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# Geology and Coal Deposits, Ragged-Chair Mountain Area, Pitkin and Gunnison Counties, Colorado*

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ABSTRACT.—The Ragged-Chair Mountain area of west-central Colorado is important as a possible source of good quality coking coal because of its proximity to Coal Basin and some of the best coking coals in the Rocky Mountain region.

Commercial quantities of generally medium-volatile coal occur at three specific horizons in the lower Mesaverde strata above the basal Rollins Sandstone Member. In ascending order, they are: (1) Coal Basin, (2) Middle, and, (3) Placita horizons. In the western portion of the map area, these zones each contain one or more beds ranging in thickness from a few inches to over 15 feet. The larger quantities and better grade coal are located in the lower stratigraphic positions. In addition the high ranked coals are found (1) near the base of the coal-bearing strata, (2) under greater amounts of overburden, and, (3) relatively far removed from the surface outcrop.

Where present in economical thicknesses of 4.0 feet or more the combined beds contain an estimated 316,376,000 tons of in-place reserves under less than 3000 feet cover. However, most of these reserves are in relatively small restricted areas and cannot, at the present time, be mined economically because of the excessive overburden and complex mining considerations.

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*A thesis submitted to the Faculty of the Department of Geology, Brigham Young University, in partial fulfillment of the requirements for the degree Master of Science.

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## INTRODUCTION

### Location and Accessibility

The area covered by this report is located in Pitkin and Gunnison counties in west-central Colorado (map, in back) and is approximately 65 miles east of Grand Junction. It is accessible from the south via State Highway 135 which connects the towns of Paonia, Somerset, Crested Butte and Gunnison. Northward, State Highway 33 to Placita and Marble crosses McClure Pass and continues down the Muddy Creek drainage to the Paonia Dam where it joins with Highway 135. This northeastern approach along with one through Grand Mesa National Forest from either Silt or Collbran is closed by snow from November until late May.

Besides the routes mentioned there are numerous unimproved dirt roads and jeep trails serving the sheep and cattle ranches or allotments in the north and west portion. Eastward the only access is by foot or on horseback over the established forest service trails.

### Purpose and Scope

This investigation represents part of a program that was initiated by Columbia-Geneva Steel Division in July, 1956, as an evaluation of potential coking coal reserves in the Placita area. At that time the author was responsible for mapping and sampling all minable coal beds between Coal Basin and Placita. The work, broadened to include adjacent terrain, was continued through succeeding summers, and, in 1959, the writer was granted permission to consolidate the data for a M.S. thesis. During the 1960 and 1961 field seasons, the subject area was enlarged to the present size of approximately 200 square miles and the investigation was expanded to include certain aspects not warranted in the original reconnaissance evaluation.

The main objective in this study has been to determine the stratigraphic position within the Mesaverde Formation of the coal-bearing rocks and their geologic relationship to the "barren" or non-coal-bearing horizons; to ascertain the character and quality of the coal through laboratory analyses; to appraise the mapped area with respect to distribution, thickness and reserves of underlying coal beds, and, where possible, predict the presence of low- or medium-volatile coking coals.

### Previous Work

One of the earliest geologic reports of the Ragged-Chair Mountain area is recorded by Peale (Hayden, *et al.,* 1876) in the *10th Annual Survey of the Territories* or Hayden Surveys as they are commonly known. This early study was performed in 1873 and 1874 by two parties; the one led by Peale explored the region drained by the Gunnison River and its tributaries including the North Fork of the Gunnison. Although the investigation embraced only the extreme southern portion of the present work, many of the physiographic features along with the general descriptions of the igneous and sedimentary rocks and coal beds can be identified from Peale's discussion.

During this same period a second group under the direction of Holmes (Hayden, *et al.*, 1876) was continuing a geologic examination of the Elk Mountains, particularly in the northwest portion from the Crystal River eastward. Along the Crystal River or Rock Creek, as it was then designated, they noted a four foot bed of anthracite near the mouth of Rapid Creek (?), and after climbing to the divide between Crystal River and Muddy Creek, in what is now called McClure Pass, they observed and estimated 2500 feet of Mesaverde sediments with an undetermined number of coal beds sloping toward the Gunnison River.

In an early account of historical interest, Thiele (1882) reported that local interests were trying to promote the growth of the newly formed town of Grand Junction and a connection of the railroad systems of Colorado and Utah by stressing the potential coal business of the region. By this date the better coals had not been found or if they had been located they were not developed because coal for domestic uses was still being freighted by wagon to Grand Junction from Crested Butte at a cost of $12.00 per ton.

Cross (1894) prepared the first detailed geologic map of the region. The work was done in the Anthracite-Crested Butte District and included discussion of the laccolithic intrusions found in the Ragged-Chair Mountain area. Later Emmons, *et al.*, (1894) mapped the geology of the entire Anthracite and Crested Butte quadrangles.

Lee (1912) mapped the Grand Mesa field from Grand Junction eastward into the Anthracite and Crested Butte quadrangles. He presented the first detailed treatise of the Cretaceous strata, using western Colorado and eastern Utah stratigraphic designations instead of the Front Range terminology employed by Emmons. He also subdivided the Mesaverde Formation into units which have served as a foundation for coal bed correlations in a number of subsequent works.

Other early studies helpful in the evaluation of the subject area are those by Storrs (1902), Gale (1906; 1907; 1910), Woodruff (1912) and the more recent ones by Erdmann (1934), Johnson (1948), and Horn & Adair (1956).

### Present Investigation

Geologic information was recorded in the field on aerial photographs of 1:20,000 scale and transferred by Kail Plotter to a mosaic base map. The distribution and sources for the base map are shown on the map (in back).

At the same time as this report was being compiled, the U.S. Geological Survey was conducting two coal studies in part of the subject area. The first is an evaluation by J. R. Donnell of the Carbondale field, including Coal Basin and Placita. D. L. Gaskill is performing the second investigation in the western or coal-bearing portions of the Snowmass and Anthracite quadrangles.

## ACKNOWLEDGMENTS

The writer takes this opportunity to acknowledge his indebtedness to J. K. Hayes, supervisor of Columbia Iron Mining Company's field exploration group, and to his associates for their assistance in this investigation and for making available the data presented herein.

L. F. Hintze has acted as chairman for the study and appreciation is extended to him and also to my family for their assistance and helpful suggestions.

## GEOGRAPHY

The area studied lies in a transitional zone between the high, lava-capped Grand Mesa tableland of the Colorado Plateau physiographic province and the highly faulted and fractured Elk Mountains of the Southern Rocky Mountain province (Fenneman, 1931). The area is principally in what Holmes (Hayden, *et al.,* 1876) originally designated as the West Elk Mountain group. The mountains are comprised of porphyritic masses, usually laccolithic, which have intruded Cretaceous and Tertiary sedimentary rocks. They differ markedly in topography and origin from the main group of Elk Mountains to the east, and are separated from them by the Crystal River drainage.

The Grand Hogback, which is a simple monoclinal structure occurring at the northeast edge of the Colorado Plateau, extends around the west rim of Coal Basin where it is known as the Huntsman Hills. From there it passes through the northern section of the mapped area, but as it continues on southeastward, the low to moderate dips become more complex as a result of the numerous Tertiary intrusions.

Because heavy vegetation and soil cover mask many geologic contacts, locally it was often necessary to rely on plant distribution in order to locate the mappable units. This was possible because larger and more varied plants were associated with sandstones and/or coals than with the intervening shales. An example of plants serving as a geologic guide is found on the north side of Chair Creek in sections 14 and 15 where oak brush growth in the Ohio Creek Conglomerate is more than double the height of that growing above the massive sandstones present near the top of the Mesaverde Formation. At this stratigraphic position water may account for part of the abrupt change in vegetation, but also found in the conglomerate is enough arkosic material which, upon decaying, will substantially increase the necessary plant nutrients. This same idea will serve to explain the heavier vegetation supported by the Wasatch Formation.

## STRATIGRAPHY

### General Statement

Upper Cretaceous and Tertiary sediments disrupted by Tertiary intrusions of quartz monzonite porphyry and related rocks constitute the general geology within the area.

The coal-bearing Mesaverde Formation crops out as a low dip monoclinal extension of the Grand Hogback structure. However as this feature continues southeastward it becomes more complex due to the numerous laccolithic intrusions. Economically important high-volatile coals occurring in the basal Mesaverde strata have been sufficiently altered by these intrusive bodies into the best quality coking coals yet found in the Rocky Mountain region.

### Paleozoic and Mesozoic Systems (Undifferentiated)

Occurring in the northeast corner of the area are a number of pre-Mancos sediments which were not mapped in detail. They include the following formations: (1) Cretaceous Dakota Sandstone, (2) Jurassic Morrison Formation, (3) Permian Maroon Formation and (4) possibly a number of the lower Paleozoic formations that were mapped and described east of Marble in the Snowmass Mountain area (Vanderwilt, 1937). These sediments are separated from the overlying Mancos Shale by a large fault or fault system which is possibly a northwest extension of the Elk Mountain fault zone discussed by Vanderwilt (1937).

