Geology and Coal Resources of the Walsenburg Area Huerfano County Colorado

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GEOLOGY AND COAL RESOURCES OF THE WALSENBURG AREA, HUERFANO COUNTY, COLORADO

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ABSTRACT

Sedimentary rocks of the Walsenburg area, which encompasses about 236 square miles of the northern part of the Raton Mesa region of southeastern Colorado, belong to marine and nonmarine formations that range in age from Late Cretaceous to Quaternary. Intrusive igneous rocks of Tertiary age are also abundant and conspicuously exposed in the area. Both kinds of rocks show structural deformation caused by forces at work during the Laramide revolution.

Beds of coal occur in the Vermejo and Raton formations of Late Cretaceous and Paleocene age. The Vermejo formation consists of 240 to 410 feet of alternating beds of sandstone, siltstone, shale, and coal. The Raton formation consists of 10 to 500 feet of alternating beds of sandstone, siltstone, shale, and coal, with a bed of conglomerate at the base of the formation.

The Vermejo contains 3 to 8 coal beds, and the Raton contains 1 to 3 coal beds, all more than 14 inches thick. The coal of the Walsenburg area is a nonagglomerating and nonweathering high-volatile *C* bituminous coal. In this area, the estimated original reserves of coal occurring in beds more than 14 inches thick and with less than 3,000 feet of overburden are 667.5 million short tons.

INTRODUCTION

The Walsenburg area covers about 236 square miles in the northern part of the Raton Mesa region, Colorado, and includes a part of the Trinidad coal field (index map, pl. 47). The boundary between the Walsenburg and La Veta areas is about 7 miles west of Walsenburg at meridian 104°55′ west longitude (Johnson and Stephens, 1954a). The eastern boundary of the Walsenburg area is at meridian 104°40′. The south and north boundaries are at 37°30′ and 37°45′ north latitude.

The area was mapped during the summer of 1951 by Ross B. Johnson and James G. Stephens as a part of the U. S. Geological Survey's study of the geology and fuel resources of the entire Raton Mesa region and the Trinidad coal field. This work was begun in 1948.

The geologic map (pl. 47) shows the areas of outcrop of Upper Cretaceous and lower Tertiary rocks and structural, geographic, and cultural features of the area. Fieldwork consisted of mapping sedimentary formations, including coal beds, and igneous and structural features on aerial photographs. These data were then transferred to a base which was compiled from township plats of the Bureau of Land Management and from planimetric maps prepared by the authors from the aerial photographs. Stratigraphic sections of the coal beds and associated rocks were measured at many places. Structure contours were drawn on top of the Trinidad sandstone from elevations determined in the field.

The presence of coal in the Walsenburg area has been known for many years. F. M. Endlich (1877), a geologist for the Hayden Survey, made the first study of the Trinidad coal field in 1875. J. J. Stephenson (1881), a geologist with the Wheeler Survey, examined part of the coal field in 1878 and 1879. R. C. Hills discussed the Trinidad coal field in a "Mineral resources" report of the Geological Survey (1893), and later prepared geologic folios of the Elmoro, Walsenburg, and Spanish Peaks quadrangles (1899, 1900, and 1901). G. B. Richardson (1910) and W. T. Lee and F. H. Knowlton (1917) wrote detailed reports on the geology of the Trinidad coal field and the Raton Mesa region. Technologic papers on mines and mining districts were published between 1897 to 1909 in volumes of "Mines and minerals."

GEOGRAPHY

The part of the Trinidad coal field that is in the Walsenburg area lies in hilly country northeast of the Spanish Peaks. South of the Cucharas River the hills have flat tops that are parts of old pediment surfaces. North of the Cuchara the hills are low and rolling, and they diminish in relief to the north and east. The eastern and northern margins of the coal field are an escarpment formed by the Trinidad sandstone; it overlooks the plains to the east and north.

The area is drained by the Cucharas and Huerfano Rivers and their tributaries. The major streams are perennial, but most of their smaller tributaries flow only after heavy summer rains. The arid lower plains area supports sparse growths of grasses and low brush; trees are largely restricted to stream courses. The higher elevations in the coal field are semiarid, but they support stands of pinon and juniper.

The Walsenburg area is served by several highways and two railroads. U. S. Highways 85, 87, and 160 and Colorado State Highway 10 are paved roads that cross the area and pass through Walsenburg. Secondary roads, many of which are graveled, extend to all parts of the Walsenburg area. The Denver and Rio Grande Western Railroad and the Colorado and Southern Railway also cross the area and pass through Walsenburg.

SEDIMENTARY ROCKS

Paleozoic, Mesozoic, and lower Cenozoic rocks crop out in or near the Walsenburg area. Paleozoic and lower Mesozoic rocks are not exposed in the area proper but are believed by the author to be in the subsurface. The upper Mesozoic and lower Cenozoic rocks that crop out are shown on the geologic map and on the graphic sections (pl. 48).

Exposures of sedimentary rocks are fair along the walls of canyons but are poor elsewhere. The Fort Hays limestone member of the Niobrara formation and the Trinidad sandstone crop out locally as well-exposed ledges. The rocks of the Walsenburg area are not so well exposed as in those areas adjacent to the Purgatoire and Apishapa Rivers to the south but are better exposed than in those areas adjacent to the Cucharas and Huerfano Rivers to the west and north.

PALEOZOIC ROCKS

PENNSYLVANIAN AND PERMIAN(?)

The oldest sedimentary rocks cropping out near the Walsenburg area are the steeply dipping and highly faulted nonmarine Pennsylvanian and Permian(?) strata of the Sangre de Cristo formation, which also form the slopes of the Sangre de Cristo Mountains in the southwestern part of the La Veta area. Because these rocks have been extensively thrust faulted along the front of the Sangre de Cristo Mountains, their thickness could not be measured, although it is apparently very great. Brill (1952, p. 829) estimated the thickness of the Sangre de Cristo formation west of Mount Mestas to be as much as 8,000 feet. Burbank and Goddard (1937, p. 956) suggest that Pennsylvanian and Permian rocks in Huerfano Park are from 5,000 to 6,000 feet thick.

A few miles northwest of the Walsenburg area the Badito formation crops out on the flanks of the Greenhorn anticline. This formation consists of from 200 (Hills, 1900, p. 1) to 382 feet (Johnson, 1945, p. 80) of rocks lithologically similar to rocks of the Sangre de Cristo formation, and probably it is equivalent to some of the upper beds of the Sangre de Cristo formation. In this area the Badito formation rests on Precambrian rocks. A well in sec. 32, T. 26 S., R. 67 W., in the extreme northwestern corner of the Walsenburg area penetrated 109 feet of red sandstone, probably belonging to the Badito formation, and then entered Precambrian schist. The Badito formation also crops out in the canyon of Cucharas River 10 miles northeast of the Walsenburg area. Hills (1900, p. 1) describes the Badito as follows:

> The upper half of this formation consists of brick-red sandstone, about 100 feet in thickness, generally massive or thick bedded, but sometimes shaly on the

weathered surface. It apparently corresponds to part of the Fountain formation, but to what portion of it is uncertain. The lower half consists of about the same thickness of very coarse conglomerate of brownish-red color.

