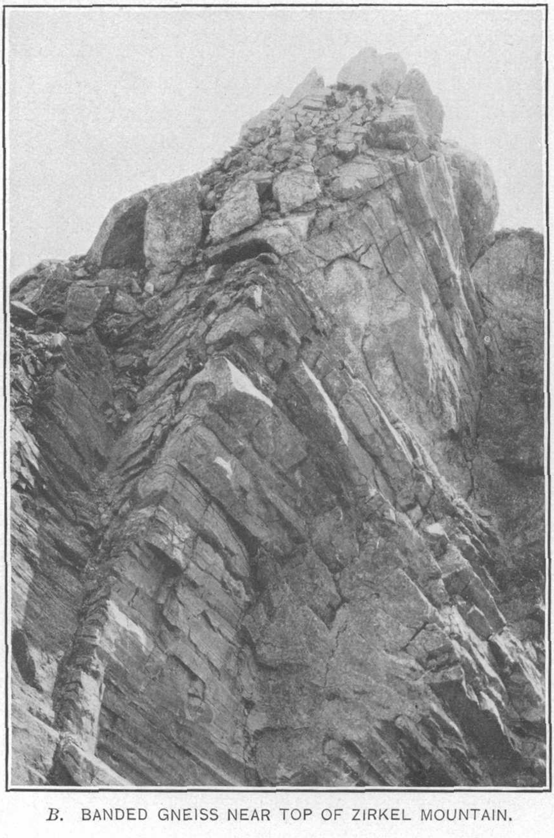
The gravel is believed to have been deposited by a stream whose meanders covered much of this section of the field, probably in early Quaternary time. The gravel-capped terraces at two different levels are probably due to corrosive stream work in two flood plains of different altitudes, rather than to recurrent uplifts in this part of the field.

DUNE SAND.

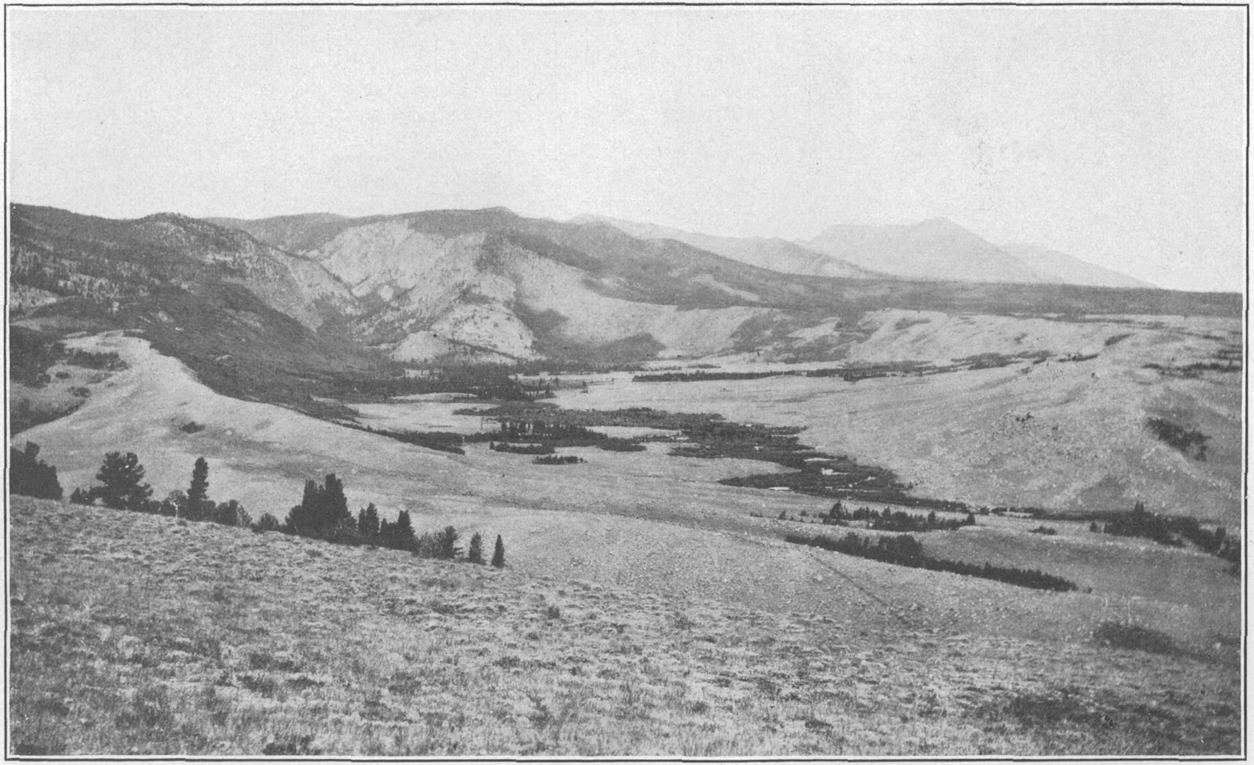
Along the northeast border of the park floor several areas of considerable size are covered with wind-blown sand, which in two localities has drifted up the dip slope and over the top of the Dakota sandstone ridge, forming light-yellow areas, conspicuous from practically all the more elevated portions of the field. One of these areas is immediately north of Sand Creek near Ute Pass and is somewhat less than a square mile in extent. (See Pl. III, *A*.) Although there is possibly 50 feet or more of sand along the foot of the Dakota hogback the top is covered by only a few feet of very fine sand from which the hard ledges of the Dakota sandstone emerge in places. The quantity of sand is, however, sufficient to kill practically all vegetation within its borders. The other conspicuous sand-covered area lies 8 to 10 miles farther northwest on the dip slope of the Dakota sandstone and is somewhat more extensive than the Sand Creek



A. DUNE SAND.



B. BANDED GNEISS NEAR TOP OF ZIRKEL MOUNTAIN.



MOUTH OF RED CANYON.

locality. A large part of several square miles lying northwest, west, and southwest of the northernmost sand drift (see Pl. XII) is covered with sand ranging in thickness from a thin film to several feet or more.

The sand composing these drifts is mostly fine grained and ranges from yellow through light-straw color to almost white in color. It is apparently made up of 90 per cent or more of white quartz and other light-colored minerals and about 10 per cent of dark-colored grains. The drift surfaces are marked by wind ripples, blow-outs, and other forms characteristic of sand dunes, though the contour of the drifts is considerably influenced by the resistant ledges of the underlying strata. The sand is undoubtedly derived from the sandy beds of the park floor and is believed to have been deposited in the Canadian Valley by the intermittent streams which empty into the Canadian in this part of the field and by the prevailingly strong southwest wind, which not only transports fine sand across the park floor but also carries it up the east slope of the Canadian Valley to the top of the Dakota sandstone ridge. The presence of sand drifts in this part of the field and not elsewhere is probably due to the prevailing southwesterly winds. The comparative lowness of the park wall from Rabbit Ears Peak to Arapaho Pass may admit stronger winds from this opening in the park wall, a theory that is borne out to some extent by statements of ranchmen that the region northeast of Walden is often swept comparatively clean of snow when other sections of the field are deeply covered.

GLACIAL DEPOSITS AND GLACIATION.

GENERAL FEATURES.

Many large areas along the lower eastern slope of the Park Range and along the western slope of the Medicine Bow Range south of Clear Creek are covered by the moraines of mountain glaciers which flowed out of the sharp canyons of these ranges in Pleistocene time. The glacial material ranges in thickness from a few feet to several hundred feet throughout these areas and is made up in each locality of rock débris from the floor and walls of the canyon through which the glacier flowed; of silt from the mountain slopes, which washed down onto the glacier during the process of glaciation; and of soil resulting from rock decay subsequent to the deposition of the glacier's load. The surface of the moraines is in many places dotted with small lakes and is characterized by ridges, hillocks, depressions, and other typical morainal forms. The glacial material of the Park Range slope, of the Clear Creek and Kelly Canyon region on the west slope of the Medicine Bow, and of Upper Arapaho Creek southeast of Spicer Peak are approximately mapped on Plate XII. The lower boundaries of the moraines of the Park Range were drawn in considerable detail, but similar glacial material elsewhere is but roughly indicated. Although no attempt was made to differentiate between the glacial and other débris which covers the mountain slopes in the southeast corner of the park, it is known that certain areas in this region are covered by moraines.

The work of snow and ice is very evident along the canyons and foothills of the Park Range, in the upper valley of Arapaho Creek at the south side of the park, and along the Medicine Bow Range from the southeast corner of the park northward to the headwaters of Clear Creek. The high peaks along the mountain walls of the park form centers of condensation of moisture, which in Pleistocene time formed glaciers that poured out from many of the canyons and deposited morainal material over large areas along the foothills. In the course of the field work rapid reconnaissance trips were made to several centers of glaciation at the top of the ranges, and more or less general notes were made on a few areas in which the records of glaciation are most conspicuous (see Pl. XII), though the amount of morainal material in the large covered area near the southeast corner of the park was not determined.

PARK RANGE.

The foothills of the Park Range are more or less covered by moraines three-fourths of the distance between Rabbit Ears Peak on the south and the vicinity of Big Creek Lake on the north. The morainal material occurs in seven areas, apparently disconnected, although glacial débris so thin as to have had little influence on the topography, or indeed to be observable, may be present on the heavily timbered and generally débris-covered surface. The moraines have highly irregular surfaces characterized by ridges and hummocks of various sizes, separated by cuplike and troughlike depressions, many of which contain ponds or small lakes.

In general, the canyons through which the glaciers poured down from the high altitudes and out onto the foothills are distinctly U-shaped, with precipitous walls, and in some localities are so close together that the dividing ridges are carved to a knife-edge top. Four cirques at the head of glacial canyons are prominent on the North Park side of the Flattop and Zirkel Mountain massif. The northernmost and largest of these heads against the highest point of Mount Zirkel. Precipitous cliffs are developed throughout the length of its U-shaped valley as well as at its head, and the lower slopes of these are mantled with an abundance of slide rock. The bottom of its canyon contains a well-developed rock stream near its head but holds no glacial lake. Well-defined lateral moraines extend from the mouth of the valley to the great hummocky mass of the terminal moraine.

This canyon is separated from the smaller ones on the south by a high, nearly vertical mountain mass of gneiss, whose top was probably level in former times with the summit of Flattop Mountain and whose steeply tilted or vertical crystalline layers are worn to a remarkably uniform plane, to all appearances the remnant of a great peneplain. This mountain mass forms the north wall of a canyon whose cirque is somewhat less than half the size of the northernmost canyon just described and which is remarkable for the series of benches along its floor and the precipitous nature of its south wall low down over its moraine.

A thin sharp divide separates this canyon from a smaller one on the south—a hanging valley that empties over a sharp cliff into the valley of North Fork.

The southernmost canyon is very precipitous near its head and descends very rapidly, with a distinct bench reaching about two-thirds of the way to its mouth. It is characteristically U-shaped, like the other canyons, and its moraine joins the great mass of glacial débris which represents the moraines of the other three.

Aside from the sketching of moraines, the glaciation of areas farther south along the Park Range was little noted except along Roaring Fork at the mouth of Red Canyon and a few miles below. Red Canyon is a comparatively long, deep glacial canyon containing several lakes near its head and having very steep and, in places, precipitous walls. Its mouth is an almost perfect U, carved in the granite and polished and striated for several hundred feet above the valley floor. (See Pl. IV.) Southeast of the granite mountain mass the stream valley is bounded by well-defined lateral moraines extending from the canyon's mouth 2 miles or more downstream and uniting in a terminal moraine.

ARAPAHO CREEK.

On the headwaters of Arapaho Creek an area of hummocks, ridges, and depressions, some of which contain small lakes, is interpreted as the moraine of a glacier which is believed to have had its source on the Continental Divide, a few miles to the southeast. Only the northern part of this area immediately southeast of Spicer Peak was closely observed, however, and the glacial origin and source of the material were not satisfactorily established. The débris, which gives the area its typically morainal appearance, is not thick and may have slumped down, with the aid of local snowslides, from the precipitous mountain walls on the southeast.

MEDICINE BOW RANGE.

The region in which the effects of glaciation are most prominent along the Medicine Bow Range is that including Clear Creek and Kelly canyons, which head near the top of the range a short distance north of Clarks Peak. These are typical U-shaped glacier tracks, roughly parallel to each other, separated by a wedge-shaped crystalline ridge, which is broad and steeply sloping at its lower extremity but is narrow, precipitous, and nearly cut through by erosion where it separates the névé grounds or cirques near the crest of the range. The floors of the canyons descend very rapidly, and many rock streams have been developed by the gradual slumping of talus and slide rock, which cover much of the lower slopes of the canyon walls. Clear Creek Canyon is fairly uniform in shape from the mouth up to a small lake which marks the base of its névé ground. Kelly Canyon is narrow, with nearly vertical walls at its mouth, but widens somewhat and has less precipitous slopes and a double cirque at its head. It is probable that the head of the glacier shifted in such a manner that its later work cut off and left isolated the earlier névé ground, which is now marked by a picturesque hanging lake. The moraines of Clear Creek and Kelly canyons, whose upper portions are about 10,000 feet above sea level, are made up of material in which granite bowlders 1 foot to 5 feet in diameter predominate, though other crystalline rocks and a small amount of black dike rock were noted. This material was deposited in the form of irregular ridges and mounds, completely rimming the mouths of the two canyons and so spread out as to practically meet between them.

North of Clear Creek canyon no distinct evidence of glaciation was seen and the range was at most only superficially affected by snow and ice. There is little doubt that glaciers poured out of many of the sharp canyons heading in the high altitudes of the range south of Clarks Peak and that considerable areas in the foothills are covered by moraines, although this region was left practically unexplored because of the generally covered condition of its sedimentary rocks.

IGNEOUS AND METAMORPHIC ROCKS.

GENERAL FEATURES.

With the exception of the large granite ridges in the northwestern part of the park and the lavas and volcanic breccia which occupy many areas along the south border, the igneous and metamorphic rocks of the field are confined to the bounding ranges. No detailed study of these rocks was attempted, and their classification is of a general nature except in localities from which specimens were collected and petrographic determinations made from thin sections. E. S. Larsen made petrographic determinations and furnished descriptions of some of the rocks.

CRYSTALLINE ROCKS.

The rock mass which forms the mountain wall on the east, north, and west sides of the park is made up mainly of crystalline rocks, of which reddish to pink granite forms the major part in some localities and granite gneiss, mica schist, and pegmatite in others. (See Pl. V.) These rocks (see Pl. XII) extend continuously from the southwest corner of the park northward to Pearl post office, thence eastward to Pinkhampton, southeastward to Clarks Peak, and southward to Bowen Mountain, at the southeast extremity of the field. They are mapped from their contact with the sedimentaries to the crest of the ranges on the east and west sides of the field. On the north, however, the natural boundary is much less definite, and the mapping was carried for a few miles and arbitrarily discontinued. It is known, however, that the rocks are generally present at the surface for many miles.

Specimens collected from localities I, II, III, IV, and XIV (see Pl. XII) represent the common types of rocks which make up the crystalline cores of the mountains. No attempt was made to differentiate these rocks in mapping, as the examination of many large areas along the ranges was of a very rapid reconnaissance nature. It is believed, however, that the specimens from localities XIV and III represent 50 per cent or more of the total, and that the same rocks altered to granite gneisses by crushing and squeezing (localities I and II) constitute much the larger part of the remainder. The specimens from locality XIV at the mouth of Red Canyon on the west side of the field, and from locality III in Clear Creek Canyon on the east side, are coarse-grained pink granite with microcline and quartz as their chief constituents. Albite or oligoclase are also present, partly as intergrowths with the microcline and partly as independent crystals. Biotite is the only dark mineral. Secondary muscovite, zoisite, chlorite, and calcite are present. The specimen from locality IV near Richthofen Mountain is a pegmatite. The rocks of this locality are, however, mainly reddish granite and beautifully banded gneiss with a less amount of black, highly micaceous schist. Granite gneiss appears most abundantly in the crystalline rocks along the north side of the park, though coarse-grained reddish granite is also common. The gneiss is represented by specimens from locality I near Pearl post office and from locality II in King Canyon near Pinkhampton. It is fairly well banded but is otherwise similar to the granite. In King Canyon near Pinkhampton the igneous rock is mainly gneiss, cut by irregular dikes of granite and veins of quartz. The crystalline wedge which is faulted up and exposed in the railroad cut in the north side of Sentinel Mountain is mainly gneiss and schist, with a small amount of granite.