### Cretaceous System

#### Mancos Shale

Cropping out in the vicinity of Placita and Marble and at locations near the Tertiary intrusions is the Mancos Shale of Late Cretaceous age. It is composed predominantly of dark-gray, silty marine shales with sandy or carbonaceous intervals. However for the most part it is a simple, monotonous lithologic unit without any distinctive physical variations which can be used in subdividing the formation. An exception to this is on the west side of Yule Creek and in the vicinity of Schofield Park to the east where a 20-40 foot limestone member was noted 200-500 feet above the Dakota Sandstone (Vanderwilt, 1937). The gray limestone beds range from six to 12 inches thick, contain numerous fragments of *Inoceramus deformis* and are interbedded with shale. Eastward in Lead King Basin and specifically in the Lead King Mine, this locally restricted member represents an important ore zone which has been designated the "Lead King lime" by the miners.

Another exception to the simple lithology noted in the outcrops is the occurrence of two sandy zones encountered in gas wells drilled on the eastern edge of Grand Mesa. Here, in what is called the Divide Creek Anticline, two gas producing sandy zones have been found in the upper 1000 feet of Mancos Shale. The upper zone is called the Cozette. It is about 120 feet thick and is approximately 650 feet below the top of the Rollins Sandstone. About 900 feet below this same horizon and separated from the overlying Cozette by 100± feet is the second or Corcoran zone which has a thickness ranging from 100-200 feet. Gas from these two horizons is currently being piped to consumers in the Delta-Montrose area.

The overall thickness of the Mancos Shale approaches 5000 feet. This has been determined from a number of oil and gas wells which have penetrated the underlying Dakota Sandstone in the Grand Mesa region near the thesis area. In the Book Cliffs, to the northwest, Erdmann (1934) stated the thickness, as obtained from oil well logs supplemented by measured sections, ranges from 3,908 to 4,150 feet with an average of 4,020 feet. Directly north in Grand Hogback-Danforth Hills area the section is about 5000 feet (Gale, 1906, p. 268). On the north slope of Mount Baldy in the area eastward 2000 feet were reported by Vanderwilt (1937), and on the south slopes Emmons, *et al.*, (1894) reported 3150 feet as the total thickness. The writer believes these thinner sections are not complete but are thinned as a result of faulting in the incompetent shales. This has happened near Placita where there are only about 500 feet of Mancos Shale separating the Dakota from the Rollins Sandstone. Inside the map boundary, the maximum thickness exposed is approximately 1000 feet which crops out south of Marble from Yule Creek westward.

In the vicinity of Marble the Mancos Shale has been extensively indurated by the early Tertiary intrusives. The slate-like shales do not contain any contact-metamorphic minerals nor have they been changed to hornfels as have the Jurassic shales below the Dakota Sandstone (Vanderwilt, 1937).

Mesaverde Formation

The term "Mesaverde" was originally applied by Holmes (Hayden, *et al.*, 1875) to a series of coal-bearing sandstones and shales enclosed between marine shales and present near the middle of the Cretaceous section in southwestern Colorado. Because that writer's lithologic subdivisions, subsequently replaced by Collier (1919), are not distinguishable beyond the locality in which they were first named, the present extended usage of the term has been applied to strata that are not strictly equivalent to the original Mesaverde Group. Present usage is mainly as a designation for the Upper Cretaceous coal-bearing series of Colorado, Utah and Wyoming (Chart 1).

In the Ragged-Chair Mountain area the Mesaverde Formation consists of massive sandstones, interbedded sandstones and shales, sandy and carbonaceous shales and commercial qualities of coal which are found in the lower or marine portion of the strata. The upper nonmarine member, which constitutes the bulk of the formation, is comprised of thick massive sandstone ledges separated by small layers of sandy shale. These lenticular sandstones are not persistent enough to be used in further subdividing the member.

The total thickness of the formation ranges from 2300 feet at DH-8 to 2712 feet and 3600± at McLaughlin No. 1 well and at McClure Pass. This northward thickening continues through the northwest corner of Coal Basin where there are approximately 4000 feet and into the Grand Hogback and Danforth Hills fields which contain nearly one mile of coal-bearing Mesaverde strata. In the Somerset District to the south the thickness ranges from 2200 to 2600 feet.

During his evaluation of the coal fields of Grand Mesa and the West Elk Mountains, Lee (1912) subdivided the Mesaverde into the Rollins Sandstone, a basal marine member; the Bowie Shale, a coal-bearing marine member; the Paonia Shale, a coal-bearing, fresh water member; and an upper undifferentiated (non-coal-bearing) member. The evidence for this subdivision is based primarily on paleontologic studies of the abundant faunal and floral specimens (Lee, 1912). However, in the Coal Basin vicinity and particularly in the subject area, there are distinctive lithologic units in the basal 1000± feet of Mesaverde strata which can be subdivided. These divisions are found only in the areas mentioned. In ascending order, the members are: (1) Rollins Sandstone Member, (2) Bowie Member, (3) Paonia Member, and (4) undifferentiated member. The Bowie and Paonia members both contain commercial qualities of coal and together they have a combined thickness of approximately 1100 feet. There are about 100 feet of section in the Rollins Sandstone Member and more than 2300 feet in the undifferentiated member.

*Rollins Sandstone Member.*—The Rollins Sandstone is the basal member of the Mesaverde Formation and is the most persistant, well-defined stratum in the entire group. It was named from the Rollins Mine located near Lands End on the west edge of Grand Mesa where it occurs as a conspicuous white cliff separating the gray Mancos Shale from the coal-bearing Mesaverde strata. It extends throughout the Grand Mesa region and into parts of the West Elk Mountain area.

The member is composed of white, medium- to coarse-grained sandstone which crops out in a prominent, massive ledge or cliff. At the top there is usually present a foot or more of bituminous sandstone overlain by a succession of coal beds. If the coals are missing a pronounced carbonaceous shale layer with coal partings is nearly always present at this horizon. These conditions are the same in the Danforth Hills field in northwestern Colorado where a persistent stratum, locally referred to as the "white rock," at the base of the coal-bearing formation is invariably overlain by a coal bed or at least carbonaceous shale matter (Gale, 1906).

Immediately under the coal or carbonaceous shale a white zone of "bleached" sandstone ranging from 5-20 feet thick has been observed. This feature has not been noted in the other sandstone units and is thus another diagnostic feature which can be used in locating the Rollins Sandstone Member.

At the base of the Rollins there is usually a transition from massive sandstone to interbedded sandstone and shale and then sandy Mancos shales. The Rollins is from about 80 to 170 feet thick with a few sandy shales less than three feet thick present near the base. The interbedded zone beneath the sandstone bed may be 200 feet thick as is indicated in measured sections and electric gas well logs in the Grand Mesa region. This lower zone, for purposes of this investigation, is included with the Mancos Shale.

According to Lee (1912) the Rollins Sandstone "marks the transition from the marine conditions that prevailed during the deposition of the Mancos Shale to the brackish-water conditions represented by the coal-bearing rocks of the Bowie Member." He further states that in the West Elk Mountain coal fields, *Halymenites major* are so abundant and persistent as to be characteristic of the Rollins. Specimens are found in sandy layers near the top of the Mancos and are present through the Bowie Member.

In the Marble-Anthracite Pass vicinity, and southeastward toward Crested Butte, the Rollins Sandstone becomes less conspicuous. The member is approximately 90 feet thick and is not a ledge-former because of an increased quantity of shale present in the sandstone. On Anthracite Pass, for example, the Rollins is represented by two sandstone beds 28 and 34 feet thick which are separated by 30 feet of sandy shale; total thickness is 92 feet. Within the Anthracite-Crested Butte quadrangles Dapples (1938 *ms.*, p. 13-21) measured 80-100 feet of Rollins, but described 200 feet of sandy shale and shaly sandstones containing seven coal beds and occurring beneath the Rollins Sandstone Member. The writer is of the opinion that this is an incorrect correlation; that there are no coals present below the Rollins sandstone. This lower unit was named the Baldwin Sandstone Member.

*Bowie Member.*—The Bowie Member is the major coal-bearing strata within the Mesaverde Formation. It is composed of shales, sandstones, interbedded sandstones and shales, and coal beds with thicknesses in excess of 15 feet. The total thickness for the member is approximately 800 feet.

The Bowie Member can be subdivided into four units as follows: (1) a basal shale, (2) the middle sandstone, (3) an upper shale, and (4) an upper sandstone. These divisions are well defined in the Ragged-Chair Mountain area and northward into the Carbondale field, but they do not correlate with the stratigraphy of Crested Butte. It is also questionable if a correlation can be extended into the Somerset field, although drill hole DH-8 does tie in fairly well with the data in the lower section of the thesis area.

The basal shale rests directly on the massive white Rollins Sandstone Member and is 300-450 feet thick and contains interbedded shales and sandstone, sandy or carbonaceous shale and coal. The shales resemble those in the upper portion of the Mancos Shale and could be easily mistaken for the Mancos Shale. This is not true in the Somerset district where considerable large and somewhat numerous sandstone beds are present in the unit. The basal coal beds rest directly on the Rollins Sandstone and are present in the lower 100 feet of the unit. Of special interest in locating these lower coals is the presence of a 1-10 foot coquina or coquinoidal shale zone which is located about 40 feet above the Rollins Sandstone Member. This coquina is largely of pelecypods and its best exposures occur between Placita and Hayes Creek at locations 23, 25 and 26 and at the head of North Anthracite Creek at location 14. The coal beds between the coquina and the Rollins Sandstone are the best and most extensive in the area studied.