By way of comparison, the Sangre de Cristo formation in the La Veta area consists of red and gray massive conglomerate and arkose, buff and red quartzose sandstone, red siltstone and shale, and gray nonmarine limestone.

From 100 to 5,000 feet or more of rocks of Paleozoic age may underlie the Walsenburg area at depth; these rocks are believed to thicken westward.

MESOZOIC ROCKS

JURASSIC

Jurassic strata assigned to the Ocate sandstone, the Wanakah formation, and the Morrison formation crop out in uplifts adjacent to the Walsenburg area. These formations have a total thickness of 350 feet along the Cucharas River south of the La Veta area, as well as west of Mount Mestas. Jurassic rocks also crop out to the northwest along the flanks of the Greenhorn anticline and in the canyon of Cucharas River 9 miles northeast of the Walsenburg area. Stose (1912, p. 3) assigned to the Morrison formation all the Jurassic strata in the Apishapa quadrangle east of the Walsenburg area. He described the rocks as red, green, and drab blocky shale or argillite, soft sandstone, and thin beds of limestone. However, in the Apishapa quadrangle only the upper 120 feet of the formation is exposed. A well in the extreme northwestern part of the Walsenburg area penetrated 348 feet of Jurassic rocks that probably belong to the Ocate, Wanakah, and Morrison formations.

The Ocate sandstone disconformably overlies either the Sangre de Cristo or Badito formation but is conformable with the overlying Wanakah formation. The Ocate consists of 60 to 70 feet of gray to buff thick- to massive-bedded fine- to medium-grained quartzose sandstone that appears to have low porosity.

The Wanakah formation consists of about 25 feet of interbedded gray shale, fine-grained sandstone, siltstone, and thin beds of light-red sandstone and shale. Thin irregular bands of jasper occur in the upper part of the formation, and a few thin beds of arenaceous limestone occur in the lower part. The Wanakah is conformable with the overlying Morrison formation.

The Morrison formation is made up of about 250 feet of alternating shale, siltstone, and sandstone. The shale and siltstone are variegated gray, red, buff, and greenish-gray. The sandstone is gray to pink and fine grained. The Morrison is disconformably overlain by the Purgatoire formation of Early Cretaceous age.

CRETACEOUS

The Purgatoire formation of Early Cretaceous age averages 110 feet in thickness where it crops out both south of the La Veta area and west of Mount Mestas. Burbank and Goddard (1937, pl. 3) estimate 350 to 400 feet as the combined thickness of the Purgatoire formation and the overlying Dakota sandstone in Huerfano Park. The Purgatoire formation is also exposed on the limbs of the Greenhorn anticline, and a thickness of 132 feet was measured in a well drilled in the northwest corner of the Walsenburg area. It is exposed in the canyon of Cucharas River about 9 miles northeast of the area, and Stose (1912, p. 4) mapped it in the Apishapa quadrangle where he measured as much as 220 feet of this unit in Huerfano Canyon.

The Purgatoire formation is fairly constant lithologically but increases in thickness from west to east. It consists of a lower light-gray crossbedded conglomeratic quartzitic sandstone with an average thickness of about 90 feet, and an upper dark-gray carbonaceous shale that ranges from 10 to 20 feet in thickness. The sandstone is made up chiefly of frosted grains of quartz and scattered very smooth and round quartz pebbles. The permeability of most of the sandstone appears to be high. The Purgatoire formation is overlain disconformably by the Dakota sandstone.

The Dakota sandstone of Early Cretaceous age is about 200 feet thick and consists of two or three beds of white to buff well-sorted cross-stratified fine-grained quartzitic sandstone separated by very thin beds of black carbonaceous shale. The Dakota forms a steep hogback in the southwestern part of the La Veta area. It is exposed west of Mount Mestas, in Huerfano Park, on the Greenhorn anticline, and in the canyon of the Cucharas River northeast of the Walsenburg area. The permeability of the strata that make up the Dakota sandstone is low in most places.

The Dakota sandstone is conformably overlain by the Graneros shale of the Colorado group. The Graneros shale consists of dark-gray to black noncalcareous shale and a few zones of bentonitic shale and calcereous concretions. The lower beds of the Graneros are Early Cretaceous in age, and the upper beds are Late Cretaceous. The Graneros shale in Huerfano Park is reported to be between 200 and 310 feet thick (Burbank and Goddard, 1937, pl. 3). The formation is about 380 feet thick where it crops out on the Greenhorn anticline, but only 235 feet of Graneros shale was identified in a well drilled in the La Veta area southwest of the Black Hills. The formation also crops out about 6 miles east of the Walsenburg area where, according to Hills (1900, columnar-section sheet), it is 200 to 210 feet thick. Stose (1912, p. 5) found the formation to have about this same thickness in the Apishapa quadrangle. The Graneros shale underlies and intertongues with the lower beds of the Greenhorn limestone.

The Greenhorn limestone of the Colorado group consists of alternating beds of gray limestone and light-gray calcareous shale. It is about 35 feet thick at its outcrops on the Greenhorn anticline and between 30 and 40 feet in Huerfano Park (Burbank and Goddard, 1937, pl. 3). Five miles east of the Walsenburg area the Greenhorn is from 30 to 40 feet thick, and in the Apishapa quadrangle (Stose, 1912, p. 6) it ranges in thickness from 30 to 50 feet.

The Carlile shale of the Colorado group conformably overlies the Greenhorn limestone and consists of a shale unit at the base and the Codell sandstone member at the top. North of the Arkansas River in eastern Colorado the Carlile shale has been subdivided, in ascending order, as the Fairport chalky shale member, the Blue Hill shale member, and the Codell sandstone member (Dane, Pierce, and Reeside, 1937, p. 214–220). In exposures near the Walsenburg area the lower shale unit consists of dark-gray to black calcareous shale and dark-gray thin-bedded chalky limestone. The Codell sandstone member generally crops out as a 5- to 10-foot rusty-brown ledge with weathered surfaces that resemble a calcareous sandstone. On fresh surface, however, the rock is a dark-gray bituminous limestone with sporadic grains of sand. A buff fine- to medium-grained sandstone found in a few places at the base of the Codell may attain a thickness of 10 to 15 feet. Both members are well exposed on the flanks of the Greenhorn anticline and are fairly well exposed east and northeast of the Walsenburg area. In the well in the northwest corner of the Walsenburg area, rocks identified as Carlile shale are 255 feet thick.