The rocks which came within the scope of a reconnaissance examination of the Mount Zirkel massif (see Pl. III, *B*, p. 72) are made up for the most part of light-colored granite gneisses, consisting mainly of quartz and feldspar, and darker hornblendic and micaceous gneisses, banded on a large scale. Associated with these are mica schist, granite, and pegmatite, named in the order of their abundance.

Delanos Butte, Sheep Mountain, and the long ridge to the north are made up mainly of pink to reddish coarse-grained granite, associated with smaller amounts of granite gneiss. The northern extremity of the crystalline mass of Delanos Butte is made up of what appears to be a dike of very fine grained light-colored aplite.

Observations incidental to the examination of the sedimentary rocks farther south along the Park Range indicate that southward from Mount Zirkel the proportion of granite increases and that it forms the major portion of the crystalline mass from Red Canyon southward.

VOLCANIC ROCKS.

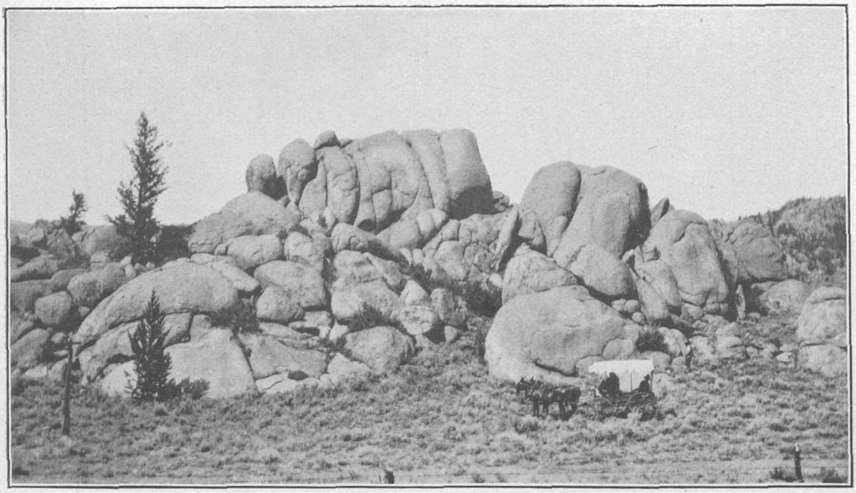
EXTENT OF VOLCANISM.

The uplifted sedimentary rocks that form the Continental Divide between North and Middle parks are covered in many places by basaltic flows and thick masses of volcanic agglomerate, and are cut by numerous dikes. The extent of the volcanism is very imperfectly known, and it should be borne in mind that some of the boundaries of volcanic rocks were sketched from considerable distances and were partly inferred, and that the presence of dikes in many places along traverse lines and reconnaissance routes strongly indicates the existence of many others in areas wholly outside the limits of detailed work. The rocks included in the following discussion were studied by E. S. Larsen, who made petrographic examinations of thin sections.

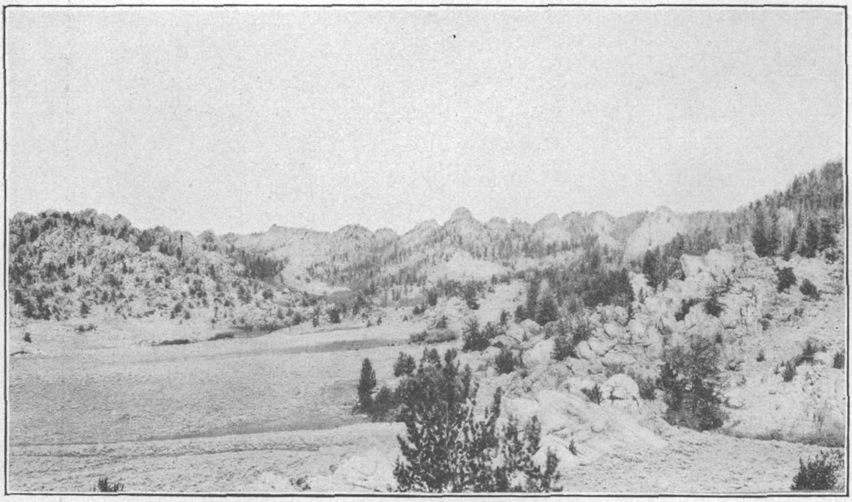
DISTRIBUTION AND CHARACTER.

The distribution of the eruptive rocks along the south border of the field may best be ascertained by reference to Plate XII, on which are designated by Roman numerals the localities from which specimens were collected for petrographic determination. Specimens from localities VII, VIII, IX, and XI are andesine basalts that are crystalline and rather even textured and are made up of olivine, augite, and andesine. Orthoclase, magnetite, and apatite are accessory minerals. The feldspars are more sodic than in normal basalts and the rocks may be called andesine basalts.

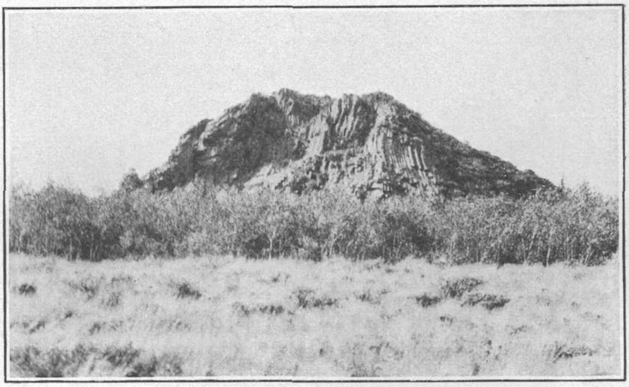
Locality VII, which lies about 4 miles southeast of Spicer Peak, is at the northwest extremity of a great though very roughly mapped mass of volcanic agglomerate, which covers the surface of more than 20 square miles on the North Park side of the Continental Divide. (See Pl. VI, *B*.) The specimen represents one of several sheets embedded in a thickness of several hundred feet of gray, ashy, tuffaceous material containing more or less angular fragments of basalt ranging from pebble size to several feet in diameter. The irregular western



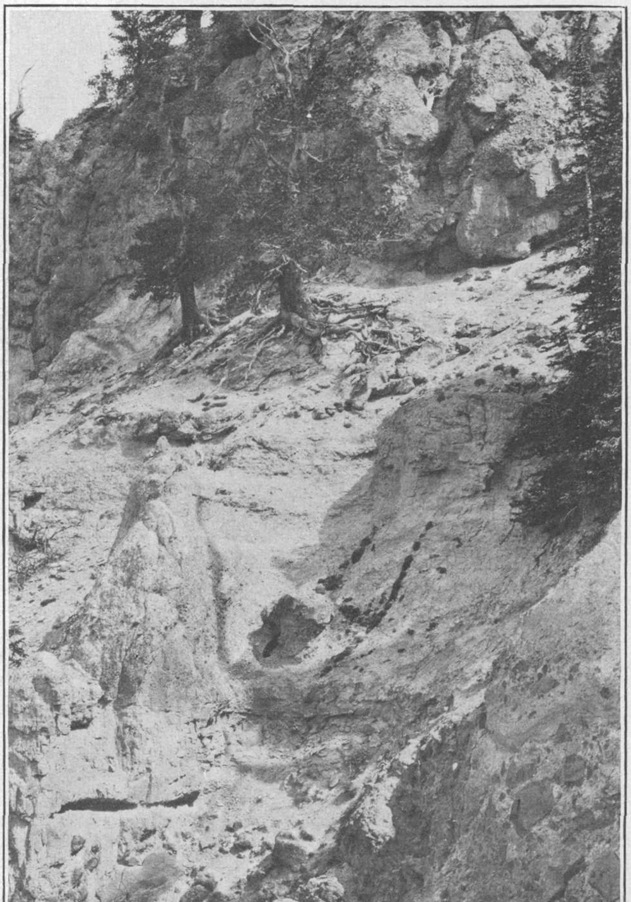
A. WEATHERED GRANITE.



B. EROSION FORMS IN GRANITE.



A. COLUMNAR BASALT CAPPING SPICER PEAK.



B. VOLCANIC BRECCIA.

continuation of this brecciated mass, which is connected with the main body by a narrow band along the Continental Divide, is the westernmost agglomerate observed in the field. The basalt at locality IX forms a small cap on the top of Spicer Peak. (See Pl. VI, *A*.) It is a very dense black lava of pronounced columnar structure and is 100 to 150 feet thick. Although the size and shape of the rock body is somewhat indicative of a volcanic plug, it is more probably a remnant left by erosion of a somewhat extensive flow, which may have been continuous at one time with the basalt sheet capping Ironclad Mountain a few miles distant. The specimen from locality VIII is a compact black basalt from the easternmost of two dikes which cut the sedimentary rocks and in places stand up rather prominently as rock walls in the area between Buffalo Mountain and the Kelly ranch. The dikes extend in a general northwest and southeast direction and range in thickness from about 10 to 30 feet, with a probable average of about 15 feet. Locality XI is at the base of the basalt sheet, whose pillar-like remnants form the "ears" of Rabbit Ears Peak, near the southwest corner of the park wall. This remnant of a lava flow covers several square miles on either side of the Continental Divide in this vicinity and appears to have a much greater thickness than most of the lava caps of the region. All of the eruptive rocks mapped in the vicinity of Rabbit Ears Peak and eastward along the Continental Divide to the neighborhood of Ironclad Mountain are thought to be basalts very similar in character and composition to those of localities VII, VIII, IX, and XI.

Specimens from localities XII and XIII are samples of a coarse basaltic float which covers the top of Pole Mountain a few miles southwest of Coalmont. The large quantity of scoria and basaltic bowlders of various sizes strewn over the mountain slopes, together with the burned and warped condition of the sedimentary rocks near the summit, indicates that Pole Mountain might possibly have been the vent of a small and comparatively recent eruption. It seems more probable, however, that the baked and in places fused shale exposed near the mountain top on the west side is due to contact with a lava flow of which the basaltic débris now capping the mountain is the last remnant. Specimen XIII has more olivine and augite than the other andesine basalts and the feldspars average about andesine-labradorite. Specimen XII is a very different rock but is probably genetically related to the others. It is about half magnetic iron ore in small grains and crystals with smaller amounts of pale-green augite and plagioclase between bytownite and anorthite. Apatite is rather abundant in nearly equant grains. The texture is fine and equigranular and the rock is very porous.[1]

[1] For a detailed description with an analysis see Washington, H. S., and Larsen, E. S., Magnetite basalt from North Park, Colo.: Washington Acad. Sci. Jour., vol. 3, p. 449, 1913.

At locality X, about 1½ miles southeast of Muddy Pass, a specimen was collected from a small lava peak which rises prominently above a ridge extending southward from the Continental Divide. The study of a thin section of this rock shows it to be a dense greenish-gray augite minette. It contains abundant crystals of biotite and pale-green augite in a fine mat of lathlike orthoclase crystals. Apatite and iron ore are present, and secondary calcite is abundant. The hand specimen shows some vesicules and flow lines. The rock may be a flow with the composition and texture of an augite minette.

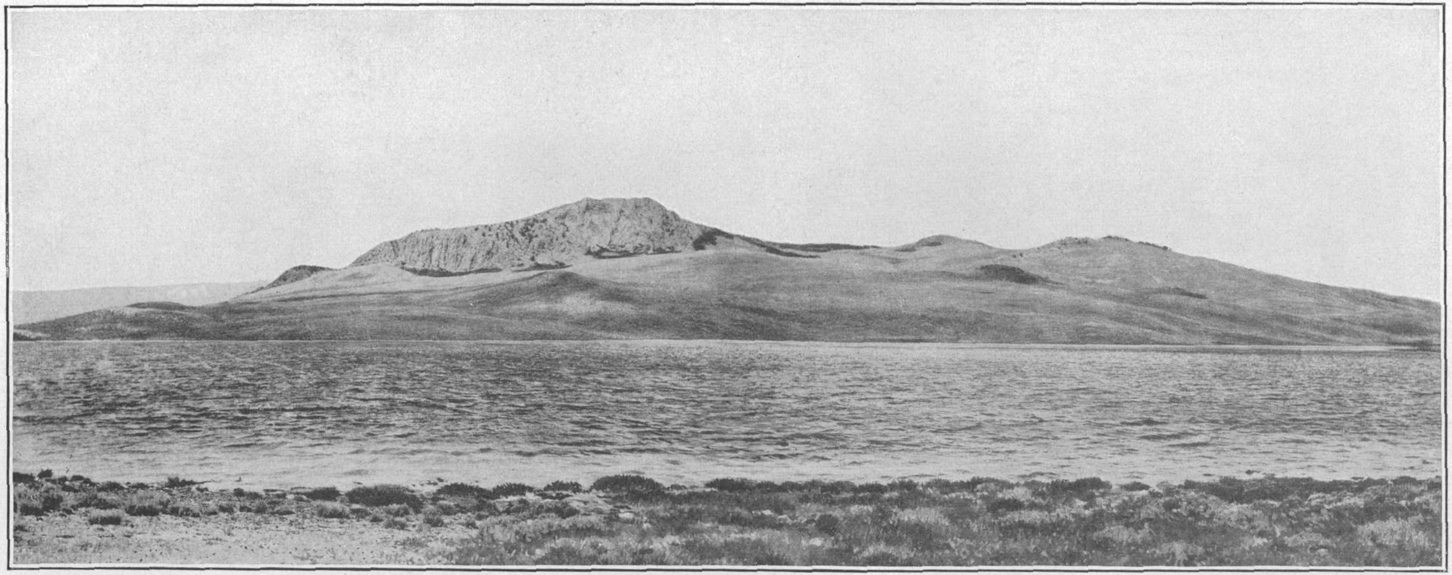
Owl Mountain, in the southeastern part of the field, is capped by 500 feet or more of volcanic rock, which is largely concealed by débris and dense timber cover but which probably extends from locality V, at the western extremity of the mountain top, to the crystallines of the main range a few miles north of Teller.

The samples collected at locality V apparently represented the major part of the eruptive mass, which shows various colors and textures but is mainly a coarse-textured porous rock, commonly light gray streaked with brownish red and dark gray. The thin section shows scattered crystals of plagioclase, augite, biotite, and hypersthene in a glassy groundmass. It is quartz latite, as the glass has the properties of a rhyolitic glass.

Several large light-colored porphyry dikes were observed from the Rand to Granby stage road, within a mile of Willow Creek Pass, on the Middle Park side. (See Pl. VII.) At locality VI, a few hundred yards south of the pass, the road runs through a gap in the largest dike, which is 30 to 50 feet thick and forms an imposing vertical rock wall 200 to 300 feet high. The rock is a greenish quartz latite porphyry, with phenocrysts of feldspar up to an inch across. The large feldspars are orthoclase and sodic plagioclase, some of them intergrown. The dark minerals are altered to calcite, chlorite, and epidote, but biotite, hornblende, and pyroxene were probably all present. The groundmass is granophyric and is made up of quartz and alkali feldspar.