The middle sandstone has an average thickness of about 65 feet, and from the top of the sandstone to the Rollins Sandstone the interval is approximately 500 feet. It is white to light-gray, medium- to coarse-grained and weathers as a resistant tan or light-brown colored ledge with an occasional shaly zone forming a slight bench near the middle of the unit. In the weathered outcrop the middle and upper sandstone units do not have the whiteness exhibited by the Rollins. Another feature typical of the middle sandstone is the "salt and pepper" texture on a fresh sample which is due to the numerous mica flakes occurring with the white, sand-sized particles of feldspar and quartz.

The upper shale unit, much like the one above the Rollins Sandstone, is composed of interbedded shales and sandstone, and dark-gray, sandy shale that is carbonaceous and fossiliferous through most of the lower portion. The average thickness for this unit ranges from 150 to 200 feet. At the base of the unit and resting upon the middle sandstone is an important coal horizon which is designated "Middle Zone" for the purposes of this investigation.

The physical characteristics of the middle and upper sandstones are very similar and are best identified by their stratigraphic relation with the Rollins Sandstone Member. Average measurements of the interval between the Rollins and the top of the middle and upper sandstones are 450 to 760 feet respectively, with about 280 feet separating the middle and upper sandstones.

The top of this unit is herein considered the contact for the Bowie-Paonia members.

*Paonia Member.*—The Paonia Member is composed of between 300-400 feet of thin-bedded to massive sandstones, sandy shales and small scattered coal beds interbedded with the shales. Lithologically the Paonia shales are much like those in the underlying Bowie Member, i.e., they are dark gray or black, depending on the amount of carbonaceous material present, sandy and fossiliferous. The coal beds are thin and only locally do they attain economical thicknesses.

There is no distinctive lithologic division in this member and for this reason there is no mappable feature dividing the Paonia and undifferentiated members. The top of the Paonia Member is where the shales give way to massive channel-like sandstones. In addition there are no coals above this contact. A typical sequence through this zone is found on the divide between North Anthracite and Rapid Creek, east of the Ragged Mountain triangulation station. Here, there are a few coal beds less than 0.5 feet thick in the interbedded Paonia sandstones and shales which in turn are overlain by massive undifferentiated sandstones having considerably less shale and no coal.

Lee's arbitrary division between the Paonia and undifferentiated portions of the Mesaverde Formation appears to have been near the base of a massive coarse-grained impure sandstone which marks the lower limit of the more sandy section, and it is approximately the same stratigraphic position as used in this report.

*Undifferentiated member.*—In general, the lithology is much like the Paonia Member except for the predominance of sandstone over shale. Many of the ledges are channel sands which pinch out laterally within a few hundred feet.

Although there are a few lenses of carbonaceous trash with small coal stringers scattered through this strata, there were no coal beds observed in the outcrops or in the various drill holes. In the coal fields to the north and west of the area, however, there are commercial beds present in the entire Mesaverde sequence.

Tertiary System

Ohio Creek Conglomerate

Separated from the underlying Mesaverde Formation by an erosional unconformity, is a white or light pink conglomerate sandstone which is known as the Ohio Creek Conglomerate.

The Ohio Creek Conglomerate in the Ragged-Chair Mountain area is represented by a generally massive, white to pink grit-sized conglomerate sandstone ranging from 10 to nearly 200 feet in thickness. The pebbles, which grade downward from 3-4 inch cobbles to grit-sized particles, occur in a loosely held conglomerate lenses within the friable sandstone. The individual pebbles are generally smooth and well-rounded and consist of white and pink quartzite, white quartz and gray, red, orange and yellowish-brown chert. They weather free from the matrix and appear as gravel near many of the outcrops.

The Ohio Creek Conglomerate is present throughout the mapped area and has been noted as far north as the Grand Hogback and Danforth Hills fields in northwest Colorado where Gale (1906) reported finding a "persistent bed of coarse conglomerate or loose boulders above the coal-bearing strata and below the varicolored Wasatch Formation which marks an erosional time break in the sedimentary deposition."

Within the subject area, the better exposures are found in the Muddy and West Muddy Creek drainages, in the area immediately south of McClure pass and along the south slopes of Coal Basin in sections 33 and 34. Here the bed is about 180 feet thick. Along the southern limit of Section 6, T. 13 S., R. 88 W., only 12 feet were measured. In measuring a number of sections through the Ohio Creek Conglomerate and upward into the overlying Wasatch Formation it was noted that there are several conglomerates and conglomeratic sandstone within the Wasatch shales, but are not to be confused with the Ohio Creek Conglomerate because they are usually red or maroon and the pebbles are predominantly andesitic.

Crinoid stems have been found within the chert pebbles, along with a few miscellaneous plant remains. Fossilized plants, collected by D. L. Gaskill of the U.S. Geological Survey and identified by J. A. Wolf (personal communication with D. L. Gaskill) are:

"Juglans" rhamnoides Lesq.
"Magnolia" magnifolia Knowl.
Platanus regularis Knowl.

The "*Juglans*" are Paleocene and Late Cretaceous but the remaining two species are interpreted by Wolf as Paleocene floras. The Ohio Creek Conglomerate is usually classed as Eocene.

Wasatch ("Ruby") Formation

The Ruby Formation was the original designation given by Cross (1892) to the metamorphosed ruby-colored sediments which constitute the mountains known as the Ruby Range near the old mining town of Irwin in Gunnison County. At this location Cross measured over 200 feet of conglomerates, sandstones and shales which consist almost entirely of andesitic debris. The entire sequence has been considerably hardened and metamorphosed by the numerous dikes that havé intruded the sedimentary series. Cross believed that the Ruby Formation extended west from the Ruby Range and disappeared beneath the Wasatch Formation. The Wasatch Formation was orginally differentiated in the Grand Mesa region by members of the Hayden Survey and until the time of Lee's study in 1907 and again in 1912 there had been no detailed investigation between the two areas. However, as is pointed out by Lee (1912), the Ruby and Wasatch formations are probably identical in addition to being characteristic of the Wasatch in southern Wyoming.

In general the Wasatch Formation in the western half of the subject area is comprised primarily of shale, sandstone and conglomerate having a diagnostic maroon or ruby coloration. The rocks are not as deeply colored as those in the Ruby Range nor is the material as coarse. The formation rests on the eroded surface of the Ohio Creek Conglomerate, but Lee (1912) and Johnson (1948) reported that the Ohio Creek Conglomerate is missing in certain localities and that the Wasatch rests directly upon the erosional unconformity at the top of the Mesaverde Formation.

The total thickness of the formation is estimated to be between 3000 and 5000 feet with an excess of 1000 feet present along the west border of the area. Gale (1906) stated that there are approximately 4000 feet of Wasatch section in the coal fields to the north of the subject area.

## IGNEOUS ROCKS

### General Statement

The large intrusive masses in the Ragged-Chair Mountain portion of the West Elk Mountains and the intrusive sheets and dikes associated with them are remarkably similar in appearance. Generally the rock is light-gray with a rather pronounced tinge of pink, coarse-grained quartz monzonite porphyry with euhedral orthoclase crystals which average approximately one inch in diameter. The potash feldspar is of the sanidine variety and frequently the phenocrysts will approach three inches in size. These large orthoclase crystals are the outstanding feature in both the large laccolithic masses and the extensive intrusive sheets or sills associated with them, except that in the sills the phenocrysts are much smaller and there is a finer-grained groundmass. In addition to the feldspars, the igneous rocks contain hornblende, biotite and quartz. The quartz phenocrysts occurring with the orthoclase do not have well developed forms; they are usually somewhat rounded and not nearly as large.

The assortment of stocks, dikes, sills and laccolithic intrusions which have disrupted the Cretaceous and Tertiary sedimentary cover throughout the general area are believed by Lee (1912) to have been intruded into the strata near the end of the deposition of the Wasatch Formation and are much earlier than the basaltic flows which rest on the Green River Formation in the Grand Mesa area.

In the western third of the area many of the streams contain numerous basalt boulders, which are remnant of the Grand Mesa flows. These flows may have extended as far east as Muddy Creek, and they may have originated as a fissure eruption from the east-trending basaltic dike which can be traced in the vicinity of Ault Creek for approximately five miles.

An interesting observation has been noted (Cross, 1894) in the different metamorphic effects on the sediments adjoining the intrusives in the West Elk Mountains as compared with the main Elk Mountain group. In the Elk Mountains the sediments are extensively metamorphosed with the development of secondary contact minerals including vesuvianite, garnet, scapolite, epidote, pyroxene, orthoclase, quartz, hematite, and magnetite. The sediments adjacent to the intrusives in the subject area are relatively free of major contact metamorphic effects. The contact zones are narrow and in direct contrast to those just described.