The Niobrara formation of the Colorado group comprises the Fort Hays limestone member and the Smoky Hill marl member. The Fort Hays limestone, the lower member, is exposed in the extreme northeast corner of the Walsenburg area, and also forms a ledge just east of the area. It also underlies a prominent hogback on the flanks of the Greenhorn anticline. The member averages 60 feet in thickness and is composed of thick beds of light-gray chalky limestone alternating with thin beds of gray calcareous shale. The Smoky Hill marl member conformably overlies the Fort Hays limestone member. The member generally is poorly exposed and forms gentle slopes. It ranges in thickness from 400 to 500 feet, and its weathered surfaces are characterized by a distinctive yellow-orange. The member consists of thin beds of white limestone alternating with much thicker beds of buff to light-gray shale and chalk. In northeastern New Mexico the Smoky Hill marl is light-gray shale (G. H. Wood, 1950, oral communication). From the Huerfano River southward toward Trinidad the member grades slowly from the chalk facies to a shale facies. The gradational contact of the Smoky Hill marl with the overlying Pierre shale is generally concealed, as it is in Las Animas County where the Smoky Hill marl member cannot be readily distinguished from the overlying Pierre shale (Harbour and Dixon, 1956).

The Pierre shale of the Montana group is 2,000 to 2,100 feet thick in the area. It is very poorly exposed, however, and no lithologic divisions were recognized. Burbank and Goddard (1937, pl. 3) report a thickness of between 1,800 and 2,000 feet of Pierre shale in Huerfano Park. The formation has a thickness of 2,300 feet in the La Veta area, and Hills (1900, columnar-section sheet) records a thickness of 1,750 to 1,900 feet in the Walsenburg quadrangle. Hills (1899, columnar-section sheet) also records a thickness of 1,200 to 1,300 feet of Pierre shale in the Elmoro quadrangle. A sandstone about 500 feet above the base of the Pierre in the La Veta area does not crop out in the Walsenburg area. The upper 150 to 200 feet of Pierre shale consists of buff fine- to medium-grained shaly sandstone interbedded with gray to black silty shale. Sandstone dominates shale near the top of the Pierre shale and grades upward into massive beds of Trinidad sandstone.

The Trinidad sandstone of Montana age consists of one or two massive beds of buff fine- to medium-grained slightly arkosic sandstone. The beds are generally tabular but are irregular and lenticular in some places. Most of the grains are of quartz but some are of mica, feldspar, and ferromagnesian minerals. Casts of *Halymenites* are common. The Trinidad sandstone outcrops characteristically consist of one or two steep ledges in most of the area. North of the Cucharas River the outcrop band, although covered, forms a bench above the softer Pierre shale. The base of the Trinidad sandstone is everywhere concealed except south of the old Ravenwood Mine. A lower tongue of the Trinidad sandstone, which constitutes a northeastward-trending lobe, was mapped in the southern part of the area. Near Santa Clara Creek the thickness of the main bed is 85 feet and that of the tongue is about 6 feet. The two beds of sandstone are separated by a 30-foot tongue of Pierre shale. The average thickness of the Trinidad sandstone in the La Veta area is slightly more than 300 feet, but the formation thins to the southeast. In the Stonewall-Tercio area the Trinidad sandstone ranges from 120 to 250 feet in thickness (Wood and others, 1951), and near Trinidad the formation ranges from 45 to 140 feet in thickness (Wood, Johnson, and Dixon, 1957, p. 22). About 200 feet of Trinidad sandstone was measured along Bear Canyon near Cuchara Pass.

The Vermejo formation, which is of Montana and Laramie age, consists of buff, gray, and gray-green slightly arkosic sandstone; buff, gray, and dark-gray siltstone; gray, dark-gray, and nearly black carbonaceous, coaly, and silty shale; and numerous coal beds. Most of the thinner beds have parallel bedding and parallel lamination, but the thicker beds are lenticular and irregular. The grains in the coarser beds range from very fine to medium and are principally quartz, but some are of weathered feldspar, mica, and ferromagnesian minerals; the cementing materials are clay and calcium carbonate. The coal is interbedded with siltstone and shale that range from a few inches to many feet in thickness. The formation rests conformably on the Trinidad sandstone, and it thins regionally from northwest to southeast. The Vermejo formation ranges in thickness from 240 feet to about 410 feet in the Walsenburg area. In the La Veta area it has an average thickness of 375 feet where it was not eroded during Poison Canyon time (Johnson and Stephens, 1954b). At Bear Canyon (Wood, Johnson, and Dixon, 1956) the Vermejo has a maximum thickness of 550 feet, and in the Stonewall-Tercio area it ranges in thickness from 220 to 380 feet. Near Trinidad the thickness is between 80 and 140 feet.

CENOZOIC ROCKS

TERTIARY

The Raton formation of Late Cretaceous and Paleocene age rests conformably upon the Vermejo formation. It consists of a siliceous and locally conglomeratic basal sandstone overlain by interbedded sandstone, shale, siltstone, and coal. This basal sandstone is correlative with the conglomeratic sandstone that is present at the base of the formation in most of the Raton Mesa region. It ranges from 5 to 35 feet in thickness, and consists of well-rounded quartz pebbles scattered in a matrix of fine to coarse subangular quartz sand.

Above the conglomeratic sandstone is an alternating sequence of quartzose, arkosic sandstone, graywacke, and arkose interbedded with shale and coal. The thicker beds of tan to buff graywacke and arkose contain weathered feldspar, and are commonly lenticular and crossbedded. Thin beds of dark olive-green fine-grained even-bedded graywacke occur in shale units. The shale is gray to dark gray and is carbonaceous.

The Raton formation in the Walsenburg area is beveled and lies unconformably at the base of the Poison Canyon formation. It ranges in thickness from 500 feet near Santa Clara Creek to only 10 feet near Delcarbon. In the Stonewall-Tercio area the formation averages 1,700 feet in thickness, and along Bear Creek it is about 1,500 feet thick. In the La Veta area the Raton formation has been beveled to a thickness of 100 feet or less, and near Trinidad the formation ranges from 1,200 to 1,600 feet in thickness.

The Poison Canyon formation of Paleocene age rests unconformably on the lower Tertiary formations, and to the south the Poison Canyon intertongues with the uppermost beds of the Raton formation. The Poison Canyon formation consists of 2,500 feet or more of alternating beds of massive buff to red arkosic sandstone and conglomerate and thin beds of yellow shale. The sandstone is coarse to medium grained and contains much unweathered feldspar. The conglomerate contains pebbles of granite, gneiss, and quartzite. The thickness of the formation is about the same in the La Veta area.

The Cuchara formation, which is probably of lower Eocene age, is exposed in the extreme southwest corner of the area where it unconformably overlies the Poison Canyon formation from which it differs greatly in lithologic character. The Cuchara is composed of thin to thick beds of red, pink, and white sandstone and thin beds of red and tan shale. The outcrop area of the Cuchara formation is largely covered by a veneer of pediment gravels and soil. The thickness of the formation is estimated to exceed 5,000 feet on the northern flank of West Spanish Peak, which is in the trough of the Raton basin. Probably no more than several hundred feet of the Cuchara formation is present in the Walsenburg area.