Beds of lava and conglomerates, made up almost entirely of volcanic rocks, outcrop prominently along the strike of the North Park formation between Owl Mountain and Illinois Creek. The lava, as exposed about 3 miles northeast of Owl, is a pink vesicular rhyolite, containing many light-colored transparent crystals and inclusions of soft white ashy material having the texture of pumice. Closely associated with this rock are considerable thicknesses of cream-colored and bluish-white tuff, consisting mainly of fine, gritty, and ashy material, with a great many small opaque pebbles, some of which are sharply angular, some subangular, and some well water-

PORPHYRY DIKE.



DELANOS BUTTE.

worn. The volcanic conglomerates are best exposed in the steep slope of the ridge, about 4 miles slightly north of west from Owl. They are commonly pinkish, though in some places nearly white. The groundmass is ashen or tuffaceous and contains fragments of various volcanic rocks as well as a great many waterworn metamorphic and crystalline bowlders that range from a few inches up to 3 feet in diameter.

AGE OF ERUPTIVE ROCKS.

The absence of volcanic material in the Coalmont formation and the presence of such material and lava beds well down toward the base of the North Park formation show that the volcanic action of the region took place after the Coalmont sediments were laid down and was in part at least contemporaneous with the deposition of the North Park formation. As the Coalmont formation is undoubtedly Eocene or late Cretaceous, and as the evidence indicates that the North Park rests unconformably on it, the earliest volcanic activity of which evidence was found probably occurred after the close of the Eocene epoch, though uncertainty concerning the age of the North Park formation precludes more definite assignment.

STRUCTURE.

GENERAL CHARACTER AND REPRESENTATION.

The structural geology of a region, as applied to the relations of its rock masses rather than to the arrangement of the more or less minute component parts of the rocks themselves, deals with the attitudes of its strata, their relations to each other as produced by bending or breaking, and their relation to unstratified rock masses. The rocks of North Park have been considerably warped or folded, and in many parts of the field large breaks or faults in the strata have been produced by the application of various forces in the earth's crust. The geologic importance of structure is apparent from its direct relation to the shaping of topographic forms and to the areal distribution of formations. Its more purely economic importance is evident from its relation to general mining conditions, which in North Park include the extent, accessibility, and particularly the character of the coal. The larger structural features of the park are for the most part well defined and susceptible of ready interpretation, but those of many of the minor features, particularly those low down on the park floor, are obscured to a greater or less degree by surface cover and the indistinctness of many of the exposures.

Faults are shown on the map (see Pl. XII) in solid lines where their existence and location are rather distinct and in broken lines where their location or extent is more indistinct. The attitude of the strata throughout most of the field may be interpreted from the symbols showing the dip and strike and from the accompanying figures, which give the degree of dip or inclination of the strata from the horizontal. The direction of dip is shown by a small arrow at right angles to a line representing the line of strike which, in approximately level country, is identical or nearly so with the line of outcrop. Although considerable areas of the rock floor are covered and although concealed local folding or faulting is probable it is believed that practically all structural features of importance are shown on the map.

MAJOR FEATURES.

LOCATION AND CHARACTER.

The sedimentary rocks of North Park form a huge synclinal trough which lies between the uplifted crystalline masses of the Medicine Bow Range on the east and of the Park Range on the west. On the north the syncline is terminated by a great fault, which cuts the strata almost at right angles to the synclinal axis, and on the south it rises over the lesser uplift or swell which forms the divide between North and Middle parks. The rise of the syncline on the south and its steeply tilted edges on the west, east, and northeast form an almost complete structural as well as topographic basin which, however, is left open by the cutting out of a short segment of its northern rim along the Independence Mountain fault. This structure can be accounted for either by the depression of the park below the surrounding rim or by the uplift of the rim above the park floor.

PARK RANGE AND MEDICINE BOW UPLIFTS.

Along the east side of the Park Range uplift the sedimentary rocks rest upon the crystallines and dip away from the uplift at angles ranging from 15° to nearly vertical. This variation in dip along the base of the range is indicated by the varying width of outcrop, which is but little more than the actual thickness of the strata where the dips are very steep but which is greater where the dips are slighter. The strata on the east side of the park are likewise tilted by the Medicine Bow uplift, on the crystalline rocks of which they rest with westward dips ranging from 20° to 50°. The steeply tilted condition of the rocks along the lower slopes of both the Medicine Bow and Park ranges gives way toward the synclinal axis to dips which are in general much less and which in places show considerable local variation.

The amount of uplift along these ranges can not be closely determined because of the uncertainty as to how extensively the cores of crystalline rocks have been worn down by erosion. It is evident, however, from the thickness of sedimentary rocks affected by the uplift and the elevation of the highest crystalline rocks above the park floor that the amount of uplift is more—probably much more—than 20,000 feet.

DIVIDE BETWEEN NORTH AND MIDDLE PARKS.

Exposures of sedimentary rocks are very rare along the divide between North and Middle parks, the greater part of the region being covered by volcanic rocks, timber, and débris. The attitude of the strata, however, is evident in a number of localities and shows a northward dip ranging from 7° to 15° from the headwaters of Buffalo Creek eastward to the southeast corner of the field. From Buffalo Creek westward there is evidence of considerable warping of the strata with dips in various directions, although the general inclination of the beds is to the east and northeast. There is little doubt that the Continental Divide uplift extended all the way from the Park Range to the Medicine Bow Range, but it is evident that it was more pronounced near the Medicine Bow.

INDEPENDENCE MOUNTAIN FAULT.

At the north end of the park the crystalline rocks of Independence and Watson mountains were thrust up, breaking the sedimentary rocks almost directly across their strike and no doubt elevating considerable thicknesses of them which have since been removed by erosion. The fault extends from the region a few miles south of Pearl post office southeast and then east to the vicinity of Sentinel Mountain in the northeast corner of the park. It cuts out 10,000 to 15,000 feet of strata a few miles west of the place where it is crossed by North Platte River, and in all probability it has a maximum displacement much greater than the thickness of faulted sedimentary rocks. The stratified rocks strike directly against the crystalline mountain mass with dips 15° to 30° W. from the east side of the field to the bottom of the synclinal trough a few miles west of North Platte River, and from this locality to the west side of the field they dip 5° to 40° E.

MINOR FEATURES.

FAULTS.

EXTENT AND INFLUENCE.

In the order of size and influence on the topography and areal geology, the principal breaks in the sedimentary rocks of North Park are the Independence Mountain fault, the Sheep Mountain series of faults (including those of the large ridge and of Delanos Butte on the north and the south), and the fault crossing King Canyon east of Sentinel Mountain. Among the faults of lesser importance which were observed and mapped are that which cuts the sharp fold of the lower sedimentary rocks near the Kerr ranch, that which duplicates the outcrops of the Benton and Niobrara formations east of the Hill ranch, and that which breaks the McCallum anticline near the mine of that name a few miles northeast of Walden. In addition to these, the strata of the park floor are broken by many faults of such slight extent and displacement that they are not shown on the geologic map.

The way in which the economic conditions of a field are affected by the forces which produce faulting is illustrated in the northwestern part of the park by the uplift and removal by erosion of the coal-bearing formation from an area probably more than 50 square miles in extent, as a result of the thrusting up of the Sheep Mountain and associated crystalline masses. Although the scarcity of coal in this formation in adjoining areas indicates that at most only a small amount of minable coal was removed in this area, still the presence of the faults and their apparent effect shows the possible extent to which similar faults might affect a formation containing continuous beds of high-grade coal or other economically important minerals.

INDEPENDENCE MOUNTAIN FAULT.

The Independence Mountain fault is discussed with the major structural features (p. 83) because of its magnitude and its relation to the general synclinal structure of the sedimentary rocks of the field.

SHEEP MOUNTAIN FAULT SERIES.

The crystalline rock masses of Delanos Butte, Sheep Mountain, and the great ridge extending northward from Sheep Mountain to the vicinity of Pearl post office were thrust upward by a force which broke the entire thickness of sedimentary rocks.

The west faces of these granite ridges are the scarps of three faults which connect with and overlap each other. (See Pl. XII.) The northernmost fault extends from the region of Big Creek Lake along the west face of the granite to the gap east of the Boetcher ranch, through which it passes, apparently dying out in the vicinity of Lake John. This fault is of greater length than those farther south but is thought to have approximately the same displacement, as all three break the entire 10,000 to 15,000 feet of strata. The whole series of formations outcrops on the east side of the upthrust granite masses upon which they lie. To the north of Boetcher Gap the fault contact is unmistakable, as the Pierre shale dips eastward into the west face of the ridge of crystalline rocks, except in a few localities where small masses of red shale and sandstone separate the two. These remnants of the Chugwater formation are believed to have been dragged up by the large fault rather than to have resulted from a system of smaller secondary fractures.

Connecting with the northernmost fault at a point just north of Boetcher Gap, the next fault of the series follows the west side of Sheep Mountain to its southern end and passes southeast through the gap, beyond which it could not be followed. A short distance west of the trace of the main fault a secondary fault is separated from the west face of Sheep Mountain by a block of Niobrara rocks dipping steeply eastward against the granite. This block, which is in contact on the west with Pierre and younger rocks of much gentler dip, extends along the west side of the Sheep Mountain ridge from near the south extremity to the region slightly north of east from the Monahan mine, where it dovetails in with several wedgelike masses of Niobrara, Benton, and Dakota formations. These masses lie in various steeply inclined attitudes and are broken by faults, which, with the exception of the short diagonal fracture extending from the main Sheep Mountain fault to the secondary fault on the west, are too small to be shown on Plate XII.

The complexity of the structure in the vicinity of Boetcher Gap is shown on the map and can best be interpreted by a study of the fault lines and dip and strike symbols. The relation of structure to economic geology is illustrated by the fact that a portion of the Monahan coal bed has been removed by the faults, which cut the bed nearly parallel to its strike and about 2,000 feet east of its outcrop.

On the east side of Sheep Mountain the Chugwater formation rests with sedimentary contact upon the granite with a dip of 25° to 50° E. The younger formations outcrop in turn to the east, with steep dips near the mountain, giving way to much gentler dips nearer the center of the park. On the north these outcrops extend along the east side of the upthrust crystallines to the north side of the field, where they strike into the Independence Mountain fault; on the south they fold sharply around the south end of the ridge, striking into the Sheep Mountain fault near its intersection with the north fork of North Platte River.

The third and southernmost fault of the Sheep Mountain series runs along the west cliff of Delanos Butte. (See Pl. VIII.) It strikes into the large fault on the north, near the south end of the Sheep Mountain ridge, and as it is apparent for only a few hundred feet south of the Butte it is not believed to extend beyond the valley of Roaring Fork. On the west side of the Butte the lower rocks of the Coalmont formation dip 15° to 26° E. against the granite, proving that the entire section of sedimentary rocks is broken. The wedgelike granite mass is likewise bounded on the east by a fault which brings it in contact with somewhat warped but generally westward dipping Dakota rocks. This fault, which connects with the main fault at the north end of the ridge, cuts the west limb of a small, sharply folded, and steeply pitching anticline in which the

Morrison and Chugwater formations outcrop, the Chugwater in contact with the lower part of the Coalmont formation and the upper Pierre shale a short distance north along the main fault. This sharp bend in the strata adjacent to the fault appears to have been caused by dragging and indicates that the fracture is one of lateral as well as vertical displacement.

SENTINEL MOUNTAIN FAULT.

In the northeast corner of the park an outlying wedge of crystalline rock was thrust upward by a force which broke the lower sedimentary rocks and lifted the resistant quartzitic Dakota sandstone to its present position at the top of Sentinel Mountain. The upthrust crystalline rocks form an ill-defined ridge somewhat more than a mile long and approximately 1,000 feet wide at the base of its widest part. It forms a secondary roll along the east side of and approximately parallel to the Sentinel Mountain ridge, and its highest point rises to within a few hundred feet of the level of the main mountain top. The east face of the crystalline mass marks a northwest-southeast fault, which ends a short distance to the northwest in the massive body of crystalline rocks north of Pinkham Creek and which probably extends southeast with gradually decreasing throw for several miles before it dies out or is obscured by surface cover. The fault cuts the Dakota sandstone approximately parallel to its strike for several miles and brings the westward-dipping Dakota strata into contact with the granite, the Chugwater, or the Morrison formations, according to the amount of displacement along the fault plane. The Morrison and Chugwater formations also outcrop with westward dips on the east side of the fault, the Chugwater resting upon the main crystalline mass of the Medicine Bow Range. The outcrops of these formations are duplicated on the west side of the fault, the Chugwater resting on the block of crystalline rocks, the Morrison showing in the saddle between the top of the granite ridge and the top of Sentinel Mountain, and the resistant Dakota sandstone outcropping broadly at the summit of the mountain and on its west slope, which conforms to the dip of the rocks.

KERR RANCH FAULT.

Along the east border of the field in the vicinity of the Kerr ranch the lower sedimentary rocks are folded into a sharp anticline with its axis near and approximately parallel to the base of the Medicine Bow Range. The east limb of this fold, in conjunction with the westward-dipping Dakota and lower formations in their normal position on the Medicine Bow crystalline rocks, forms a supplemental syncline on the east side of the anticline. This sharp S-shaped fold is broken by a fault which bears approximately N. 45° W. and extends diagonally from the trough of the syncline on the northwest almost to the anticlinal axis on the southeast. This cuts out a portion of the eastward-dipping beds and brings the axis of the two folds somewhat nearer to each other at their southern extremities than they are farther north. From the Kerr ranch house, near which the trace of the fault is located, the fault extends northwestward for about a mile, beyond which it is believed to die out rapidly in the Pierre shale. On the southeast it extends several miles from the ranch and ends along the contact of the sedimentary and crystalline rocks. The amount of displacement along the fault plane is very small near the ranch house, but it gradually increases to the southeast, where the cutting out of the Dakota, Morrison, and probably the greater part of the Chugwater indicates a throw of 1,200 to 1,800 feet. The present relations of the strata—with eastward-dipping lower Chugwater strata faulted into contact with upper Dakota rocks of similar dip—indicate that the displacement near the southern end of the fault was an upward and eastward thrusting of the south end of the anticline.

The fact that the northern end of the fault does not bring rocks of different formations in contact with each other to any considerable extent indicates that the throw of the fault at the north is slight. On the east of the fault the dip slope of the Dakota sandstone, 20° to 40°, forms the valley wall, and on the west the dip slope of the same sandstone, having eastward dips of similar amounts, forms the east slope of the ridge on that side. The anticline is well marked topographically by the prominent horseshoe-shaped ridge on whose east, north, and west sides the resistant Dakota sandstone outcrops. In the inclosure of this ridge the Chugwater formation outcrops along the axis of the anticline, and the Morrison formation outcrops in a narrow band along the base of the Dakota. Resting on the outer slopes of the Dakota sandstone ridge the Benton and Niobrara rocks dip away from the anticlinal axis at angles ranging from 5° to nearly vertical.

Concerning the source of the pressure which folded and fractured the rocks of this locality there are two hypotheses. One of these is that here, as in various localities along the ranges bounding the park, a fault block or wedge of crystalline rocks has been forced up through the sedimentary rocks, bending and breaking the strata. The other hypothesis, to which the writer is more strongly inclined, is that the tremendous uplifts on either side of the park squeezed the sedimentary rocks to such a degree as to cause buckling or folding in many localities, including the region under discussion.

HILL VALLEY FAULT.

In the valley east of the Hill ranch, in the northwest corner of the park, the outcrops of the Benton and Niobrara formations are duplicated by a strike fault which breaks all of the sedimentary strata below the Pierre shale and which extends nearly due north and south for about 5 miles. On the south it dies out near the south boundary of T. 11 N., R. 81 W., and on the north it strikes into the northwest limb of the Independence Mountain fault. The upthrow of 600 to 800 feet is on the east side of the fault plane and lifts eastward-dipping lower Benton rocks into contact with similarly dipping upper Niobrara beds. The presence and location of the fault are established by the duplication of Benton and Niobrara outcrops, which is substantiated by an abundance of fossil evidence along the fault zone.

