Coal Geology and Coal, Oil, and Gas Resources of the Erie and Frederick Quadrangles, Boulder and Weld Counties, Colorado

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By FRANK D. SPENCER

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By Frank D. Spencer

ABSTRACT

This report describes in detail the structural and environmental geology, coal resources, and oil and natural gas production of the Erie and Frederick quadrangles in southeastern Boulder and southwestern Weld Counties, Colorado. Rocks exposed in the area are all of Late Cretaceous age. The coal occurs in the lower part of the Laramie Formation of Late Cretaceous age.

Investigation has shown that more than 584,000,000 short tons of original resources of subbituminous coal were contained in seven beds more than 2.5 ft thick. Approximately 135,000,000 short tons have been mined or lost in mining. Total remaining resources are 447,000,000 tons.

Of these seven beds, only three (No. 3, No. 5, and No. 6) are presently economically important. Coal bed No. 3, the most persistent and important bed in the field, contained about 385,000,000 short tons or 66 percent of the original resources. Almost 280,000,000 short tons or 62 percent of all remaining reserves are in coal bed No. 3. More than 210,000,000 short tons of these resources are contained in coal beds that have an average thickness of 5 ft or more. Approximately 174,000,000 short tons of coal contained in coal bed No. 3 are in deposits where the coal is 5 ft thick or more. Original resources of coal bed No. 5 are 110,000,000 short tons, about 10,700,000 short tons of which have been mined or lost in mining. Original resources of coal bed No. 6 are about 42,000,000 short tons, about 5,700,000 short tons of which have been mined or lost in mining.

INTRODUCTION

This report describes the structural and environmental geology, coal resources, and oil and gas production of a 115-mi² area in north-central Colorado (fig. 1); 32 mi² of this area are in east-central Boulder County, and 83 mi² are in southwestern Weld County.

Purpose of the report

This investigation was undertaken (1) to determine the number, thicknesses, and areal and vertical distribution of coal beds, (2) to determine the amount of coal resources present, (3) to delineate areas where coal can be recovered by strip mining, (4) to compile stratigraphic and structural data that will aid exploration for coal, oil, and gas, and (5) to plan for geologic engineering and environmental studies. Surface geologic mapping and collection and study of mine maps, drillers' logs, and other data were done intermittently by the author from 1952 to 1954.

Demand for low-sulfur coal as a powerplant fuel has renewed interest in the coal resources of the Boulder-Weld County coal field of Colorado. The proximity of this field to the metropolitan Denver area adds to its importance. Population movement into rural areas adjacent to this metropolitan area has created a demand for more information regarding its stability for building construction. Knowledge of the structural geology, stratigraphy, coal, oil and gas resources, and location of mined-out areas therefore is essential in land-use planning to determine groundwater conditions, subsidence potential, and other unstable conditions detrimental to general construction and habitation.

Previous geologic investigations

Early U.S. Geological Survey geologists visited the area during reconnaissance surveys (Hayden, 1873, p. 111–155; Stevenson, 1875, p. 303–410) and established general geologic relationships for the region. Most of the area was included in an extensive geologic report on the Denver area by Emmons and others (1896), in which G. H. Eldridge gave a detailed description of the coal deposits (p. 317–386). The stratigraphy, structure, and petroleum geology of the area immediately west of the Erie and Frederick quadrangles were studied and described by Fenneman (1902, 1905) soon after oil was discovered in the Boulder field.

More general reports that have contributed to an understanding of the stratigraphy and structure of the area include those of Darton (1905), Lee (1900, 1915, 1923, 1927), Mather and others (1928), Ziegler (1917), and Lovering and Goddard (1950). Laurie (1966) used many of this author's notes and maps in preparing an analysis of the coal industry in the Boulder-Weld County coal field. Colton and Laurie (1973) also used and revised many of these notes and maps as well as data on later mining in the preparation of a map showing the generalized extent of coal mining in parts of Boulder and Weld Counties.

A detailed study prepared for the Colorado Geological Survey by the firm of Amuedo and Ivey (Myers and others, 1975) dealt extensively with mine-subsidence hazards in this area. A final report was to be published in 1977. Although none of these data have been included in this report, it is nevertheless of prime environmental importance to those planning construction in this area. More recent works on the area were published by Trimble (1975), Colton and Anderson (1977), Machette (1977), and Colton (1978). In 1980, the author collected all available new data to update the revised maps prepared earlier and to prepare this report.

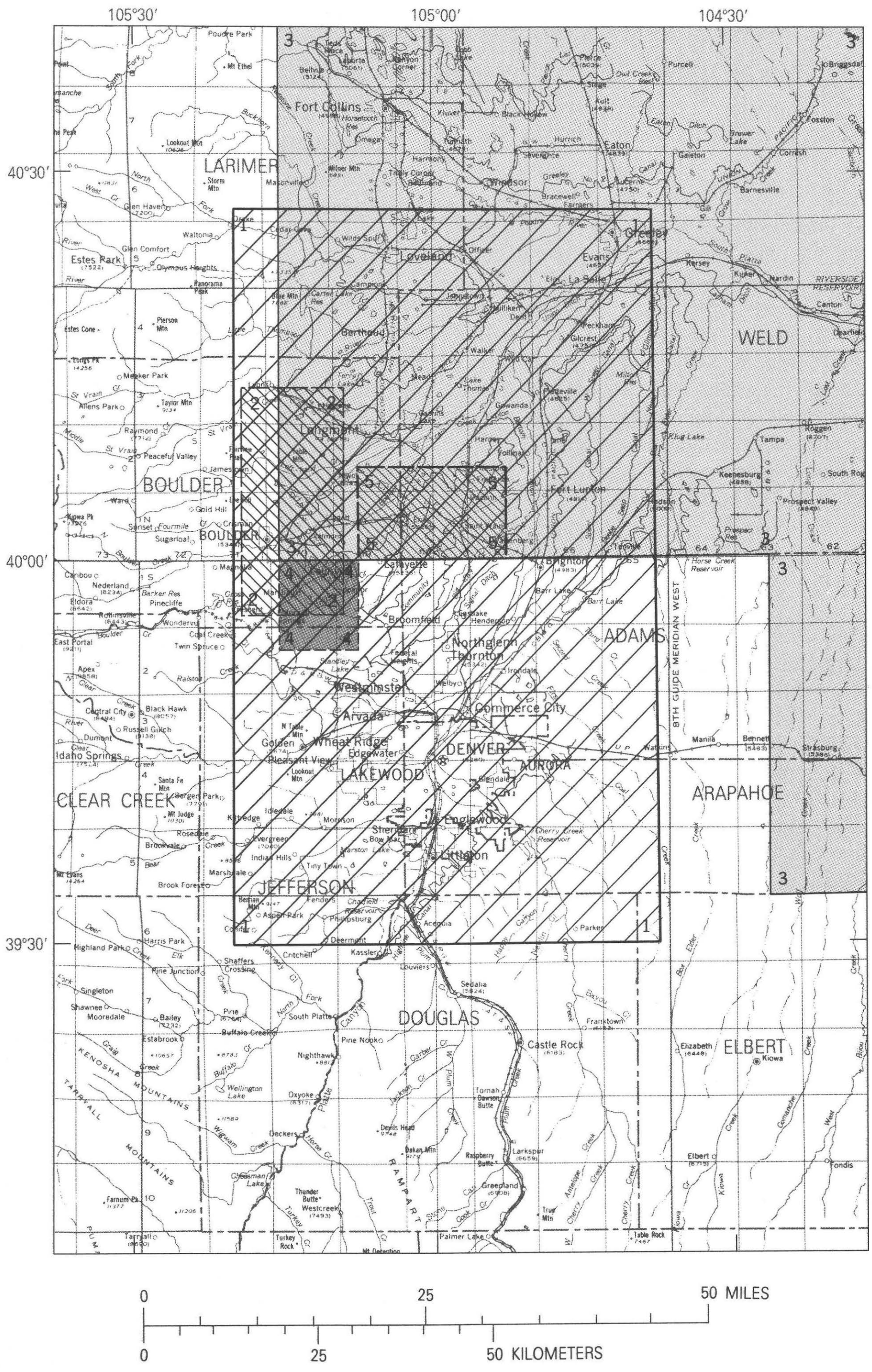

Figure 1. Index map of north-central Colorado showing the location of the area studied in this report and previous Geological Survey reports on this area. 1, Emmons and others (1896); 2, Fenneman (1905); 3, Mather and others (1928); 4, Spencer (1961); 5, this report.

ACKNOWLEDGMENTS

The author is indebted to many individuals, most of whom are now deceased, and their associated companies, most of which are not presently operating, for their courteous cooperation and assistance. George and James Brennan of the Imperial Coal Company, Denver, Colo.; I. M. Charles, chief engineer of the Union Pacific Coal Company, Rock Springs, Wyo.; the Cooley brothers of the Erie Coal Company, Denver; Howard Crandall of the Clayton Coal Company, Denver; Harry Jones of the Rocky Mountain Fuel Company, Denver; Charles Liley of the Black Diamond Coal Company, Lafayette, Colo.; Fred Nesbit and William H. Peletier of the Boulder Valley Coal Company, Dacano, Colo.; E. L. Peart of the Shamrock Mining Company, Erie, Colo.; and Frank Yates, Jr., of the Louisville-Lafayette Coal Company, Lafayette, were especially helpful and contributed information on past mining operations, drillers' logs of test holes, and other data. Thomas Allen, then Colorado State Inspector of Coal Mines, and his office personnel were most cooperative in furnishing records and data on the coal mines of this district. Charles Albi, consulting engineer, Denver, furnished drill log information; F. H. Canis, consulting engineer, Denver, contributed wholeheartedly a wealth of knowledge and data concerning this field; Kirk Cammack and C. M. McConnell, mining engineers in the U.S. Geological Survey's Conservation Division (now the Minerals Management Service), also contributed much information and advice regarding the coal in the area. Bruce F. Curtis, regional geologist for the Continental Oil Company, Denver, made available to the author much geologic information pertaining to this area. W. B. Ferguson, superintendent of the Lincoln coal mine of the Clayton Coal Corporation; Frank Kolar, superintendent of the Imperial Coal Company; A. W. Neucomb, superintendent of the Sterling mine, McNeil Coal Corporation; and John Stevens, superintendent of the Washington coal mine, Clayton Coal Company, were most cooperative in furnishing information garnered from their experience in this coal field and gave freely of their time for mine visits. J. B. Hays of the Colorado School of Mines, Golden, Colo.; Charles Lavington, consulting geologist, Denver; and Warren O. Thompson and Harrison Murray of the Geology Department, University of Colorado, Boulder, Colo.; gave valuable advice and data regarding the stratigraphy and structure of the area. George Waneka, driller, Lafayette, contributed freely from his broad experience and knowledge of coal and water-well drilling in the area.

LOCATION AND EXTENT OF THE AREA

The area described in this report (fig. 1) comprises two 7½-min quadrangles, Erie and Frederick, which are limited on the north by latitude 40°07′30″, on the south by latitude 40°, on the west by longitude 105°07′30″, and on the east by longitude 104°52′30″. It embraces an area of 115.5 mi^2; the western 32 mi^2 are in east-central Boulder County, and the remaining 83 mi^2 are in the southwestern corner of Weld County. Figure 1 shows the location of the area and previous geologic reports on this area.

GEOGRAPHY

The mapped area is located on the western edge of the Denver Basin, about 18 mi north of Denver, and lies east of the Front Range of the Rocky Mountains, west of the South Platte River, south of Longmont, and north of Lafayette, within the western part of the Colorado Piedmont lowlands of the Great Plains province. The Colorado Piedmont is an undulating plain modified by elevation of a few hundred feet and slopes ranging from an altitude of about 5,500 ft in the west to 4,000 ft in the northeast. The western margin of the Colorado Piedmont is occupied by low rounded hills, undulating ridges, and shallow valleys that reflect to a great extent the attitude and nature of the exposed rocks.

In the map area, altitudes range from 5,000 to 5,300 ft above sea level. The relief is moderate to low. The master tributaries have low gradients and flow in meanders across a flood plain that varies in width from 0.5 to 1.5 mi.

Drainage and water supply

All of the area covered in this report is drained by tributaries of the South Platte River. These tributaries generally flow northeast and reach the South Platte several miles east of the report area. The most important tributary is Boulder Creek. A 51-yr streamflow record compiled from a gaging station on South Boulder Creek near Eldorado Springs (Bell, 1954, p. 144, 147, 148) shows a maximum daily discharge of 2,370 ft^3/s, a minimum of 4.0 ft^3/s, and an average of 76.5 ft^3/s for an area of 114 mi^2. Many diversions of water for irrigation and most of the water for the Colorado River "take out" occur above the station. However, at Middle Boulder Creek, 18 mi to the west at Nederland, 39-yr records (1907–40, 1945–51) for an area of 35.5 mi^2 show an average daily discharge of 53.6 ft^3/s, a maximum of 800 ft^3/s, and a minimum of 3.5 ft^3/s, with no diversion above the station. There are no gaging stations on

Boulder Creek in the area of this report, but streamflow rates per square mile are probably similar to those reported above. Even though the stream-gaging records do not give a complete picture, the confluence of South Boulder Creek and Boulder Creek at Valmont, on the eastern edge of the city of Boulder, makes it a sizable stream. Records computed for a period of 22 yr at a gaging station at the mouth of Boulder Creek near Longmont for a drainage area of approximately 512 mi^2 show an average daily discharge of 59.5 ft^3/s, a maximum of 154.0 ft^3/s, and a minimum of 0.3 ft^3/s, with diversions and storage above the station for irrigation.

Coal Creek enters the Erie quadrangle about 1 mi east of Lafayette and flows north of Erie, where it joins Boulder Creek. Big Dry Creek and Little Dry Creek in the Frederick quadrangle flow northeastward into the South Platte River.

Climate

The climate of this portion of Boulder and Weld Counties is semiarid. The average annual precipitation is slightly more than 14 in. and falls mostly as rain from June through September; the remainder falls as snow and rain through the other eight months.

ELECTRIC POWER

The Boulder-Weld County coal field, formerly called the Northern coal field, of which the Erie and Frederick quadrangles have been a very important part, has been a prolific producer of coal since 1890. During this period, mines in the Erie, Frederick, Louisville, and Lafayette quadrangles furnished fuel for domestic and industrial heat and electric power for the cities of Denver and Boulder and their surroundings.

Electric power is generated near the report area at the Public Service Company of Colorado's Valmont plant, which is about 4 mi east of Boulder. Electricity from this plant is used principally in the immediate and surrounding areas, but some of its output goes to Denver. The plant uses either coal or natural gas as fuel. About 1½ lb of coal are required to produce 1 kW (about 750 t/d of coal are consumed). When the coal mines were operating in the Erie and Frederick quadrangles, approximately 250,000 t/yr of coal were used at the Valmont and Denver generating powerplants.

STRATIGRAPHY

Rocks ranging in age from Precambrian to Late Cretaceous crop out 20 mi to the west and are inferred to underlie the quadrangles. By the end of the Cretaceous or early Tertiary time, about 18,000 ft of sediments were deposited in the study area. The lower section of approximately 3,500 ft is predominantly sandstone, conglomerate, and arkose; the middle section of approximately 9,000 ft is predominantly shale; the upper section of approximately 5,500 ft is predominantly sandstone and siltstone, only about 1,000 to 2,000 ft of which remain. Only the Fox Hills Sandstone and the Laramie Formation are considered in this study. A generalized section showing the Fox Hills Sandstone and the Laramie Formation is given in figure 2.

Fox Hills Sandstone

The Fox Hills Sandstone (Upper Cretaceous) crops out near the southwestern edge and in the northwestern third of the Erie quadrangle. The Fox Hills Sandstone crops out in the area surrounding the Panama No. 2 reservoir and is bounded on the south and southeast by alluvium along Boulder Creek. The Fox Hills Sandstone is not exposed in the Frederick quadrangle, and the depth to the top of the Fox Hills is no more than 700 ft. In the map area, sandstone about 200 to 300 ft thick is an important regional source of ground water. The ground water, which is generally suitable for domestic use, has been used by local communities, the suburbs of Denver, and industry. A few drill holes in T. 2 N., R. 68 W. have penetrated the upper part of the Fox Hills Sandstone. The "White Rocks" in T.1 N., R. 69 W. (Trimble, 1975), 10 mi to the west of the reported area on the northern side of Boulder Creek, is an excellent exposure of the unit. The contact between the Laramie Formation and the Fox Hills Sandstone is not well defined. As it is used in this report, the Fox Hills Sandstone includes at the top two massive light-gray to buff sandstone beds called A and B by Emmons and others (1896, p. 71, 74) and by Fenneman (1905, p. 33) but included in the basal part of their Laramie Formation. Trimble (1975) mapped the A and B sandstones at White Rocks with the Fox Hills. Machette (1977) mapped what he considered to be these same two sandstones with the Laramie. Romero and Hampton (1972), however, indicate that, on the basis of subsurface information, the Fox Hills Sandstone (that is, the A and B sandstones of Eldridge (Emmons and others, 1896, p. 71, 74)) in the area south of Lafayette is 500 ft or more below the surface. The contact between the A and the B at White Rocks is well defined and marked by a thin bed of coal or carbonaceous shale 2 to 4 ft thick that sometimes has been misidentified as coal bed No. 1 and that marks the base of the Laramie Formation. The thickness of the Fox Hills Sandstone ranges between 200 and 300 ft. The base of the unit is not exposed in the White Rocks and in the Erie or Frederick quadrangle areas. Elsewhere, eletric log data indicate a range of thickness from 120 to 160 ft, and maps by Romero and Hampton (1972) show that the approximate configuration and depth to the top of the Laramie-Fox Hills aquifer indicated a thickness of 80 to 170 ft for the aquifer in the Denver Basin.