Tertiary formations of middle Eocene and younger age are present in the La Veta area and Huerfano Park to the northwest. These rocks may have overlain the rocks now exposed in the Walsenburg area.

QUATERNARY DEPOSITS

Alluvial deposits extend from the bottomland along the streams to the higher valley flats. Extensive pediments covered by gravel lie at many different elevations. Soil mantles most of the area.

IGNEOUS ROCKS

Many of the dikes and some of the sills and small plugs exposed in the Walsenburg area appear to be part of the great intrusive bodies that form the Spanish Peaks. In general, there was less igneous activity in the Walsenburg area than in the La Veta area (Johnson and Stephens, 1954a) or in the Spanish Peaks area. Coal beds near or adjoining sills and dikes are locally coked.

DIKES

The distribution of dikes in the Walsenburg area suggests that there are five superimposed intrusive systems. All dikes in the area are vertical or nearly vertical. Most of the dike rock is dark, aphanitic, and basic in composition.

The most prominent and extensive system consists of subparallel dikes that cross the entire area and that strike from N. 60° E. to N.

70° E. Because this strike is normal to the general strike of the folded sedimentary rocks, it is assumed that the dikes were intruded along fractures resulting from tension during the folding of the structural basin.

Dikes of a second system occur only in the southwest corner of the area and appear to radiate from the West Spanish Peak.

Several of the largest dikes extend across the area in an east-west direction. They are generally arcuate, with the concave face toward the south. The strike of one many vary as much as 12° from one end to the other. The rock is gray, phaneritic, probably less basic than the rock that forms most of the dikes in the Walsenburg area, and is apparently the early monzonite porphyry described by Hills (1900, p. 4).

Three small dikes that strike from N. 10° W. to N. 30° W. intersect a large dike near Delcarbon. One and one-half miles northeast of Delcarbon a small cream-colored aplite dike trends N. 68° E. It apparently does not contain ferromagnesian minerals.

SILLS

A few sills occur throughout the eastern half of the Walsenburg area, but the greatest concentration is in the southeastern quarter. The sills form complex structures in the shaly units of the Upper Cretaceous formations. They are generally more resistant to erosion than the shale and commonly underlie ridges that trend in the same direction. They are not thick individual sheets, but are commonly anastomotic stringers of igneous rocks that seem to be concentrated in narrow zones. Some of the sills probably cut across the bedding, but the exact relations are impossible to determine from the poor exposures. The sill rock is dark, aphanitic, and basic, and some thick sills have phaneritic interiors.

PLUGS

Five small plugs, each less than 400 feet long, are exposed in the Walsenburg area. One is intruded into the Pierre shale about 1½ miles northeast of Delcarbon and is cut by the aplite dike. This circular mass consists of dark and scoriaceous rock with inclusions of gneissic cobbles as much as 6 inches in diameter. Its perimeter is pumiceous.

Two plugs about one-fourth mile apart are intruded into the Pierre shale about 2 miles northeast of Walsenburg. The northernmost of these elliptical masses is about three times the size of the one to the south. Both consist of light-gray trachyte-porphyry. The other two plugs are intruded into the Smoky Hill marl member of the Niobrara formation. They are about 700 feet apart and are more than 5½ miles east-southeast of Walsenburg. They consist of gray phaneritic diorite. All rocks were identified megascopically.

STRUCTURAL GEOLOGY

The complex folding in the Wet Mountains northwest of the Walsenburg area and the complex thrusting in the Sangre de Cristo Mountains west of the area had the greatest influence on structure in the Walsenburg area. Formation of the Las Animas-Sierra Grande arch to the east may have played a minor role in the structural development of the area.

The structural trough of the Raton basin, which crosses the southwestern part of the La Veta area, has been named the La Veta syncline. The southward plunge of the Greenhorn anticline splits the La Veta syncline into two parts, the larger part on the west and the smaller Delcarbon syncline on the east (Johnson and Stephens, 1954a). The Walsenburg area includes a little of both parts of the La Veta syncline.

Two normal faults in the northern part of the area cut the two flanks of the Delcarbon syncline and trend generally parallel to the axis of the syncline, with the upthrown blocks on the sides toward the axis. The vertical displacement of each fault is less than 50 feet.

GEOLOGIC HISTORY

During Pennsylvanian and early Permian time the Raton Mesa region was part of a basin that received large quantities of detrital material from the ancestral Rocky Mountains that lay to the west and northwest. The Precambrian core of the Wet Mountains to the northwest may have been a highland mass that furnished sediments to the Walsenburg area. The upper Pennsylvanian and Permian sediments laid down on piedmonts and flood plains that bordered the highlands were consolidated into the strata of the Sangre de Cristo formation. By the end of early Permian time the ancestral Rockies had passed their period of greatest relief; by the end of middle Permian time they were reduced to lowlands, and the erosional remnant of the old Wet Mountains was overlapped by lower and middle Permian sediments.

Rocks of late Permian and Triassic age are missing in the Walsenburg and surrounding areas, and correlation of upper Permian and Triassic strata has not been made across the Raton Mesa region. The nearest surface exposures of known Triassic rocks are near Eagle Nest, N. Mex., about 60 miles to the south, and near Higbee, Colo., about 65 miles to the east. The southernmost exposures of the Lykins formation, which may be in part Triassic, are near Canon City, Colo., 50 miles to the north. To reconstruct the history of geologic events that took place in the Walsenburg area during late Permian and Triassic time is difficult because it depends upon the interpretation of meager data from wells east of Walsenburg and Trinidad.

The geologic history may be outlined tentatively as follows: During late Permian and Early Triassic time, the region was of low relief and sediments accumulated on flood plains. At the end of Triassic or at the beginning of Jurassic time epeirogenic movements tilted the region eastward, and the late Permian or Triassic sediments, as well as the uppermost beds of the Sangre de Cristo formation, were eroded from the area. Subsidence of the old erosion surface was followed by marine transgression from the southeast; the sands that compose the Ocate sandstone of Jurassic age accumulated offshore and along the beaches of the advancing sea. Later the sea regressed and mud, silt, sand, and perhaps some limestone were deposited on deltas and flood plains and in estuaries and lakes. These sediments were later indurated and formed the strata of the Wanakah and Morrison formations.

By the end of Jurassic time the region was generally near base level, but some erosion may have taken place, and it may have continued until late in Early Cretaceous time when the sea again advanced across the region from the southeast. Sand and gravel that make up the lower sandstone of the Purgatoire formation were deposited on and near the shore of this sea. The sea then withdrew, and the upper shale of the Purgatoire formation was deposited in estuaries and coastal swamps and on deltas and flood plains. Near the end of Early Cretaceous time the region was again uplifted and some of the shale in the Purgatoire formation was subsequently eroded.