Intrusive Masses

*Ragged-Chair Mountain.*—One of the largest mountains in the West Elk Group is the porphyry intrusion known as Ragged-Chair Mountain. This mountain, as Mount Marcellina to the south, is composed of quartz monzonite porphyry and is characterized by numerous euthedral orthoclase crystals that are often more than three inches in diameter. At the northern limit the intrusive body has arched up the Mancos and Mesaverde sediments into a prominent flatiron with northly dips of over 45 degrees. The intrusive-Mancos contact is about 400 feet below the Rollins Sandstone and the coal near the base of the coal-bearing strata is a semi-anthracite variety. On the south, according to Cross (1894), the structure is typical of the laccolithic masses in the Henry Mountains. A laccolithic "lip" in a wedge-shaped position in the undifferentiated member of the Mesaverde Formation is best viewed from the Crested Butte road above Ericksons' Springs Camp Ground, Section 6, T. 13 S., R. 88 W. It occurs north of the Munsey Creek drainage and it is overlain by a large intrusive sheet which probably originated from Mount Marcellina.

The western border of the mountain is marked by an almost sheer face; the Mesaverde and Wasatch formations are mostly of moderate dips and the contact is likely a result of a fracture occurring in the overlying sediments at the time of igneous emplacement.

*Snowmass Mountain Stock.*—In the extreme northeast corner of the area is an extension of the Snowmass Mountain Stock. A description can be found in Vanderwilt (1937).

*Mount Marcellina.*—Mount Marcellina, as discussed by Cross (1894), is an asymmetric laccolith. The mountain is immediately south of Ragged Mountain and is one of the most isolated and interesting laccoliths in the West Elk Mountain group. The writer concurs with Cross' explanation of the abrupt contact of the intrusives of the West Elk Mountain group as being a fault contact, as this would explain not only the abrupt face already mentioned but also the extension of a number of faults which are not traceable in the sediments near the intrusion. A case in point is the north-south trending fault cutting across Buck Creek west of the McIntyre prospect. There is good surface evidence for the fault in Section 26, but southward it was not traceable. If Cross' theory were applied here the fault, having a throw in excess of 2000 feet, would continue southward along the intrusive contact.

A large sill, occupying a synclinal trough with an axis approximately parallel with the Raspberry Creek drainage, is believed to have had its origin with Mount Marcellina. In the North Anthracite drainage the sill has been eroded to the underlying Mesaverde sediments thus separating the northern extension from its counterpart which is present in the Kite Creek area. However, the intense metamorphism of the sandstones and shales in North Anthracite Creek suggests that the sill extended across this area and northward to Section 22, T. 11 S., R. 88 W. East and west from Raspberry Creek the Mesaverde strata dips beneath the sill to form a major syclinal structure with an axis parallel to Raspberry and North Anthracite creeks. Other smaller sills near the eastern border are of the same character and differ only in the size of the constituent crystals.

*Dikes*.—Two exposures of diabase or basaltic dikes were observed in the western section of the area. The first starting in Section 31, T. 11 S., R. 89 W. and continuing almost due west for about five miles is composed of two small dikes, one about five feet thick and the other approximately two feet. They are from five to 15 feet apart and nearly vertical. The invaded Wasatch shales are extensively metamorphosed along the contact so that a conspicuous ridge has been left standing along the entire outcrop; local relief exceeding 200 feet is common along the resistant ridges. Due to this intensive alteration, it is believed that the dikes served as a fissure from which flowed the basalt now found as boulders scattered over the area from Muddy Creek westward.

Other dikes of the same general composition are found in Section 33, T. 10 S., R. 90 W. and on the west rim of Coal Basin north of the mapped area.

## STRUCTURE

The Ragged-Chair Mountain area is located structurally in a transitional zone between the highly folded and faulted Elk Mountain, on the east, and the Unita Basin structure, to the west. The Grand Hogback, which is a simple monoclinical fold marking the eastern boundary of this basin is complicated by the synclinal Coal Basin structure and the disruptions caused by the laccolithic intrusions as it is traced southeastward through the area.

The most apparent single structural feature within the map area is the broad, south plunging Muddy Creek syncline which has resulted in the development of consequent drainage pattern in the soft, maroon shales of the Wasatch Formation. A second distinct synclinical structure occurs in the vicinity of Anthracite Pass. The axis is parallel to Raspberry and North Anthracite Creeks with the large intrusive sheet from the Marcellina igneous mass occupying most of the synclinal depression. Elsewhere in the area the Cretaceous and Tertiary sedimentary cover is inclined as a result of the intrusive activity. In most cases the sedimentary rocks near the intrusions now form steeply dipping flatirons. Associated with these are numerous faults which are difficult to trace because of the slumping nature of the Mesaverde and Wasatch formations.

Certain igneous contacts are represented by abrupt, nearly vertical faces which may be the result of a fault occurring in the overlying strata above the contact at the time of injection. An example of this is along the west side of

TABLE I
CLASSIFICATION OF COALS BY RANK

Legend: F.C. = Fixed Carbon V.M. = Volatile Matter Btu.= British thermal units.

| Class | Group | Limits of Fixed Carbon or Btu Mineral-Matter-Free Basis | Requisite Physical Properties |
|---|---|---|---|
| I. Anthracitic | 1. Meta-anthracite | Dry F.C., 98 per cent or more (Dry V.M., 2 per cent or less) | |
| | 2. Anthracite | Dry F.C., 92 per cent or more and less than 98 per cent (Dry V.M., 8 per cent or less and more than 2 per cent) | |
| | 3. Semianthracite | Dry F.C., 86 per cent or more and less than 92 per cent (Dry V.M., 14 per cent or less and more than 8 per cent) | Nonagglomerating[b] |
| II. Bituminous[d] | 1. Low volatile bituminous coal | Dry F.C., 78 per cent or more and less than 86 per cent (Dry V.M., 22 per cent or less and more than 14 per cent) | |
| | 2. Medium volatile bituminous coal | Dry F.C., 69 per cent or more and less than 78 per cent (Dry V.M., 31 per cent or less and more than 22 per cent) | |
| | 3. High volatile A bituminous coal | Dry F.C., less than 69 per cent (Dry V.M., more than 31 per cent); and moist[c] Btu., 14,000[e] or more. | |
| | 4. High volatile B bituminous coal | Moist[c] Btu., 13,000 or more and less than 14,000[e] | |
| | 5. High volatile C bituminous coal | Moist Btu., 11,000 or more and less than 13,000[e] | Either agglomerating or nonweathering [f] |
| III. Subbituminous | 1. Subbituminous A coal | Moist Btu., 11,000 or more and less than 13,000[e] | Both weathering and nonagglomerating |
| | 2. Subbituminous B coal | Moist Btu., 9500 or more and less than 11,000[e] | |
| | 3. Subbituminous C coal | Moist Btu., 8300 or more and less than 9,500[e] | |
| IV. Lignitic | 1. Lignite | Moist Btu., less than 8,300 | Consolidated |
| | 2. Brown coal | Moist Btu., less than 8,300 | Unconsolidated |

[a] This classification does not include a few coals which have unusual physical and chemical properties and which come within the limits of fixed carbon or Btu. of the high-volatile bituminous and subbituminous ranks. All of these coals either contain less than 48 per cent dry, mineral-matter-free fixed carbon or have more than 15,500 moist, mineral-matter-free Btu.

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

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

[d] It is recognized that there may be noncaking varieties in each group of the bituminous class.