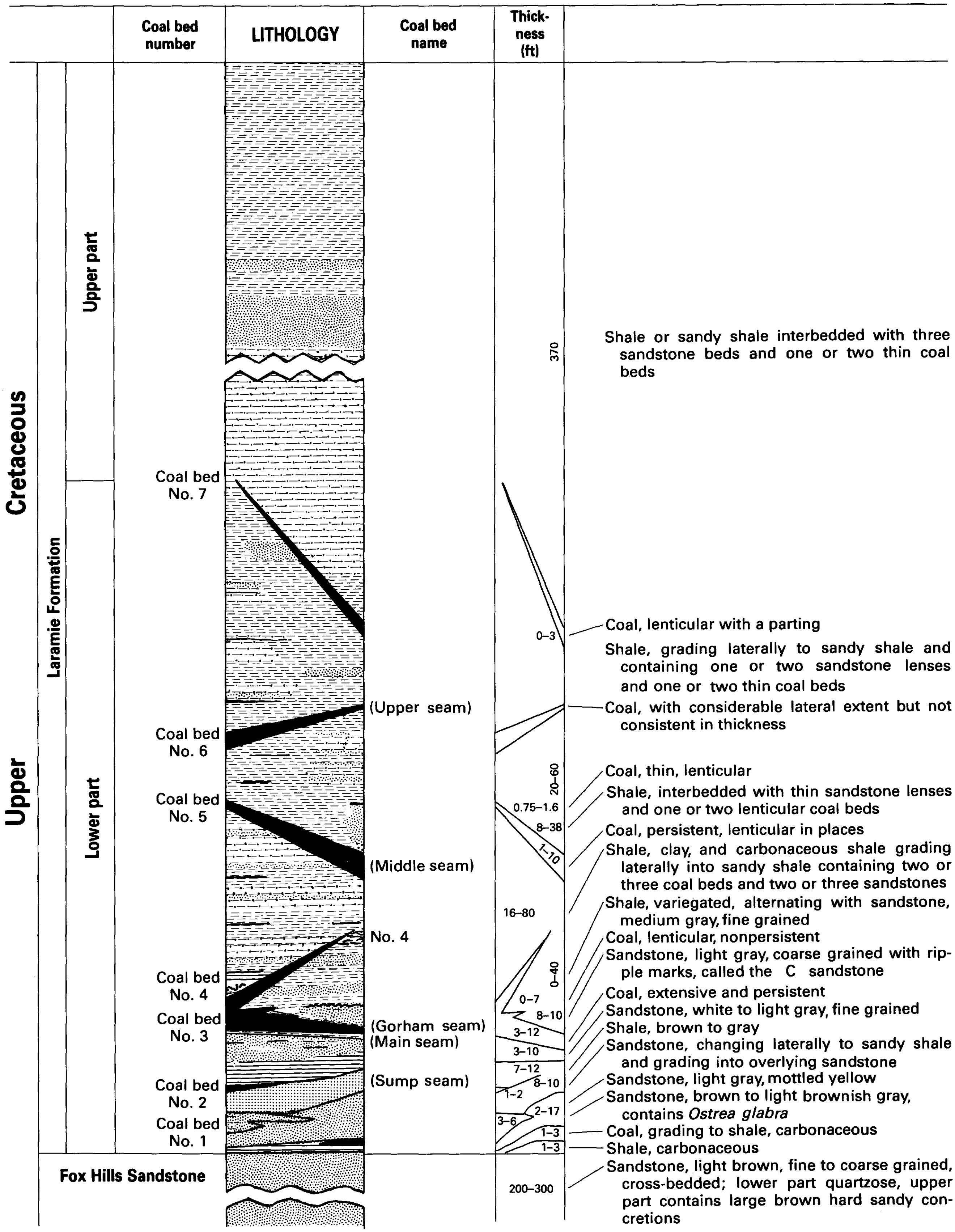

Figure 2. Generalized columnar section showing the Fox Hills Sandstone and the Laramie Formation, Erie and Frederick quadrangles, Boulder and Weld Counties, Colorado.

Laramie Formation

In this report, the Laramie Formation includes all Cretaceous rocks above the B sandstone of the Fox Hills Sandstone. In the Lafayette quadrangle to the south, Machette's (1977) mapping of the contact of the Laramie with the overlying lower part of the Arapahoe Formation suggests the possibility that the lower Arapahoe may be present in the southeastern corner of the Erie quadrangle. The Laramie conformably overlies the massivve B sandstone; the base of the Laramie Formation is a gray to black, locally carbonaceous shale bed 1.0 to 3.0 ft thick. The carbonaceous shale is overlain locally by a thin coal bed herein called coal bed No. 1. The Laramie Formation is as much as 870 ft thick in some places and can be divided into two parts.

The lower part of the Laramie Formation (or strata between the base of coal bed No. 1 and the top of coal bed No. 7 in fig. 2 ranges in thickness from 110 to 500 ft, and the base of the Laramie to the top of the C sandstone of the Laramie (fig. 2) is best exposed in the Marshall area on Pine Ridge in SE¼NE¼ sec. 20 and in NE¼ sec. 15 in T. 1 S., R. 70 W., south of the Davidson ditch.

Coal bed No. 1 in the Erie District (Emmons and others, 1896, p. 360), in drill holes in the Welch mine, in the Louisville district (location doubtful), and in the Stewart Garfield mines in NE¼ sec. 24 in T. 1 N., R. 69 W., below a 5-ft coal apparently was miscorrelated as coal bed No. 1, and in the Mitchell mine, sec. 25, T. 1 N., R. 69 W., near Lafayette, a coal bed 5 ft thick is called coal bed No. 1 but should be called coal bed No. 2. Overlying coal bed No. 1 is a unit of hard, fine-grained, quartzose, light-gray sandstone that is mottled with yellow, ranges in thickness from 2 to 17 ft, and changes laterally in places to include a 3- to 6-ft brown to light-brownish-gray sandstone. The base of the brown sandstone is 4 to 6 ft above the base of the gray quartzose sandstone unit. The brown sandstone commonly contains abundant pelecypods identified by Emmons and others (1896, p. 74) as *Ostrea glabra.* The brown sandstone changes laterally to sandy shale and locally grades into an overlying fine-grained thin-bedded white sandstone that varies in thickness from 8.0 to 10.0 ft and contains lignite and iron-oxide stains. The white sandstone is overlain by a brown to gray lignitic shale unit that varies in thickness from 7 to 12 ft. In places, this shale contains a coal near its base that is 1 to 2 ft thick and is probably coal bed No. 2, locally called the Sump seam and shown on plate 3. This brown to gray shale grades upward into a white to light-gray, fine-grained, lignitic, shaly quartzose sandstone that ranges in thickness from 3.0 to 10.0 ft. A thin bed of shale or clayey shale comformably overlies this sandstone.

Coal bed No. 3 (Emmons and others, 1896, p. 361–363), locally called the Main seam in the Erie and Frederick quadrangles, overlies the shale or clayey shale and the lignitic sandstone. Coal bed No. 3 attains a maximum thickness of more than 12 ft in the Frederick quadrangle (pl. 4). Although lenticular and unminable in some areas, it is the most persistent and has been the most productive bed in the coal field. Resources of this coal have been calculated. In the Frederick quadrangle, the roof rock of coal bed No. 3 is either sandy shale, shale, or carbonaceous shale ranging from 3.0 to 40 ft in thickness. However, at surface exposures in the Marshall district, the coal is overlain by 8.0 to 10.0 ft of light-gray, coarse-grained, quartzose concretionary sandstone containing casehardened ripple marks at its top. Emmons and others (1896, p. 346) called this sandstone the C sandstone of the Laramie.

The remainder of the lower part of the Laramie Formation (that is, from the top of the C sandstone to the top of coal bed No. 7) in the Frederick quadrangle consists of as much as 420 ft of predominantly clay, shale, sandy shale containing a few thin, sporadic, lenticular sandstones, and coal beds. Four coal beds (No. 4–No.7) are lenticular but locally attain minable thickness in the quadrangle. Resources of these beds have been calculated, and coal beds No. 5 and No. 6 have been mined in the Frederick quadrangle.

The stratigraphic section between coal beds No. 3 and No. 4 is about 0 to 40 ft thick and consists of up to four or five lithologic subunits. The basal subunit is locally developed and consists of a shale or carbonaceous shale that ranges in thickness up to 2 ft. It is overlain by a coaly shale or coal that is as much as 1 ft thick and may be part of coal bed No. 3. This subunit is overlain in turn by variegated shale alternating with medium-gray sandstone that is from 6 to 40 ft thick. The highest subunit generally consists of shale or sandy shale that is from 1 to 2 ft thick. Locally, however, coal bed No. 4 is underlain by clay or claystone that is about 6 to 7 ft thick.

Coal bed No. 4 ranges in thickness from less than 1 ft to more than 7 ft in sec. 32, T. 1 N., R. 69 W. (pl. 5); at most points where it has been observed, however, it is too thin to be included in resource calculations.

The interval between coal beds No. 4 and No. 5 varies from 16 to 80 ft in thickness. The base of the interval consists of 1 to 10 ft of thick clay, carbonaceous shale, or shale that locally grades laterally in the upper part to sandy shale. Overlying this basal unit is an interval of alternating shale and sandy shale that ranges in thickness from 5 to 50 ft (1.52 to 15.24 m.) and contains two or three coal beds 4 to 20 in. thick and two or three fine-grained sandstone beds from 8 to 12 in. thick.

Coal bed No. 5 ranges from less than 1 to more than 10 ft (3.04 m.) thick, as plate 6 shows. Rocks between coal beds No. 5 and No. 6 range in thickness from 20 to 60 ft. The section generally consists of 8 to 38 ft of shale that contains one or two lenticular coal beds ranging in thickness from 6 in. to 2 ft. In places, the base of this shale changes laterally to as much as 5 ft of coarse sandstone grading upward to as much as 18 ft of fine-grained sandstone. Locally overlying this fine-grained sandstone is a coal bed 9 in. to 1.6 ft thick. This coal is overlain by 8 to 24 ft of shale containing a few thin sandstone lenses and in places grading laterally into sandy shale. A shale or carbonaceous shale forms the seat rock for coal bed No. 6.

Coal bed No. 6 ranges in thickness from less than 1 to more than 7 ft, as plate 7 shows. More than 2,600 acres of resources 2.5 ft thick or more are believed to be in the quadrangle. Only about 10 acres have been mined.

Between the top of coal bed No. 6 and the base of coal bed No. 7 (where it is present) lies a sequence of rocks ranging in thickness from 25 to 110 ft. This interval consists predominantly of shale that grades laterally in places to sandy shale and contains one or two sandstone lenses 1 to 2 ft thick and one or two coal beds less than 2 ft thick.

Coal bed No. 7 is lenticular and contains a parting of bony coal or bone. The coal is more than 4 ft thick, as plate 7 shows.

The upper part of the Laramie Formation in the report area is preserved, notably, in downthrown blocks of faulted areas. Drilling in some of these fault blocks revealed as much as 370 ft of indurated rock above a coal bed identified tentatively as No. 7. The rocks are primarily shale that locally grades to sandy shale. Interbedded with the shale are two sandstone beds ranging in thickness from 7 to 20 ft and one or two coal beds that are less than 2 ft thick.

STRUCTURAL GEOLOGY

The area included in this report is mostly on the western limb of the structural Denver Basin. The regional dip of the rocks in the area varies somewhat, but the strike is basically uniform. Rocks in the western part of the basin lie within the foot of the Foothills monocline, are more steeply dipping, and have a regional dip of about 10° SE. and a northeast strike. Throughout the Erie and Frederick quadrangles, the regional dip is low, averaging about 50 ft/mi to the southeast, and the strike is about 35° NE.-SW. The regional dip is interrupted by numerous faults and folds. The dip of the rocks is usually high near faults but decreases a short distance away and resumes approximately the regional dip.

In general, it may be presumed that the major folds and faults of this area were caused by the same stresses that formed the Foothills monocline. It would be logical to assume that, as the distance from the Foothills monocline increases, the magnitude of the folding decreases, and this assumption is apparently true. The strike of the axis of the major folds and of many of the fault planes approximates that of the regional strike. The trend of the fault system is in good alinement with the trend of the Precambrian shear zone described by Lovering and Goddard (1950, p. 25–54) in the mountains southwest of the area of this report and mapped to the sedimentary contact on the eastern edge of the Front Range. This shear zone probably extended east of the Front Range and was a zone of weakness in which movement was repeated throughout later geologic time. At least, it appears to have been a zone in which there was considerable fracturing in Late Cretaceous and (or) Tertiary time.

Many of the faults in the area (pl. 1 and 2) are not visible at the surface because of lack of exposures and thick alluvium cover but were found by studying coal-mine and well records and, where it was possible, by checking in the mines. Many more faults are believed to be present in the subsurface in the area, but evidence for them could not be found during this investigation. From the available data, it was not possible to determine the depths to which these faults continue. However, on the basis of what is known about the regional geologic setting, the underlying sedimentary sequence, and the many fractures present in the apparently more brittle sediments of the Fox Hills Sandstone and Laramie Formation, the author believes that the faults do not persist with depth but die out in the upper 4,000 ft of the underlying Upper Cretaceous Pierre Shale and are probably nonexistent in the Hygiene Sandstone Member in the lower part of the Pierre. The following history is suggested.

Tectonic movements that caused the upwarping of sediments along the Front Range during Cretaceous or Tertiary time also caused movements along the northeastern extension of the Precambrian shear zone as well as folding and faulting of the sedimentary rocks (Lovering and Goddard, 1950, p. 25–54). It is noteworthy that Lovering and Goddard (1950, pl. 2) showed a fault of Tertiary age coursing along the Precambrian shear zone in Coal Creek Canyon.

Folding accompanied by minor faulting took place in the lower part of the Cretaceous section of sandy rocks where, even though the beds are relatively competent, pressure resulting from the overburden was sufficient to allow flexing along with excess fracturing. Folding and flowage were probably dominant, and only small amounts of faulting occurred in the middle part of the Cretaceous section. However, because the upper part of the Cretaceous section of sandstone, conglomerate, and siltstone had less weight of overburden, it tended to be faulted more easily than folded. The case for a growth-faulting origin of most of the faults in the Golden-Leyden area southwest of the area and in the Marshall area southwest of Louisville in the Boulder-Weld County coal field, as developed by Davis (1974), Weimer, (1972, 1973), and Rahmanian (1975), is convincing. However, drill and mine records indicate that there is no perceptible abnormal thinning or thickening of the coal or of sediments over the horst or graben blocks in the area of this report. Thinning of coal over the horst block appears to be one of the criteria Weimer (1972, p. 661; 1973, p. 84) presents for a growth origin of the faults.

COAL MINING

During the period 1884 to 1955, 3,867,865 short tons of coal were produced in the mines of the Erie quadrangle in Boulder County. Eldridge (Emmons and others, 1896, p. 318) indicated that 270,870 short tons were produced from the Erie-Canfield area during the period from 1872 to 1876. Production records for individual mines are not available, but the production from 1884 to 1955 (all coal beds) of the area is shown in table 1. The total coal known to have been mined from 1872 to 1955 is 4,138,735 short tons. Coal that has been mined and lost in mining in the Erie quadrangle in Boulder County is estimated to be about 10,687,000 short tons. This estimate would indicate a recovery ratio of about 40 percent, a low recovery factor by present standards for most mines. This recovery factor is probably in error because of the poor to inadequate production records available for the Boulder County part of the Erie quadrangle. However, the estimated tonnage of coal mined and lost in mining (all coal beds) for the entire Erie quadrangle coal-bearing area (parts of Boulder and Weld Counties) is about 44,000,000 short tons (see table 2), and known and recorded production is about 26,525,086 short tons. The recovery ratio for all coal mined in the Erie quadrangle thus would be about 56.0 percent. A negligible amount of the coal mined was strip mined.

Coal mining in the Frederick quadrangle in Weld County occurred mostly after 1900, the major part during the 60-yr period from 1915 to 1975. Peak production in Weld county of 879,267 short tons occurred in 1951. Total cumulative production in the Erie and Frederick quadrangles in Weld County was 66,219,434 short tons (see table 1). Coal mined and (or) lost in mining is estimated at 104,585 short tons (see table 2). These records indicate a high mining recovery ratio of 63.3 percent.

ECONOMIC GEOLOGY

Coal beds

Eldridge (Emmons and others, 1896, p. 360) originally used numbers 1 through 5 to designate coal beds in ascending order in the Coal Creek syncline. He correlated and identified five coal beds by their stratigraphic position and distance relative to the B sandstone and with the coal beds in surrounding areas. Subsequently, most of the beds were given additional names locally to indicate their economic importance or relative stratigraphic position. Coal bed No. 1 was called seam no. 1; coal bed No. 2 was called the Sump vein or seam; coal bed No. 3, the most important stratigraphically, was called the Lower or Main seam; coal bed No. 5 was known as the Middle seam; and coal bed No. 6, which Eldridge did not mention by name (Emmons and others, 1896), locally is called the Upper seam.

Coal beds No. 6 and No. 7 had not been identified before this report or numbered in the literature primarily because they were not mined or well known. All seven beds mentioned are of workable thickness in various places within the Erie and Frederick quadrangles. Plate 2 shows the correlation of these coal beds throughout the area as determined from drillers' logs. Coal bed No. 3, the most extensive and persistent, has been mined more extensively than the others. Three coal beds (No. 3, No. 5, and No. 6), although lenticular, are the most economically important coal beds in the report area. From the standpoint of original resources, the importance of all beds, in decreasing order, is No. 3, No. 5, No. 6, No. 4, No. 2, No. 7, and No. 1 (see table 2 for summary and appendix for classification breakdown of these coal resources).