Late in Early Cretaceous time the region again subsided and a broad shallow sea spread northwestward over the region. The sediments that make up the Dakota sandstone accumulated as strand deposits in this advancing sea. As the shoreline moved farther northwestward, the sands of Dakota age in the Raton Mesa region were buried beneath several thousand feet of mud, silt, lime, and fine sand deposited in relatively deep water. This sequence of sediments has been indurated to form the Graneros shale, Greenhorn limestone, Carlile shale, Niobrara formation, and Pierre shale.

During the last phases of Pierre deposition some early epeirogenic movements of the Laramide revolution caused withdrawal of the sea and the deposition of sand to form a sequence of strand deposits eastward across the region. Thus, the Trinidad sandstone accumulated as a regressive beach and offshore deposit. As the sea continued its slow retreat, the mud, silt, sand, and carbonaceous material that make up the strata of the Vermejo formation in the area were deposited on deltas and flood plains, and in swamps. Near the end of Vermejo or Laramie time, there were orogenic movements in the area west of the Raton Mesa region. Coarse sediments derived from the resultant mountains were deposited over the region.

After deposition of the sand and gravel that form the basal conglomerate of the Raton formation, intermittent minor disturbances continued to occur in the highland area west and northwest of the Walsenburg area. Sediments of the Raton formation accumulated on flood plains and in swamps at the same time that sediments of the Poison Canyon formation were being deposited in piedmont surfaces farther west. In intermediate areas these sediments intertongued or graded into one another. In early Paleocene time when the sediments that constitute the uppermost beds of the Raton formation were accumulating in the central part of the Raton Mesa region, mountains were uplifted to the northwest. The intervening Walsenburg area was brought above base level and tilted southeastward, and the Raton formation, Vermejo formation, Trinidad sandstone, Pierre shale, and a part of the Smoky Hill marl member of the Niobrara formation were beveled by erosion.

Sediments derived from erosion of these formations in Huerfano Park and the La Veta area were deposited in most of the Raton Mesa region as layers of pebbles, cobbles, and coarse sand. These were later compacted to form the upper beds of the Poison Canyon formation. Gradually the northwestern part of the region was reduced nearly to baselevel; coarse sediments derived from mountains still farther west and north were laid down on the erosional surface.

In late Paleocene or early Eocene time the mountains to the west were again uplifted and the Raton Mesa region and Huerfano Park were tilted and folded. Uplifting of the Wet Mountains probably began about this time. The Poison Canyon formation was eroded in the uplifted areas and sediments of the Cuchara formation of Eocene age were deposited on piedmont and flood plain in the northern part of the Raton Mesa region and in Huerfano Park. Later in early Eocene time extensive thrusting and folding occurred in the Sangre de Cristo Mountains, eastward into Huerfano Park, and along the northwestern margin of the Raton Mesa region. The Wet Mountains probably continued to be uplifted during this time. Tilting of the Huerfano Park area in early middle Eocene time perhaps accompanied the eastward thrusting of the highlands west and northwest of the Raton Mesa region. Sills of intermediate to silicic igneous rocks intruded the Cretaceous shales in the western part of the region.

The great thrusting, normal faulting, and folding that occurred in later Eocene time formed the present structures of the Sangre de Cristo and Wet Mountains. This is shown by the faulted and folded beds of the Huerfano formation of Eocene age in Huerfano Park, and by the thick deposits of boulder conglomerate overlying these beds in the northern and northeastern parts of Huerfano Park. The structural basin of the Raton Mesa region and Huerfano Park formed by these forces was intruded by many sills, dikes, plugs, and stocks before the end of Eocene time.

COAL RESOURCES

The coal-bearing formations in the Walsenburg area are the Vermejo and Raton formations, which form a narrow, poorly exposed outcrop belt from the southeast to the northwest corner of the Walsenburg area. In the northwest corner strata of these formations dip into the trough of the Delcarbon syncline.

About 100 square miles of the Walsenburg area is underlain by coal, but a large part of the coal cannot be reached by present mining methods because it lies more than 3,000 feet beneath the surface. Coal beds are thicker and more numerous in the Vermejo formation than in the Raton formation. Thick beds of coal occur throughout the Vermejo formation, but only in the upper part of the Raton formation.

The Raton formation undoubtedly has some beds of coal at depth in the area where it is beveled and unconformably overlain by the Poison Canyon formation.

The Vermejo contains from 3 to 8 coal beds and the Raton contains from 1 to 3 coal beds that are more than 14 inches in thickness. These coal beds are lenticular, irregular in thickness, and interbedded with shale and siltstone. The floors and roofs are generally carbonaceous shale and claystone, but locally they may be carbonaceous siltstone and sandstone. Bony coal, carbonaceous shale, or carbonaceous siltstone form partings in the coal beds. The coal is brittle and friable and consists of vitrain alternating with bands of fusain and durain. It has prismatic cleat and platy cleavage. Impurities, common in most of the beds, are mainly pyrite and sulfur with sporadic grains of silt and sand. The coal is a nonagglomerating and nonweathering high-volatile C bituminous coal as is indicated in the accompanying table of analysis of coal (table 3) from mines in the Walsenburg area (George, 1937, p. 76–85) and according to the American Society for Testing Materials system of coal classification (table 4).

The original reserves of coal in the Walsenburg area in beds more than 14 inches thick and with less than 3,000 feet of overburden are estimated to have been 667.5 million short tons. This estimate is based on thicknesses of coal beds measured at scattered outcrops, several logs of diamond-drill holes, and published thicknesses of beds (George, 1937, p. 184–198) measured in coal mines. These data are shown graphically in the coal sections (pl. 49); the locations of wells and measured sections are shown on the map (pl. 47). In table 1 the reserves are divided according to township, amount of overburden, thickness of beds, and classified as measured and indicated and inferred, terms which indicate the reliability of the estimates.

The reserves of coal are given in three thickness categories: 14 to 28 inches, 28 to 42 inches, and more than 42 inches. In order to estimate tonnage in each category, isopach maps of the coal beds were drawn. The areal extent and average thickness of each coal bed within each isopach interval were determined, and from this information the tonnage of coal reserves was calculated.

Estimates of measured and indicated reserves are based on specific measurements of coal in outcrops, wells, and mine workings; where geologic evidence permits, estimates are made of coal thought to lie as much as 1 mile from a point of observation. Inferred reserves are based on a geologic inference regarding the underground extent of the coal beds. All coal included in this category lies more than 1 mile from the point of observation.

Reserves are also classified according to the thickness of overburden. The classifications are: a thin wedge to 1,000 feet; 1,000 to 2,000 feet; and 2,000 to 3,000 feet. A large part of the coal in the Vermejo and Raton formations in the Walsenburg area has more than 3,000 feet of overburden and is therefore not included in the reserves.