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

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

TABLE II
COAL ANALYSES-PAONIA COAL

| Area | Location No. | Stratagraphic Position | Sample No. | Type of Sample | Thickness (Feet) Bed | Thickness (Feet) Sample | Moisture Free: Proximate V.M. | F.C. | Ash | Ultimate S | C | $H_2$ | $N_2$ | $O_2$ | Plastometer: I.S. Temp. C° | M.F. Temp. C° | D.D. Per Min | S. Temp. C° | Agg. Index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CHAIR MTN. | | | | | | | | | | | | | | | | | | | |
| Buck Creek | 4 | Placita | 649 | Channel | 3.2 | 3.2 | 20.6 | 71.5 | 7.9 | 0.61 | 71.8 | 3.6 | 1.7 | 14.1 | | | | | NA |
| do. | 4 | Paonia | 648 | do. | 2.0 | 2.0 | 39.1 | 52.4 | 8.5 | 0.54 | 59.7 | 3.1 | 1.3 | 26.8 | | | | | NA |
| do. | 5 | Placita | 839 | do. | 3.5± | 3.5± | 33.1 | 57.7 | 9.2 | 0.50 | 67.2 | 2.7 | 1.4 | 19.0 | | | | | NA |
| do. | 5 | do. | 285 | do. | 3.5 | 3.5 | 16.8 | 75.9 | 7.3 | 0.54 | 80.0 | 3.4 | 1.7 | 17.0 | | | | | NA |
| do. (B. of Mines) | Near 5 | do. | | do. | 3.2 | 3.2 | 10.2 | 84.1 | 5.7 | 0.6 | 85.3 | 3.5 | 1.9 | 3.0 | | | | | |
| Rapid Creek | 10 | do. | 1701 | do. | 5.9 | 4.8 | 10.2 | 85.3 | 4.6 | 0.56 | 86.4 | 3.4 | 1.4 | 3.8 | | | | | NA |
| do. | 10 | do. | 1702 | do. | 5.9 | 1.1 | 9.1 | 71.9 | 19.0 | 0.54 | 73.3 | 3.1 | 1.4 | 2.6 | | | | | NA |
| Chair Creek | 9 | do. | 1703 | do. | 0.5 | 0.5 | 16.5 | 72.1 | 11.4 | 0.93 | 78.5 | 3.1 | 1.3 | 4.8 | | | | | NA |
| COAL BASIN | | | | | | | | | | | | | | | | | | | |
| Drill Hole | CB-4 | do. | 764 | Core | 3.8 | 6.8 | 30.9 | 64.7 | 4.4 | 0.45 | 83.5 | 5.4 | 1.7 | 4.6 | 348 | 422 | 734 | 478 | Good |
| do. | CB-4 | do. | 765 | do. | 3.0 | 6.8 | 30.8 | 64.7 | 4.5 | 0.71 | 82.5 | 5.4 | 1.8 | 5.2 | 351 | 416 | 502 | 484 | do. |
| Hayes Creek | 22 | do. | 490 | Channel | 7.0 | 7.0 | 38.1 | 56.4 | 5.5 | 0.36 | 67.4 | 5.1 | 1.4 | 20.3 | 325 | 363 | 2 | | NA |
| do. | 24 | do. | 489 | do. | 4.8 | 4.8 | 36.4 | 55.1 | 8.5 | 0.55 | 63.8 | 4.9 | 1.5 | 20.9 | 325 | 412 | 2 | | NA |
| MARBLE | | | | | | | | | | | | | | | | | | | |
| Galloway Prospect | | do. | 849 | do. | 0.9 | 0.9 | 13.3 | 82.5 | 4.2 | 0.59 | 84.5 | 3.9 | 2.9 | 4.0 | | | | | NA |
| MUDDY CREEK | | | | | | | | | | | | | | | | | | | |
| Spatafore No. 1 | | Paonia | 1706 | Drill Cutt. | 0.5 | 0.5 | 33.4 | 62.3 | 4.3 | 0.54 | 81.8 | 5.5 | 1.7 | 6.2 | 351 | 438 | 1540 | 480 | A-4 |
| do. | | do. | 1707 | do. | 3.0 | 3.0 | 34.2 | 58.8 | 7.0 | 0.61 | 79.0 | 5.4 | 1.7 | 6.3 | 351 | 438 | 3600 | 480 | A-4½ |
| do. | | Placita | 1708 | do. | 6.0 | 6.0 | 33.7 | 62.0 | 4.4 | 0.72 | 81.2 | 5.5 | 1.7 | 6.5 | 351 | 438 | 9200 | 474 | A-5 |
| McLaughlin No. 1 | | do. | 841 | do. | 4.0 | 4.0 | 32.3 | 56.6 | 6.2 | 0.59 | 77.4 | 5.8 | 1.6 | 8.5 | 369 | 426 | 150 | 465 | A-2½ |
| MUNSEY CREEK | | | | | | | | | | | | | | | | | | | |
| Bear Prospect | | Paonia | 546 | Channel | 5.1 | 4.8 | 7.8 | 64.5 | 27.7 | 0.55 | 63.7 | 2.9 | 1.4 | 3.7 | | | | | NA |
| do. | | do. | B. of Mines | do.(?) | | 3.0(?) | 6.7 | 88.3 | 5.0 | | | | | | | | | | NA |
| Deep Creek Pass | 11 | do. | 547 | do. | 2.0 | 2.0 | 19.5 | 74.4 | 6.1 | 0.87 | 71.7 | 2.5 | 1.6 | 17.2 | | | | | NA |
| do. | 11 | do. | 548 | do. | 2.1 | 2.1 | 23.8 | 67.2 | 9.0 | 0.78 | 73.1 | 1.7 | 1.4 | 14.1 | | | | | NA |
| do. | 11 | do. | 549 | do. | 1.7 | 1.7 | 19.6 | 67.2 | 13.2 | 0.66 | 66.8 | 2.9 | 1.3 | 15.1 | | | | | NA |
| PLACITA | | | | | | | | | | | | | | | | | | | |
| Holgate Mine | | Placita | | do.(?) | 3.7 | 3.7 | 31.3 | 62.8 | 5.9 | 0.48 | 80.0 | 5.6 | 1.8 | 6.7 | 331 | 411 | 660 | 451 | Good |
| Holgate (Oven Test) | | do. | | do.(?) | 3.5± | 3.5± | | | | | | | | | 345 | 419 | 1292 | 467 | do. |
| SOMERSET | | | | | | | | | | | | | | | | | | | |
| Drill Hole | DH-8 | Paonia | 397 | Core | 2.5 | 2.5 | 39.6 | 58.4 | 2.1 | 0.51 | 78.0 | 5.9 | 1.7 | 11.9 | 357 | 380 | 0.2 | 403 | Fair |
| do. | do. | do. | 395 | do. | 6.9 | 2.5 | 36.7 | 54.0 | 9.4 | 0.66 | 72.2 | 5.3 | 1.4 | 11.1 | 373 | 417 | 2 | 449 | do. |
| do. | do. | do. | 396 | do. | 6.9 | 4.4 | 36.2 | 51.7 | 12.1 | 0.54 | 69.3 | 5.5 | 1.5 | 11.1 | 370 | 409 | 2 | 438 | do. |

Ragged-Chair Mountain where the sedimentary beds are only moderately warped against a vertical cliff of quartz monzonite porphyry, and where a fault extends northward from the contact. This fault, which is directly west of the McIntyre prospect, has a displacement of more than 2000 feet and cannot be traced southward into the sediments that are dipping away from the intrusion.

## COAL BEDS

### General Statement

Since carbon, in the form of coke which is derived from the destructive distillation of selected coals, is the best reducing agent suited for the economical production of iron, it is essential that desirable coking coals be made available to the iron and steel industry. In the eastern United States this has not been a problem because of the cokability of most of the bituminous coals. But in the Rocky Mountain province only a few select areas contain the necessary coking coal reserves. One of these is the Coal Basin District. In this area are some of the best coking coals in the Rocky Mountain region.

The coal-bearing interval is restricted to the 1000-1200 feet of the lower Mesaverde strata above the basal Rollins Sandstone Member. There are no coals below this marker bed, although in the Gunnison River valley between Delta and Grand Junction, there are a number of lenticular, lignitic coals in the Dakota Sandstone (Woodruff, 1912).

The coal beds within the limits of this investigation range in thickness from a few inches to over 15 feet. They occur above each of the three sandstones and at scattered intervals in the shale units separating these sandstones. Within the area of this study only the coal beds immediately above the sandstones are of economic importance; other thin beds within the shales, as shown on the accompanying charts, contain considerable reserves in adjacent areas but are not important in the mapped areas.

### Classification

The rank of the coals is determined in accordance with the specifications of the American Society for Testing Materials (ASTM) which are reproduced in Table I (Spencer & Erwin, 1953). The rank of the coals sampled ranges from high-volatile A bituminous to anthracite, but most of the coal is medium-volatile. Considerable variations occur locally near the intrusive bodies where the coal-bearing rocks have been folded, faulted and metamorphosed. As would be expected, the anthracite is located near the intrusion or in beds altered by the metamorphic effects of a dike or sill. Outward from the porphyry masses, are the only small restricted areas that show a gradual decrease in rank from anthracite to medium-volatile. In most cases there are no definite gradations of rank in relationship to the distance between the coal bed and the intrusive body. Medium-volatile beds were observed in many areas within less than 50 feet of large intrusions from three to four miles in diameter. Also, similarly ranked beds or even coals of higher rank were encountered in some of the drilling done on Grand Mesa which is far removed from any surface exposures of igneous material. There were few beds found which could be classified as low-volatile. Specifically these were Paonia coals on the north and south ends of Ragged-Chair Mountain where the zones are narrow and economically unimportant. In the other areas sampled, the low-volatile zones, if they actually existed, were so small that they were not detected.

This work does not consider the temperatures necessary for the formation of these various ranks, but a relative comparison between the anthracite and shales was noted. In areas with coals ranging from low-volatile to anthracite the underlying or interbedded shales were well indurated. But where the shales were associated with medium-volatile coals there were no apparent physical variations in the shales.

In summary, the observations and analyses made in the Ragged-Chair Mountain vicinity and adjacent areas reveal that the formation of medium-volatile coking coals are either directly or indirectly associated with the Tertiary intrusives which have disrupted the coal-bearing Mesaverde strata. However it is the writer's opinion that the direct metamorphic effects on the coals is of only local extent and that the extensive medium-volatile reserves have resulted from the stresses applied to the sediments as they were compressed, folded and faulted during emplacement of the igneous masses; additional heat from the intrusives undoubtedly supplemented that created by these confining pressures.

## Distribution of Coal Beds

### General Statement

There are three persistent coal horizons in the area of investigation and each is located on, or slightly above a pronounced sandstone unit. Two of the horizons are in the Bowie Member. The first and most important zone is found at the bottom of the basal shale unit resting on the underlying Rollins Sandstone Member. The second zone is situated on the middle sandstone, while the third and least important of the three horizons occupies a position in the Paonia Member above the upper sandstone.