FAULT NEAR NORTH END OF McCALLUM ANTICLINE.

In the vicinity of the McCallum mine the anticline is cut by a fault, which, though of comparatively slight extent, is economically important because of its relation to the thick coal bed of that region.

In the McCallum mine on the east limb of the anticline the coal bed dips approximately 20° NE. and by its fractured condition suggests its proximity to a fault. The disappearance of the coal outcrop and the presence of Pierre fossils in rocks on its line of strike disclosed the presence, about 200 feet southeast of the mine, of a fault which bears N. 5° W. from this locality and which cuts into the coal bed and associated rocks diagonally across their dip. The trace of the fault could be followed for less than a mile, at the end of which the coal bed again strikes into the fault. On the west side of the fault the lowest coal-bearing strata strike N. 55° W. and dip northeastward normal to the east limb of the anticline. On the east side of the fault, however, the lower members of the formation swing around the region of local uplift, with gradually changing strike until they meet the fault about a mile north of the mine, where they strike S. 80° W., or approximately at right angles to the fault. The maximum upthrow on the east side of the fault plane is very near the mine, or a short distance south of it, at a spot where rocks well down toward the base of the Pierre shale are faulted into contact with strata normally 2,000 feet or more higher in the section. Northward from the mine the displacement decreases to 600 or 700 feet at the place where the coal bed strikes into the fault from the east, and if this rate of decrease is constant the displacement dies out in the coal-bearing rocks a short distance farther north. South of the mine the apparently unbroken condition of the coal and associated beds about a mile distant on the west limb of the anticline indicates that the fault dies out very rapidly in the Pierre shale. The elevation and subsequent erosion of the rocks east of the fault has resulted in the removal of a thick coal bed from an area approximately a square mile in extent.

MISCELLANEOUS SMALL FAULTS.

Along the east side of the field the Dakota hogback is broken by numerous faults too small to be mapped on the scale used for Plate XII. These faults represent very little displacement, usually less than 100 feet, and are no doubt incident to the bending and compression of the strata caused by the Medicine Bow uplift. A fault of very small throw was observed in the valley of Mexican Creek about 2 miles south of Pole Mountain. It is a normal fault, nearly parallel to the strike of the rocks, which include a coal bed that outcrops in duplicate on opposite sides of the fault plane. Evidence of a fault was observed in the north side of Arapaho Creek valley near the road east of the McIsaac ranch, but data indicating the throw or linear extent of the fracture could not be obtained because of surface cover. The sedimentary rocks of North Park are probably broken by many other small undiscovered faults.

FOLDS.

LOCATION AND ORIGIN.

The sedimentary rocks of North Park have undergone considerable local folding in addition to the great broad flexure which gave a synclinal structure to the field as a whole. The most prominent of the folds are the syncline in the south half of the field, which is approximately outlined by the boundary of the North Park formation, the McCallum anticline and its supplemental syncline between Walden and Canadian River, and the sharp folds in the lower sedimentary beds farther east in the vicinity of the Kerr ranch.

These local folds are believed to be mainly incident to the major synclinal fold produced by the extensive uplifts of the Park and Medicine Bow ranges. These uplifts were sufficient to tilt a thickness of nearly 15,000 feet of strata more or less steeply from both sides toward a central axis, and it is evident that they must have subjected the rock layers to stress in the form of lateral pressure. Near the base of the series this stress may have been so slight that it was mainly taken up in the rocks in the form of increased density, but from the base upward it increased in intensity until it had to be relieved by the folding or breaking of the strata. In the opinion of the writer, both the folding of the sedimentary rocks and the upthrusting of the various crystalline blocks or wedges which caused the larger faults of the field may in large measure be properly assigned to this compression.

NORTH PARK SYNCLINE.

The name North Park syncline is applied to a long synclinal fold extending from near the southeast corner of the park northwestward to within a few miles of Delanos Butte in the central-west part of the field. The synclinal axis extends from near the angle made by Michigan Creek and Owl Mountain ridge, about N. 40° W., to slightly northeast of the Mason ranch, where it swings westward and follows a direction 70° west of north to the west side of the field. The location and approximate extent of the synclinal trough is shown by the boundary of the North Park formation (see Pl. XII), which outcrops entirely within the syncline, occupying the axial zone and major portion of the area affected by the fold. At the western extremity of the syncline the rocks are well exposed, particularly along Grizzly Creek and eastward to the Walden-Coalmont road. In this locality the syncline is somewhat asymmetric, its north limb being tilted about 30° and its south limb about 15°. It maintains this form eastward to the vicinity of Illinois Creek, beyond which the strata are somewhat more sharply though still asymmetrically folded, dipping 40° to 45° SW. immediately south of the Miller ranch and about 25° NE. between Owl and Illinois creeks. So far as could be ascertained, this structure is maintained as far as Owl Mountain, which apparently occupies the southeastern extremity of the syncline. The strata occupying the south limb of the fold farther to the northwest outcrop on the west and south slopes of the mountain below the thick mass of volcanic rock which forms the crest of the ridge. The Owl Mountain region is one of thick timber and surface débris, however, and although the attitude of the strata could not be ascertained, it is evident from the proximity to the Medicine Bow Range that the syncline ends abruptly.

McCALLUM ANTICLINE.

In the area between Michigan and Canadian rivers east of Walden the strata are folded into a large anticline, on which erosion during or subsequent to the folding has removed the Coalmont formation from an area of about 8 square miles, leaving a large exposure of Pierre shale entirely surrounded by outcrops of the younger formation. This anticline is supplemented on the east by a sharp syncline which is marked by the long narrow band of coal-bearing rocks separating the Pierre outcrops of the anticline from those of the Canadian Valley.

The structural details of this region were studied with much care because of their relation to the thick coal bed which outcrops along the base of the Coalmont formation almost completely around the syncline. The several small mines and the many prospects on this coal bed are of value in determining the structural conditions of the region, for their locations show the strike and their entries show the dip of the strata much more definitely and accurately than they could otherwise be ascertained in a region of so much cover. In T. 9 N., R. 78 W., where the folds are sharpest and of greatest magnitude, the outcrops of the coal bed on opposite sides of the anticline are approximately 1¾ miles apart, and between them the upper 2,000 to 3,000 feet of the Pierre shale reach the surface along the eroded anticlinal crest. From this locality the anticline flattens in both directions, as a result of which the coal outcrop closes around the southern extremity of the exposed Pierre shale, crossing the axis of the fold a short distance southwest of the Kerr mine. Farther south the fold continues with much gentler dips to the vicinity of the Dryer ranch on Michigan River, where it meets the east limb of the Owl Mountain syncline. The northward extent of the McCallum anticline and its supplemental syncline is a matter of considerable doubt because of the thoroughly covered condition of the strata north and northwest of the Manning and McCallum coal openings. However, the absence of eastward dips or other evidence of the persistence of this structure in the vicinity of the Dwinell ranch leads to the conclusion that the folds flatten rapidly and die out in the intervening covered area.

The axis of the anticline in the area of outcropping Pierre approximately follows the long axis of the ellipse formed by the boundary of the outcrop. (See Pl. XII.) Northwest of this area its direction is about N. 45° W., and from the vicinity of the Kerr mine southward it describes a gentle reverse curve, first extending nearly due south, then curving eastward for several miles, and finally resuming the southerly direction by another curve. The axes of the anticline and of the syncline on the east are approximately parallel, but they diverge slightly at their northwest and southeast ends, where the rocks are less sharply folded. Marked variations in dip occur along the sharply folded section of the syncline and particularly along the east limb, which is overturned in two localities. One of these is at the Lange shaft, in which the dip is believed to be eastward, though only a few degrees from vertical. The shaft is entirely within the coal bed, however, and the dip reading was obtained on fracture planes of the coal, and this, in the absence of corroborating evidence, is unsatisfactory. About half a mile south of this locality the coal bed dips 57° W., and 1 to 2 miles northwest a sandstone immediately below the coal dips only 23° W. At the Sudduth mine, farther northwest, the strata are again overturned, the comparatively low westward dips giving way to a dip of 85° E. Northwest of the Sudduth mine no dips were obtained on the east side of the syncline short of the abandoned Ballinger coal mine, where the beds dip 27° W.

The west limb of the syncline likewise shows considerable diversity of dip, but so far as known the rocks are nowhere overturned. At the McCallum mine the rocks dip 20° E. into the fault, which (see p. 88) breaks the rocks diagonally between the synclinal and anticlinal axes. East of the region affected by the fault the rocks dip 50° E. but steepen to vertical in the locality due west and across the syncline from the Sudduth mine. From this locality southward the strata resume eastward dips, decreasing gradually to 56° at the Marr mine and 45° at the point where the strike turns westward near the Kerr mine. On the west side of the anticline the evidence indicates a uniform dip of 30° W. along the coal outcrop with gradual flattening toward the center of the park. In the vicinity of Moore Mountain the syncline widens considerably and is much shallower than farther north, as indicated by its dips, which average about 20° E. along the west side of the mountain and about 25° W. in the Canadian Valley.

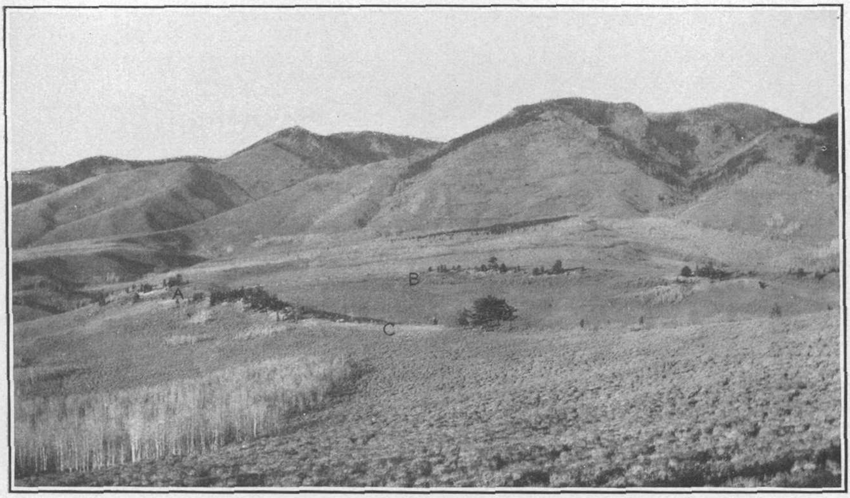
The folds in the rocks of this region are of much greater economic importance than other minor structural features because of their effect on the thick coal bed in the basal portion of the Coalmont formation. This coal bed, which ranges from 30 to 50 feet in thickness, outcrops persistently around the exposure of Pierre shale along the crest of the anticline, and it was almost undoubtedly continuous, previous to the folding and erosion, across the area now occupied by the Pierre. As a coal bed 1 acre in extent and 1 foot thick contains approximately 1,800 tons, the removal of a 30-foot bed from 8 square miles means the loss of over 275,000,000 tons of coal. This loss, however, is in large measure or perhaps entirely compensated by the enhanced quality of the coal resulting from the driving off of volatile matter by the stress of folding and also by the increased accessibility of a large part of the coal bed which, had it not been folded, might have been left below the depth limit at which coal can be advantageously mined.

FOLDS NEAR THE KERR RANCH.

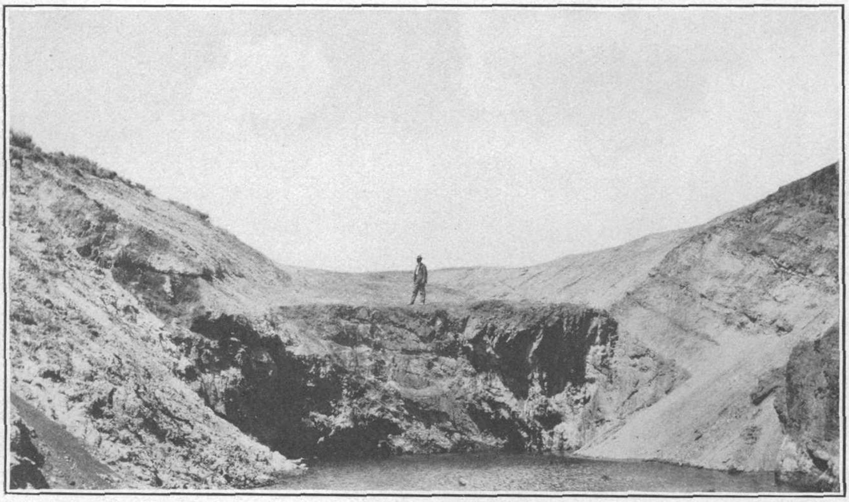
Across the Canadian Valley from the McCallum anticline and the adjacent region of folded rocks similar folds affect a smaller area of the oldest sedimentary rocks along their contact with the crystalline mass of the Medicine Bow Range. The folds in this locality are broken by the Kerr ranch fault. (See p. 86.)

PINKHAM CREEK FOLDS.

Along Pinkham Creek, near the mouth of King Canyon, in the northeast corner of the park, the westward-dipping strata of Sentinel Mountain strike northward directly against the granite brought up by the major fault on this side of the field. A short distance west-



A. V-SHAPED FOLD (B-A-C) IN DAKOTA SANDSTONE.



B. MARR COAL BANK.

ward along the fault these rocks rise again in a small steeply pitching anticline, around which the Morrison, Dakota, Benton, and Niobrara formations outcrop in the shape of a V with both limbs terminated by the fault. Plate XII shows the extent, shape, and magnitude of this anticline and its relation to the small syncline supplementing it on the east.

MISCELLANEOUS SMALL FOLDS.

A great many small and relatively unimportant folds were observed in the strata at various localities, but these, with the exception of a few of the more conspicuous, are not shown on the geologic map. Those which may serve as landmarks are a small sharp prominent fold in the Dakota hogback near the center of T. 10 N., R. 78 W. (see Pl. IX, *A*), a small syncline containing an isolated area of Niobrara rocks along the Roaring Fork below Red Canyon, a shallow synclinal fold in the region of the Mitchell mine, and a small synclinal fold marked by a low, indistinct sandstone ridge in the Pierre shale at locality 23, about 3 miles northwest of Delanos Butte.

ECONOMIC GEOLOGY.

MINERAL RESOURCES.

The coal of North Park is by far its most important known mineral resource, although in past years comparatively small quantities of certain metallic minerals have been mined at various localities around the border. Nearly all these attempts to carry on metal mining were made on low-grade ores and at a time when North Park was practically isolated through lack of transportation facilities. It is certainly not beyond the bounds of possibility that, with present railroad facilities, considerable quantities of low-grade copper, silver, or gold ore may in future be mined from the ranges bounding the park, but as the investigation of the coal resources was the primary object of the work here reported only a few brief notes concerning the metals and nonmetallic minerals other than coal were made. (See pp. 116–118.)

Coal was discovered in North Park more than 30 years ago, and since that time small quantities have been mined for local domestic use. Development and operation on a commercial scale were, however, impossible until the completion of the railroad early in 1912, since when the Northern Colorado Coal Co. has marketed a small amount of coal outside of the park.

COAL.

GEOLOGIC OCCURRENCE.