Analyses recorded in reports of the U.S. Bureau of Mines (Fieldner and others, 1937, p. 126–131; Aresco and Haller, 1953, p. 9.13–9.14) show the coal to be largely of subbituminous B rank.

Coal bed No. 1

Coal bed No. 1 was mentioned by Eldridge (Emmons and others, 1896, p. 360), and its relative position was shown to underlie the B sandstone in the Garfield, Stewart, and Mitchell mines near Erie and Canfield, Colo. Eldridge reported that it was worked in the Mitchell mine and determined by drilling to be present in the Stewart and Garfield mines. However, this author's lateral tracing through mining of coal bed No. 3 (Spencer, 1961, this report) has thrown some doubt upon Eldridge's correlation (Emmons and others, 1896, pl. XVII). This author believes the coal bed shown by Eldridge in the Erie District as coal bed No. 1 is actually No. 2 (Sump seam); his No. 2 is actually No. 3, his No. 3 actually No. 4, and his No. 4 actually No. 5. The B sandstone of Emmons, and others (1896, pl. XVII) appears to be some other sandstone higher in the section.

Coal bed No. 1 as used in the current report is a thin, nonpersistent coal bed or carbonaceous shale that occurs in places on the top of the B sandstone. The base of the coal bed or carbonaceous shale marks the base of the Laramie Formation.

Drilling in the coal fields east of the Gun Barrel Hill area rarely penetrated lower than the horizon of coal bed No. 3 (Main seam). An exception was the drilling associated with the Columbine mine to explore the Sump seam. Thus, few data are available concerning the resources of coal bed No. 1. Resources have been estimated from drilling information in sec. 13, sec. 14, sec. 22, and sec. 23 of T. 1 N., R. 68 W. (see fig. 3), but, in other drill holes, the coal is too thin to use for estimating resources. Coal thicknesses for these coal beds are shown on plate 3 and figure 3. Tonnage estimates are given in table 2, on p. 12, and in the appendix.

Coal bed No. 2 (Sump seam)

Coal bed No. 2 is locally designated the Sump seam because it lies a short distance below coal bed No. 3 in this coal field. Eldridge (Emmons and others, 1896, p. 360) called this bed seam No. 2 and designated it as the bed lying immediately above sandstone B. This identification of the B sandstone does not appear to be correct because coal bed No. 1 lies on the top of the B sandstone at Pine Ridge, and the top of the sandstone is herein considered to be the top of the Fox Hills Sandstone. Coal bed No. 2 has been drilled from the base of the workings in coal bed No. 3 in the Columbine mine (sec. 20 and sec. 29, T. 1 N., R. 68 W.) and in the Standard mine (sec. 1 and sec. 12, T. 1 S., R. 69 W.). The interval in this area between the bases of these coal beds varies from 10 to 40 ft. Because the thickness of coal bed No. 3 in areas near where coal bed No. 2 is close to coal bed No. 3 is often greater than it is in other places, it is suggested that, at some of these places, the beds have coalesced. Coal bed No. 2 generally overlies a thin shale bed, which in turn overlies a massive sandstone; however, it does not everywhere immediately overlie a sandstone, as Eldridge suggested (Emmons and others, 1896, p. 360). Coal bed No. 2 lies 11 to 16 ft above coal bed No. 1 and 10 to 60 ft below coal bed No. 3. In the Columbine mine, where much drilling was done from mine workings on coal bed No. 3, coal bed No. 2 occurs from 15 to 45 ft below coal bed No. 3 and ranges in thickness from 1 to more than 9 ft. It is generally a clean coal; however, in several places, it is split into two or three benches. In the Standard mine (sec. 1 and sec. 12, T. 1 S., R. 69 W.), coal bed No. 2 ranges in thickness from 4 ft 10 in. to 5 ft 3 in. and lies 12 to 26 ft below coal bed No. 3. Coal bed No. 2 is of workable thickness in the area west and southeast of Erie and in sec. 21, T.1 N., R. 68 W., where it ranges in thickness from less than 2.5 to more than 8 ft. In the area of the Gladstone mine (sec. 35, T. 1 N., R. 69 W.), this coal bed attains a maximum thickness of more than 6 ft. In most areas, this coal has a shale roof and a sandstone floor. Plate 4 shows details of thickness, location, and extent of resources calculated for coal bed No. 2 in T. 1 N., R. 69 W.

Coal bed No. 3 (Main seam)

Coal bed No. 3, locally designated the Main or Lower seam, is by far the most persistent and economically important coal bed in this report. This bed has been extensively mined in the Frederick quadrangle, many of those mines being interconnected. The persistent thickness and lateral extent of coal bed No. 3 justify its use as a key bed for structure contouring. Westward into the Erie quadrangle, the bed has been offset or displaced by faulting, but the similar thickness, position in the section, composition of the roof and floor, and extensive mining in the Columbine and State coal mines conclusively show it to be present. Westward from these mines and across the Coal Creek faults, a persistent coal is believed to be coal bed No. 3. The stratigraphic position of these coal beds in the section (in places, they overlie two lower coal beds) and the degree to which mine workings interconnect in the Erie district substantiate the correlation of these coal beds with coal bed No. 3. All the coal mines active in this area in 1953 (table 1) were on coal bed No. 3, with the exception of the Erie strip, the Morrison, and the Shamrock. Only the Black Diamond mine was operating as late as 1953 in the part of Boulder County covered by this report, and it, too, was on coal bed No. 3. In the Frederick quadrangle, the Lincoln mine operated until 1976. A review of coal-mine records for the Erie and Frederick quadrangles since 1884 (table 1) shows only a small number of mines to have mined coal beds other than coal bed No. 3. The Cleveland, Garfield No. 1, and McGregor mined coal bed No. 4, the Peerless, Puritan, Shamrock, and Sterling mined coal bed No. 5, and the Morrison and Reliance mined coal bed No. 6. The Columbine and Gladstone mines mined locally both coal bed No. 3 and No. 4. The proximity of the two beds in the Columbine mine almost certainly has made the unmined bed worthless for future mining; thus, the two beds are shown on plates 5 and 6 and mined or lost in mining.

Table 3 presents chemical analyses of coal from three districts in coal bed No. 3. Table 4 presents other laboratory analyses of coal bed No. 3. Table 5 gives analyses of tipple and delivered samples during fiscal year 1951. Tables 6*A*, 6*B*, and 6*C* provide analyses of three samples taken from the Eagle Mine, Imperial Coal Company, the only analyses of this type available of samples taken from coal bed No. 3 in this coal field.

Coal beds No. 3 and no. 4 were treated as a single bed by Eldridge (Emmons and others, 1896, p. 361) because of their coalescence in the Gladstone mine. Information derived from the large number of coal holes drilled since 1896 has led this author to consider these beds separately

Table 1. Coal mines of the Erie and Frederick quadrangles, Boulder and Weld Counties, Colorado
[Compiled from records of the Colorado State Coal Mine Inspector]

Mine name	Coal bed no.	Location Sec.	Location T.	Location R.	Years operated[3]	Total production to Jan. 1, 1956 (in short tons)
Boulder County						
Arrow	3	13	1 N.	69 W.	1933–35	7,031
or Crescent	3				1905	5,111
or Star	3				1884	
					1890–91	
					1918–20	60,846
Black Diamond No. 2	3	33,34	1 N.	69 W.	1931–55	759,238
Canfield	3	13	1 N.	69 W.	?	?
Chase	3	13	1 N.	69 W.	1892–93	29,219
Cleveland	4	24	1 N.	69 W.	1888–95	51,916
Excelsior	3	35	1 N.	69 W.	1899–1913	590,102
Garfield No. 1	4	24	1 N.	69 W.	1884–?	
					1890–93	
					1895–97	90,774
Gladstone	3,4	35	1 N.	69 W.	1890–1906	386,905
Haywood	3	36	1 N.	69 W.	1899–1906	193,228
Independent	3	34	1 N.	69 W.	1906–07	
					1921–22	16,115
Lister	3	24	1 N.	69 W.	1905–07	20,146
Longs Peak	3	13	1 N.	69 W.	1893–95	140,498
					1896–1900	
Marfel	3	24	1 N.	69 W.	1897–98	
					1901–02	
					1903–04	14,302
McGregor	4	24	1 N.	69 W.	1885–97	126,906
Mile Hill	3	27	1 N.	69 W.	1913–18	16,286
Mitchell (New)	3	35	1 N.	69 W.	1893–97	117,540
					1898–1920	1,151,183
Northrup	3	13	1 N.	69 W.	1884–85	16,787
Stewart	3	24	1 N.	69 W.	1888–90	73,732
					1890–92	
Total (part of Boulder County)						3,867,865
Weld County						
Andrew	3	20	1 N.	68 W.	1910–12	11,242
Baum	3	35,36	2 N.	68 W.	1913–53	4,013,856
Boulder Valley	3	17,20,21	1 N.	68 W.	1884–93	
No. 2 or State.					1917–46	4,408,030
Boulder Valley No. 3	3	1,2	1 N.	68 W.	1944–69	2,539,662
Clayton	3	16	1 N.	68 W.	1920–43	3,333,225
Columbine	3,4	20,28,29	1 N.	68 W.	1920–46	7,316,275
Eagle	3	15	1 N.	68 W.	1938–76	7,758,500
Emerson	3	20	2 N.	67 W.	1897–1904	13,179
Erie[1]	6	33	2 N.	68 W.	1948–1953	126,563
Evans or Lilly	3	30,31	2 N.	67 W.	?	1,629,271

Table 1. Coal mines of the Erie and Frederick quadrangles, Boulder and Weld Counties, Colorado—Continued

[Compiled from records of the Colorado State Coal Mine Inspector]

Mine name	Coal bed no.	Location Sec.	T.	R.	Years operated[3]	Total production to Jan. 1, 1956 (in short tons)
Weld County						
Eureka or Whitehouse	3	27,34	2 N.	68 W.	1900	
					1903–05	
					1913–18	
					1921–26	157,379
Firestone	3	30	2 N.	67 W.	1908–20	333,336
Frederick	3	25	2 N.	68 W.	1917–29	707,876
Garfield No. 2	3	19	1 N.	68 W.	1895–96	
					1897–1905	171,567
Golden Ash	3	36	2 N.	68 W.	1906–13	578,509
Graden	3	11,12	1 N.	68 W.	1935–55	889,526
Grant	3	19,30	2 N.	67 W.	1914–39	2,230,143
Imperial	3	10	1 N.	68 W.	1927–72	4,448,788
Lehigh	3	19	1 N.	68 W.	1902–10	315,244
Lincoln (New)	3	13,24	1 N.	68 W.	1950–76	3,420,417
		18,19	1 N.	67 W.		
Lincoln (Old)	3	31,32	1 N.	68 W.	1896–1902	
or Park	3					20,325
or Monroe	3				1932–40	54,000
or Baseline	3				1941–42	3,878
McKissic	3	19	2 N.	67 W.	1890–93	22,370
					1895–97	
					1907–07	
Mitchell (Old)	3	19	1 N.	68 W.	1884–90	1,151,183
					1898–20	
Monroe	3	34	2 N.	68 W.	1907–25	
or Ideal	3				1907–25	384,470
Morrison	6	9,16	1 N.	68 W.	1930–53	2,139,664
Parkdale[2]	3	31	1 N.	68 W.	1907–16	584,701
Peerless	5	4	1 N.	67 W.	1913–19	
or Witherby						
or Silver State						9,601
Puritan	5	2,3	1 N.	68 W.	1908–39	5,933,537
		34,35	2 N.	68 W.		
Reliance	6	8	1 N.	68 W.	1903–07	43,416
Russell	3	20,29	2 N.	67 W.	1914–47	2,078,166
Shamrock	5	26,27,	2 N.	68 W.	1905–49	
		34,35			1951–56	2,167,869
Sterling	5	31,32	2 N.	67 W.		
		6,7	1 N.	67 W.	1920–65	2,769,493
Warwick	3	30	2 N.	67 W.	1908–12	48,782
Washington	3	22,23,27	1 N.	68 W.	1939–67	4,405,391
Total, Weld County						66,219,434
Grand total, Weld County and part of Boulder County						70,087,299

[1] Strip mine.
[2] Haulage slope in Adams County, sec. 6, T. 1 N., R. 68 W.
[3] Last year of operation coincides with year abandoned.

Table 2. Summary of coal resources in Erie and Frederick quadrangles

	Original resources									Mined and lost in mining as of January 1, 1980			
	Measured and indicated resources				Inferred resources								
Coal bed no.	2.5-5.0 ft	5.0-10.0 ft	More than 10.0 ft	Total	2.5-5.0 ft	5.0-10.0 ft	More than 10.0 ft	Total	Total original resources	2.5-5.0 ft	5.0-10.0 ft	More than 10.0 ft	Total
6	12,506	9,620		22,126					22,126	289	5,279		5,568
5	22,300	3,220		25,520					25,520	43			43
4	20,431	8,180	479	29,090					29,090	1,325	3,194	479	4,998
3	46,154	55,925	2,791	104,870	1,058			1,058	105,928	3,592	27,470	2,416	33,478
2	9,301	4,183		13,484					13,484				
Total	110,692	81,128	3,270	195,090	1,058			1,058	196,148	5,249	35,943	2,895	44,087
7	1,997	362		2,359					2,359		134		134
6	17,715	2,322		20,037					20,037	190	8,789	1,740	10,719
5	52,857	29,233	2,527	84,617					84,617				
4	754	340		1,094					1,094	389		11,479	11,868
3	42,900	186,626	25,472	254,998	17,410	6,828		24,238	279,236		81,864		81,864
1	946			946					946				
Total	117,169	218,883	27,999	364,051	17,410	6,828		24,238	388,289	579	90,787	13,219	104,585
Total	227,861	300,011	31,269	559,141	18,468	6,828		25,296	584,437	5,828	126,730	16,114	148,672

[1]Assuming the majority of resources to be nonstrippable and using 50-percent recoverability.

in this paper. Although the previously mentioned coalescence of these beds does occur, more than 30 ft of strata are present locally between them (pl. 3). Coal bed No. 3 generally has a shaly or sandy roof. This coal bed almost everywhere overlies a massive sandstone considered the C sandstone in this report but locally may have a floor of thin shale.

Coal bed No. 4

Coal bed No. 4 was designated by Eldridge (Emmons and others, 1896, p. 361) as seam no. 4, but, as this report stated previously, coal beds No. 3 and No. 4 of the current study in the Lafayette district coalesce in places and have been treated as one bed. Coal bed No. 4 of this report was mined before 1900 in the Cleveand and Garfield No. 1 mines (table 1, pl. 7). Eldridge (Emmons and others, 1896, pl. XVII) believed this coal bed to be coal seam no. 3 (coal bed No. 3). However, later mining and coal drilling make a correlation with coal bed No. 4 more feasible, and the bed is herein designated coal bed No. 4. Analyses of the coal mined in the Cleveland, McGregor, and Garfield No. 1 mines have been extracted from Eldridge (Emmons and others, 1896, p. 376, table 1) and are shown here as table 7. This bed is of minable thickness in several sizable areas in the Erie quadrangle in Boulder County, where more than 11,000,000 short tons of original resources more than 2.5 ft thick are estimated. Also in the Erie quadrangle in Weld County, more than 17,000,000 short tons of original coal resources more than 2.5 ft thick are estimated for this bed. Coal bed No. 4 ranges in thickness from less than 2.5 to 11 ft. In Weld County in the Frederick quadrangle, resources have been computed for two small areas of coal bed No. 4 and are shown in the appendix. The thicknesses and extents of these areas are shown in figures 4*A* and 4*B*.

Coal bed No. 5 (Middle seam)

Coal bed No. 5 has locally been designated the Middle seam. This coal bed has considerable lateral extent, is believed to extend from the southwestern corner of the Erie quadrangle to the northeastern corner of the Frederick quadrangle, and has several sizable areas of coal of minable thickness in both quadrangles (pl. 6). But, because the thickness of this bed varies considerably and because of the lack of available information, Eldridge (Emmons and others, 1896) did not consider this coal bed to be important. Considerable tonnage of coal has been mined from this bed in the Shamrock and Puritan mines in T. 2 N., R. 68 W. Analyses of mine samples from the Puritan mine are shown in table 8. Thickness of this bed ranges from less than 2.5 to more than 10 ft. Details of resources and tonnages are shown in table 2 and the appendix. The stratigraphic interval between coal bed No. 5 and coal bed No. 3 varies from 40 to 90 ft; varying amounts of sandstone and shale are included with these coal beds, one of which, in some places, is designated as coal bed No. 4. In most places, the floor of the coal is shale or sandy shale; the roof is generally shale or, less commonly, sandstone.