For purposes of discussion, these three coal horizons have been designated, in ascending order, as follows: (1) Coal Basin, (2) Middle, and (3) Placita horizons. In addition there are a number of thin, sporadic beds occurring in the shale sequence above the horizons mentioned. They are not of economic importance in the area discussed, but do contain large important reserves, particularly in the Bowie Member in the Somerset field.

As a general rule the larger quantities and the better grades of coal are found in the lower stratigraphic units with a gradual decrease in bed thickness and quality in the higher stratigraphic positions.

Tonnage estimates for the individual beds along with the analyses are tabulated in the accompanying tables.

### Coal Basin Horizon

This position is named from the thick coal interval on top of the Rollins Sandstone in the vicinity of Coal Basin which is directly north of the area. The basal coal, designated A-bed, rests immediately on, or just slightly above, the Rollins. It is from one to seven feet thick and has a high ash content. The bed could be washed but the estimated low yield would make it impractical; for this reason the A-bed is considered only a poor grade domestic coal. The next higher coal in this sequence is the B-bed which is the thickest coal bed in the area studied; McLaughlin No. 1 well had 15 feet and drill hole DH-8 had a thickness of 21.9 feet. On the west side of Coal Basin the A- and B-beds are represented by a single large bed averaging approximately 16-18 feet in thickness, and Mid-Continent Coal & Coke Company has located their mine on the upper bench of these combined beds.

TABLE III

ANALYSES-MIDDLE AND MISCELLANEOUS COAL HORIZONS

| Area | Location No. | Stratagraphic Position | Sample No. | Type of Sample | Thickness (Feet) | | Moisture Free | | | | | | | | Plastometer | | | | Agg. Index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Proximate | | | Ultimate | | | | | I.S. Temp. C° | M.F. Temp. C° | D.D. Per Min | S. Temp. C° | |
| | | | | | Bed | Sample | V.M. | F.C. | Ash | S | C | $H_2$ | $N_2$ | $O_2$ | | | | | |
| MIDDLE COAL HORIZON | | | | | | | | | | | | | | | | | | | |
| CHAIR MTN. | | | | | | | | | | | | | | | | | | | |
| McIntyre Prospect | | Middle | 650 | Channel | 7.6 | 7.1 | 12.2 | 81.8 | 6.0 | 0.94 | 84.1 | 3.7 | 1.8 | 3.4 | | | | | NA |
| do. | | Mid. Zone | 1705 | 11 | 0.8 | 0.8 | 16.0 | 74.5 | 9.4 | 1.94 | 74.7 | 2.8 | 1.3 | 9.8 | | | | | NA |
| Buck Creek | 3 | do. | 1704 | Grab | | | 9.4 | 85.1 | 5.6 | 1.07 | 85.3 | 3.0 | 1.5 | 3.5 | | | | | NA |
| do. | 2 | Middle | 840 | Channel | 6.0 | 5.5 | 34.2 | 57.9 | 7.9 | 0.84 | 72.3 | 2.7 | 1.5 | 14.7 | | | | | NA |
| Genter Mine | | Mid. Zone | 4 | Grab | 3.9(?) | 3.9(?) | 9.9 | 86.2 | 3.9 | 0.57 | | | | | | | | | NA |
| COAL BASIN | | | | | | | | | | | | | | | | | | | |
| Drill Hole | CB-4 | Middle | 806 | Core | 6.4 | 2.1 | 27.5 | 66.0 | 6.5 | 1.04 | 80.8 | 5.0 | 1.8 | 4.9 | 346 | 420 | 249 | 469 | Good |
| do. | do. | do. | 807 | do. | 6.4 | 1.4 | 14.0 | 30.1 | 55.9 | 0.44 | 39.8 | 2.8 | 1.1 | 0.1 | 354 | 444 | 3534 | 486 | do. |
| do. | do. | do. | 808 | do. | 6.4 | 2.9 | 23.9 | 53.2 | 22.9 | 0.47 | 68.2 | 4.7 | 1.5 | 2.2 | 366 | 430 | 1146 | 488 | do. |
| do. | do. | do. | 809 | do. | 1.6 | 1.6 | 16.5 | 33.8 | 49.7 | 0.45 | 45.0 | 3.3 | 0.8 | 0.8 | 358 | 436 | 5616 | 490 | do. |
| MARBLE | | | | | | | | | | | | | | | | | | | |
| Prospect | 12 | Mid. Zone | 850 | Channel | 4.2 | 4.2 | 6.1 | 88.7 | 5.2 | 0.27 | 89.1 | 1.2 | 1.1 | 3.1 | | | | | NA |
| MIDDLE CREEK | | | | | | | | | | | | | | | | | | | |
| Spatafore No. 1 | | Middle Zone | 1712 | Drill Cutt. | 6.0 | 6.0 | 29.6 | 62.8 | 7.6 | 0.69 | 79.0 | 5.4 | 1.6 | 5.7 | 357 | 441 | 1000 | 477 | A-5 |
| do. | | do. | 1713 | do. | 3.0 | 3.0 | 29.9 | 61.4 | 8.7 | 0.72 | 78.2 | 5.3 | 1.6 | 5.5 | 351 | 444 | 2400 | 471 | A-6 |
| do. | | Middle | 1714 | do. | 3.0 | 3.0 | 30.1 | 63.3 | 6.6 | 0.72 | 80.0 | 5.3 | 1.6 | 5.8 | 360 | 441 | 3500 | 480 | A-5 |
| McLaughlin No. 1 | | do. | 842 | do. | 16.0 | 16.0 | 35.2 | 59.3 | 5.5 | 0.72 | 79.6 | 5.6 | 1.7 | 7.0 | 375 | 432 | 220 | 465 | A-3 |
| do. | | do. | 843 | do. | same bed | | 35.1 | 58.7 | 6.2 | 0.77 | 78.5 | 5.6 | 1.7 | 7.2 | 372 | 438 | 173 | 468 | A-3 |
| SOMERSET | | | | | | | | | | | | | | | | | | | |
| Drill Hole | DH-8 | Middle (?) | 394 | Core | 1.3 | 1.3 | 40.7 | 46.1 | 13.3 | 0,83 | 69.1 | 5.6 | 1.4 | 9.8 | 344 | 400 | 3 | 428 | Fair |
| MISCELLANEOUS COAL HORIZON | | | | | | | | | | | | | | | | | | | |
| ANTHRACITE CREEK | | | | | | | | | | | | | | | | | | | |
| Dark Canyon | 13 | (?) | 626 | Channel | 2.0 | 2.0 | 5.9 | 79.5 | 14.6 | 0.73 | 76.4 | 2.6 | 1.7 | 4.0 | | | | | NA |
| do. | 13 | (?) | 627 | do. | 2.0 | 2.0 | 4.7 | 85.9 | 9.4 | 0.68 | 83.5 | 2.9 | 1.7 | 1.9 | | | | | NA |