The coal beds of North Park are contained in the Coalmont formation, of late Cretaceous or early Tertiary age, and are mainly, if not entirely, confined to the lower 2,000 to 3,000 feet of the formation. The most important bed, which outcrops around the McCallum anticline in the eastern part of the field, is almost at the very base of the formation, immediately above the great unconformity which separates the basal sandstone of the Coalmont formation from the highest Pierre strata of the Upper Cretaceous. Two comparatively thin coal beds which outcrop very near each other in a zone approximately 2,000 feet above the main coal bed on the west side of the anticline are stratigraphically the highest coals found in the east half of the field. This fact, together with the stratigraphic position of the beds mined at the Monahan and Mitchell mines on the west side of the park and the possibility that the top of the Pierre is brought very close to the surface by the Pole Mountain uplift (which, if true, means that the coals of the Coalmont district are in the lower part of the Coalmont formation), strongly indicates that all the coal beds of North Park are confined to the lower part of the Coalmont formation.

The apparent impossibility of tracing the coal outcrops beyond the points to which they are mapped on Plate XII leads to the belief that the beds are very lenticular. Their disappearance might be attributed to the widespread mantle of surface cover which obscures the major portion of the park floor were it not for variations in thickness that are so great as to indicate lenticularity and for the fact that the coals are absent at a few localities where rocks at what is assumed to be their true geologic horizon were exposed. The formation, in very small areas, of such extraordinarily thick beds of coal as those of the Coalmont and McCallum anticline regions is of much interest because of their probable formation either in marshes which underwent constant depression and filling for a much longer period than usual or in marshes in and around which conditions were exceptionally favorable to the rapid accumulation of vegetal or other organic matter. The apparent absence of carbonaceous shale beds, such as commonly connect the coal lenses of each horizon in other regions of lenticular coal, points to the local occurrence of coal-forming conditions or of conditions closely approaching that character and indicates that the surface of the region was made up of land, lake, and marsh areas existing contemporaneously at various epochs during the coal-forming period.

The coal beds are associated for the most part with layers of soft shale or with thin friable, slightly resistant sandstones which weather down rapidly, obscuring the outcrops to a very large extent except in localities where stream erosion is most active.

The coal beds of greatest commercial importance outcrop in the McCallum anticline district between Michigan and Canadian rivers and in the Coalmont district in the southwestern part of the field.

Thinner beds of relatively small extent are apparently isolated in the Monahan and Mitchell mine localities on the west side of the field and in two localities near the southwest corner of the park—one on Colorado Creek below the Clover Valley ranch, the other near Arapaho Pass.

McCALLUM ANTICLINE DISTRICT.

GENERAL FEATURES.

On the basis of quantity and quality of the coal the McCallum anticline district is believed to be of much greater importance than all the remaining coal areas of the field combined, notwithstanding the facts that it is undeveloped except for local consumption and that the thick bed of the Coalmont district was apparently the objective point of the railroad and is being mined commercially.

The coal outcrops are mapped on Plate XII in solid heavy lines where their existence is known beyond reasonable doubt and in broken lines where their existence beneath surface cover has to be inferred. Reference to the map and to the discussion of the structure of this region (pp. 90–92) will be of value in connection with the following description of this district.

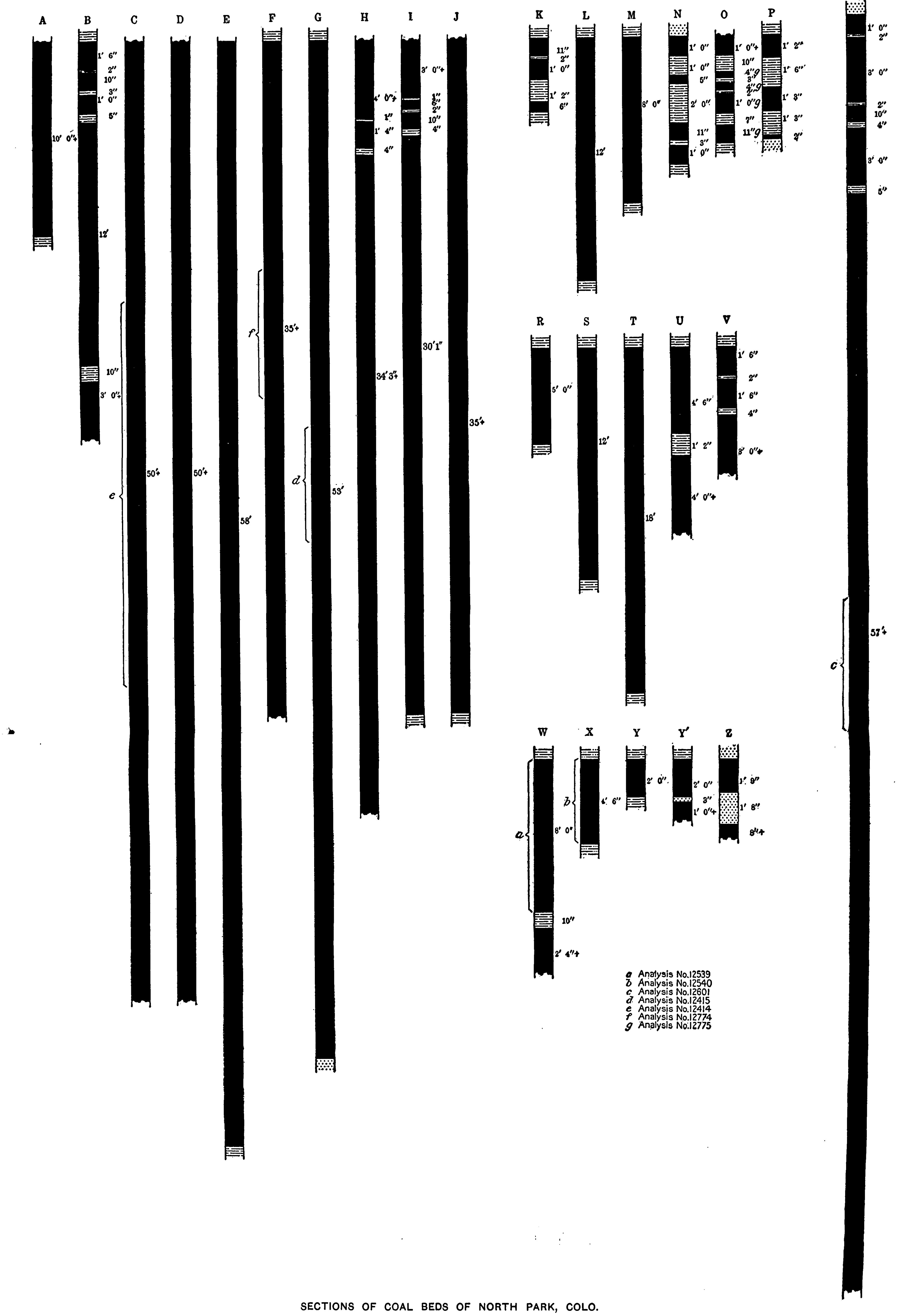
The district is located east of Walden, occupying most of the elongated northwest-southeast region between the Michigan and Canadian River valleys. It comprises a strip about 16 miles long by 4 to 5 miles wide, all of which is believed to be underlain by coal, with the exception of about 7 square miles along the crest of the anticline in the heart of the region, from which the coal has been removed by erosion.

COAL BEDS OF THE DISTRICT.

Sudduth bed.—The principal coal bed, which nearly all of the mines and prospects of the east side of the field have opened, is designated the Sudduth bed because of Mr. D. N. Sudduth's activities in locating the outcrop and prospecting the bed, which he subsequently developed to some extent at the Sudduth mine. This bed outcrops near the base of the coal-bearing formation and closes around the exposures of Pierre shale along the anticlinal axis. The outcrop is visible at several places around the anticline and is precisely located (see Pl. XII), except in the region northwest of the McCallum and Manning coal openings, where the rocks are completely obscured by surface cover, thus leaving indefinite the locality at which the outcrop closes on the northwest. The steep easterly dips of the east limb of the anticline carry the coal bed to a depth of 1,500 to 2,000 feet along a zone roughly parallel to the anticlinal axis and about 1 to 1½ miles distant, east of which the strata are sharply folded, bringing the coal bed to the surface again along the east side of the syncline thus formed. This outcrop follows closely the easternmost boundary of the coal-bearing rocks from the area east of the Dwinell ranch for 15 miles or more along Canadian River nearly to the Winscom ranch, on the headwaters of that stream. East of the Dwinell ranch a trench was dug across the outcrop zone near the southeast corner of sec. 24, T. 10 N., R. 79 W., exposing 10 feet of much weathered coal dipping 30° W. (See section A, Pl. X.) The coal was recognized as the Sudduth bed by its position immediately above the top of the Pierre shale and by its relation to a ridge-forming sandstone similar to that which marks the bed farther south between the Sudduth and Lange coal openings.

On the northwest the outcrop disappears beneath surface cover and the extent of the bed in this direction is unknown. On the southeast the outcrop zone lies in the meadows of the Canadian Valley for several miles. The next exposure of the coal occurs in the south side of sec. 32, T. 10 N., R. 78 W., at what is known as the Ballinger bank. Here the coal bed is well exposed, having a thickness of approximately 20 feet and a dip of 27° W. Between this locality and the Sudduth mine the outcrop is concealed except on the hillside about one-fourth mile south of the Two-Bar ranch road, where a considerable quantity of coal bloom and coarser coaly material dug up by badgers marks the location of the bed. At the Sudduth mine the coal bed is slightly overturned, having been tilted past vertical to 85° E. The thickness of coal exposed in the mine is 21 feet, but the total thickness reported by Mr. Sudduth as having been determined by drilling is at least 50 feet.

Southeastward from this mine the coal bed resumes its normal westward dip. It flattens to 22° in sec. 23, T. 9 N., R. 78 W., which it crosses diagonally from the northwest to the southeast corner, and though not accessible for measurement is well marked by its association with a small reddish-brown sandstone ridge. Farther southward across sec. 25, the bed again assumes a nearly vertical position at the Lange shaft, where a somewhat doubtful reading indicates a dip of 85° W. and where it is reported to be more than 50 feet thick. A trench across the coal outcrop about half a mile south of the Lange shaft shows 58 feet of weathered coal dipping 57° W. This is the last locality on the southeast at which the coal is accessible for measurement, but the location of its outcrop is indicated at places almost to the center of T. 8 N., R. 77 W., by the presence of coal bloom near a small sandstone ridge which is evidently a continuation of the small ridge northwest of the Lange shaft. About one-half mile southeast of the Doner ranch house coal bloom is very evident on the surface of a strip several hundred feet long and about 30 feet wide. This was trenched at one locality to a depth of nearly 6 feet, and although only shale mixed with coaly material was found, it



SECTIONS OF COAL BEDS OF NORTH PARK, COLO.

Letters at head of sections indicate localities marked by corresponding letters on Plate XII.

seems evident that coal of considerable thickness is present beneath the mantle of surface cover.

Westward across the syncline from the Lange shaft the Sudduth bed appears at the surface along the east limb of the McCallum anticline; its northernmost accessible point being at the McCallum mine. Although the thickness of coal exposed in the mine is not more than 15 feet, neither top nor bottom of the bed is exposed, and the total thickness is reported as 35 feet. The coal dips 20° NE. into a fault which cuts the bed diagonally across the strike a few hundred feet east of the mine and which also cuts off the outcrop at a like distance on the southeast. About one-half mile northward, on the east side of this fault, the strata adjacent to the coal bed strike into the fault from the east, but the coal is concealed by surface cover and is not accessible for measurement. The outcrop swings around the uplifted region east of the fault and resumes its normal southeasterly strike, as indicated by the coal bloom on the hillside near the center of sec. 8, T. 9 N., R. 78 W. From this locality southeastward the bed is concealed for a distance of several miles, throughout which no data concerning it are available except about one-half mile west of the Sudduth mine, where the vertical attitude of some outcropping sandstones indicates that the coal bed is on edge.

The location of the concealed bed again becomes evident in sec. 26 by its relation to the sandstone horizon marker, which is more or less prominent along the coal outcrop at many localities in the district and which is indistinctly discernible at places across the section. As indicated by outcropping sandstones of the Pierre shale, which are known to lie only a short distance stratigraphically below the coal, the dip of the Sudduth bed is here about 65° slightly north of east.

At the Marr mine, in the north side of sec. 35, the coal bed is well exposed except for a few feet at the base. It dips 56° E. The total thickness of the bed is reported by Alex Marr as 53 feet, of which about 40 feet is exposed in the open cut, with the base covered and inaccessible. This is well shown in Plate IX, *B*. South of the Marr mine the outcrop is trenched at several places and is fairly evident for about 1½ miles, to the vicinity of the Kerr mine, in the SW. ¼ sec. 2, T. 8 N., R. 78 W. Here the bed dips 45° slightly south of east and is reported to be more than 40 feet thick. The mine shaft was nearly full of water, and only a few feet of coal near the top of the bed was visible, so this report could not be verified. The bed strikes southwestward at this locality, and within a mile of the mine it swings westward across the anticlinal axis and thence northwestward with westerly dip on the west side of the anticline. The location of the outcrop is marked by coal bloom and weathered coaly material at places from the Kerr mine to the coal exposure in the north side of sec. 28, T. 9 N., R. 78 W., at which locality a partial exposure of the bed shows 20 feet of coal dipping 30° SW. The coal bed was opened in this locality at one time, and it is reported that the total thickness of coal is approximately 35 feet. From this exposure northwestward to the Manning prospect the outcrop is marked at widely separated places by coal dust and in one locality by red slag and baked sandstone and shale, caused by the local burning of the coal. At the Manning prospect the opening exposes about 15 feet of coal near the middle of the bed. The thickness of weathered coal which was uncovered above and below the exposed zone indicates, however, a total thickness of at least 35 feet. The bed dips 30° SW. and strikes approximately N. 60° W. From this prospect northwestward the coal outcrop can be followed for about a quarter of a mile to a spot where it disappears in the flat sage-covered bench which conceals both sides of the anticline at its northern extremity.

In mapping the Sudduth bed between the Lange shaft and the Sudduth mine coal bloom was observed at several horizons a few hundred feet higher than the large bed in sec. 23. The indications of coal are very slight, and although considerable prospecting has been done no coal of value was found, and it seems probable that the coaly material on the surface represents the weathered outcrops of several thin coal streaks.

The chemical character of the coal of the Sudduth bed is shown by analyses of three samples collected from the Marr, Sudduth, and McCallum mines (Nos. 12415, 12414, 12774, respectively, in the table on p. 113).

Capron beds.—In the SE. ¼ sec. 19, T. 9 N., R. 78 W., a coal bed that has a thickness of 12 feet outcrops in an abandoned open cut which marks the location of what was once known as the Capron mine. About 300 feet stratigraphically below this bed is a 6-foot bed of brownish-black carbonaceous shale containing several thin layers of coal. Northwest of the Capron mine these beds are apparently covered, but southeast of it their outcrops were mapped for about 2 miles, to the south side of sec. 29. Here the distance between beds is approximately the same as at the Capron mine, but the character and thickness of the beds are apparently reversed, the upper 7 feet consisting of carbonaceous shale containing thin layers of coal and the lower 8 feet consisting of coal. (See section M, Pl. X.) These beds are approximately 2,000 feet stratigraphically above the Sudduth bed on the west side of the anticline and dip uniformly 22° SW.

Winscom beds.—In sec. 14, T. 8 N., R. 78 W., a thin coal bed containing several shale partings has been mined by William Winscom. This bed occupies approximately the stratigraphic position of the upper Capron bed and like it is separated by several hundred feet of strata from a lower bed of similar character and thickness. It seems highly probable that these beds represent the Capron beds, and although the coal is evidently not persistent as a minable bed from one area to the other, it is not improbable that lenses of commercially valuable coal occur in various localities at this horizon.

The Winscom mine is located on the east side of the McCallum anticline, and the coal dips 27° slightly south of east into the west side of Moore Mountain. (See sections N and O, Pl. X, and analysis 12775, p. 113.)