Mining activity in the Walsenburg area began in 1881, reached a climax during the period from 1900 to 1930, and has tapered off since 1930. The Calumet No. 2, Gordon, Morning Glory, and Pictou mines are the largest mines now in operation in the Walsenburg area. A new mine was opened near the old Maitland mines in 1952.

The accompanying table of depletion (table 2) of coal reserves includes all available data. Because the tonnage figures for some years are missing the depletion figure of 58.4 million short tons is approximate only. The names of some mines have changed through the years, and some errors may have been made in the correlation of names. No data are available regarding the percentage of coal recovered by mining operations in the Walsenburg area, but it may be assumed, from mining averages in Western United States, to be 50 percent. On that basis, the amount of coal recovered and lost in the area to January 1, 1951, is about 117 million short tons. The remaining reserves in beds more than 14 inches thick with less than 3,000 feet of overburden total about 667.5 million short tons.

Future exploitation of the coal resources of the Walsenburg area may necessitate mining by deep shafts or steeply inclined drifts or slopes. Before the development of any mining program, it would be advisable to outline the areal extent of the individual coal beds by drilling, as has been done in several instances. It would also be advisable to weigh the economic aspects concerning the relationships of the depth of the proposed shaft, the dip of the bed, and the thickness of the coal bed.

TABLE 1.—*Estimated original coal reserves of the Vermejo and Raton formations in the Walsenburg area, Huerfano County, Colo.*

Coal bed and thickness of overburden	Estimated reserves, in thousands of short tons, in beds of thickness shown											
	Measured and indicated [1]				Inferred				Total reserves			
	14 to 28 inches	28 to 42 inches	More than 42 inches	Total	14 to 28 inches	28 to 42 inches	More than 42 inches	Total	14 to 28 inches	28 to 42 inches	More than 42 inches	Total
VERMEJO FORMATION **T. 27 S., Rs. 66 W. and 67 W.**												
Less than 1,000 feet of cover:												
Cameron bed	3,000	9,600	19,400	32,000	100	3,600	7,300	11,000	3,100	13,200	26,700	43,000
Lenox bed	5,800	8,600	14,800	29,200		2,200	1,600	3,800	5,800	10,800	16,400	33,000
Walsen bed	3,200	1,700	1,000	5,900	600	100		700	3,800	1,800	1,000	6,600
Pryor bed	2,300	1,800	200	4,300	300			300	2,600	1,800	200	4,600
Lower Robinson bed	1,900	6,400	6,900	15,200	2,700	1,100		3,800	4,600	7,500	6,900	19,000
Total	16,200	28,100	42,300	86,600	3,700	7,000	8,900	19,600	19,900	35,100	51,200	106,200
1,000 to 2,000 feet of cover:												
Cameron bed	300	100		400	2,400	1,000		3,400	2,700	1,100		3,800
Lenox bed		1,100	2,900	4,000		200	12,600	12,800		1,300	15,500	16,800
Total	300	1,200	2,900	4,400	2,400	1,200	12,600	16,200	2,700	2,400	15,500	20,600
2,000 to 3,000 feet of cover:												
Lenox bed						1,200	8,300	9,500		1,200	8,300	9,500
Township total	16,500	29,300	45,200	91,000	6,100	9,400	29,800	45,300	22,600	38,700	75,000	136,300

T. 28 S., R. 66 W.

Less than 1,000 feet of cover:												
Cameron bed	4,500	8,100	5,700	18,300	2,500			2,500	7,000	8,100	5,700	20,800
Lenox bed	4,800	3,900	100	8,800	2,200	800		3,000	7,000	4,700	100	11,800
Walsen bed	4,200	3,900	4,500	12,600	900	300		1,200	5,100	4,200	4,500	13,800
Pryor bed	1,900	5,000	5,400	12,300	400	1,000		1,400	2,300	6,000	5,400	13,700
Lower Robinson bed	2,800	4,300	1,200	8,300	2,200	600	200	3,000	5,000	4,900	1,400	11,300
Rider	3,600	2,000		5,600	8,000			8,000	11,600	2,000		13,600
Upper Robinson bed	3,800	1,100		4,900	6,600			6,600	10,400	1,100		11,500
Total	25,600	28,300	16,900	70,800	22,800	2,700	200	25,700	48,400	31,000	17,100	96,500
1,000 to 2,000 feet of cover:												
Lenox bed	700	200		900	2,600			2,600	3,300	200		3,500
Walsen bed	300	500		800	700	400		1,100	1,000	900		1,900
Pryor bed					800	200		1,000	800	200		1,000
Lower Robinson bed	300	400		700	300			300	600	400		1,000
Rider					3,000			3,000	3,000			3,000
Upper Robinson bed					1,700			1,700	1,700			1,700
Total	1,300	1,100		2,400	9,100	600		9,700	10,400	1,700		12,100
Township total	26,900	29,400	16,900	73,200	31,900	3,300	200	35,400	58,800	32,700	17,100	108,600

See footnote at end of table.

TABLE 1.—*Estimated original coal reserves of the Vermejo and Raton formations in the Walsenburg area, Huerfano County, Colo.*—Con.

Coal bed and thickness of overburden	Estimated reserves, in thousands of short tons, in beds of thickness shown											
	Measured and indicated [1]				Inferred				Total reserves			
	14 to 28 inches	28 to 42 inches	More than 42 inches	Total	14 to 28 inches	28 to 42 inches	More than 42 inches	Total	14 to 28 inches	28 to 42 inches	More than 42 inches	Total
VERMEJO FORMATION—Continued **T. 28 S., R. 67 W.**												
Less than 1,000 feet of cover:												
Cameron bed		200	800	1,000	400	3,200	1,900	5,500	400	3,400	2,700	6,500
Lenox bed		400	300	700		1,400	500	1,900		1,800	800	2,600
Walsen bed	300			300	200			200	500			500
Pryor bed					1,900	1,200		3,100	1,900	1,200		3,100
Lower Robinson bed	400	500	400	1,300	200	400	1,200	1,800	600	900	1,600	3,100
Rider					400			400	400			400
Upper Robinson bed	2,100	2,500	2,300	6,900	400			400	2,500	2,500	2,300	7,300
Total	2,800	3,600	3,800	10,200	3,500	6,200	3,600	13,300	6,300	9,800	7,400	23,500
1,000 to 2,000 feet of cover:												
Cameron bed					2,400	400		2,800	2,400	400		2,800
Lenox bed			100	100	2,900	8,400	2,900	14,200	2,900	8,400	3,000	14,300
Pryor bed					2,800	400		3,200	2,800	400		3,200
Rider					2,100			2,100	2,100			2,100
Total			100	100	10,200	9,200	2,900	22,300	10,200	9,200	3,000	22,400
2,000 to 3,000 feet of cover:												
Lenox bed					6,000	10,800	500	17,300	6,000	10,800	500	17,300
Rider					200			200	200			200
Total					6,200	10,800	500	17,500	6,200	10,800	500	17,500
Township total	2,800	3,600	3,900	10,300	19,900	26,200	7,000	53,100	22,700	29,800	10,900	63,400