Coal bed no. 6 (Upper seam)

Coal bed No. 6, locally designated the Upper seam, is a bed of considerable lateral extent running from the southwestern corner of the Erie quadrangle to the north-

Remaining resources									Recoverable resources[1]									
Measured and indicated resources				Inferred resources					Measured and indicated resources				Inferred resources					
2.5–5.0 ft	5.0–10.0 ft	More than 10.0 ft	Total	2.5–5.0 ft	5.0–10.0 ft	More than 10.0 ft	Total	Total remaining resources	2.5–5.0 ft	5.0–10.0 ft	More than 10.0 ft	Total	2.5–5.0 ft	5.0–10.0 ft	More than 10.0 ft	Total	Total recoverable resources	
Erie quadrangle																		
12,217	4,341		16,558					16,558	6,108	2,171		8,279					8,279	
22,257	3,220		25,477					25,477	11,129	1,610		12,739					12,739	
19,106	4,986		24,092					24,092	9,553	2,493		12,046					12,046	
42,561	28,455	376	71,392	1,058			1,058	72,450	21,280	14,227	188	35,696	529			529	36,225	
9,301	4,183		13,484					13,484	4,650	2,092		6,742					6,742	
105,442	45,185	376	151,003	1,058			1,058	152,061	52,720	22,593	188	75,502	529			529	76,031	
Frederick quadrangle																		
1,997	362		2,359					2,359	998	181		1,179					1,179	
17,715	2,188		19,903					19,903	8,858	1,094		9,952					9,952	
52,667	20,444	787	73,898					73,898	26,334	10,222	394	36,950					36,950	
754	340		1,094					1,094	377	170		547					547	
42,511	104,762	13,993	161,266	17,410	6,828		24,238	185,504	21,255	52,381	6,996	80,632	8,705	3,414		12,119	92,751	
946			946					946	473			473					473	
116,590	128,096	14,780	259,466	17,410	6,828		24,238	283,704	58,295	64,048	7,390	129,733	8,705	3,414		12,119	141,852	
Erie and Frederick quadrangles																		
222,032	173,281	15,156	410,469	18,468	6,828		25,296	435,765	111,015	86,641	7,578	205,235	9,234	3,414		12,648	217,883	

eastern corner of the Frederick quadrangle. However, the bed is not of consistent thickness in these quadrangles. It is of workable thickness in numerous areas and locally attains thicknesses of more than 8 ft in the Morrison mine (sec. 9 and sec. 16, T. 1 N., R. 68 W.), where it was mined extensively (pl. 7). A small amount of coal was mined in the Reliance mine (sec. 8, T. 1 N., R. 68 W.). At the Erie strip mine, in sec. 33, T. 2 N., R. 68 W., this coal bed is near the surface and was recovered by open-pit mining.

Plate 2 shows representative thicknesses of coal sections. In most places, the floor of coal bed No. 6 is shale, carbonaceous shale, or bony coal. Locally in the Morrison mine, a ½- to 1-in.-thick sandstone parting occurs from 5 ft 10 in. to 8 ft 2 in. below the top of the coal. The correlation of the coal bed within and between the numerous fault blocks is difficult owing to a lack of data and in many places is questionable. Coal bed No. 6 is from 25 to 65 ft above coal bed No. 5; this stratigraphic interval contains variable amounts of sandstone, sandy shale, shale, and thin coal beds (pl. 3). Table 8 shows the analysis of two mine samples taken from coal bed No. 6 in the Morrison mine.

Coal bed No. 7

Coal bed No. 7 is sporadic, occurring about 70 to 100 ft above coal bed No. 6, and is of minor importance. There has been no production from this bed. Correlation of this bed across the area is tentative. Representative stratigraphic intervals between coal beds No. 6 and No. 7 consist of sandstone, sandy shale, shale, and thin beds of coal in variable amounts as shown on plate 2. The extent of known reserves is shown on plate 7. The thickness, type of roof material, and partings are illustrated by sections on plate 2.

COAL RESOURCES

Sources of information

In preparing this report on the coal resources of the Erie and Frederick quadrangles of Colorado, this author investigated many sources of data. Chief among these were the mine maps of the Colorado State Mine Inspector's office, the Colorado State Planning Commission, U.S. Geological Survey Bulletins and Monographs, and drill maps and drillers' logs from coal mining companies.

Methods of preparing resource estimates

The coal beds in the area of this report are largely concealed by noncoal-bearing rocks, and most of the available information about them is confined to the data sources mentioned above. Thus, to prepare an estimate of coal resources, it was necessary to establish certain standardized procedures and definitions to insure uniform interpretation and classification of the data. These classifications are dependent upon the characteristics of the coal and the abundance and reliability of the data.

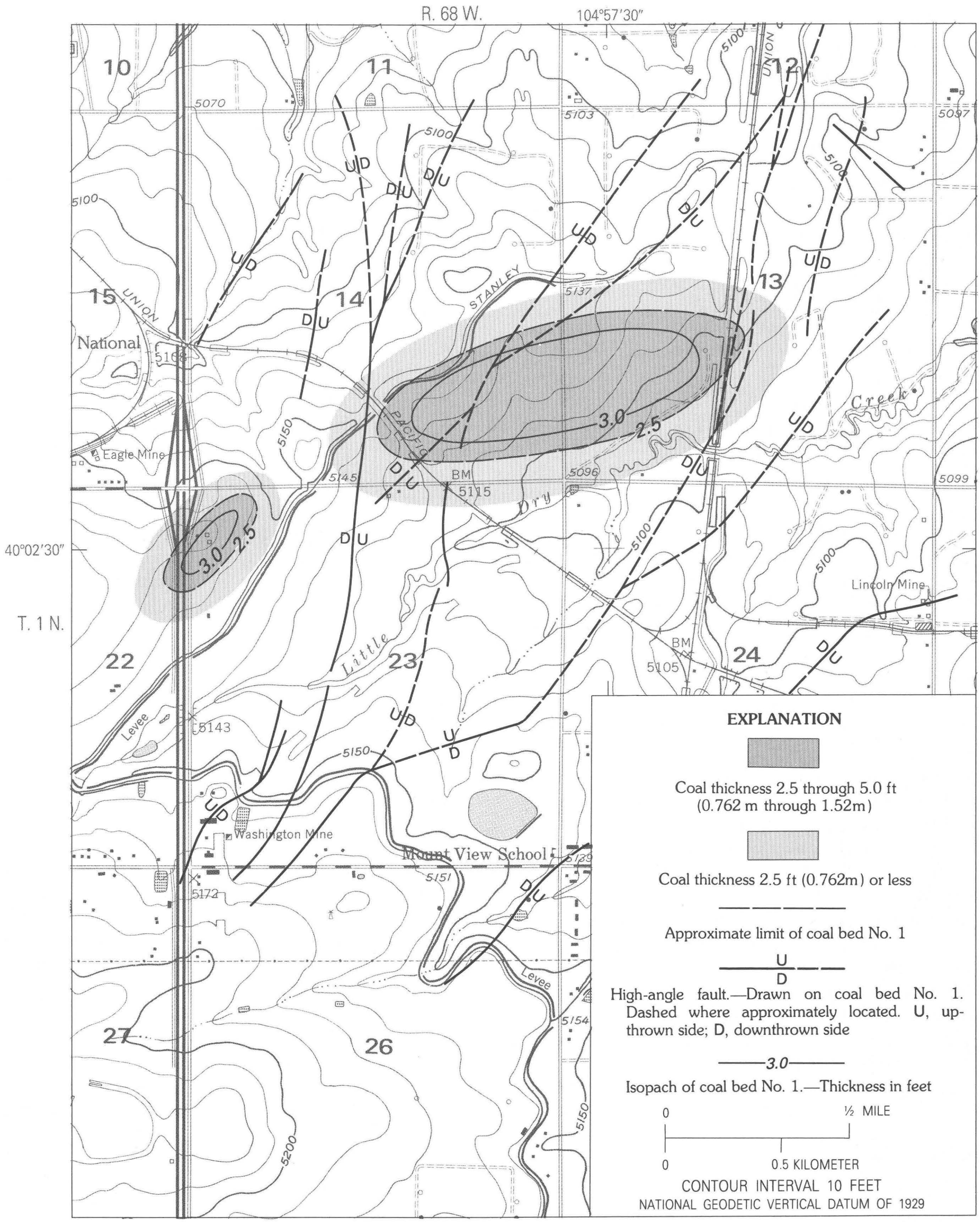

Figure 3. Isolated patches of coal resources of coal bed No. 1, T. 1 N., R. 68 W., Frederick quadrangle, Boulder and Weld Counties, Colorado.

Table 3. Chemical analyses of coal bed No. 3
[Excerpted from Emmons and others (1896, table 1, p. 376-377). —, no data]

No.[1]	Mine	Fixed carbon content, in percent	Volatile combustible content, in percent	Water content, in percent	Ash content, in percent	Sulfur content, in percent	Color of ash	Specific gravity at °F	Fuel ratio c/v-c[2]
				Erie-Canfield district					
125	New Boulder Valley	42.34	37.81	14.90	4.95	0.49	Yellow gray	1.35 at 19.4	1.12
18	Progress	44.73	33.57	16.64	4.51	.55	Light yellow	1.341 at 13.0	1.33
31	Star	43.86	32.10	18.54	4.99	.51	Yellow white	1.336 at 12.0	1.37
32	do	44.51	32.51	17.03	5.35	.60	Reddish white	1.335 at 10.0	1.37
33	Jackson	45.15	33.37	16.04	4.86	.58	White	1.350 at 10.5	1.35
34	do	44.69	32.34	17.61	4.70	.76	White, slight red, tint	1.336 at 14.0	1.38
35	do	45.55	33.01	16.42	4.25	.77	Yellow white	1.333 at 15.0	1.38
36	do	44.62	31.35	17.75	5.53	.75	do	1.338 at 17.5	1.42
				Mitchell district					
44	Lehigh	35.54	35.53	22.94	4.92	1.07	Light gray	1.334 at 13.0	1.00
45	do	34.74	32.95	22.15	8.48	1.68	White	1.388 at 11.0	1.05
19	Stewart	44.97	33.43	17.25	3.79	.56	Light yellow	1.338 at 12.0	1.35
20	do	45.62	34.54	15.44	3.76	.64	White	1.339 at 12.0	1.32
21	do	44.43	32.63	18.32	3.97	.65	Slightly reddish	1.331 at 19.0	1.36
27	Mitchell	44.86	33.42	17.01	4.22	.49	Reddish	1.350 at 12.0	1.34
28	do	44.16	34.03	16.96	4.39	.46	Light red	1.335 at 13.0	1.30
29	do	45.26	33.80	17.01	3.52	.41	Red	1.339 at 16.0	1.34
30	do	43.06	32.53	16.84	6.47	1.10	Yellowish gray	1.352 at 13.0	1.32
				Lafayette district					
108	Gladstone	44.93	36.70	13.72	4.65	0.36	Yellowish gray	--	1.22
105	Excelsior	45.10	37.82	13.42	3.66	.34	do	1.36 at 21.2	1.19
106	do	45.16	37.81	13.04	3.99	.46	do	--	1.19
107	do	44.56	38.13	13.47	3.84	.53	do	--	1.17

[1] Numbers keyed to plate 1.
[2] *c*, carbon; *v*, volatile material.

Classification according to characteristics of coal

The characteristics of coal considered in preparing the resource estimates are rank, weight, and bed thickness. The rank of coal is determined by its physical and chemical properties and is therefore important in determining utilization. The rank assigned to the coal in the area of this report is based on the standard specifications of the American Society for Testing Materials (table 9). A determination of coal rank is made by applying the Parr Formula (American Society for Testing Materials, 1981, p. 21-216) to the analysis of the coal shown in table 5. Aresco and Haller (1953, p. 14) provided analyses of tipple and delivered samples from several mines that were operating during the period 1950 to 1975. Most of the coal in the Erie and Frederick quadrangles is subbituminous B. Analyses of coal samples shown in tables 3 through 8 are from mines currently not operating.

The specific gravity of coal determines the weight of coal in the ground. However, analyses showing specific gravities for the coals in this area are not available; thus, the weight of coal adopted for this report is that recommended for subbituminous coal by the U.S. Geological Survey, 1,770 short tons per acre foot (a volume of coal equivalent to 1 acre of coal 1 ft thick).

Because bed thickness is one of the factors determining the feasibility of mining operations, the coal resources are calculated and tabulated in three thickness categories—2.5 to 5 ft, 5.0 to 10.0 ft, and more than 10.0 ft. (These ranges are being used in all recent subbituminous coal estimates made by the U.S. Geological Survey and accord with recommendations of the National Bituminous Coal Advisory Council.) Partings thicker than ⅜ in. are excluded from the bed thickness. Benches of thinner coal that occur above or below the thicker partings and that would be left underground also are excluded from the total bed thickness.

Table 4. Analyses of coal bed No. 3, Weld County, Colorado

[Analyses by Fieldner and others (1937, p. 126–128). A, mine sample collected by U.S. Bureau of Mines inspector; B, mine sample collected by U.S. Geological Survey geologist. 1, sample as received; 2, sample dried at 105 °C; 3, sample moisture and ash free. All samples analyzed at U.S. Bureau of Mines Pittsburgh laboratory or at fuel-testing plant in St. Louis, Mo. Asterisk preceding laboratory number indicates volatile matter determined by the modified method]

			Sample			Content by proximate analysis, in percent					Content by ultimate analysis, in percent					Calorific value		
County, town, or township	Mine	Location in mine	Kind	Condition	Laboratory no.	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Hydrogen	Carbon	Nitrogen	Oxygen	Air-drying loss, in percent	Calories	British thermal units	Softening temperature, in °F
Dacono	Golden Ash	Face of main north entry, 1,100 ft north of shaft.	B	1	351-D	24.5	34.0	37.6	3.9	0.3	--	--	--	--	10.5	5,250	9,450	--
				2			45.1	49.8	5.1	.4	--	--	--	--	--	7,044	12,680	
Do	Baum	22 room off 9 entry off 1 and 2 south entries.	A	1	*A97231	25.4	27.7	42.8	4.1	.5	--	--	--	--	14.4	5,150	9,270	2,180
Do	do	19 room off 15 entry off 1 and 2 south entries.	A	1	*A97232	25.9	27.5	43.0	3.6	.2	--	--	--	--	15.2	5,139	9,250	2,270
Do	do	2 south entry, 90 ft south of 22 entry.	A	1	*A97233	25.0	27.9	43.7	3.4	.2	--	--	--	--	14.2	5,222	9,400	2,270
Do	do	Face of 17 east entry, inby 13 room.	A	1	*A97234	26.1	27.3	43.0	3.6	.3	--	--	--	--	15.9	5,100	9,180	2,310
Do	do	Composite of A97231 to A97234.	A	1	*A97235	25.6	28.1	42.7	3.6	.3	6.4	54.3	1.1	34.3	14.9	5,156	9,280	--
				2			37.7	57.4	4.9	.4	4.8	73.0	1.5	15.4	--	6,933	12,480	
				3			39.7	60.3	--	.4	5.0	76.7	1.5	16.4	--	7,283	13,110	
Dacono, ½ mi east of	Sterling	800 ft off 10 east entry on 13 east entry.	A	1	*A97679	25.9	28.4	41.3	4.4	.4	--	--	--	--	12.2	5,106	9,190	2,140
Do	do	900 ft off 10 east entry on 8 north entry.	A	1	*A97680	23.9	28.5	42.6	5.0	.6	--	--	--	--	10.5	5,228	9,410	2,040
Do	do	New entry, between 4 and 5 east entries.	A	1	*A97681	25.3	28.0	42.5	4.2	.3	--	--	--	--	11.1	5,189	9,340	2,140
Do	do	Mouth, 15 north entry off 8 east entry.	A	1	*A97682	26.1	28.4	41.3	4.2	.3	--	--	--	--	11.9	5,122	9,220	2,080
Do	do	Composite of A97679 to A97682.	A	1	*A97683	25.2	28.3	42.0	4.5	.4	6.4	53.4	1.2	34.1	11.4	5,172	9,310	--
				2			37.9	56.0	6.1	.5	4.7	71.5	1.7	15.5	--	6,197	12,450	
				3			40.3	59.7	--	.6	5.1	76.1	1.8	16.4	--	7,361	13,250	

County, town, or township	Mine	Location in mine	Sample: Kind	Sample: Condition	Sample: Laboratory no.	Content by proximate analysis, in percent: Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Content by ultimate analysis, in percent: Hydrogen	Carbon	Nitrogen	Oxygen	Air-drying loss, in percent	Calorific value: Calories	British thermal units	Softening temperature, in °F
Eaton, 1 mi east of	Star	325 ft southeast of shaft bottom.	B	1	6406	31.4	28.1	35.1	5.4	.5	6.7	45.6	1.0	40.8	26.1	4,417	7,950	--
				2			41.0	51.2	7.8	.7	4.7	66.4	1.4	19.0	--	6,439	11,590	
				3			44.5	55.5	--	.7	5.0	72.1	1.5	20.7	--	6,989	12,580	
Erie:																		
1 mi northeast of	Lehigh	750 ft north of shaft bottom.	B	1	6841	22.9	29.2	44.4	3.5	.4	6.2	54.9	1.2	38.8	16.7	5,306	9,550	--
				2			37.9	57.6	4.5	.5	4.8	71.3	1.5	17.4	--	6,883	12,390	
				3			39.7	60.3	--	.5	5.0	74.7	1.6	18.2	--	7,206	12,970	
1½ mi east of	Boulder Valley	9 south entry, 150 ft off main west entry.	A	1	*A96873	22.6	30.7	43.2	3.5	.3	--	--	--	--	10.5	5,433	9,780	2,090
Do	do	10 room, 18 south entry off panel 8.	A	1	*A96874	23.0	29.5	43.8	3.7	.3	--	--	--	--	11.5	5,378	9,680	2,080
Do	do	9 north entry, 1,150 ft off main east entry.	A	1	*A96875	21.9	29.9	44.2	4.0	.2	--	--	--	--	10.0	5,467	9,840	2,030
Do	do	3 north entry, 500 ft off 15 west entry off main north entry.	A	1	*A96876	21.5	29.9	45.0	3.6	.3	--	--	--	--	10.5	5,533	9,960	2,140
Do	do	Left rib of 1 room off 6 south entry, 700 ft off main north entry.	A	1	*A96877	23.2	29.4	43.6	3.8	.3	--	--	--	--	11.3	5,372	9,670	2,100
Do	do	Composite of A96873 to A96877.	A	1	*A96878	22.4	29.9	44.1	3.6	.3	6.3	56.7	1.3	31.8	10.7	5,433	9,780	--
				2			38.6	56.7	4.7	.3	4.9	73.0	1.7	15.4	--	7,006	12,610	
				3			40.5	59.5	--	.4	5.1	76.6	1.8	16.1	--	7,350	13,230	