TABLE IV

ANALYSES-COAL BASIN HORIZON

| Area | Location No. | Stratagraphic Position | Sample No. | Type of Sample | Thickness (Feet) Bed | Thickness (Feet) Sample | Moisture Free Proximate V.M. | Moisture Free Proximate F.C. | Moisture Free Proximate Ash | Moisture Free Ultimate S | Moisture Free Ultimate C | Moisture Free Ultimate $H_2$ | Moisture Free Ultimate $N_2$ | Moisture Free Ultimate $O_2$ | Plastometer T.S. Temp. C° | Plastometer M.F. Temp. C° | Plastometer D.D. Per Min | Plastometer S. Temp. C° | Agg. Index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ANTHRACITE CREEK | | | | | | | | | | | | | | | | | | | |
| Drill Hole | DH-23 | | A | Core | 1.8 | 1.8 | 40.6 | 54.2 | 5.2 | 2.7 | 78.5 | 5.5 | 1.7 | 6.4 | | | | | 5.3 |
| do. | do. | C-Bed | B | do. | 1.3 | 1.3 | 39.4 | 52.5 | 8.1 | 0.7 | 76.5 | 5.4 | 1.7 | 7.6 | | | | | 5.5 |
| do. | do. | A- & B- Beds | C | do. | 1.0 | 1.0 | 40.0 | 44.6 | 15.4 | 1.9 | 69.7 | 5.2 | 1.5 | 6.3 | | | | | 5.7 |
| do. | do. | do. | D | do. | 4.1 | 3.3 | 36.9 | 49.0 | 14.1 | 0.5 | 71.2 | 5.1 | 1.5 | 7.6 | | | | | 5.2 |
| Drill Hole | DH-13 | B-Bed (?) | E | do. | 4.8 | 4.0 | 40.8 | 55.4 | 3.8 | 0.8 | 81.0 | 5.6 | 1.8 | 7.0 | | | | | 5.4 |
| do. | do. | B-Bed | F | do. | 6.1 | 4.3 | 39.2 | 55.9 | 4.9 | 0.5 | 80.1 | 5.5 | 1.8 | 7.2 | | | | | 4.8 |
| do. | do. | do. | G | do. | 6.1 | 1.3 | 35.9 | 49.6 | 14.5 | 0.5 | 71.4 | 5.0 | 1.6 | 7.0 | | | | | 5.7 |
| do. | do. | A-Bed | H | do. | 7.6 | 7.6 | 39.0 | 54.9 | 6.1 | 0.6 | 79.1 | 5.5 | 1.8 | 6.9 | | | | | 6.2 |
| CHAIR MTN. | | | | | | | | | | | | | | | | | | | |
| Deep Creek Pass | 11 | A-Bed | 848 | Channel | 1.1 | 1.1 | 32.2 | 53.3 | 14.5 | 0.94 | 58.6 | 2.2 | 1.4 | 22.3 | | | | | NA |
| COAL BASIN | | | | | | | | | | | | | | | | | | | |
| Drill Hole | CB-4 | B-Bed | 827 | Core | 5.9 | 2.7 | 23.7 | 63.3 | 13.0 | 0.51 | 73.1 | 4.7 | 1.9 | 6.8 | 382 | 430 | 436 | 461 | Good |
| do. | do. | do. | 828 | do. | 5.9 | 3.2 | 27.0 | 66.1 | 6.9 | 1.55 | 82.9 | 4.9 | 1.9 | 1.9 | 376 | 430 | 692 | 490 | do. |
| do. | do. | do. | 829 | do. | 5.9 | 5.9 | 24.3 | 69.6 | 6.1 | 0.58 | 83.4 | 5.3 | 2.1 | 2.6 | 376 | 428 | 855 | 490 | do. |
| do. | do. | A-Bed | 830 | do. | 6.9 | 0.4 | 18.5 | 46.2 | 35.3 | 3.90 | 52.8 | 4.0 | 1.2 | 2.9 | 380 | 455 | 293 | 486 | Fair |
| do. | do. | do. | 831 | do. | 6.9 | 1.1 | 22.7 | 68.6 | 8.7 | 3.36 | 78.7 | 4.7 | 1.8 | 2.7 | 380 | 436 | 1416 | 488 | Good |
| do. | do. | do. | 832 | do. | 6.9 | 0.7 | 18.3 | 44.7 | 37.0 | 0.63 | 53.9 | 3.4 | 1.1 | 4.0 | 389 | 462 | 489 | 484 | |
| do. | do. | do. | 833 | do. | 6.9 | 2.2 | 22.1 | 58.5 | 19.4 | 0.49 | 70.3 | 4.3 | 1.5 | 4.0 | 384 | 447 | 528 | 502 | do. |
| do. | do. | do. | 834 | do. | 6.9 | 2.5 | 22.9 | 63.6 | 13.5 | 0.55 | 76.1 | 4.5 | 1.7 | 3.6 | 388 | 442 | 362 | 479 | do. |
| Hayes Creek | 25 | B-Bed | 488 | Channel | 2.3 | 2.3 | 33.1 | 51.9 | 15.0 | 0.52 | 60.0 | 4.6 | 1.6 | 18.1 | 320 | 430 | 1 | 485 | NA |
| do. | 23 | A-Bed | 491 | do. | 6.0 | 6.0 | 36.3 | 58.0 | 5.7 | 0.69 | 68.5 | 4.9 | 1.8 | 18.4 | 325 | 441 | 1 | | NA |
| MUDDY CREEK | | | | | | | | | | | | | | | | | | | |
| Spatafore No. 1 | | | 1715 | Drill Cutt. | 2.0 | 2.0 | 29.9 | 56.9 | 13.2 | 3.7 | 73.4 | 5.2 | 1.5 | 3.1 | 354 | 444 | 28,500 | 486 | A-9 |
| do. | | | 1716 | do. | 2.0 | 2.0 | 26.9 | 63.3 | 9.8 | 1.1 | 77.7 | 5.2 | 1.6 | 4.7 | 354 | 438 | 1620 | 474 | A-8 |
| do. | | C-Bed (?) | 1717 | do. | 10.0 | 10.0 | 27.2 | 65.1 | 7.7 | 0.78 | 80.3 | 5.4 | 1.7 | 4.2 | 360 | 444 | 2400 | 483 | A-8 |
| McLaughlin No. 1 | | B-Bed | 844 | do. | 15.0 | 15.0 | 34.2 | 59.5 | 6.3 | 0.80 | 79.0 | 5.1 | 1.6 | 7.1 | 372 | 432 | 170 | 465 | A-3 |
| do. | | A-Bed | 845 | do. | 6.0 | 6.0 | 32.8 | 59.3 | 7.9 | 0.55 | 78.6 | 5.1 | 1.8 | 6.1 | 350 | 446 | 8832 | 480 | Good |
| do. | | A- & B- Beds | 846 | do. | | 21.0 | 34.6 | 61.1 | 4.3 | 0.57 | 81.0 | 5.7 | 1.8 | 6.6 | 351 | 432 | 11,864 | 482 | do. |
| SOMERSET | | | | | | | | | | | | | | | | | | | |
| Drill Hole | DH-8 | C-Bed | 393 | Core | 7.8 | 2.2 | 37.7 | 53.2 | 9.2 | 0.59 | 72.2 | 5.7 | 1.5 | 10.7 | 344 | 389 | 2 | 421 | Fair |
| do. | do. | C-Bed | 392 | do. | 7.8 | 4.8 | 37.9 | 54.2 | 7.9 | 0.60 | 74.1 | 5.7 | 1.5 | 10.2 | 348 | 395 | 3 | 418 | do. |
| do. | do. | B-Bed | 391 | do. | 14.1 | 6.7 | 37.4 | 53.0 | 9.6 | 0.80 | 73.8 | 5.4 | 1.5 | 8.9 | 349 | 407 | 6 | 423 | do. |
| do. | do. | do. | 390 | do. | 14.1 | 1.8 | 37.6 | 53.2 | 9.3 | 0.46 | 73.3 | 5.4 | 1.5 | 10.0 | 337 | 359 | 0.2 | 405 | Poor |
| do. | do. | do. | 389 | do. | 14.1 | 5.6 | 36.1 | 48.9 | 15.0 | 0.52 | 68.1 | 5.6 | 1.4 | 9.4 | 326 | 363 | 0.2 | 380 | NA |
| do. | do. | do. | 388 | do. | 7.8 | 7.8 | 32.4 | 41.5 | 26.1 | 0.49 | 58.6 | 4.8 | 1.3 | 8.7 | 375 | 429 | 3 | 453 | NA |
| do. | do. | A-Bed | 387 | do. | 2.1 | 2.1 | 34.5 | 40.2 | 25.3 | 9.93 | 55.0 | 4.5 | 1.1 | 4.1 | | | | | |

In the eastern portion of the Ragged-Chair Mountain area, in the general vicinity of Marble, there are no important beds at the Coal Basin horizon. What coals do appear are thin and boney. Also at scattered locations throughout the northern portion of the area, is a pronounced one to ten foot coquina or coquinoidal shale bed that occurs about 40 feet above the Rollins Sandstone. All important beds in the Coal Basin horizon are found below this marker bed.

Separated from the underlying B-bed by an interval of 20 to 50 feet, is a third coal seam which is referred to as the C-bed. In hole DH-8, this bed is 7.8 feet thick, but in the outcrop area it is much thinner and very sporadic.

Except for Dapples' (1938) report of finding seven coal beds below the Rollins Sandstone in a member which he called the Baldwin Sandstone Member, there have been no coal beds observed below the Rollins Sandstone. The Rollins is the lithologic unit dividing the basal coal-bearing Mesaverde Formation from the Mancos Shale. It is the writer's opinion that the coals lying below the "Rollins" are actually Bowie coals and that the lower standstone is correlated incorrectly due to the intensive faulting in the Baldwin area.

### Middle Horizon

There are present in the map area two widespread sandstones in the lower Mesaverde strata in addition to the Rollins. Atop each of these sandstones (middle and upper) is a coal zone having a variable thickness and quality. The interval above the middle sandstone locally contains a high quality bed having a thickness in excess of five feet, which for present purposes has been described as the Middle horizon. In the vicinity of the McIntyre prospect, the main bed in this zone is from 6.0 to 7.6 feet thick, is of a semi-anthracite variety and contains a 0.5 foot boney band near the center of the bed. Toward hole CB-4 the bed is 6.4 feet thick and impregnated with small sandstone lenses. The maximum thickness for the bed is in McLaughlin No. 1 where there are 16 feet of medium-volatile coal containing about six percent ash.

### Placita Horizon

The approximately three to seven foot bed, present locally in the northern area at the base of the Paonia Member and on top of the upper sandstone is called the Placita bed because of the mined unit present near the abandoned town of the same name. Here the old Placita and Holgate mines were developed on a three to four foot bed which has the highest plasticity of any coal in the area.

### Miscellaneous Horizons

Within the thesis area there are a number of thin unimportant beds distributed through the section in the intervals between the three zones just discussed. The lower horizon is situated between the middle sandstone and the Coal Basin C-bed, and the other major sequence occurs above the Placita bed. Both zones contain coals of no economic proportions but in the Carbondale field there are commercial quantities in the upper portion of the Paonia Member. The same is true of the lower zone in the Somerset District to the south where a series of mined beds range upward from the Old King or A-bed through to the Hawksnest or E-bed (Chart II).