T. 29 S., Rs. 65 W., 66 W., and 67 W.

Less than 1,000 feet of cover:												
Cameron bed	1,400	2,800	200	4,400	2,600	1,000		3,600	4,000	3,800	200	8,000
Lenox bed	2,700	4,300		7,000	300	3,900		4,200	3,000	8,200		11,200
Walsen bed	600	1,300	5,300	7,200		10,200	700	10,900	600	11,500	6,000	18,100
Pryor bed	1,600	4,300	5,900	11,800	1,000	5,000	2,100	8,100	2,600	9,300	8,000	19,900
Lower Robinson bed	8,300			8,300	1,600			1,600	9,900			9,900
Rider	4,600	7,200		11,800	2,700	1,300		4,000	7,300	8,500		15,800
Upper Robinson bed	3,800	4,100	6,800	14,700	600	800		1,400	4,400	4,900	6,800	16,100
Total	23,000	24,000	18,200	65,200	8,800	22,200	2,800	33,800	31,800	46,200	21,000	99,000
1,000 to 2,000 feet of cover:												
Lenox bed	100	600		700	6,500	6,100		12,600	6,600	6,700		13,300
Walsen bed	2,200	1,500	6,400	10,100	100	6,900	500	7,500	2,300	8,400	6,900	17,600
Pryon bed					2,900	500		3,400	2,900	500		3,400
Lower Robinson bed	8,900	100		9,000	3,400			3,400	12,300	100		12,400
Rider	1,200	500		1,700	13,300	3,700		17,000	14,500	4,200		18,700
Upper Robinson bed	800	8,800	3,400	13,000	7,300		700	8,000	8,100	8,800	4,100	21,000
Total	13,200	11,500	9,800	34,500	33,500	17,200	1,200	51,900	46,700	28,700	11,000	86,400
2,000 to 3,000 feet of cover:												
Lenox bed					3,800			3,800	3,800			3,800
Walsen bed					3,400	2,600		6,000	3,400	2,600		6,000
Lower Robinson bed	1,000			1,000	3,000			3,000	4,000			4,000
Rider					10,300			10,300	10,300			10,300
Upper Robinson bed					13,500			13,500	13,500			13,500
Total	1,000			1,000	34,000	2,600		36,600	35,000	2,600		37,600
Township total	37,200	35,500	28,000	100,700	76,300	42,000	4,000	122,300	113,500	77,500	32,000	223,000
Vermejo formation total	83,400	97,800	94,000	275,200	134,200	80,900	41,000	256,100	217,600	178,700	135,000	531,300

See footnote at end of table.

TABLE 1.—*Estimated original coal reserves of the Vermejo and Raton formations in the Walsenburg area, Huerfano County, Colo.*—Con.

Coal bed and thickness of overburden	Estimated reserves, in thousands of short tons, in beds of thickness shown											
	Measured and indicated [1]				Inferred				Total reserves			
	14 to 28 inches	28 to 42 inches	More than 42 inches	Total	14 to 28 inches	28 to 42 inches	More than 42 inches	Total	14 to 28 inches	28 to 42 inches	More than 42 inches	Total
RATON FORMATION												
T. 27 S., R. 67 W.												
Less than 1,000 feet of cover:												
A bed	5,100	8,800		13,900	4,400	1,500		5,900	9,500	10,300		19,800
B bed	300			300	900			900	1,200			1,200
Mutual bed					100			100	100			100
Total	5,400	8,800		14,200	5,400	1,500		6,900	10,800	10,300		21,100
1,000 to 2,000 feet of cover:												
A bed					2,700			2,700	2,700			2,700
Township total	5,400	8,800		14,200	8,100	1,500		9,600	13,500	10,300		23,800
T. 28 S., R. 66 W.												
Less than 1,000 feet of cover:												
A bed	800	5,200		6,000	2,500	6,400		8,900	3,300	11,600		14,900
B bed	1,500			1,500	2,600			2,600	4,100			4,100
Mutual bed	100	2,800	4,700	7,600	2,300	3,800	8,600	14,700	2,400	6,600	13,300	22,300
Total	2,400	8,000	4,700	15,100	7,400	10,200	8,600	26,200	9,800	18,200	13,300	41,300
Township total	2,400	8,000	4,700	15,100	7,400	10,200	8,600	26,200	9,800	18,200	13,300	41,300

T. 28 S., R. 67 W.

Less than 1,000 feet of cover:												
A bed	----------	3,300	----------	3,300	5,600	6,900	----------	12,500	5,600	10,200	----------	15,800
B bed	----------	----------	----------	----------	100	----------	----------	100	100	----------	----------	100
Mutual bed	----------	1,000	----------	1,000	3,600	1,600	----------	5,200	3,600	2,600	----------	6,200
Total	----------	4,300	----------	4,300	9,300	8,500	----------	17,800	9,300	12,800	----------	22,100
1,000 to 2,000 feet of cover:												
A bed	----------	----------	----------	----------	4,600	----------	----------	4,600	4,600	----------	----------	4,600
Township total	----------	4,300	----------	4,300	13,900	8,500	----------	22,400	13,900	12,800	----------	26,700

T. 29 S., Rs. 65 W and 66 W.

Less than 1,000 feet of cover:												
A bed	3,400	----------	----------	3,400	3,700	----------	----------	3,700	7,100	----------	----------	7,100
B bed	3,100	----------	----------	3,100	9,700	----------	----------	9,700	12,800	----------	----------	12,800
Mutual bed	100	5,200	7,500	12,800	5,100	4,200	2,400	11,700	5,200	9,400	9,900	24,500
Total	6,600	5,200	7,500	20,200	18,500	4,200	2,400	25,100	25,100	9,400	9,900	44,400
Township total	6,600	5,200	7,500	20,200	18,500	4,200	2,400	25,100	25,100	9,400	9,900	44,400
Raton formation total	14,400	26,300	12,200	52,900	47,900	24,400	11,000	83,300	62,300	50,700	23,200	136,200
Grand total	97,800	124,100	106,200	328,100	182,100	105,300	52,000	339,400	279,900	229,400	158,200	667,500

[1] Includes mostly indicated reserves.