Table 5. Analyses of tipple and delivered samples from coal bed No. 3 during fiscal year 1951

[Excerpted from Aresco and Haller (1953, table 3, p. 9, 13–14). All samples subbituminous from the Laramie Formation. —, no data]

Town and mine	Sample size	Approximate tonnage sampled	Kind of sample[1]	Content by proximate analysis, in percent: Moisture, as-received coal	Dry coal: Volatile matter	Dry coal: Fixed carbon	Dry coal: Ash	Content by ultimate analysis in percent, Dry coal: Sulfur	Hydrogen	Carbon	Nitrogen	Oxygen	Calorific value: British thermal units, as-received basis	British thermal units, dry basis	No. of analyses[2]	Ash-softening temperature, in °F	No. of ash-softening temperatures[2]	Agglomerating index[3]	Hardgrove grindability index
Boulder County																			
Lafayette, Hi-Way																			
mine	8-in. lump	20	T	21.2	38.7	56.2	5.1	0.3	--	--	--	--	9,960	12,640	1	2,180	1	NAa	--
Do	4×8 in.	30	T	20.4	39.6	55.3	5.1	.3	--	--	--	--	10,070	12,650	1	2,130	1	NAa	--
Do	2½×4 in.	10	T	20.7	39.1	55.5	5.4	.2	--	--	--	--	9,940	12,540	1	2,130	1	NAa	--
Do	0×2½ in.	60	T	20.7	38.2	53.2	8.6	.4	--	--	--	--	9,640	12,160	1	2,360	1	NAa	45
Weld County																			
Dacono:																			
Boulder Valley																			
No. 3	4-in. lump	60	T	24.6	38.8	56.3	4.9	0.3	--	--	--	--	9,500	12,600	1	2,210	1	NAa	--
Do	0×4 in.	150	T	25.1	38.6	56.0	5.4	.3	--	--	--	--	9,390	12,530	1	2,150	1	NAa	48
Do	0×1½ in.	1,125	D	23.7	39.6	54.5	5.9	.4	--	--	--	--	9,480	12,420	8	2,070	2	NAa	--
Do	0×¾ in.	5,936	D	22.8	39.2	54.2	6.6	.6	--	--	--	--	9,490	12,290	18	2,100	4	NAa	--
Sterling	8-in. lump	30	T	24.5	39.1	55.0	5.9	.3	--	--	--	--	9,400	12,450	1	2,100	1	NAa	--
Do	1½×8 in.	60	T	24.1	38.4	55.1	6.5	.4	--	--	--	--	9,400	12,380	1	2,100	1	NAa	--
Do	0×1½ in.	150	T	24.3	37.1	55.6	7.3	.6	--	--	--	--	9,310	12,290	1	2,050	1	NAa	50

				Content by proximate analysis, in percent				Content by ultimate analysis in percent					Calorific value						
					Dry coal														
Town and mine	Sample size	Approximate tonnage sampled	Kind of sample[1]	Moisture, as-received coal	Volatile matter	Fixed carbon	Ash	Sulfur	Hydrogen	Carbon	Nitrogen	Oxygen	British thermal units, as-received basis	British thermal units, dry basis	No. of analyses[2]	Ash-softening temperature, in °F	No. of ash-softening temperatures[2]	Agglomerating index[3]	Hardgrove grindability index
Erie:																			
Eagle	8-in. lump	50	T	23.4	39.6	55.8	4.6	.3	--	--	--	--	9,720	12,700	1	2,150	1	NAa	--
Do	2½ × 8 in.	60	T	22.7	38.7	56.1	5.2	.3	--	--	--	--	9,770	12,640	1	2,100	1	NAa	--
Do	0 × 2½ in.	150	T	23.3	39.5	55.4	5.1	.3	--	--	--	--	9,740	12,690	1	2,130	1	NAa	45
Do	0 × 1½ in.	4,348	D	21.3	39.1	54.7	6.2	.4	--	--	--	--	9,770	12,420	24	2,100	7	NAa	--
Do	0 × ¾ in.	10,133	D	21.2	38.8	54.3	6.9	.5	--	--	--	--	9,700	12,310	23	2,090	10	NAa	--
Imperial	Run of mine, crushed to 2½ in.	250	T	23.3	38.9	55.4	5.7	.4	--	--	--	--	9,640	12,580	1	2,080	1	NAa	48
Do	0 × 1½ in.	248	D	21.9	39.7	53.6	6.7	.5	--	--	--	--	9,630	12,330	2	--	--	NAa	--
Do	0 × ¾ in.	3,580	D	21.2	39.0	54.1	6.9	.5	--	--	--	--	9,700	12,310	11	2,120	2	NAa	--
Lincoln	Run of mine, crushed to 2½ in.	225	T	25.0	38.1	55.1	6.8	.4	4.7	71.7	1.6	14.8	9,320	12,420	1	2,050	1	NAa	46
Washington	8-in. lump	50	T	22.5	39.6	55.5	4.9	.4	--	--	--	--	9,860	12,730	1	2,150	1	NAa	--
Do	2½ × 8 in.	85	T	22.7	39.9	55.2	4.9	.3	--	--	--	--	9,820	12,690	1	2,130	1	NAa	--
Do	1½ × 2½ in.	167	D	18.2	39.5	55.9	4.6	.3	--	--	--	--	10,460	12,790	11	--	--	NAa NAb	--
Do	0 × 2½ in.	200	T	23.8	38.7	55.3	6.0	.4	--	--	--	--	9,550	12,530	1	2,100	1	NAa	47
Do	0 × 1½ in.	1,000	D	20.7	39.5	54.9	5.6	.5	--	--	--	--	9,960	12,550	1	2,100	1	NAb	--
Frederick, Erie mine	Run of mine	175	T	23.1	39.5	53.4	7.1	.5	--	--	--	--	9,330	12,140	1	2,210	1	NAa	50
Do	2½ × 8 in.	15	T	23.4	39.5	54.0	6.5	.4	--	--	--	--	9,410	12,280	1	2,260	1	NAa	--
Do	1½ × 2½ in.	15	T	23.2	39.4	53.8	6.8	.4	--	--	--	--	9,410	12,260	1	2,260	1	NAa	--
Do	¾ × 1½ in.	15	T	23.8	39.2	54.5	6.3	.5	--	--	--	--	9,380	12,310	1	2,260	1	NAa	--

[1] T, tipple; D, delivered.
[2] Numbers above 1 indicate the number of deliveries averaged.
[3] Numbers in parentheses indicate the number of determinations made. NAa, nonagglomerating noncoherent residue; NAb, nonagglomerating coherent residue.

Table 6A. Sample number, location, coal bed, description, and chemical analyses of three coal samples from the Denver Basin, Colorado

[Excerpted from Swanson and others (1976, tables 38*A*, 38*B*, p. 423–424). All samples are from coal bed No. 3, Weld County, Colo., and all are subbituminous. Sample D173490, channel sample, 7 ft 2 in. thick; sample D173489, channel sample, 5 ft 9 in. thick; sample D173490, run-of-mine tipple. Analyses by Coal Analysis Section, U.S. Bureau of Mines, Pittsburg, Pa. All except British thermal units are in percent. Original moisture content may be slightly more than value shown because samples were collected and transported in plastic bags to avoid metal contamination. Form of analyses: 1, as received; 2, moisture free; 3, moisture and ash free. --, no data]

	Proximate analysis				Ultimate analysis							Forms of sulfur		
Sample no. and form of analysis	Moisture	Volatile matter	Fixed carbonate	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	British thermal units	A.D. loss	Sulfate	Pyritic	Organic
D173488:														
1	22.3	31.9	41.5	4.3	6.3	56.0	1.2	31.8	0.4	9,700	8.09	0.01	0.13	0.23
2	--	41.0	53.4	5.6	4.9	72.0	1.6	15.4	.5	12,480	--	.01	.17	.30
3	--	43.5	56.5	--	5.2	76.3	1.7	16.3	.5	13,200	--	.01	.18	.31
D173489:														
1	23.0	32.5	40.2	4.3	6.3	55.7	1.3	32.1	.3	9,640	8.13	.00	.04	.27
2	--	42.2	52.2	5.6	4.9	72.4	1.6	15.1	.4	12,530	--	.00	.05	.35
3	--	44.7	55.3	--	5.2	76.7	1.7	16.0	.4	13,270	--	.00	.05	.37
D173490:														
1	19.5	28.1	34.5	17.9	5.4	47.5	1.1	27.8	.3	8,200	7.55	.02	.06	.18
2	--	34.9	42.9	22.2	4.0	59.0	1.3	13.2	.3	10,180	--	.02	.08	.22
3	--	44.9	55.1	--	5.2	75.9	1.7	16.8	.4	13,080	--	.03	.10	.28

Classification according to abundance of data

Estimates of resources are further divided into reliability categories (measured, indicated, and inferred), in this case based on distance from points of measurements of coal bed thicknesses; resources are classified according to the reliability of the available information. The categories "measured" and "indicated" are the highest degrees of geologic assurance for which tonnages can be computed with regard to coal thickness and extent as determined from outcrop measurements, mine workings, and drill holes. These categories are applied in areas where the points of observation are not more than 1½ mi apart. If drill-hole information is used for calculations, the outer limit of a block of measured and indicated coal is considered to be ¾ mi beyond the outermost hole.

The category of inferred resources is used for resources that lie beyond the areas of measured and indicated coal and is based on projections of the data from ¾ mi to 3 mi beyond the control point used to compute measured and indicated resources.

COAL RESOURCES SUMMARY

The total original coal resources in the parts of the Erie and Frederick quadrangles in Boulder and Weld Counties that contain coal greater than 2.5 ft thick are more than 584,000,000 short tons; about 227,000,000 short tons are in beds 2.5 to 5.0 ft thick, more than 300,000,000 short tons are in beds 5.0 to 10.0 ft thick, and more than 31,000,000 short tons are in beds more than 10.0 ft thick. Coal production and coal lost in mining from 1872 through January 1, 1975, amounted to approximately 148,000,000 short tons, leaving more than 430,000,000 short tons of remaining resources. On the basis of a probable recovery factor of 50 percent, there are about 205,000,000 tons of recoverable resources in this area. Details of resources by bed, by thickness, and by reliability category are found in table 2 and the appendix. Of the total 584,000,000 short tons of original resources in T. 1 N., R. 69 W. (Boulder County) cited in this report by not summarized in table 2, there are about 62,000,000 short tons or original resources and about 7,000,000 short tons of mined-out coal, leaving about 55,000,000 short tons of remaining resources. There are about 522,000,000 short tons of original resources in Weld County, about 141,000,000 short tons of which have been mined or lost in mining, leaving 381,000,000 short tons of remaining resources. More than 196,000,000 short tons of original resources are estimated for the Erie quadrangle, and more than 388,000,000 short tons are estimated for the Frederick quadrangle. No coal is believed to be under as much as 1,000 ft of overburden in this field. There are no hypothetical resources.

By January 1, 1980, 528 oil or oil and gas wells of the Spindle field and 29 gas wells (some of which also produce oil) were producing in Weld County, mostly in the Frederick quadrangle and the northeastern quarter of the Erie quadrangle. In the Frederick quadrangle, about 70 percent of an approximately 52.5-mi^2 area is producing from a well density of 16 wells per square mile or 1 well

Table 6B. Major- and minor-oxide and trace-element compositions of laboratory ash of three coal samples from the Denver Basin, Colorado

[Excerpted from Swanson and others (1976, tables 38C and 38*D*, p. 425–426). Coals ashed at 525 °C. L, less than value shown; ND, not detected. Italics indicate value determined by semiquantitative spectrographic analysis. Spectrographic results to be identified with geometric brackets whose boundaries are 1, 2, 0.83, 0.56, 0.38, 0.26, 0.18, 0.12, and so on but reported arbitrarily as midpoints of those brackets (1.0, 0.7, 0.5, 0.3, 0.2, 0.15, 0.1, and so on). Precision of spectrographic data approximately one bracket at 68-percent confidence and two brackets at 95-percent confidence. Trace-element analyses made on coal air dried at 32 °C]

Oxide or element	Major- and minor-oxide content			Trace-element content		
	Sample D173488	Sample D173489	Sample D173490	Sample D173488	Sample D173489	Sample D173490
Ash, percent	5.1	5.0	16.3			
SiO_2, percent	33.	36.	67.			
Al_2O_3, percent	13.	11.	11.			
CaO, percent	13.	13.	3.8			
MgO, percent	2.46	2.39	1.05			
Na_2O, percent	5.36	5.41	1.82			
K_2O, percent	.35	.16	1.3			
Fe_2O_3, percent	5.4	5.7	2.5			
MnO, percent	.028	.029	.020L			
TiO_2, percent	.76	.63	.52			
P_2O_5, percent	.29	.25	.10			
SO_3, percent	17.	18.	4.3			
Cl, percent	.10L	.10L	.10L			
Cd, ppm	1.0L	1.0L	1.0L			
Cu, ppm	70.	68.	26.			
Li, ppm	40.	33.	27.			
Pb, ppm	35.	25.	25.L			
Zn, ppm	20.	31.	30.L			
B, ppm	*1,500.*	*1,500.*	*500.*			
Ba, ppm	*1,500.*	*2,000.*	*700.*			
Be, ppm	*3*	*7*	ND			
Co, ppm	*15*	*15*	*10*L			
Cr, ppm	*70*	*30*	*30*			
Ga, ppm	*30*	*30*	*15*			
Ge, ppm	ND	*20*L	ND			
La, ppm	ND	*100*L	ND			
Mo, ppm	*15*	*7*	ND			
Nb, ppm	*30*	*20*	*20*L			
Ni, ppm	*20*	*30*	*20*			
Sc, ppm	*15*	*15*	*10*L			
Sr, ppm	*1,000*	*1,000*	*500*			
V, ppm	*150*	*100*	*70*			
Y, ppm	*30*	*70*	*20*			
Yb, ppm	*3*	*5*	*2*			
Zr, ppm	*150*	*150*	*200*			
As, ppm				1.	1.L	1.
F, ppm				20.L	20.L	60.
Hg, ppm				.01	.01	.02
Sb, ppm				.2	.3	.2
Se, ppm				3.3	.7	.7
Th, ppm				3.0L	3.0L	3.0L
U, ppm				.4	.4	.7

per 40 acres. In the Erie quadrangle in Weld County, production is from the northeastern part of the quadrangle, part of T. 2N., R. 68 W.; about 47 percent of an approximately 7.5-mi^2 area is producing from 16 wells per square mile (see pl. 1.) This density of producing wells will most certainly curtail any possible future coal production because of State or other civic laws that may regulate coal production near such wells.

Table 6C. Major-, minor-, and trace-element composition of three coal samples from the Denver Basin, Colorado, reported on a whole-coal basis

[Excerpted from Swanson and others (1976, table 38*E*, p. 427). Al, Ca, Fe, Mg, Na, K, Si, Cl, Mn, P, Ti, Cd, Cu, Li, PB, and Zn values calculated from analyses of ash; As, F, Hg, Sb, Se, Th, and U values calculated from direct determinations on air-dried (32 °C) coal. Remaining values calculated from spectrographic determinations on ash. L, less than the value shown; ND, not detected. Italics indicate value determined by semiquantitative spectrographic analysis]

Element	Sample D173488	Sample D173489	Sample D173490
Si, in percent	0.78	0.85	5.1
Al, in percent	.35	.30	.95
Ca, in percent	.48	.47	.45
Mg, in percent	.075	.072	.103
Na, in percent	.202	.200	.220
K, in percent	.015	.007	.18
Fe, in percent	.19	.20	.28
Mn, in ppm	11.	11.	25.L
Ti, in percent	.023	.019	.051
P, in ppm	64.	55.	72.
Cl, in percent	.005L	.005L	.016L
As, in ppm	1.	1.L	1.
Cd, in ppm	.1L	.1L	.2L
Cu, in ppm	3.6	3.4	4.2
F, in ppm	20.L	20.L	60.
Hg, in ppm	.01	.01	.02
Li, in ppm	2.0	1.6	4.4
Pb, in ppm	1.8	1.2	4.1L
Sb, in ppm	.2	.3	.2
Se, in ppm	3.3	.7	.7
Th, in ppm	3.0L	3.0L	3.0L
U, in ppm	.4	.4	.7
Zn, in ppm	1.0	1.5	4.9
B, in ppm	*70*	*70*	*70*
Ba, in ppm	*70*	*100*	*100*
Be, in ppm	*.15*	*.3*	ND
Co, in ppm	*.7*	*.7*	*1.5*L
Cr, in ppm	*3*	*1.5*	*5*
Ga, in ppm	*1.5*	*1.5*	*2*
Ge, in ppm	ND	1 L	ND
La, in ppm	ND	5L	ND
Mo, in ppm	*.7*	*.3*	ND
Nb, in ppm	*1.5*	*1*	3L
Ni, in ppm	*1*	*1.5*	*3*
Sc, in ppm	*.7*	*.7*	*1.5*L
Sr, in ppm	*50*	*50*	*70*
V, in ppm	*7*	*5*	*10*
Y, in ppm	*1.5*	*3*	*3*
Yb, in ppm	*.15*	*.2*	*.3*
Zr, in ppm	*7*	*7*	*30*

T. 1 N., R. 69 W., Boulder County

T. 1 N., R. 69 W. in Boulder County, only partially underlain by coal beds, contains varying amounts of resources from all coal beds in the field except No. 1 and No. 7. The total area of all beds in the township containing coal resources is about 7,900 acres, from which about 62,000,000 short tons of original resources have been estimated. More than 7,000,000 short tons have been mined or lost in mining from approximately 800 acres; all the mining was done in coal beds No. 2, No. 3, and No. 4. The tonnage of original resources for the various beds has been calculated as follows: about 36,000,000 short tons or 58.0 percent for coal bed No. 3;

Table 7. Chemical analyses of coal bed No. 4
[Excerpted from Emmons and others (1896, table 1, p. 376)]

No.[1]	Mine	Fixed carbon content, in percent	Volatile combustible content, in percent	Water content, in percent	Ash content, in percent	Sulfur content, in percent	Color of ash	Specific gravity at °F	Fuel ratio $\frac{c}{v\text{-}c}$[2]
37	Garfield No. 1	47.86	30.82	17.25	3.55	0.52	Red	1.345 at 12.0	1.55
24	do	44.63	34.51	16.80	3.52	.54	Light yellow	1.331 at 12.0	1.29
25	do	43.89	34.14	17.03	4.53	.41	Yellow	1.336 at 11.0	1.29
26	do	44.68	34.59	17.06	3.25	.42	Red yellow	1.336 at 15.0	1.29
22	McGregor	44.74	34.98	16.38	3.38	0.52	Reddish	1.330 at 19.0	1.28
23	do	44.55	33.85	17.58	3.48	.54	do	1.334 at 18.5	1.32
16	Cleveland	43.77	33.84	18.07	3.84	0.48	Reddish white	1.331 at 12.5	1.26
17	do	45.30	33.81	16.76	3.60	.53	Light red	1.334 at 14.0	1.34

[1]Numbers keyed to plate 1.
[2]*c*, carbon; *v*, volatile material.