### Sampling Methods and Analyses

Channel samples were obtained from the outcrops, mines, and prospects whenever possible. If, however, for any reason the bed was masked by heavy vegetation or soil cover so that the bed thickness could not be measured, a grab sample was substituted. This was particularly true of the old mine and prospect workings which had fairly large dumps but were usually sealed at the portals by slumping. Where attainable, the prospective channel surface was cleared to what was considered relatively clean coal and no effort was made to obtain fresh, unoxidized samples. Unweathered coal cannot be reached until depths of 25 feet or more, thus no fresh coal is included with the surface samples. In general the field procedures used in describing and sampling the coal beds were in accordance with those recommended by Schopf (1960).

TABLE V
Holes Drilled In or Near Ragged-Chair Mountain Area

| *Diamond Drill Holes* *Hole Designation* | *Company* | *Location* |
|---|---|---|
| CB-4 | Columbia-Geneva Steel Div. | NW¼, Sec. 28, T. 10 S., R. 89 W. |
| DH-3 | Placita Coal Mining Co. | SW¼, Sec. 5, T. 11 S., R. 88 W. |
| DH-4 | do. | SE¼, Sec. 5, T. 11 S., R. 88 W. |
| DH-5 | do. | SE¼, Sec. 6, T. 11 S., R. 88 W. |
| DH-6 | do. | NE¼, Sec. 6, T. 11 S., R. 88 W. |
| DH-8 | Columbia-Geneva Steel Div. | SE¼, Sec. 3, T. 13 S., R. 90 W. |
| DH-13 | U.S. Bureau of Mines | NE¼, Sec. 4, T. 13 S., R. 89 W. |
| DH-23 | do. | NW¼, Sec. 13, T. 13 S., R. 89 W. |
| Spatafore No. 1 | Delhi-Taylor Oil Corp. | NW¼, Sec. 27, T. 11 S., R. 90 W. |
| McLaughlin No. 1 | do. | SE¼, Sec. 17, T. 12 S., R. 89 W. |

Most samples were analyzed at Columbia-Geneva's laboratory facilities according to American Society for Testing Material (ASTM) standards. The coal analyses from the Ragged-Chair Mountain and adjacent areas are grouped in relationship to their stratigraphic position and appear in Tables II, III and IV.

A close examination of the coal analyses along with the geologic map will reveal not only the varying degrees of oxidation in the surface samples, but that the higher-ranked coals are usually (1) in the lower stratigraphic positions (Coal Basin horizon), (2) beneath greater amounts of overburden and (3) more remote from the outcrop.

### Mines and Prospects

There are no active mines presently operating within the boundaries of this investigation. The Coal Basin Mine located on the west side of a large basin north of the area is the nearest operating property. The mine is situated on what is herein designated the Coal Basin horizon. The A- and B-beds have combined at this point to form a single bed averaging about 17 feet thick. Originally this area was developed by the Colorado Fuel and Iron Company. Gale (1906) reported that it contained two beds with a two inch to four foot separation. An upper bench (B-bed) contained 7 to 19 feet of good quality coking coal while the coal in the lower bed was much dirtier and had little economic importance. Because this lower bed was below the mine workings there was considerable gas present in the mine.

Placita and Holgate Mines

The abandoned Placita and Holgate mines were developed on the Placita horizon above the upper sandstone with a maximum bed thickness of slightly less than four feet. Because of the high plasticity of this bed it was one of the earlier coals exploited for coke production, particularly for Colorado Fuel and Iron Company's Pueblo works. In the Holgate Mine the volatile matter is approximately 31 percent with 5.9 percent ash which is about average for the Placita horizon in the areas not extensively affected by the intrusions.

Genter Mine

The portal for the Genter Mine rock tunnel is on the south side of the road between Placita and Marble. The tunnel runs south from this point and intersects the high-ranked coals resting above the middle sandstone which was dragged up and altered by the Ragged-Chair Mountain porphyry intrusive. The bed is approximately five feet thick and is believed to be the same horizon as that of the McIntyre prospect to the west. A grab sample from the dump was semi-anthracite, although some pieces containing "islands" of porphyry were definitely of anthracite rank. These isolated blebs of porphyry are disseminated through the coal without any feeder connection to one another or to the sill which acted as a source. This phenomenon is possibly due to a sill being injected into the bed which was subsequently faulted while the coal was still plastic. The disruption would cause the dislocation of the sill material into the isolated fragments now observed.

Bear Prospect

This prospect contains about five feet of semi-anthracite coal at the Placita horizon in the steeply dipping beds at the south end of Ragged Mountain. The area is practically inaccessible except on foot and the reserves have only limited domestic possibilities.

McIntyre Prospect

Although the McIntyre Prospect occupies a lower stratigraphic position (middle horizon) it is nearly identical with the Bear Prospect, i.e. the strata are steeply dipping, the area is not conducive for development, the prospects are only a short distance from the intrusive and the coal beds are semi-anthracite.

At location 4 and 5 (map in back) above the McIntyre Prospect there are a number of prospects in the lower Paonia Member that were worked as late as 1959 or 1960. However these beds are less than four feet thick and although they do contain some of the few low-volatile reserves that are present in the area, they could not at present be mined economically.

Miscellaneous Prospects

In the Paonia Member north of Marble the Galloway Prospect evidently supplied a limited amount of either semi-anthracite or anthracite to the domestic market in Marble. The only bed found here however was a 0.9 foot bed of semi-anthracite resting directly on the upper sandstone. Any mined bed at this location is probably in the Paonia Member and has been covered by the slides which are common in this area. There is another prospect south of

TABLE VI
ESTIMATED IN-PLACE RESERVES

| General Area | Sections | Average Thickness (Feet) | Acres | Overburden 0-2000 | Overburden 2000-3000 | Overburden 0-3000 |
|---|---|---|---|---|---|---|
| | **Placita Horizon** | | | | | |
| Measured-Indicated | | | | | | |
| Hole CB-4 to Placita<br>McLaughlin No. 1 | 28, T 10 S, R 89 W<br>17 & 20, T 12 S, R 89 W | 6<br>4 | 640<br>640 | 6,912,000 | 4,608,000 | 11,520,000 |
| Inferred | | | | | | |
| Hole CB-4 to Placita<br>McLaughlin No. 1 | 3-5, T 11 S, R 89 W, 20-27, 29, 32-36, T 10 S, R 89 W<br>7-9, 16-21, 28-30, T 12 S, R 89 W | 6<br>4 | 4932<br>5855 | 31,568,000 | 21,697,000<br>42,156,000 | 95,421,000 |
| | **Middle Horizon** | | | | | |
| Measured-Indicated | | | | | | |
| Chair Mountain<br>McLaughlin No. 1 | 23-26, T 11 S, R 89 W<br>17 & 20, T 12 S, R 89 W | 6<br>16 | 698<br>640 | | 18,432,000 | 7,538,000<br>18,432,000 |
| Inferred | | | | | | |
| McLaughlin No. 1 | 7-8, 16-21, 28-30, T 12 S, R 89 W | 10 | 1470 | 6,570,000 | 19,890,000 | 26,460,000 |
| | **Coal Basin Horizon** | | | | | |
| Measured-Indicated | | | | | | |
| McLaughlin No. 1<br>Hole CB-4 | 17 & 20, T 12 S, R 89 W<br>28, T 10 S, R 89 W | 21<br>12 | 441<br>640 | 8,273,000 | 16,670,000<br>5,551,000 | 30,494,000 |
| Inferred | | | | | | |
| McLaughlin No. 1<br>Hole CB-4 | 17-21, 28-30, T 12 S, R 89 W<br>20-22, 27, 29, 32-34 | 18<br>6 | 3048<br>2570 | 13,478,000 | 98,755,000<br>14,278,000 | 126,511,000 |
| Totals | | | | 66,801,000 | 242,037,000 | 316,376,000 |

Notes:
1. Reserves are estimated on an 1800-ton per acre-foot basis.
2. Measured-indicated reserves extent approximately ½-mile beyond point of observation; inferred reserves are about two miles.
3. Reserves are not estimated for beds less than 4.0 feet thick.

Marble on the middle sandstone and directly under the large intrusive sheet that has metamorphosed the coal to a semi-anthracite.

Between the Genter Mine and the McIntyre Prospect there are a considerable number of pits and adits that confirm the continuation of the middle horizon across the north end of Chair Mountain.

### Reserves

There are three persistent coal horizons in the lower Mesaverde strata that contain one or more beds of commercial quality with thicknesses in excess of four feet. In-place reserves for each bed more than four feet thick have been calculated using a factor for 1800 tons per acre-foot. No attempt was made to calculate recoverable reserves. The in-place reserves are calculated according to the amount of overburden and they are classified as either measured-indicated or inferred, depending on distance from established data. Reserves less than approximately one-half mile from known thickness in drill hole data or measured outcrops are classified as measured-indicated; all those beyond this limit are considered in an inferred grouping. The total of all types of reserves in Ragged-Chair Mountain area under 3000 feet of cover are estimated at 316,376,000 tons. This figure, however, does not include any of the reserves north of T. 11 S. because of the present competitive interest in the coal leases on the south slopes of Coal Basin by the Columbia-Geneva Steel Company. A tabulated summary of these reserves is shown on Table VI.

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