On the Charles Winscom ranch, near the northeast corner of sec. 29, T. 8 N., R. 77 W., 5 feet of alternating shale and coal, dipping 7° SW., outcrops in a small gully on the east side of the syncline. From the character of the bed and its stratigraphic position it is believed to represent the upper Capron coal and possibly to connect with the bed mined in the Winscom mine. (See section P, Pl. X.)

Hill bed.—On the east side of the Michigan River valley, in the NW. ¼ sec. 19, T. 10 N., R. 79 W., a coal bed is opened at what is known as the Hill mine. This is an abandoned coal opening which is separated from the main part of the McCallum anticline district by several miles of territory in which the rocks are very much covered, so that the relation of this coal bed to others of the district is largely a matter of conjecture. The bed dips 10° W. in this locality, which is probably some distance north of the region affected by the McCallum anticline and is evidently very near the axis of the major syncline of the field. Although the bed appears to be somewhat higher in the section than the Capron and Winscom coals, the uncertainty as to the dips and the location of the Pierre-Coalmont contact to the east of the mine render the stratigraphic position of the bed very doubtful. As this bed is very similar in character, however, to the Capron and Winscom beds, and as there is no proof that it does not occur at the same horizon, there seems to be strong ground for correlating it with them. The coal is covered and is not accessible except in the immediate vicinity of the mine. (See section K, Pl. X.)

DEVELOPMENT.

In the McCallum anticline district mining has been carried on only to supply local domestic needs, and the mines from which most of the coal has been taken are very crudely equipped and in size are scarcely beyond the prospect stage.

McCallum mine.—The McCallum mine is about 5 miles northeast of Walden, in the NE. ¼ sec. 18, T. 9 N., R. 78 W. It is an opening on the thick Sudduth bed, which in this locality strikes N. 55° W. and dips 20° NE. At the time of the field work on which the present report is based the mine consisted of a slope driven down the dip of the coal bed for 50 feet, beyond which it is widened into a room with a nearly horizontal floor extending about 50 feet farther in the direction of dip. This room is of irregular shape, 20 to 25 feet wide and about 10 to 12 feet high, and is crudely timbered. No particular system of mining had been followed and the mine is in bad shape for further development work. The slope and room were driven in the middle of the coal bed, which is reported 35 feet thick, so that both roof and floor are of coal. The exposed portion of the bed consists of fairly hard black coal, practically free from partings but showing considerable fracturing, no doubt due to its proximity to a fault which breaks the bed a few hundred feet east of the outcrop. The mine has been worked intermittently in past years, and the total output has been used locally for domestic purposes. It was reported in 1911 that the mine was to be equipped and operated on a commercial scale during the winter season. The cutting off of the coal bed, however, by the fault a few hundred feet east of the mine opening precludes the possibility of extensive development in that direction. (See section F, Pl. X, and analysis 12774, p. 113.)

Sudduth mine.—The Sudduth mine, owned by D. N. Sudduth, is in the SW. ¼ sec. 15, T. 9 N., R. 78 W., about 7½ miles slightly north of east from Walden. The mine consists of an entry or room driven horizontally about 70 feet into the Sudduth coal bed, which outcrops in the hillside in a practically vertical position. The room widens from about 8 feet at the opening to approximately 25 feet at the face of the coal and it varies in height from 10 to 15 feet, the roof being supported by posts. The coal exposed in the mine is clean, hard, and glossy black, and though only 25 feet of the bed could be measured the total thickness is said by Mr. Sudduth to be in excess of 50 feet. The comparatively small amount of coal mined here has been used by ranchmen of the community and is said to be a very satisfactory domestic fuel. (See section C, Pl. X, and analysis 12414, p. 113.)

Marr mine.—The Marr mine is about 8½ miles a little south of east from Walden, in the NE. ¼ sec. 35, T. 9 N., R. 78 W. At this locality two openings have been made on the large coal bed by A. K. Marr and a small quantity of coal has been mined for local use. At the time of the field examination both entries were full of water and inaccessible, as a result of which but little is known concerning the workings. The southernmost entry is at the bottom of an open cut in which about 40 feet of coal is exposed. The bed is reported by Mr. Marr to be 53 feet thick and to consist throughout of a very good grade of coal, free from partings except for several 1-inch sandy layers near the top. The coal is considerably weathered at the surface but is very firm and solid at a depth of a few inches, and, so far as could be observed, it contains but two or three unimportant partings. (See section G. Pl. X, and analysis 12415, p. 113.)

Kerr mine.—The Sudduth bed was opened some years ago in the SW. ¼ sec. 2, T. 8 N., R. 78 W., by William Kerr, who sunk a shaft in the outcrop of the bed and mined a small amount of coal. The rocks strike approximately S. 20° W. and dip 45° SE. at the mine, which is on the east limb of the McCallum anticline, less than a mile from where the coal outcrop swings westward across the anticlinal axis. At the time of the field examination the shaft was nearly full of water, so that only the upper 10 to 12 feet of the coal was visible. Near the top the bed contains several sandy partings, each less than an inch in thickness, which, from their similarity in character and position to the partings near the top of the coal in the Marr mine, are thought to be persistent for a considerable distance. The thickness of the bed, which was reported as more than 40 feet, could not be determined by actual measurement but is believed to be conservatively reported, judging from the proximity to the thick coal sections at the Marr mine and south of the Lange shaft. (See section H, Pl. X.)

Lange, Manning, and Ballinger prospects.—The Lange prospect is about a mile east of the Marr mine in the SW. ¼ sec. 25, T. 9 N., R. 78 W. It consists of a shaft about 45 feet deep (sunk by August Lange) in the upturned coal bed, which is nearly vertical. The work was done for prospecting purposes, and, so far as known, no attempt has been made to market the coal. (See section D, Pl. X.)

The Manning prospect is in the SW. ¼ sec. 18, T. 9 N., R. 78 W., about a mile southwest of the McCallum mine. It consists of a slope driven down the dip of the coal for probably 30 to 50 feet, though the entry was caved and inaccessible and its length could not be measured. The development work at this locality was done in compliance with requirements of the coal-land law, and, so far as known, none of the coal mined was placed on the market. (See section J, Pl. X.)

A coal bank marks the site of what was formerly known as the Ballinger mine, about a mile west of the headquarters of the Two-Bar ranch, in the SW. ¼ sec. 32, T. 10 N., R. 78 W. The Sudduth bed, having a thickness of approximately 20 feet and dip of 27° W., is exposed here in a much weathered open cut or cavity due to the caving of the old Ballinger entry. The appearance of the weathered coal indicates that the bed at this locality contains several soft shaly layers and in general has a high ash content. This accords with the statement of a former employee of the Ballinger mine, who reports that the workings were abandoned because the coal was less satisfactory than that available elsewhere in the park. (See section B, Pl. X.)

Capron mine.—The abandoned Capron mine is about 4½ miles east of Walden, near the center of sec. 19, T. 9 N., R. 78 W. This mine was operated on a small scale in former years, and its output was used locally for domestic fuel. The mine was abandoned some years ago, however, because of the poor quality of the coal as compared with that mined in other localities, and at present only a weathered coal dump and a small amount of débris left from the mine equipment remain as evidence of the former activity. The coal is soft and somewhat shaly, and the bed, which dips 22° SW., is 12 feet thick. (See section L, Pl. X.)

Winscom mine.—The Winscom mine, in the NE. ¼ sec. 14, T. 8 N., R. 78 W., is owned by William Winscom, who has done considerable development work on it. The beds are exposed on the west slope of Moore Mountain, striking nearly north and south and dipping 25° to 30° into the mountain. A prospect entry was first driven in the lower bed in the section north of the mine, but the bed failed to show the anticipated improvement in quality and increase in thickness at increasing depths from the surface, and the prospect was abandoned. The entry now known as the Winscom mine was then driven on the upper bed. In the fall of 1911 it consisted of an entry about 125 feet long, approximately following the strike of the bed. The bed as exposed in the entry (see section D, Pl. X) consists of alternating layers of coal and carbonaceous shale or clay with coal roof and shale floor. So far as known to the writer no coal has been sold from this mine. (See analysis 12775, p. 113.)

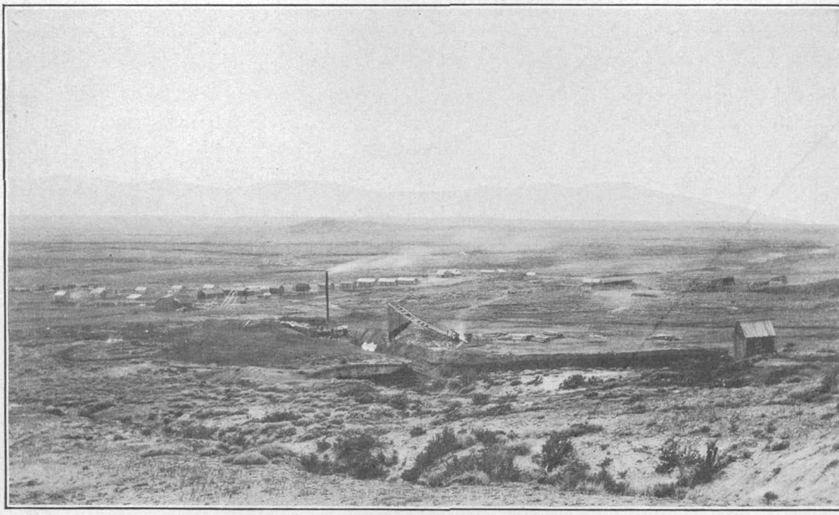
Hill mine.—A thin coal bed, comparable in character to the Winscom bed, was opened some years ago in the NW. ¼ sec. 19, T. 10 N., R. 79 W., by an opening known as the Hill mine. Only a partly caved open cut remains, but it is reported that a small amount of coal was mined in past years. The coal bed (see section K, Pl. X) contains shale partings of such thickness that the bed is of little commercial value, unless the partings thin or the coal thickens considerably with depth.

COALMONT DISTRICT.

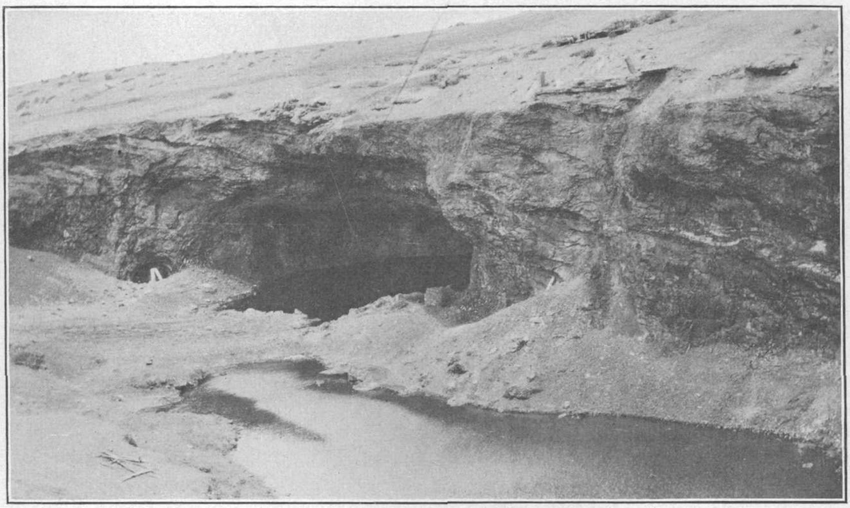
GENERAL FEATURES.

The construction of the railroad to the heart of the Coalmont district and the commercial operations of the Northern Colorado Coal Co. at Coalmont make the district of primary importance in the field from the standpoint of present and perhaps near future development and production. The actual coal exposures of the district are indicated on Plate XII.

The coal of the Coalmont district, which occupies the central part of the southwest quarter of the field, is thought to be mainly confined to the area between the forks of Grizzly Creek, north and northeast of Pole Mountain. The district centers about the coal outcrops near



A. COALMONT FROM THE SOUTHEAST.



B. UPPER 30 FEET OF RIACH COAL BED.

Coalmont (see Pl. XI, *A*) but is ill defined because of the uncertain extent of the beds. The great thickness of the Riach coal bed and of two lower beds in the immediate vicinity of Coalmont indicates that these beds may be persistent over a considerable area. The failure to find them exposed along the forks of Grizzly Creek in either direction on the line of strike is notable, however, notwithstanding the débris-covered condition of the interstream areas and the partly concealed stream banks and valley walls. Owing to the scarcity and conflicting nature of the evidence the extent of the coal-bearing region is very doubtful and can probably not be determined except by extensive drilling or further development work. In the opinion of the writer the coal exposures indicate probably 5 square miles of coal land or possibly a little more. A less conservative statement placing the area underlain by coal at 50 square miles or more would, however, be extremely difficult to disprove.

COAL BEDS.

Riach bed.—The most important bed of the district is the thick bed mined by the Northern Colorado Coal Co. at Coalmont. This bed has been known to the inhabitants of the park as the Riach bed since its discovery more than 30 years ago by the Riach brothers on their ranch, which included the present site of Coalmont. About 30 feet of coal is exposed in the large open cut (see Pl. XI, *B*), which was known as the Riach mine up to the time when the present company started underground operations. The main entry of the mine passes below the north end of the open cut and is connected with it by an air shaft in which a thickness of 40 to 50 feet of practically solid coal is visible. Supt. Stewart Kennedy reported the maximum thickness of coal, as determined by drilling in the immediate vicinity of the mine, as 66 feet, and stated that this thickness consists of clean hard coal throughout, except for several 3 to 5 inch layers of shale and clay, known to the miners as "slate" and "soapstone," which occur from 5 to 10 feet below the top of the bed. The rocks strike N. 25° W. and dip 18° NE. at the mine but change abruptly in strike and dip about 1,500 feet to the north, where an exposure of sandstone and shale shows a strike N. 35° E. and a dip of 27° SE. The persistent northwest strike of the lower beds and the underground workings of the mine, however, indicate that the attitude of the beds 1,500 feet north of the mine is probably surficial and may not represent that of the coal bed. At an equal distance slightly east of south from the mine well-exposed beds strike N. 50° W. and dip 22° NE. The large coal bed, however, does not appear at the surface in either of these localities, and in fact is not definitely known to outcrop anywhere except in the open cut at the mine. Near the site of the old Spicer mine, in the NE. ¼ sec. 31, T. 7 N., R. 80 W., a considerable thickness of coal outcrops in the bed of Grizzly Creek, and 2 to 6 feet of coal containing thin shale partings is exposed in the creek bank just above the water. The coal in the creek bed is under 1 to 2 feet of water but is apparently well preserved, judging from the condition and appearance of several blocks of coal which were dug out and examined. This coal resembles that of the Riach bed in fracture and general appearance, and because of its location approximately on the strike line of that bed it is believed to be at about the horizon of the Riach coal bed and perhaps to be a continuation of it. Just below the old Spicer mine the stream flows over coal for a distance of 100 feet or more, indicating a bed of considerable thickness, notwithstanding the fact that the dip is here not over 15°. The old Spicer mine has long been abandoned and inaccessible and no information was obtained as to the total thickness of the coal, though several reports agree that the total thickness was considerably in excess of the 8 or 10 feet formerly exposed in the mine entry. The correlation of this coal with the Riach bed is admittedly doubtful, because of the absence of additional outcrops between or on either side of these two, as might be expected in the case of so thick a bed. However, the similar character of the coal from these two localities, together with their apparent occurrence at the same geologic horizon and the fact that an almost equally thick coal bed is completely concealed throughout longer distances in the McCallum anticline district, seems to indicate that the correlation is well founded.