5,000,000 short tons or 8.0 percent for coal bed No. 2; about 11,000,000 short tons or 18.0 percent for coal bed No. 4; about 9,000,000 short tons or 15.0 percent for coal bed No. 5; and 626,805 short tons or slightly less than 1.0 percent for coal bed No. 6. The appendix shows the tabulated tonnages, areal extent, and overburden for each coal bed by section, township, and range. The thicknesses and areal extents of the coal beds in this township are shown on plates 3, 4, 5, 6, and 7.

Coal bed No. 2 (Sump seam)

Coal bed No. 2 averages about 4 ft thick in the Jackson mine in SW¼ sec. 13, T. 1 N., R. 69 W. The base of the coal is at an altitude of about 4,950 ft above sea level. (The altitudes given on the coal beds in this report are not surveyed elevations but were calculated from the surface to the base of the coal beds from drill-hole data.) Coal bed No. 2 is 5.0 ft thick in the Lister mine area and 4.5 ft thick in the Garfield No. 1 mine area. The altitudes of these points of observation are 4,897 and 4,918 ft, respectively. A drill hole in SW¼SE¼ sec. 33 penetrated a coal bed 3.75 ft thick correlated with coal bed No. 2 at an altitude of 5,297 ft. A drill hole in SW¼SE¼ sec. 34 penetrated a coal bed 3.0 ft thick correlated with coal bed No. 2 at an altitude of 5,198 ft. Three drill holes in SW¼SW¼ sec. 35 cut a coal bed 4.0 ft thick at altitudes of 4.971, 4,973, and 4.975 ft. A coal bed measuring 6.75 ft thick in the Excelsior mine area at altitude 4,904 ft is believed to be coal bed No. 2, as is a coal bed 2.0 ft thick at altitude 4,874 ft cut by a drill hole in SW¼ sec. 36. These points of observation formed the basis for the resource areas shown on plate 3 and the resource tonnages tabulated and given in the appendix.

Coal bed No. 3 (Main seam)

Coal bed No. 3 contains more resources than any bed in the Boulder County part of T. 1 N., R. 69 W.; the distribution of these resources is shown on plate 4. The coal attains a thickness of 7.0 ft at the Crescent and Jackson mines in W½ sec. 13, T. 1 N., R. 69 W. At the Longs Peak, Northrop, and Chase mines in the eastern part of sec. 13, the coal bed has thicknesses of 5.5, 4.0, and 4.5 ft, respectively. In the eastern half of sec. 14, two mines (names) unknown) are reported to have operated in a coal bed that is 3.5 to 4.5 ft thick and that appears to correlate with coal bed No. 3.

Coal bed No. 3 was mined in the northern and eastern parts of sec. 24 in the Tynan, Lister, Garfield No. 1 and No. 2, Mitchell, and Marfel mines. The thickness of coal in the area of these mines varies from 4.5 to 5.5 ft. Coal bed No. 3 was mined extensively in the Black Diamond mine in the southern part of sec. 34, where it ranges from 5.0 to 7.0 ft in thickness. At the Mile-Hi mine in SE¼ sec. 27, the coal ranged from 4.0 to 5.5 ft in thickness. Coal bed No. 3 was extensively mined in sec. 35 in the Mitchell and Gladstone mines. The thickness of this coal was between 5.0 and 6.0 ft.

Coal bed No. 3 thins perceptibly in the center of sec. 25 and sec. 36. A small area was mined in SW¼ sec. 36 in the Gladstone mine, and another small area in SE¼ sec. 36 was mined in the Hayward mine.

Locally, coal beds No. 3 and No. 4 have coalesced, specifically in the Gladstone, Mitchell, and Hayward mines. In the Gladstone mine, the combined beds attain a maximum thickness of 14 ft. Drill holes in SE¼ sec. 34 and NW¼SW¼ sec. 35 give an aggregate a thickness of 13.6 ft for coal beds No. 3 and No. 4. However, coal beds No. 3 and No. 4 again coalesce here and attain a composite maximum thickness of 14.0 ft.

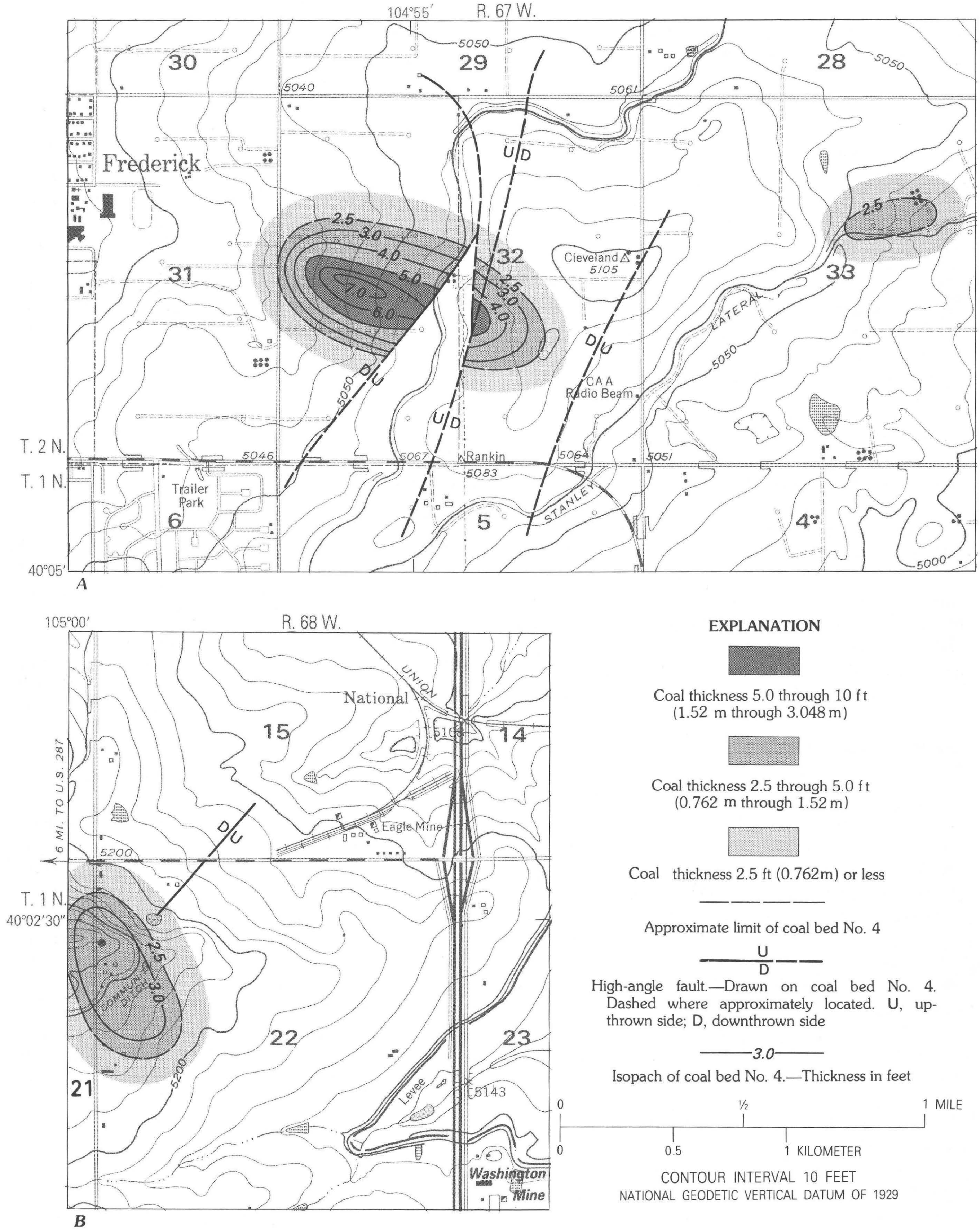

Figure 4. Resources of coal bed No. 4, Frederick quadrangle, Boulder and Weld Counties, Colorado. *A*, Sec. 32 and sec. 33, T. 2 N., R. 67 W. *B*, Sec. 21 and sec. 22, T. 1 N., R. 68 W.

Table 8. Analyses of mine samples of coal beds No. 5 and No. 6 from the Puritan, Ideal, and Morrison mines, Weld County, Colorado [Analyses by Fieldner and others (1937, p. 126–128). A, mine sample collected by U.S. Bureau of Mines inspector; B, mine sample collected by U.S. Geological Survey geologist. 1, sample as received; 2, sample dried at 105 °C; 3, sample moisture- and ash-free. All samples analyzed at U.S. Bureau of Mines Pittsburgh laboratory or at fuel-testing plan in St. Louis, Mo. Asterisk preceding laboratory number indicates volatile matter determined by the modified method]

Town and mine	Location in mine	Sample: Kind	Sample: Condition	Sample: Laboratory no.	Content by proximate analysis, in percent: Moisture	Volatile matter	Fixed carbon	Ash	Content by ultimate analysis, in percent: Sulfur	Hydrogen	Carbon	Nitrogen	Oxygen	Air-drying loss, in percent	Calorific value: Calories	British thermal units	Softening temperature, in °F
							Coal bed No. 5										
Dacono:									0.4	6.1	54.3	1.1	33.8	16.2	5,211	9,380	
Puritan	175 ft west of shaft bottom	B	1	6842	24.3	27.6	44.8	3.3	.5	4.5	73.0	1.4	16.3		6,878	12,380	
			2			36.5	59.2	4.3	.5	4.7	76.3	1.5	17.0		7,189	12,940	
			3			38.1	61.9										
Do	Face of 13 room, 4 northwest entry.	A	1	*31323	24.6	29.8	42.0	3.8	.3	6.3	54.8	1.2	33.8	16.4	5,289	9,520	2,170
			2			39.6	55.6	4.8	.5	4.7	72.7	1.6	15.7		7,017	12,630	
			3			41.6	58.4		.5	5.0	76.3	1.7	16.5		7,367	13,260	
Ideal	300 ft west of slope bottom, lower bench.	B	1	6374	21.1	31.1	44.2	3.6	.4	6.1	56.5	1.1	32.3	12.7	5,556	10,000	
			2			39.5	55.9	4.6	.5	4.8	71.5	1.4	17.2		7,039	12,670	
			3			41.4	58.6		.5	5.0	74.9	1.5	18.1		7,372	13,270	
							Coal bed No. 6										
3 mi. E. of Erie	3 east entry, 600 ft from 2 south entry.	A	1	*A97133	22.5	29.3	43.3	4.0	0.3					12.3	5,317	9,547	2,000
Morrison	13 west entry, 500 ft off 2 south entry.	A	1	*A97134	22.2	29.5	42.4	5.9	.3					12.5	5,256	9,460	2,190
Do	15 room off 5 east entry 2 north entry.	A	1	A97135	22.4	30.0	42.5	5.1	.2					12.5	5,306	9,550	2,080
Do	9 room neck off 1 west entry off 5 south entry.	A	1	*A97136	21.7	30.3	42.5	5.5	.4					12.1	5,356	9,640	2,050
Do	Composite of A97133 to A97136.	A	1	*A97137	22.2	30.1	42.4	5.3	.3	6.2	55.2	1.2	31.8	12.3	5,300	9,540	
			2			38.6	54.6	6.8	.4	4.9	71.0	1.6	15.3		6,811	12,260	
			3			41.5	58.5		.4	5.2	76.2	1.7	16.5		7,311	13,160	

Table 9. Classification of coals by rank[A,1]

Class	Group	Fixed carbon limits, percent (dry, mineral-matter-free basis) Equal or greater than	Fixed carbon limits, percent (dry, mineral-matter-free basis) Less than	Volatile matter limits, percent (dry, mineral-matter-free basis) Greater than	Volatile matter limits, percent (dry, mineral-matter-free basis) Equal or less than	Calorific value limits, BTU per pound (moist,[B] mineral-matter-free basis) Equal or greater than	Calorific value limits, BTU per pound (moist,[B] mineral-matter-free basis) Less	Agglomerating character
I. Anthracite*	1. Meta-anthracite	98	--	--	2	--	--	
	2. Anthracite	92	98	2	8	--	--	Nonagglomerating
	3. Semianthracite[C]	86	92	8	14	--	--	
II. Bituminous	1. Low volatile bituminous coal	78	86	14	22	--	--	
	2. Medium volatile bituminous coal	69	78	22	31	--	--	
	3. High volatile *A* bituminous coal	--	69	31	--	14,000[D]	--	Commonly agglomerating[E]
	4. High volatile *B* bituminous coal	--	--	--	--	13,000[D]	14,000	
	5. High volatile *C* bituminous coal	--	--	--	--	11,500	13,000	
		--	--	--	--	10,500	11,500	Agglomerating
III. Subbituminous	1. Subbituminous *A* coal	--	--	--	--	10,500	11,500	
	2. Subbituminous *B* coal	--	--	--	--	9,500	10,500	Nonagglomerating
	3. Subbituminous *C* coal	--	--	--	--	8,300	9,500	
IV. Lignite	1. Lignite *A*	--	--	--	--	6,300	8,300	
	2. Lignite *B*	--	--	--	--	------------	6,300	

[A]This classification does not include a few coals, principally nonbanded varieties, which have unusual physical and chemical properties and which come within the limits of fixed carbon or calorific value 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 British thermal units per pound.

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

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

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

[E]It is recognized that there may be nonagglomerating varieties in these groups of the bituminous class, and there are notable exceptions in the high-volatile *C* bituminous group.

[1]American Society for Testing and Materials (1981, p. 215).

*Modified from American Society for Testing and Materials (1981).

Altitudes of the base of the coal bed were obtained from mine maps and coal drill holes, which furnished the data for the structure contours shown on plate 1 and the coal thicknesses shown on plate 4. Acreages and tonnages of coal reserves for this bed are shown in the appendix.

Coal bed No. 4

Coal bed No. 4 has a thickness exceeding 3.0 ft at altitude 4,959 ft in the Longs Peak shaft in sec. 13 T. 1 N., R. 69 W., and apparently thickens southward. In the Tynan mine in sec. 24, its thickness is 4.0 ft at altitude 4,959 ft; in the Lister mine, 4.0 ft at 5,967 ft; in the Garfield No. 1 mine, 5.0 ft at 4.988 ft; in the Marfel mine, 4.5 ft at 4,971 ft; in the McGregor mine, 4.0 ft at 4,995 ft; and, in the Cleveland mine, 4.5 ft at 4,969 ft. The coal thins perceptibly southwestward to less than 2.5 ft in the southwestern part of sec. 24, most of sec. 25, sec. 27, sec. 34, and sec. 36, and all of sec. 23 and sec. 26 (see pl. 5).

In the western part of sec. 27, on the eastern side of Bullhead Gulch, coal bed No. 4 is 4.0 ft thick at altitude 5,148 ft, but, east of there, near Erie Lake, the coal is only 1.0 ft thick.

According to information from drill records, coal bed No. 4 is 4.0 ft thick just west of the Lafayette water tanks, where its altitude is 5,328 ft. The coal bed thins perceptibly northeastward and drops in altitude to 5,066 ft on the eastern edge of sec. 33.

North of the Black Diamond mine in sec. 34, coal bed No. 4 is 2.5 ft thick and thickens to 5.0 ft in the southeastern quarter of the section. In the southeastern corner of sec. 34 and the southwestern corner of sec. 35, coal beds No. 3 and No. 4 coalesce, and their total thickness aggregates 13.6 ft. This coalescence is also evident in the Gladstone mine in sec. 35. The parting between the beds increases in thickness in all directions away from the area of coalescence. Coal bed No. 4 attains a maximum thickness of 8.0 ft in sec. 35 and thins to less than 2.5 ft (0.76 m) at the northern line of the section and in SW¼ sec. 36. Plate 5 shows the areal distribution of the coal bed and its estimated thickness. Tonnages are tabulated in the appendix.