TABLE 2.—*Coal mined in the Walsenburg area of Colorado from 1885 to 1950*

Coal mine	Coal mined, in short tons, during the periods shown														
	1881–85	1886–90	1891–95	1896–1900	1901–05	1906–10	1911–15	1916–20	1921–25	1926–30	1931–35	1936–40	1941–45	1946–50	Total
Walsen	170, 577	308, 323	273, 551	486, 982	769, 761	722, 423	546, 741	1, 849, 142	1, 843, 406	1, 174, 598	30, 385				8, 175, 889
Cameron						185, 564	448, 877	952, 986	919, 421	864, 163	1, 022, 258	899, 258	1, 058, 556	37, 567	6, 388, 650
Old Rouse		48, 710	1, 055, 495	749, 761	1, 037, 432	1, 038, 501	957, 126	816, 723							5, 703, 748
Pictou			353, 233	605, 728	624, 251	712, 196	324, 836	281, 776	784, 618						3, 686, 638
Calumet No. 1 Turner						9, 883	68, 091	496, 517	1, 555, 892	980, 057	168, 318				3, 278, 758
Pryor				171, 288	431, 082	504, 670	385, 067	378, 303	273, 820	208, 451	199, 673	293, 916	181, 859		3, 028, 129
Calumet No. 2 Brennan								70, 922	233, 557	403, 713	196, 423	453, 862	750, 739	448, 817	2, 558, 033
Robinson		19, 400	212, 737	162, 224	657, 255	881, 691	324, 635								2, 257, 942
Lester							550, 512	500, 056	886, 187	543, 453					2, 480, 208
Ideal						109, 615	399, 017	750, 138	811, 369	399, 494					2, 469, 633
Toltec			17, 583	199, 292	239, 178	366, 685	175, 492	229, 455	243, 234	249, 756	61, 655	40, 452	905		1, 823, 687
Maitland				159, 562	339, 090	449, 310	174, 122	133, 130	154, 871	131, 686	60, 210	41, 414	31, 424	65, 189	1, 740, 008
Gordon						106, 315	85, 886	243, 591	295, 157	263, 620	209, 562	186, 316	465, 241	225, 895	2, 081, 583
Ravenwood						70, 750	355, 521	304, 631	359, 456	303, 487	156, 139	96, 858	10, 854	445	1, 658, 141
Mutual							44, 221	636, 316	570, 322	224, 867	21, 102				1, 496, 728
Morning Glory Vista							5, 872	190, 219	92, 126	55, 030	68, 298	134, 707	495, 306	352, 809	1, 394, 367
Sunnyside					45, 659	322, 015	181, 756	389, 572	310, 246	118, 498	17, 091				1, 384, 837
Midway				58, 881	505, 779	813, 016									1, 377, 676
Others		3, 300	6, 456	168, 143	738, 435	1, 398, 727	999, 326	625, 260	269, 446	383, 516	95, 690	166, 783	163, 310	368, 673	5, 387, 065
Total	170, 577	379, 733	1, 919, 055	2, 761, 861	5, 387, 922	7, 691, 361	6, 027, 098	8, 848, 637	9, 603, 128	6, 304, 389	2, 306, 804	2, 313, 566	3, 158, 194	1, 499, 395	58, 371, 720

TABLE 3.—*Analysis of coals from the Walsenburg area*

Mine	Bed	Laboratory no. of sample	Proximate analysis				Ultimate analysis					Heating value	
			Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Hydrogen	Carbon	Nitrogen	Oxygen	Calories	Btu
Calumet No. 1-Turner	Walsen (Lenox)	A 26671	7.0	36.7	44.8	11.5	0.6	5.4	64.6	1.2	16.7	6,289	11,320
Calumet No. 2-Brennan	Cameron	A 26611	7.0	36.3	46.1	10.6	1.0	5.5	66.8	1.2	14.9	6,456	11,620
Cameron	Walsen	34242	5.3	35.3	44.8	14.6	.5	5.0	65.3	1.2	13.4	6,439	11,590
Do	Cameron	A 59293	4.2	37.2	46.2	12.4	.6	5.4	67.4	1.3	12.9	6,717	12,090
Gordon	Cameron	33566	6.8	35.7	46.7	10.8	.8	5.1	64.7	1.3	17.3	6,444	11,600
Lester	Walsen	34195	3.3	36.8	49.1	10.8	.6	5.2	70.9	1.4	11.1	7,056	12,700
Maitland	Robinson (Lower)	33817	6.1	34.4	45.1	14.4	.6	4.9	63.2	1.2	15.7	6,267	11,280
Do	Lenox	33818	7.1	35.3	44.9	12.7	.7	5.2	63.7	1.3	16.4	6,317	11,370
Mutual	Walsen	33949	4.8	36.1	44.2	14.9	.5	5.0	64.8	1.2	13.6	6,378	11,480
Pictou	Cameron and Walsen	33498	4.8	38.6	46.0	10.6	.7	5.3	68.1	1.3	4.0	6,722	12,100
Pinon	Cameron	33817	6.1	34.4	45.1	14.4	.6	4.9	63.2	1.2	15.7	6,267	11,280
Pryor	Cameron	6540	3.4	35.6	51.4	9.6	.8	5.2	71.0	1.2	12.2	7,106	12,790
Do	Pryor	6541	3.6	34.5	50.3	11.6	.6	5.3	69.8	1.1	11.6	6,889	12,400
Ravenwood	Cameron	31408	4.8	38.2	48.9	8.1	.7	5.4	71.0	1.4	13.4	7,000	12,600
Robinson	Walsen	33900	4.7	36.3	49.9	11.1	.5	5.1	68.1	1.2	14.0	6,694	12,050
Sunnyside	(Lenox)	6551	10.2	34.3	43.8	11.7	.6	5.6	61.8	1.0	19.3	6,033	10,860
Toltec	Walsen	33492	5.7	37.9	46.6	9.8	.8	5.2	67.9	1.3	15.0	6,750	12,150
Do	Cameron	33493	5.7	37.5	46.9	9.9	1.0					6,728	12,110
Walsen	Rouse	6529	4.1	34.5	52.8	8.6	.7	5.3	71.2	1.2	13.0	7,161	12,890

Table 4—Classification of coals by rank [a]

[From American Society of Testing Materials, September 1954, standards on coal and coke, p. 80]

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 percent or more (Dry V. M., 2 percent or less).	
	2. Anthracite	Dry F. C., 92 percent or more and less than 98 percent (Dry V. M., 8 percent or less and more than 2 percent).	
	3. Semianthracite	Dry F. C., 86 percent or more and less than 92 percent (Dry V. M., 14 percent or less and more than 8 percent).	Nonagglomerating.[b]
II. Bituminous [d]	1. Low volatile bituminous coal.	Dry F. C., 78 percent or more and less than 86 percent (Dry V. M., 22 percent or less and more than 14 percent).	
	2. Medium volatile bituminous coal.	Dry F. C., 69 percent or more and less than 78 percent (Dry V. M., 31 percent or less and more than 22 percent).	
	3. High volatile A bituminous coal.	Dry F. C., less than 69 percent (Dry V. M., more than 31 percent; 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., 9,500 or more and less than 11,000.[e]	
	3. Subbituminous C coal	Moist Btu., 8,300 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 percent 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 percent 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.

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