Lower beds of Coalmont section.—About one-fourth mile south of the Coalmont mine a 5-foot coal bed is exposed in the bank of a dry stream channel. This coal, which lies approximately 360 feet stratigraphically below the Riach bed, is overlain by dark carbonaceous shale and is separated from a brown shale bed below by a thin hard brownish layer apparently containing much iron. Because of the variable thickness and soft shaly character of the coal it has little or no commercial value. The bed, which strikes N. 60° W. and dips 22° NE., is exposed for only a short distance. (See section R, Pl. X.)

The next bed occurs about 1,000 feet lower in the section and is exposed in a prospect shaft located 3,500 feet S. 16° W. from the mouth of the Coalmont mine. The thickness of coal exposed in the shaft is 12 feet and although not accessible for detailed examination it is reported to be of very good quality. Lumps of coal several inches in diameter were obtained from a stock pile near the mouth of the shaft and were found to be very well preserved notwithstanding their partial exposure to the weather for a long period of time. The physical character of the coal appears to resemble very closely that of the Riach bed. The extent of this 12-foot bed is entirely a matter of conjecture, as the strata are concealed by surface cover and no evidence of outcropping coal is to be seen outside of a radius of 100 feet from the shaft. (See section S, Pl. X.)

A coal bed measuring 18 feet in thickness is exposed in a shaft in the NW. ¼ sec. 26, T. 7 N., R. 81 W., about a mile nearly due southwest of Coalmont. This bed is about 1,250 feet stratigraphically below the 12-foot bed and like it is entirely concealed except where opened by the shaft. At the time of the field examination the shaft was nearly filled with water and only the upper part of the bed was visible. This was examined with difficulty and apparently consists of clean hard coal, which Mr. Kennedy states is representative of the entire 18 feet. In this locality the rocks strike N. 45° W. and dip 16° NE. (See section T, Pl. X.)

The Taylor bed, whose stratigraphic relation to the beds just described could not be definitely determined, outcrops near the south quarter corner of sec. 21, T. 7 N., R. 81 W., in what is known as the old Taylor mine. This consists of a caved entry, apparently long abandoned, from which, it is reported, a small amount of coal was mined in past years for local ranch use. The bed (see section U, Pl. X) is made up of two benches of coal separated by a shale parting 14 inches thick. The upper bench is 4 feet 6 inches thick and the lower is somewhat more than 4 feet, complete measurement being impossible because of water which filled the bottom of the prospect. The two benches, though much weathered, are apparently uniformly hard and free from bone or other partings. The attitude of this bed, which strikes nearly due north and south and dips 10° W., as opposed to the eastward dip of the 18-foot bed last described, shows anticlinal structure which is, in all probability, due to an uplift centering about the region of Pole Mountain. Exposures across the fold are not sufficient, however, to determine the relation of the Taylor bed to those on the east side of the Pole Mountain ridge, and though it may be the same as the 18-foot bed it is believed to lie at a somewhat lower horizon.

A coal bed (see section V, Pl. X) is exposed near Mexican Creek in the SW. ¼ sec. 9, T. 6 N., R. 81 W. This locality is approximately 2 miles due south of the summit of Pole Mountain and is within the region affected by the Pole Mountain uplift. The coal bed is broken by a strike fault of small throw which causes duplicate outcrops of the coal only a few hundred feet apart. The direction of the fault is N. 60° W., corresponding to the strike of the rocks on the northeast. On the southwest or upthrow side, however, the strike is N. 30° W. and the dip is 12° SW., differing slightly in direction but not in degree from that on the opposite side of the fault. The coal bed consists of 6 feet of fairly hard black coal of woody appearance, containing a 2-inch clay parting 18 inches below the top and a 4-inch clay parting at the middle of the bed. A small amount of surface mining has been done in this locality by ranchmen, but the evidence indicates that the work was carried but little if any beyond the prospect stage. The coal is exposed for only a few hundred feet, and in both directions it disappears beneath surface cover.

DEVELOPMENT.

Mine development in the Coalmont district is at present confined to the activity of the Northern Colorado Coal Co., at Coalmont. In several localities there still remain evidences of coal openings made in former years, but with the development of the comparatively high grade and easily minable Riach bed efforts to mine coal in other localities of the district have been abandoned.

Northern Colorado Coal Co.'s mine.—The Northern Colorado Coal Co.'s mine is the present-day development of what has been known for many years as the Riach mine. It is on the Riach coal bed at Coalmont, in the SW. ¼ sec. 24, T. 7 N., R. 81 W., where the bed dips 18° NE. and is reported to be 66 feet thick. For many years the local market was supplied with coal from the large open cut, which is now approximately 250 feet long, 100 feet wide, and 25 to 40 feet deep, and in which about half of the reported thickness of the coal bed is exposed. The mine is owned by the Northern Colorado Coal Co., for which Mr. Stewart Kennedy is superintendent of operations. The tipple, which is constructed over the railroad about 500 feet west of the mine opening, and the steam haulage machinery constitute the principal outside equipment. In October, 1912, the underground workings consisted of a main slope or haulage way, which had been driven about 800 feet on the dip of the bed with side entries extending about 1,000 feet in both directions along the strike. From these side entries the coal is mined by working out rooms, between which pillars are left to support the roof. Both roof and floor are of coal, as the underground workings are confined to the central zone of the thick bed. The mine employs 30 to 40 men and has a capacity of about 800 tons per day but was reported by the superintendent as producing at about half capacity because of the shortage of railroad cars. A considerable portion of the output of the mine is sold for domestic use in the park and in various towns along the main line of the Union Pacific Railroad. (See section Q, Pl. X, and analysis 12601, p. 113.)

Abandoned mines.—Development work in former years is indicated by remaining evidence of prospecting and mining. The Spicer mine, which was opened many years ago, is on the bank of Grizzly Creek in the NE. ¼ sec. 31, T. 7 N., R. 80 W. Practically all evidence of mining in this locality is obliterated and the coal bed is not accessible except as it appears in the creek bed a short distance from the depression which marks the former mine opening. The coal resembles that of the Riach bed in appearance and character and is not improbably a continuation of the same bed. It is reported that the Spicer mine at one time supplied a considerable local demand.

The mouth of an abandoned entry near the south quarter corner of sec. 21, T. 7 N., R. 81 W., is the only remaining evidence of what was formerly the Taylor mine. The extent of the development work is not known, as the entry is caved and inaccessible. Although it is reported that some coal was sold from the mine, the general appearance of the place indicates that it was little more than a prospect.

LOCAL COAL AREAS.

MITCHELL.

Location and extent.—The Mitchell area is near the base of the Park Range, about a mile south of Norris Creek. The coal is exposed only in the SE. ¼ sec. 24, T. 8 N., R. 82 W., but from the direction of outcrop and attitude of the bed it is evident that portions of the sections adjoining on the south, southeast, and east are also coal bearing.

Coal bed.—The Mitchell bed, which has been opened at the Mitchell mine and at another locality about one-half mile farther north, outcrops around the nose of a shallow-pitching syncline. The strata are almost entirely concealed by soil and débris, rendering information as to the character and attitude of the rock very meager. The synclinal structure is proved, however, by the strike and dip of the coal bed in the Mitchell mine and in the abandoned prospect on the north. At the mine the bed dips 11° NE. and strikes N. 40° W., continuing in this direction for about 1,500 feet, where the strike swings abruptly northward and thence northeastward, bearing approximately N. 45° E. at the abandoned prospect near fossil locality No. 67 (Pl. XII). To the northeast of this prospect and to the southeast of the mine the coal is concealed, leaving the extent of the bed a matter of conjecture. The total thickness of coal exposed in the mine is 10 feet 4 inches, of which the lower 2 feet 4 inches is separated from the remainder of the bed by a 10-inch shale parting. (See section W, Pl. X.)

Mitchell mine.—The Mitchell mine was opened and has been operated intermittently for several years by J. F. Mitchell. It is in the SE. ¼ sec. 24, T. 8 N., R. 82 W., slightly over a mile west of the Baker ranch. The mine consists of a main entry extending about 350 feet N. 12° E. from the opening and of two side entries driven 30 to 50 feet westward from the main entry. The coal bed consists of an upper bench 8 feet thick separated from a lower 2½-foot bench by 14 inches of carbonaceous shale. The shale parting is used as the floor of the mine, and about 7 feet of the upper bench is mined, the upper foot being left for a roof throughout most of the workings, though in some places the entire 8-foot bench has been taken out, leaving a dark micaceous sandy shale roof exposed. Of the 8-foot bench the upper 3½ feet is clean and glossy black but breaks up badly in mining; the next lower 2½ feet is laminated and soft, and the lowest 2 feet is hard and glossy black, with a pronounced woody structure. The output of the mine has been used by Mr. Mitchell and neighboring ranchmen for domestic fuel and is said to have given fairly satisfactory results. For a chemical analysis of the coal see No. 12539 (p. 113).

MONAHAN.

Location and extent.—A coal bed 4½ feet thick outcrops on a hillside about halfway between the Monahan and Boetcher ranches, in the SE. ¼ sec. 31, T. 10 N., R. 81 W. Except for a few hundred feet near the Monahan mine the coal outcrop is concealed, and the northward and southward extent of the bed could not be determined. The bed dips toward a strike fault, which brings up the Niobrara formation about 2,700 feet to the east of the outcrop and limits the coal on that side. The coal-bearing area is confined to the strip between the outcrop and the fault, and though it may be coextensive with the Coalmont formation on the north and south, the absence of coal exposures north of the mine and along the stream to the south indicate that the bed represents part of a lens which probably had a radius of one-half mile to 1 mile.

Coal beds.—The only measurable coal exposure of the area is in the Monahan mine on what is known as the Monahan bed. This bed is 4½ feet thick and is made up of clean hard coal, free from partings. At the mine the bed strikes N. 15° W. and dips 22° slightly north of east. On the hillside above the mine a streak of coal bloom on the surface indicates the presence of a thin coal bed about 50 feet stratigraphically above the Monahan bed. This upper bed was not accessible for measurement, but is thought to be below minable thickness.

Monahan mine.—The coal entry known as the Monahan mine is in the SE. ¼ SE. ¼ sec. 31, T. 10 N., R. 81 W. The development work was done by William Monahan and consists of a slope of 125 feet on the dip of the bed. The work was mainly for prospecting purposes, and the small output of the mine has been used for domestic fuel by ranchmen of the vicinity. The coal is soft and practically worthless to a depth of 75 feet or more from the outcrop, but at the working face of the slope it is hard, black, and clean and of comparatively good quality. (See section X, Pl. X, and analysis 12540, p. 113.)

COLORADO CREEK.

A coal bed is exposed in two localities along Colorado Creek, about 3 miles southeast of the Clover Valley ranch. The bed strikes N. 55° W. and dips 11° NE. in the region of these exposures, but it maintains this attitude for only a short distance in either direction, as shown by the diverse dips and strikes in closely adjoining areas. Both exposures of the coal are in sec. 32, T. 6 N., R. 81 W.; one in the NW. ¼ and the other near the center of the SE. ¼. At the former locality the coal is 2 feet thick and, though considerably weathered, it is evident that the upper half of the bed is of fair quality and the lower half is very shaly and soft. In the latter locality the bed consists of 3 feet of shaly coal with a thin sandy layer a foot above the base. Aside from these two exposures the outcrop of the bed is concealed and its extent is unknown. (See sections Y and Y′, Pl. X.)

ARAPAHO PASS.

A thin coal bed is exposed about one-half mile east of Arapaho Pass in the bank of the west fork of Arapaho Creek. The exposure is about one-half mile south of the forest rangers' station and is near the northwest corner of sec. 26, T. 5 N., R. 81 W. This location was established by intersection of compass sights to distant points, however, and its relation to land lines is only a rough approximation, as no corners were found in this region and the land lines were constructed over this part of the map by projection from distant locations. The coal bed consists of 1 foot 9 inches of black and fairly clean coal separated by an equal thickness of sandstone from an 8-inch layer of softer coal. The associated rocks both above and below the coal are coarse yellow sandstones. The bed strikes approximately N. 35° W. and dips possibly 8° or 10° NE., accurate determination being impossible from the nature of the exposure. The coal is exposed only in one locality and its extent is unknown. It is below minable thickness, however, and at present has little or no economic value. (See section Z, Pl. X.)

CHARACTER OF THE COAL.

PHYSICAL PROPERTIES.

The physical character of the coals of North Park shows considerable variation throughout the field, probably owing to their occurrence at various horizons in the Coalmont formation and to diversity of conditions at the time of their formation. The Sudduth bed on the east side of the field is no doubt much altered both physically and chemically by the stress which attended the sharp folding of the strata in the McCallum anticline region. Wherever this bed is exposed in a comparatively unweathered condition in the region of folding the coal is uniformly clean, is of more than medium hardness, and has a glossy-black luster and brownish-black streak. It breaks with very irregular fracture, conchoidal, angular, or ragged in one direction and along fairly well developed joint planes in the other. In general the coal is much fractured in the bed and slickensided surfaces are common in practically all exposures. Though apparently less resistant than very hard bituminous coal, it withstands the weather much better than the best lignites known to the writer. In several open cuts coal that has been exposed to the weather for one or two years is quite hard and firm beneath 3 or 4 inches of crumbly coal, which is commonly weathered into small fragments of somewhat irregular but in general roughly cubical shape. Unweathered exposures of the Sudduth bed are not available outside of the region of sharp folding, but the weathered coal exposed in the Ballinger bank and east of the Dwinell ranch is much less firm and glossy and more closely approaches lignite in appearance. The Capron and other higher coal beds on the east side of the field are softer and of a duller black than the Sudduth bed and appear to contain many thin shaly layers.

The coal of the Riach bed in the Coalmont district is hard, brittle, and black, predominantly of very shiny luster though streaked with duller bands in such a way as to indicate woody structure. It is remarkably clean and when freshly broken can be rubbed vigorously over white cloth without leaving a trace. A very characteristic feature of this coal is its pronounced conchoidal fracture which, with the grainlike arrangement of dull and shiny laminæ and its absolute cleanness, gives it a very distinctive appearance. The coal resists weathering much better than lignite but can not be classed as a good stocking coal because of the checking, cracking, and general softening which begin soon after exposure to the air and continue slowly until the coal can not be handled without crumbling. When protected from the sun and from air currents, however, the coal stocks fairly well and can be kept with little deterioration for a year or more after being mined. The 18 and 12 foot beds of the Coalmont district, as studied in a somewhat weathered condition, are apparently very similar in character to the Riach coal. The stocking quality of these coals is indicated by the fact that samples which had lain for several years on the surface protected only by a few inches of slack and fine coal were found to be firm and very well preserved. The remaining coals of this district are much alike in color, hardness, and general physical character. They are made up of various proportions of hard, clean glossy-black coal and soft, shaly dull-black coal arranged in layers varying in thickness from a few inches to several feet. The outcrops of these coals are much weathered and the surface coal is crumbly and of a faded black color, indicating high ash content and poor stocking quality. No mining has been done on these beds in recent years, however, and no definite information was obtained as to their stocking quality or desirability for domestic fuel.

A brief statement of the physical character of the Mitchell and Monahan coals is given in connection with the mine descriptions. The Mitchell bed consists of three zones, of which the upper is clean and glossy black but breaks badly in mining; the middle is thinly laminated and crumbly; and the lower is very hard and is streaked glossy and dull black, with a pronounced appearance of woody structure. The Monahan coal has a black glossy luster, is hard and clean, and, except for a somewhat more pronounced conchoidal fracture, closely resembles the Sudduth coal on the east side of the field.

CHEMICAL PROPERTIES.

The chemical composition of the principal coals of North Park is shown by the table (p. 113), which contains analyses of samples from all coal openings in which fresh or but slightly weathered coal is available.