Coal bed No. 5 (Middle seam)

Coal bed No. 5 is 3.0 to 4.0 ft thick in sec. 13, T. 1 N., R. 69 W. In NW¼ sec. 13, a drill hole penetrated 3.0 ft of coal at an altitude of 4,986 ft. A coal bed 4.0 ft thick at altitude 4,989 ft in the shaft of the Jackson mine is herein correlated as coal bed No. 5. In SE¼ sec. 4, an auger hole revealed about 4.5 ft of coal at an altitude of 5,040 ft, and auger holes in NE¼ sec. 23 show a coal bed varying from 2.5 to 3.0 ft thick from 20 to 40 ft below the surface. Another auger hole in SW¼ sec. 23 shows 4.0 ft of soft coal at an altitude of 5,096 ft. Traces of coal blossom or smut were observed in SW¼ sec. 23, which is believed to be the surface marker of the coal bed No. 5 outcrop. The base of a coal bed 3.5 ft thick is found at altitude 4,989 in the Tynan shaft in sec. 24. A coal bed herein correlated as coal bed No. 5 is 3.5 ft thick in the Lister shaft at altitude 4,989 ft and 4.5 ft thick in the Garfield No. 1 shaft at altitude 5,008 ft.

An auger hole in NE¼ sec. 26 cut 4.0 ft of coal at an altitude of 5,127 ft, one in the center of the section cut 4.0 ft at 5,148 ft, and one in the center of SW¼ cut 3.0 ft at 5,150 ft; all are believed to be coal bed No. 5. A group of six closely spaced coal drill holes in SW¼ sec. 27 discloses a small area in which the coal is as much as 5.0 ft thick and lies from 50 to 75 ft below the surface; this coal is correlated with coal bed No. 5.

In SE¼ sec. 33 near the Lafayette water tanks, two drill holes outline a small area where the coal bed varies from 3.1 to 3.3 ft thick and lies from 130 to 150 ft below the surface. A drill hole in NW¼ sec. 34 was reported to have cut coal bed No. 5. At this location, there was 2.6 ft of coal, a 1.0-ft shale split, and 2.6 ft of coal at altitude 5,127 ft. In SW¼SE¼ sec. 34, coal bed No. 5 varies in thickness from 3.3 to 4.6 ft at altitudes from 5,070 to 5,080 ft.

The isolated deposits of coal described herein are shown on plate 6. The areas surrounding these deposits contain coal, but it is less than 2.5 ft thick. The appendix shows the estimated resources of this coal by sections, by overburden limits, and by tabulated tonnages.

Coal bed No. 6 (Upper seam)

Resources of coal bed No. 6 are limited in T. 1 N., R. 69 W. in Boulder County. A coal bed that is 3.2 ft thick is the basis for estimating a small isolated patch of coal in this area. Sec. 13 contains small areas of coal bed No. 6 outlined by a 3.0-ft-thick coal bed in the Lister and Garfield no. 1 shafts at altitudes 5,019 and 5,040 ft, respectively. Except for an area presumed to be more than 2.5 ft thick in NW¼ sec. 34 and extending into SW¼ sec. 27, the coal bed is less than 2.5 ft thick throughout the rest of the township. The areas considered to be resources of coal bed No. 6 are shown on plate 7; resources are tabulated in the appendix.

T. 2 N., R. 68 W., Weld County

The Weld County part of T. 2 N., R. 68 W. within the Erie and Frederick quadrangles contains known resources for coal beds No. 3, No. 5, and No. 6. The combined acreage of the three coal beds in both quadrangles totals more than 5,700 acres, and original resources are estimated to be about 54,000,000 short tons. More than 20,000,000 short tons of coal have been mined or lost in mining from about 1,400 acres. The total remaining resources in this part of the township are about 34,000,000 short tons contained in an area of more than 4,200 acres. Plates 4, 6, and 7 show the areal distribution of these beds, and the appendix shows the overburden limits, thickness, and acreage by section of each coal bed in this township.

Coal bed No. 3 (Main seam)

Coal from coal bed No. 3 in much of T. 2 N., R. 68 W. is either nonexistent, less than 2.5 ft thick, or so badly split with partings that it has no value. The bed is reported to have been mined in a small area in SW¼SW½ sec. 24 in the Davis and Maxwell mines and is reported to have been as much as 5.0 ft thick. The coal bed was mined extensively in sec. 25 and sec. 36 and in a small area of SE¼ sec. 35.

The coal is badly split by partings and is thin in sec. 22, sec. 23, sec. 26, and sec. 27. In parts of sec. 25, sec. 33, and sec. 35, the coal is absent or contains partings, a suggestion that this area may have been near or at the margin of the coal swamp. In sec. 25 at the Frederick mine, the coal is more than 10.0 ft thick but thins to the north and west, where it is locally absent. Drill-hole data in the area of the Shamrock mine (sec. 34, T. 2 N., R. 68 W.) and the Puritan mine (sec. 3, T. N., R. 68 W.), both of which mined coal bed No. 5, show 2.5 to 5.0 ft of coal bed No. 3; the bed thickens in SW¼ sec. 34, where it is reported to attain a thickness of more than 7.0 ft. Coal thickness in the Baum mine in sec. 36 varies from 5.0 to more than 10.0 ft. Plate 4 shows the distribution and thickness of resources in the township. Plate 1 shows structure contours drawn on the base of this coal bed. The appendix gives details of resources.

Coal bed No. 5 (Middle seam)

The resources of coal bed No. 5 in the Weld County part of T. 2 N., R. 68 W. are contained in an area of more than 2,600 acres calculated to have a total tonnage of about 27,000,000 short tons. More than 10,000,000 short tons have been mined or lost in mining from about 740 acres; approximately 16,000,000 short tons are left in an area of slightly more than 1,800 acres.

Midway along the western section line of sec. 30, T. 2 N., R. 67 W., coal 8.25 ft thick is found at an altitude of 4,851 ft; in SW¼SW¼ sec. 30, coal bed No. 5 is 8.0 ft thick at an altitude of 4,860 ft. In the central part of sec. 25, T. 2 N., R. 68 W., there appears to be no coal, but, midway along the western section line, 4.5 ft of coal exists at 4,860 ft. In the northwestern corner of sec. 36, 4.0 ft of coal is found at 4,841 ft, and, in the northwestern corner of sec. 36, 4.0 ft of coal exists at 4,841 ft.

Coal bed No. 5 in the Shamrock mine is more than 10.0 ft thick in the southwestern and central parts of sec. 26 and thins rapidly to the north and south, where it is absent. Coal bed No. 5 was extensivley mined in the southern half of sec. 27, where it was as much as 9.0 ft thick. The coal bed north of the mined-out area in sec. 27 is split with shale partings and is thin. However, in the center of NE¼ sec. 27, coal bed No. 5 is 8.2 ft thick at altitude 4,881 ft. This coal bed is intermittently exposed across the northwestern part of the section, but the mantle of soil is such that the crop line is very poorly defined. The coal bed was mined almost to the crop line in SE¼ sec. 28 in the Eureka No. 1 mine. The maximum thickness of the bed here is 5.7 ft.

In the eastern half of sec. 33, the coal varies in thickness from 2.5 to more than 5.0 ft and back to 2.5 ft in a short distance. The altitude of the coal bed in this area varies from 4,874 to 4,914 ft. Approximately all of the eastern two-thirds of sec. 34 has been mined out by the Shamrock and Puritan mines. The thickness of the coal in these mines varies from 5.0 to more than 10.0 ft, and the overburden varies from 75 to 132 ft. Along the western edge of SW¼ sec. 33, the coal is 4.0 ft thick. The Shamrock and Puritan workings extended eastward into sec. 35 locally to the North Puritan fault, where the coal bed was cut off. The thickness of the coal varies from 1.0 ft in NE¼NW¼ to more than 10.0 ft in NW¼SW¼ of the section. Coal bed No. 5 is 4.0 ft thick at 4,841 ft in NW¼ sec. 36; in the northeastern corner, the coal is 3.6 ft thick at 4,884 ft. At the Baum shaft in sec. 35, coal bed No. 5 was described as follows: a lower bench of coal 2.5 ft thick overlain by a shale parting 1.5 ft thick and then an upper bench of coal 2.0 ft thick at 4,888 ft. The limits of this coal bed in T. 2 N., R. 68 W., along with thicknesses and areas of no coal, are shown on plate 6. The reserves are tabulated by sections and overburden zones, indicated in the appendix.

Coal bed No. 6 (Upper seam)

In T. 2 N., R. 68 W., more than 1,000 acres of resources of coal bed No. 6 containing about 7,800,000 short tons of coal are present. Only about 12 acres containing 120,000 short tons have been mined or lost in mining. The coal bed is near the surface and may be of economic potential for strip mining in an area containing more than 2,000,000 short tons of this resource 5.0 ft thick or more. In a sizable area of sec. 33, the coal ranges in thickness from 5.0 to 7.2 ft, and the overburden ranges in thickness from 30 to 90 ft.

A mine slope along the western edge of sec. 34 cuts a coal bed 6.0 ft thick, and the overburden varies from 60 to 110 ft in thickness. In the northwestern corner of sec. 36, there are 3.5 ft of coal at altitude 4,915 ft; in the southwestern corner of sec. 36, there are 4.0 ft at altitude 4,903 ft. At the Baum shaft, there is 4.0 ft of coal at altitude 4.931 ft. The western and northwestern parts of sec. 2 contain a sizable area of coal bed No. 6 ranging in thicknesses from 2.5 to more than 5.0 ft. Plate 7 shows the thickness and areal extent of this bed in this township, and the appendix gives details as to overburden and tonnage.

T. 1 N., R. 68 W., Weld County

T. 1 N., R. 68 W. in Weld County contains more than 47 percent of the total resources calculated for the area of this report. There are almost 36,000 acres of measured and indicated and inferred original coal resources in the township, for which the tonnage is estimated to be about 338,000,000 short tons. These tonnages comprise the resources in coal beds No. 1, No. 2, No. 3, No. 4, No. 5, No. 6, and No. 7. About 83,000,000 short tons in an area of more than 8,000 acres has been mined or lost in mining, leaving about 20,000 acres of resources containing an estimated 282,000,000 short tons. The inferred resources are estimated to occupy almost 700 acres containing just over 4,600,000 short tons. Plates 3, 4, 5, 6, and 7 and figure 3 show the areal extent of these resources, and the appendix gives the tabulated tonnages and estimated overburdens. Structure contours on plates 1 and 2 show the altitude of the base of coal bed No. 3.

Coal bed No. 1

Known resources of coal bed No. 1 in T. 1 N., R. 68 W., Weld County, are small, being only 178.1 acres containing an estimated tonnage of about 945,000 short tons, none of which have been mined. A drill hole in the center of SW¼ sec. 13 cut 3.5 ft of coal at altitude 4,520 ft, and a drill hole in NE¼ sec. 13 penetrated 2.0 ft of coal at altitude 4,886 ft on the opposite side of a fault. A drill hole in NW¼ sec. 23 cut 4.0 ft of coal at altitude 4,663 ft. The coal in this drill hole lies below the base of a sandstone believed to be stratigraphically equivalent to the sandstone overlying coal bed No. 1 in the Marshall district. These isolated holes are the basis for the limited reserves estimated for coal bed No. 1 in this area. Figure 3 illustrates the areal extent of this bed in the township area. Overburdens and tonnages for each section are listed in the appendix.

Coal bed No. 2 (Sump seam)

The resources of coal bed No. 2 are not believed to be large. However, in T. 1 N., R. 68 W., Weld County, more than 1,000 acres are underlain by this coal. The total resources of the bed are more than 8,000,000 short tons, about 40 percent of which is more than 5.0 ft thick. In some areas, notably in sec. 20, the proximity to coal bed No. 3 (which has been mined out) might make mining of this bed hazardous or impossible. None of the resources of coal bed No. 2 have been mined.

At the Mitchell shaft and in a drill hole in SW¼ sec. 19, a coal bed about 6.0 ft thick at altitudes ranging from 4,912 to 4,890 ft is correlated with coal bed No. 2. Several holes were drilled in sec. 20, and a few were drilled in the northern part of sec. 29 from the base of the mined coal (coal bed No. 3). A block of coal having a maximum thickness of more than 9.0 ft has thus been outlined. The areal extent of the bed is shown on plate 3, and the tonnages are tabulated and the overburden zones shown for each section in the appendix.

Coal bed No. 3 (Main seam)

Coal bed No. 3 in T. 1 N., R. 68 W. is estimated to have an areal extent of more than 16,000 acres and to contain more than 183,000,000 short tons of original resources. About 66,000,000 short tons of coal have been extracted or lost in mining from an area of about 4,700 acres in this township. It is further estimated that the remaining 11,766.1 acres contain about 116,000,000 short tons of coal. The areal extent of this bed is shown on plate 4, and the overburden zones and tonnages for each section are shown in the appendix. Plate 1 shows structure contours drawn on the base of this coal bed.

Coal bed No. 3 has been extensively mined, and information from the mine maps of the mined areas and from several drill holes shows that, in most of sec. 1, the coal ranges in thickness from 7.0 to more than 8 ft. On the western side of sec. 2, which was mined, coal bed No. 3 was as much as 10.0 ft thick, but the coal thins to about 4.0 ft thick in the center of the section. Most of the coal in sec. 3 has been mined out, and the thickness varied from slightly less than 6.0 to 10.0 ft. In the horst in the northern part of sec. 3, there is no coal. However, in the western third of the section, the thickness of coal bed No. 3 varies from 5.0 to more than 7.0 ft. In the southern and eastern portions of section 4, coal bed No. 3 has a thickness exceeding 10.0 ft but thins westward to less than 2.5 ft.

In sec. 5 and sec. 6 and most of sec. 7, coal bed No. 3 is known to be more than 2.5 ft thick. It is slightly less than 5.0 ft thick at the Reliance mine in sec. 8; in the Clayton mine workings, coal bed No. 3 is as thick as 7.0 ft but shows a gradual thinning northward to less than 2.5 ft.

The coal in sec. 9 has been partially worked out. The coal bed in the mined-out area ranges in thickness from 5.90 to more than 8.0 ft, and reported drill-hole data in the unmined area in the eastern part of the section indicate that this bed varies from less than 6.0 to more than 8.0 ft in thickness and contains some partings.

Most of the resources of sec. 10 have been mined out. The coal ranges in thickness from 5.0 to more than 14 ft and contains a sizable area where thicknesses of more than 10 ft were reported. West of the mined-out area, in a horst block, the coal has been eroded away.

In sec. 11, in an area extending NW–SE across the section and ¼ to ½ mi wide, the coal is less than 2½ ft thick and is flanked by an area of coal varying in thickness from 2.5 to 8.0 ft in SW¼ and from 2.5 to 7.0 ft in the northeastern corner. The coal in the northern third of sec. 12 ranges from 6.0 to 7.0 ft in thickness and has been mined. The southern half of sec. 12 contains a coal bed having a thickness that varies from less than 3 to more than 7 ft. An area of no coal or coal less than 2.5 ft thick is delineated by drill holes in NE¼ sec. 14 and SW¼ sec. 13. West of this barren area, drill data show the coal to attain thicknesses of as much as 10 ft in sec. 14. East of the barren area in sec. 13, drill data and mine maps show the coal bed to be more than 6 ft thick. Most of the coal resources in sec. 15 have been mined out. Drill-hole and mine-map data show that the coal in much of this section was more than 10 ft (3.05 m) thick.

Coal bed No. 3 varies from 6 to 8 ft in thickness in the western half of sec. 16, but reported drill-hole information indicates thinning of the bed southeastward from the mined-out area. Coal bed No. 3 ranges in thickness from 6.5 to more than 8 ft in the western part of the Clayton mine in sec. 17. A wedge or horst of sandstone, possibly the Fox Hills Sandstone, is bounded by faults and abuts the mined-out area on the west. Drill holes west of the horst wedge show the coal to be less than 2.5 ft thick in part of SW¼ sec. 17. The northwestern quarter of the section has been drilled, and coal bed No. 3 here attains a maximum thickness of more than 7 ft. Sec. 18 contains a sizable area of coal 4.0 ft thick or more as determined from drill-hole and mining data.

The western and southwestern parts of sec. 19 have been mined, and the eastern part has been extensively drilled. The section contains a large quantity of coal ranging in thickness from 5 to 6 ft. In SE¼ sec. 19, a wedge of sandstone extends northeastward from NE¼ sec. 30 across the western half of sec. 20 and the southern two-thirds of the length of sec. 17, which is barren of coal. This wedge is the northern part of a horst extending from sec. 36, T. 1 N., R. 69 W. to the northern two-thirds of sec. 17, T. 1 N., R. 68 W. East of the wedge in sec. 20, the thickness of coal bed No. 3 varies from 4 to 10 ft and has been nearly mined out.

Coal bed No. 3 has been mined out in parts of NW¼SW¼ sec. 21. Two drill holes in the center of the section show that the coal bed is split and that it is less than 3.0 ft thick. A large part of the eastern half of sec. 22 has been mined out by the Washington and Eagle mines. Mine maps and drill holes show the coal to be more than 8 ft thick in most of this area. In the western part of the section, the coal ranges from 4.6 to more than 8 ft in thickness. Most of the W½ sec. 23 has been mined out by the Washington mine. Mine maps and drill data indicate that coal bed No. 3 varied from 8 to more than 10 ft in thickness. Data from drilling in the unmined area of the eastern half of the section and from the coal exposed along a haulage road indicate a sizable area underlain by coal ranging from 7.5 to 10.0 ft in thickness. Coal has been mined along the eastern edge of sec. 24. The section has been prospected by drilling, and data indicate a sizable area containing coal ranging in thickness from 6 to 9 ft. In addition, drill-hole information from adjoining sections supports the conclusion that coal bed No. 3 is 3 ft thick or more throughout.