In collecting samples the utmost care was exercised to remove all slack and foreign material, such as dirt and burned blasting powder, from the face of the bed and to channel from top to bottom of the bed to insure a representative sample. After the coal was pulverized and thoroughly mixed it was screened through a half-inch mesh and was sealed in a galvanized-iron can, remaining thus sealed until opened in the chemical laboratory.

In analytical work chemists generally recognize that it is not possible to determine the proximate constituents of coal with the same degree of accuracy as the ultimate constituents. Therefore the air-drying loss, moisture, volatile matter, fixed carbon, and ash are given to one decimal place only, whereas the ash (in an ultimate analysis), sulphur, hydrogen, carbon, nitrogen, and oxygen are given to two decimal places. It is also understood that calorific determinations to individual units are not reliable; therefore in the column headed "Calories" the heat values are given to the nearest five units, and in the column headed "British thermal units" they are given to the nearest tens, the value of a British thermal unit being about one-half that of a calorie.

In the table the analyses are given in four forms, marked A, B, C, and D. Analysis A represents the composition of the sample as it comes from the mine. This form is not well suited for comparative purposes, for the amount of moisture in the sample as it comes from the mine is largely a matter of accident, and consequently analyses of different samples of the same coal expressed in this form may vary widely. Analysis B represents the sample after it has been dried at a temperature a little above the normal until its weight becomes constant. This form of analysis is best adapted to general comparisons. Analysis C represents the theoretical condition of the coal after all the moisture has been eliminated. Analysis D represents the coal after all moisture and ash have been theoretically removed. This is supposed to represent the true coal substance, free from the most important impurities. Forms C and D are obtained from the others by recalculation.

A comparative study of the analyses shows a marked similarity in the moisture, volatile matter, and ash content of the coals of North Park as received in the chemical laboratory, without having been air-dried after leaving the mine. The moisture content ranges from a minimum of 16.7 per cent at the Marr mine, where the coal was undoubtedly air-dried to a slight degree in the bed, to a maximum of 22.8 per cent in the Riach bed at Coalmont and averages 19.5 per cent. The percentage of volatile matter varies from 32.5 to 36.2 and averages 33.7 per cent. The ash content is in general very low, varying in five samples from 3.5 to 6.9 per cent, though in two samples it runs up to 9.9 and 12.1 per cent. The percentage of fixed carbon shows somewhat greater variation, ranging from a minimum of 34.1 to 46.7. The sulphur content of these coals is remarkably low, ranging from a minimum of 0.16 to a maximum of 0.83 per cent. The heat values of the samples as received range from 9,010 to 10,360 British thermal units. On the air-dried basis, however, which more nearly represents the condition of the coal when it reaches the consumer and which is used by the Department of the Interior for coal-land classification and valuation, the heat values range from 9,430 to 11,190 British thermal units.

Analyses of coal samples from the North Park coal field.

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

Letter on Pls. X and XII.	Laboratory No.	Mine.	Bed.	Location.				Air-drying loss.	Form of analysis.	Proximate.			Ash.	Ultimate.					Heating value.	
				Quarter.	Sec.	T. N.	R. W.			Moisture.	Volatile matter.	Fixed carbon.		Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
W	12539	Mitchell ..	Mitchell ..	SW. ¼ SE. ¼.	24	8	82	4.1	A	20.7	33.6	35.7	9.96	0.83	6.32	51.27	1.27	30.35	5,025	9,040
									B	17.3	35.1	37.2	10.39	.87	6.11	53.46	1.32	27.85	5,240	9,430
									C	....	42.4	45.0	12.56	1.05	5.07	64.67	1.60	15.05	6,335	11,410
									D	....	48.6	51.4	....	1.20	5.80	73.96	1.83	17.21	7,245	13,050
X	12540	Monahan .	Monahan..	SE. ¼ SE. ¼...	31	10	81	4.8	A	19.7	32.8	44.0	3.47	.68	6.39	57.70	1.49	30.27	5,715	10,290
									B	15.7	34.4	46.3	3.65	.71	6.16	60.61	1.57	27.30	6,005	10,810
									C	....	40.8	54.9	4.32	.85	5.23	71.85	1.86	15.89	7,120	12,810
									D	....	42.7	57.3	....	.89	5.47	75.09	1.94	16.61	7,440	13,390
Q	12601	Riach.....	Riach.....	NW. ¼ SW. ¼.	24	7	81	5.9	A	22.8	36.2	34.1	6.90	.70	6.30	51.74	1.14	33.22	5,005	9,010
									B	18.0	38.5	36.2	7.33	.74	5.99	54.98	1.21	29.75	5,320	9,570
									C	....	46.9	44.2	8.94	.91	4.88	67.03	1.48	16.76	6,485	11,670
									D	....	51.5	48.5	....	1.00	5.36	73.61	1.63	18.40	7,120	12,820
G	12415	Marr......	Sudduth..	NW. ¼ NE. ¼.	35	9	78	7.4	A	16.7	33.0	46.7	3.59	.16	5.63	60.20	.70	29.72	5,755	10,360
									B	10.1	35.6	50.4	3.88	.17	5.19	65.01	.76	24.99	6,215	11,190
									C	....	39.7	56.0	4.31	.19	4.53	72.29	.84	17.84	6,910	12,440
									D	....	41.4	58.6	....	.20	4.73	75.54	.88	18.65	7,220	13,000
C	12414	Sudduth..	...do.......	NW. ¼ SW. ¼.	15	9	78	8.2	A	20.0	32.5	42.5	5.00	.59	5.82	57.05	.78	30.76	5,420	9,750
									B	12.8	35.5	46.3	5.45	.64	5.35	62.15	.85	25.56	5,905	10,630
									C	....	40.7	53.1	6.25	.74	4.50	71.28	.97	16.26	6,770	12,190
									D	....	43.4	56.6	....	.79	4.80	76.03	1.03	17.35	7,225	13,000
F	12774	McCallum.	...do	NE. ¼ NE. ¼..	18	9	78	5.2	A	19.2	33.5	41.0	6.29	.27	5.75	56.34	.82	30.53	5,355	9,640
									B	14.8	35.3	43.3	6.63	.28	5.45	59.43	.87	27.34	5,645	10,170
									C	....	41.4	50.8	7.78	.33	4.48	69.71	1.01	16.69	6,625	11,920
									D	....	44.9	55.1	....	.36	4.86	75.59	1.10	18.09	7,180	12,930
O	12775	Winscom .	Winscom .	SW. ¼ NE. ¼..	14	8	78	5.2	A	18.1	34.5	35.3	12.13	.80	5.82	52.44	1.11	27.70	5,155	9,280
									B	13.6	36.4	37.2	12.80	.84	5.53	55.32	1.17	24.34	5,435	9,790
									C	....	42.1	43.1	14.80	.98	4.65	64.00	1.35	14.22	6,290	11,320
									D	....	49.4	50.6	....	1.15	5.46	75.12	1.58	16.69	7,380	13,290

CLASSIFICATION.

The principal factors which enter into the classification of coals by the United States Geological Survey are heat values, measured in British thermal units, and stocking quality, or ability to resist weathering. The latter factor is of primary importance in distinguishing between bituminous and subbituminous coals and between subbituminous coals and lignites. The bituminous coals are much more resistant than those of lower grade and on weathering exhibit a well-developed and regular system of jointing, even down to the smallest fragments. The subbituminous coals and lignites deteriorate and crumble much more rapidly on exposure to the weather and break with irregular fracture into fragments which show no evidence of regular or systematic outline. Six grades of coal are recognized by the United States Geological Survey, anthracite, semianthracite, semibituminous, bituminous, subbituminous, and lignite. The coals of North Park belong in the subbituminous grade because of their position between lignite and bituminous coal with respect to both heat value and stocking quality.

PRODUCTION.

Until the recent advent of the railroad North Park has remained practically isolated from the main routes of commerce, as a result of which it has not been an important factor in the commercial coal production of the West but has produced only the small quantity sufficient for local domestic needs. Since the completion of the railroad, however, the Northern Colorado Coal Co. has marketed considerable shipments of coal in northeastern Colorado and from Laramie eastward along the Union Pacific in Wyoming. The total production of the North Park field in 1912 is roughly estimated at 40,000 to 60,000 short tons, of which more than 95 per cent is the product of the Northern Colorado Coal Co.'s mine at Coalmont.

ESTIMATED TONNAGE.

The available data on the coal beds of the field are too meager to form a satisfactory basis for estimating tonnage except in the McCallum anticline district, where there is evidence that a thick coal bed is persistent beneath the surface of many square miles of territory. In this district the outcrop of the Sudduth bed was traced or located at many places for nearly 15 miles along the Canadian Valley and also around the McCallum anticline, except at the northwestern extremity, where the coal is covered. Because of the unusual thickness of this coal bed and the thickness of cover, which nearly everywhere conceals part or all of it, the actual opening and measuring of the coal by the field party was impracticable, and the thicknesses stated in this report were mainly furnished by the men who had done prospecting and development work. The general appearance of the coal exposures and the conditions existing about them indicate that the thicknesses were in the main accurately reported, and they are verified in large measure by the complete exposures of the bed in two prospect trenches, one near the Marr mine and the other about half a mile south of the Lange shaft. The writer is of the opinion that the total area in which the Sudduth bed is present within minable depth of the surface is not less than 60 square miles. Throughout this area all but two of the measured or reported thicknesses of coal range from 30 to 58 feet, and it is believed that an estimate of an average thickness of 30 feet is very conservative, particularly as the coal bed in all known localities dips from 20° to vertical, causing the portion of the coal bed underlying each square mile of surface to be considerably more than a square mile in extent. The specific gravity of the coal is such that a bed of it 1 acre in extent and 1 foot thick contains approximately 1,800 short tons or 1,152,000 short tons to the square mile. Calculations based on an estimated area of 60 square miles and an estimated thickness of 30 feet of coal, therefore, show a total tonnage of 2,073,600,000 short tons. It should be borne in mind, however, that these figures represent the gross tonnage and that the prevailing proportion of recoverable coal in many mining regions is only about 55 per cent of the total. Accepting this figure arbitrarily as applicable to the North Park field, the amount of recoverable coal under present mining conditions is 1,152,000,000 short tons.

The above figures are believed by the writer to be a conservative estimate of the tonnage of coal in the Sudduth bed of the McCallum anticline district. It should not, however, be considered other than a guess worked out with some care on the basis of the available facts.

FUTURE DEVELOPMENT.

There can be no doubt that development of the coal resources of North Park will continue to be, as in the past, largely influenced by natural conditions. The commercial isolation of the field has prevented other than a strictly local market for the coal for many years, and the conditions which kept the field isolated will tend to discourage large-scale development, at least in the immediate future. The necessity of crossing the great mountain wall, which forms a practically complete natural boundary of the park, not only made the cost of railroad construction very high but also makes maintenance and operation expensive, causing high freight rates. Thus, it is evident without consideration of comparative quality that the coal of North Park is at a disadvantage in the open market in competition with other coals of Colorado and Wyoming. Still more to its disadvantage, however, is its quality and subbituminous grade as compared with the higher grade coals of neighboring fields. The chief competitors of the coal of the North Park district are the well-known Rock Springs bituminous coal of southwestern Wyoming and the subbituminous Hanna coal of Wyoming, about 100 miles north of the North Park field. The former of these is much better, and the latter is equal to or better than the coal of North Park for steaming purposes, and both are on the main line of the Union Pacific Railroad and are easily accessible. Other important competing coals are the high-grade bituminous coals of the Trinidad field in southeastern Colorado and the Glenwood Springs, Grand Hogback, and Yampa fields of west-central and northwestern Colorado.

One feature which may create a considerable demand for the product of the Northern Colorado Coal Co.'s mine is its remarkable cleanness. If this quality becomes somewhat widely recognized the coal may command a price which will enable it to be shipped with profit for a considerable distance from the field. In the opinion of the writer the creation of such a demand or the rapid development of a large local market are the only factors which might result in a large coal production in this field in the near future. The creation of an outside demand is not considered likely, as it is believed that the lower heat value of the coal of North Park as compared with the Rock Springs and other bituminous coals will more than offset its cleanness. The rapid growth of a large local market also seems highly improbable, owing to the comparatively small area of the park floor, the high altitude, which prevents intensive farming, and the improbability that industries requiring steam coal in large quantities may arise within the park.

METALS.

COPPER.

Pearl post office is an abandoned copper camp near the Wyoming boundary, on the line between T. 12 N., R. 81 W., and T. 12 N., R. 82 W. Considerable prospecting has been done in this vicinity, and development work was started on a somewhat extensive scale here some years ago. A small amount of low-grade ore was mined, and the promoters erected a smelter, said to have cost $75,000. This, however, was never fired, and the camp was abandoned about the time the smelter was completed, owing, it is said, to lack of operating funds and to litigation. Inhabitants who are to some extent familiar with the former operations believe that the property contains considerable ore which, though of low grade, can be mined at a profit under better management and more favorable transportation conditions.

Prospecting has been done intermittently for many years, and is still carried on to some extent along the crystalline rocks of Independence Mountain and eastward to the Medicine Bow Range in the vicinity of Pinkhampton. It is reported that a number of copper-bearing zones have been found, but that the samples assayed have not been rich enough to encourage mine development.

GOLD.

A small amount of gold was mined some years ago in the south-central part of T. 11 N., R. 81 W., by washing a quantity of the sand and gravel which covers portions of the south slope of Independence Mountain and extends downward into the valley a few miles east of Hill ranch. A pipe line was constructed at great expense from Big Creek Lake, in T. 11 N., R. 82 W., and the placer was operated for a short time. The gold content of the gravel was much less than had been anticipated, however, and the project was soon abandoned as unprofitable.

SILVER.

Teller, in the southeast corner of the park, is the site of a former mining camp, which is said to have had a population of more than 1,500 in the early eighties. Some of the ore mined at this locality is reported to have been rich in silver and copper, though the quantity of rich ore was in all probability very small. There is little doubt that the general region still contains bodies of very low grade ore, some of which may be profitably mined in the future with the increased transportation facilities afforded by the railroad.

GILSONITE.

The gilsonite mine near Willow Creek Pass was examined by the writer while on a reconnaissance trip to the headwaters of Willow Creek, in Middle Park, and though it is a few miles outside of North Park, a brief description of it may be of interest. The property is in secs. 15 and 22, T. 4 N., R. 77 W., about 4 miles southeast of Willow Creek Pass, and is owned by a company of which Jerome Smith is president and W. H. Spellesacy superintendent of operations. Mr. Spellesacy reported that approximately 3,000 tons of gilsonite had been mined previous to September, 1911, and that this output had been sold at an average price of about $60 per ton. The gilsonite bears a general resemblance to a glossy coal. It is very brittle, breaks with somewhat conchoidal fracture in one direction and along smooth regular cleavage planes in the other, and is of a very lustrous, satiny black color. The product of the mine was used principally in the manufacture of varnish and paint, and was experimented with in connection with Trinidad asphalt for paving purposes. The use of 10 per cent of this material with 90 per cent of the Trinidad product is reported to have been successful in an experimental way.

The gilsonite occurs apparently as a vein in a sandy clay which contains lenses of friable sandstone and bowlders or nodules of soft sandy clay. The vein has been followed in mining for several hundred feet and varies from a few inches to 8 feet in thickness at depths of 25 to 60 feet. The rocks of the region are apparently broken by faults of very slight displacement, as shown by numerous breaks or offsets in the gilsonite body, which when broken could invariably be found again within a few feet. The outcrop of the vein could not be followed on the surface and is believed to be more or less local, though this is entirely conjecture. The formation in which the gilsonite occurs is believed to represent a zone near the base of the Coalmont formation of North Park, though it does not closely resemble any known section of that formation and is separated from the nearest Coalmont exposures by several miles of thickly covered territory.

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