Considerable mining has been done in NE¼ sec. 25, and two drill holes provide data for estimating resources in this section. A large part of the resources in sec. 26 of coal bed No. 3, which ranged in thickness from 5 to more than 9 ft, has been mined out through the Washington mine in the northern and western parts of sec. 26. The coal appears to thin to less than 2.5 ft in the southeastern part of sec. 26 and in the southwestern part of sec. 25.

Available information indicates that little drilling was done for coal in sec. 27; the resources in this section are indicated only by drilling and mining information in the northeastern quarter of the section, which was mined out by the Washington mine, and by drilling in the surrounding sections. Sec. 28 has been mined in the western part, where coal bed No. 3 is as much as 11.0 ft thick, but data from several drill holes also in the western half of the section show that the bed thins, becomes dirty, and is split by partings toward the east.

Most of the resources of coal bed No. 3 have been depleted by mining in sec. 29. The coal in this section varies in thickness from 2.5 to more than 11 ft. Drill-hole data indicate only comparatively thin coal in sec. 30.

Coal resources in sec. 31 have been well defined by mining and drill-hole data. Approximately one-third of the section is underlain by coal bed No. 3, which has thicknesses ranging from 5 to more than 7 ft. The remaining two-thirds of the section is believed to be underlain by coal 2.5 ft thick or more. A small area contains coal that is more than 5 ft thick, as drill-hole and mine data indicate. Additional drill-hole data indicate that the coal thins to the east and northeast and is absent in the northeastern quarter of the section.

Although drill-hole data are not available for sec. 33, sec. 34, sec. 35, and sec. 36, some resources have been calculated for these sections on the basis of other drill information (see the appendix).

Coal bed No. 4

Coal bed No. 4 is estimated to have an areal extent of about 2,300 acres in T. 1 N., R. 68 W. and to contain more than 17,800,000 short tons of original resources. Approximately 5,000,000 short tons of coal from an area of about 460 acres have been mined or lost in mining. The proximity of this bed to coal bed No. 3 in places is such that, if the coal of coal bed No. 4 was not simultaneously recovered during mining on the No. 3 bed, the resources in the No. 4 bed would probably be lost.

Coal bed No. 4 has not been mined in sec. 18 or sec. 19. Numerous drill holes show the bed to be thin but of minable thickness in a large part of sec. 19 and in the southern part of sec. 18. Many of the coal resources of this bed have been depleted by mining in sec. 20, sec. 21, sec. 28, and sec. 29. Drill holes in sec. 28 show that the coal attains a maximum thickness of 6.0 ft but thins to the south and east. Drill-hole data in sec. 30, sec. 31, and sec. 32 show a sizable area of coal more than 2.5 ft thick that attains a maximum thickness of more than 7.0 ft but includes partings. The appendix shows the extent, tonnage reserves, and overburden of this coal bed in the township. Some resources have been outlined but not estimated for coal bed No. 4 in sec. 22 on the basis of one drill hole that shows a thickness of 3.0 ft. Plate 5 and figure 4*A* show the areal extent, and plate 2 shows the thickness of the coal and the lithologic character of the roof, floor, and partings.

Coal bed No. 5 (Middle seam)

The resources of coal bed No. 5 in T. 1 N., R. 68 W. are contained in an area of more than 4,200 acres and are calculated to be more than 29,800,000 short tons. Coal bed no. 5 has not been mined in this township. Although the coal bed is widespread, it is not persistent in its thickness, and only about 17 percent of the estimated tonnage is contained in areas where the bed is 5.0 ft thick or more.

Data from several drill holes serve to outline a small area of coal bed No. 5 in sec. 1 that is more than 3 ft thick. A small area in the western part of sec. 4 contains coal having a maximum thickness of more than 5 ft. Also, data from a few drill holes outline a resource area that includes parts of sec. 4, sec. 7, sec. 8, and sec. 9 having maximum coal-bed thicknesses of more than 5 ft. Drill-hole data in sec. 13 and sec. 24 show some resources.

Drill-hole data indicate a sizable area of coal bed No. 5 in sec. 14, sec. 15, sec. 22, and sec. 23 in which the coal attains a maximum thickness of more than 7 ft. Other areas of resources include sec. 20 and sec. 21 and an area of considerable extent in sec. 18, sec. 19, and sec. 30 in which the coal thickness ranges from 2.5 to 6.4 ft. Drill-hole data in SE¼ sec. 30 and along the western margin of sec. 29 show an area of coal bed No. 5 to be 5.0 ft thick or more but split with partings. Drill-hole data indicate areas of coal bed no. 5 that attain a thickness of more than 6 ft in the northern part of sec. 32, the southern edge of sec. 29, and the northeastern corner of sec. 31; in NW¼ sec. 28, a small area of coal bed No. 5 is smutty, bony, and benched by partings but attains a maximum thickness of more than 6 ft. Coal sections showing the thickness of the roof, floor, and parting material are shown on plate 2. Tonnage reserves, overburdens, and areal extents are given in the appendix.

Coal bed No. 6 (Upper seam)

Coal bed No. 6, although occurring sporadically, contains more than 25,000,000 short tons of coal in T. 1 N., R. 68 W.; the bed ranges in thickness from 2.5 to more than 8.0 ft and is in combined areas of more than 3,300 acres. Approximately 34 percent of the resource tonnage is contained in portions of the bed that are more than 5.0 ft thick. More than 5,500,000 short tons of coal have been mined or lost in mining from an area of approximately 360 acres in T. 1 N., R. 68 W. Plate 7 shows the areal extent of these resources, plate 2 shows the thicknesses of coal and of the roof, floor, and partings, and the appendix gives tabulated tonnages by sections, the acreages, and the overburden thicknesses.

Coal drilling shows that an area of coal bed No. 6 extends from sec. 36, T. 2 N., R. 68 W. into the northern and northwestern parts of sec. 2, T. 1 N., R. 68 W., where it achieves a maximum thickness of 5.8 ft. A lobe of this thick area of coal bed No. 6 is inferred to extend into sec. 1, where it is shown to be more than 4 ft thick. Coal sections for this area are not shown on plate 2.

A large area of strippable coal bed in sec. 4 has a maximum thickness of 6.0 ft and from 30 to 80 ft of overburden. In NW¼SW¼ sec. 3, the overburden ranges from 80 to 100 ft. This area of strippable coal was outlined by data from drill holes. Another area of strippable coal that ranges from 2.5 to 5.0 ft in thickness and that has overburden ranging from 30 to 65 ft is in sec. 7 and extends into parts of sec. 5, sec. 6, and sec. 8 as indicated resources. The area has been outlined by drill-hole data.

Sec. 8, sec. 9, sec. 10, and sec. 16 contain a sizable area of coal bed No. 6 that is more than 2.5 ft thick. Part of the coal bed has been mined out in sec. 9 and sec. 16, where it achieves a maximum thickness of more than 8.0 ft. The coal bed was also mined at the Reliance mine in sec. 8. One sizable area of coal bed No. 6 thicker than 2.5 ft occurs in sec. 13 and extends into the southeastern quarter of sec. 12 and sec. 14. There are also small areas of coal thicker than 2.5 ft in sec. 11, sec. 14, sec. 17, sec. 18, sec. 19, sec. 20, sec. 21, sec. 28, sec. 29, and sec. 30 (pl. 7). In one place in sec. 18, the bed attains a maximum thickness of 8.0 ft. The locations of drill holes used to outline these areas of coal are shown on plate 1.

Coal bed No. 7

Coal bed No. 7 is of small importance in T. 1 N., R. 68 W. The estimated areal extent (from drill holes) is about 16 acres in sec. 22 and sec. 23 (pl. 7), maximum thickness is more than 4.0 ft, and resources are only about 79,000 short tons (appendix).

T. 2 N., R. 67 W., Weld County

T. 2 N., R. 67 W. in Weld County contains more than 57,000,000 short tons of original measured and indicated and inferred coal resources; where the coal is more than 2.5 ft thick, the areal extent of the bed is more than 6,500 acres. Tonnages were compiled for measured and indicated and inferred; indicated and inferred categories comprise resources estimated for coal beds No. 3, No. 4, No. 5, No. 6, and No. 7 (appendix). Part of the original resources of coal bed No. 3, comprising an area of more than 1,200 acres and more than 16,000,000 short tons of coal, has been produced or lost in mining (appendix). The remaining resources for this partial township are estimated to be about 40,000,000 short tons contained in all beds cited above and comprise a combined area of more than 5,000 acres. More than 22,000,000 tons of remaining resources are estimated for coal bed No. 3 (appendix). About 1,500,000 short tons of inferred resources are estimated for coal bed No. 3 (appendix). The extent of these resources and the thicknesses of beds are shown on plates 4, 5, 6, and 7 and in figure 4. Coal sections are shown on plate 2, and overburden and tonnages are given in the appendix.

Coal bed No. 3 (Main seam)

The coal resource for all but about 18 acres of sec. 19 and all but 65 of about 230 acres of resources in the western half of sec. 20 in T. 2 N., R. 67 W. have been mined or lost in mining. Measured coal sections obtained during mining and drill data show that the thickness of coal in this mined-out area ranges from 6.0 to 10.7 ft and thinned perceptibly to the east. Logs from two drill holes in sec. 22 (not in this report area) indicate some minor resources of thin coal assigned as inferred resources. One drill hole is known to have been drilled in sec. 27 but outside of the map area. On the basis of these scant data, however, resource estimates of coal more than 5.0 ft thick have been estimated for a large part of the area of sec. 27 that is contained in this report. No available records of drilling substantiate reserve estimates in sec. 28 and the eastern part of sec. 29; the coal bed is indicated to be thin (that is, less than 2.5 ft) in much of this area. The western half of sec. 29 contains coal ranging in thickness from 5.7 to 6.6 ft and increasing to more than 8 ft toward the south. Eastward, the coal is reported to be thin.

Most of the resources of coal bed No. 3 have been mined out in sec. 30 and sec. 31. A narrow horst between the Dacano-Frederick fault on the west and the Grant-West Sterling fault on the east traverses these sections (pl. 1, 4) and contains sediments at the surface that may be the Fox Hills Sandstone, which, in this area, contains little or no coal. Drilling in the horst area in sec. 19, sec. 30, and sec. 31 encountered sandstone, silty sandstone, and sandy shale and no coal. Coal bed No. 3 on either side of the horst varies from 5 to almost 10 ft in thickness as determined from mine and drilling data.

The western half of sec. 32 has been mined out, but this area contained coal in northwestern quarter of the southwestern quarter varying from 8 to 11 ft in thickness. Coal in NW¼ sec. 32 has been mined out but in places contains one or two partings. A wedge-shaped upthrown block in the southwestern part of the section contains little or no coal. East of this block, drill holes show that coal bed No. 3 ranges in thickness from 5.9 to 9.0 ft; the maximum true coal thickness here, however, is probably less than 8.5 ft because of the steep dip of the bed. Sec. 33 and sec. 34 have not been extensively prospected, but four drill holes give some evidence that the coal is more than 5.0 ft thick in sec. 34 but thins westward into sec. 33. A drill hole 500 ft deep just northwest of the center of NW¼ sec. 33 would have been deep enough to encounter coal but did not.

Coal bed No. 4

Coal bed No. 4 is estimated to occupy an area of only about 100 acres and to contain slightly less than 800,000 short tons of original resources of coal. This bed has not been mined in T. 2 N., R. 67 W. and is of very little value. Four drill holes in sec. 32 and two in sec. 33 outline two small areas of coal more than 2.5 ft thick, shown in figure 4. Reserves for these areas are tabulated in the appendix.

Coal bed No. 5 (Middle seam)

The resources of coal bed No. 5 in T. 2 N., R. 67 W. occupy an area of more than 2,000 acres, which contain estimated original resources of about 16,000,000 short tons. Approximately seven-eighths of these resources are in coal more than 2.5 and less than 5.0 ft thick. Plate 6 shows the estimated areal extent and thickness of this bed in T. 2 N., R. 67 W.; plate 2 shows the thickness and the type of strata in the roof, floor, and partings; the appendix shows the tabulated tonnages, acreages, and overburden zones for each section.

Drill holes in sec. 19, sec. 20, and sec. 21 show a coal, herein correlated as coal bed No. 5, having a maximum aggregate thickness of more than 7 ft. Because of the thickness of partings in the coal, however, only one bench could be used to calculate the resources in most of these sections. Most of sec. 21 and sec. 22 and the southwestern part of sec. 19 included in this report contain no area of coal bed No. 5 that is 2.5 ft thick or more.

Several drill holes in sec. 30 and more in sec. 32 show a coal bed varying in thickness and in places having one or more partings at the approximate horizon of coal bed No. 5. No data are available to support the calculation of any resources for sec. 27, sec. 28, and sec. 31. A drill hole in SE¼NE¼ sec. 33 and one in W½SW¼ sec. 34 show a coal bed believed to be coal bed No. 5 and were the basis for computing resources for the area; another drill hole in the eastern part of the section (not shown) confirms, however, that the coal is less than 2.5 ft thick in the area shown.

Coal bed No. 6 (Upper seam)

Resources of coal bed No. 6 in T. 2 N., R. 67 W. comprise small deposits of a nonpersistent bed. The total acreage of the area containing these resources is estimated to be approximately 200 acres and to contain about 1,300,000 short tons of coal. The areal extent and thickness of this bed are shown on plate 6, and coal, stratigraphy, and overburden, acreage, and tonnages per section are given in the appendix.

Coal bed No. 7

Drill-hole reports in NW¼ sec. 32, T. 2 N., R. 67 W., show coal bed No. 7 to be present. Less than 600,000 short tons were estimated in an area of 85 acres (appendix).

T. 1 N., R. 67 W., Weld County

The coal reserves of T. 1 N., R. 67 W. in Weld County are contained in beds No. 3, No. 5, No. 6, and No. 7. A total acreage in the township of more than 12,000 acres contains about 122,000,000 short tons of measured and indicated original resources. Inferred resources bring the total to more than 141,000,000 short tons in more than 15,000 acres. About 104,000,000 short tons (about 73 percent) of this tonnage are contained in nearly 10,000 acres of coal bed No. 3. About 21 percent is in almost 4,000 acres containing nearly 29,000,000 short tons of coal bed No. 5; about 5.0 percent is in more than 1,000 acres containing more than 6,670,000 short tons of coal bed No. 6; and about 1.0 percent is in about 270 acres containing nearly 1,700,000 short tons of coal bed No. 7. Because coal bed No. 3 is relatively persistent in this field, more than 19,000,000 short tons of coal occupying more than 2,600 additional acres have been inferred and included in these statistics. Estimated tonnage figures, acreages, and overburden zones are given in the appendix. The areal extent of each coal bed in shown on plates 4, 5, and 7; the thickness of coal and material in the roof, floor, and partings are shown on plate 2.

Coal bed No. 3 (Main seam)

Coal bed No. 3 has not been prospected in the part of sec. 3, T. 1 N., R. 67 W. included in this report, and only one record, consisting of a water-well log, is available for sec. 4. Data from the water well drilled in NE¼ sec. 4 indicate possible thickening of the coal to the east and northeast. Unconfirmed reports on coal drilling in the central and southeastern parts indicate that coal bed No. 3 has been extensively drilled, and a considerable acreage east of the horst block containing coal to more than 10 ft thick is indicated for most of the section. Much of the coal in sec. 6 has been mined or lost in mining. However, coal thicknesses for the mined-out area were shown only sparsely on mining maps. The horst on the eastern and western sides of the Sterling mine are barren of coal. The thickness of the coal in the mined areas in sec. 6 ranges from 6.5 to about 8.5 ft.

Two drill holes in sec. 7, six drill holes in sec. 8, and two drill holes in NW¼ sec. 9 provide most of the information on this tier of sections. Coal bed No. 3 has been mined out in N½ sec. 7 through the Sterling mine. Mine-map data augmented by drill data in sec. 7 and sec. 18 show the coal to range from 7 to more than 9 ft in thickness in sec. 7. Drill data on coal bed No. 3 in sec. 8 show considerable areas of resources where the coal is more than 9 ft thick but has a 0.5 to 1.0 ft parting. Three drill holes in E½ sec. 8 appear to have been drilled deep enough to encounter the coal bed, but no coal was reported. This barren area is presumed to be due to faulting and subsequent erosion inasmuch as the drill holes in sec. 9 show some coal at the horizon of coal bed No. 3, although most of it is either too thin or unworkable.

Reported data on coal east of the area of this report are the basis for inferring resources of coal bed No. 3 in sec. 10 and sec. 15. Five drill holes, one abandoned mine, and data on coal thickness in mined-out areas in the northeastern part of the Lincoln mine furnish evidence of considerable resources ranging from 5 to 10 ft thick in sec. 18. Poorly founded reports indicate that coal bed No. 3 thins eastward in sec. 17, and the distance from points of information necessitated a calculation of inferred resources for the eastern part of this section and the western part of sec. 16.

Coal bed No. 3 has been mined in NW¼ sec. 19 through the Washington (old) shaft. Exploratory drilling for coal elsewhere in this section indicates that coal bed No. 3 ranges in thickness from 6 to more than 10.3 ft. This bed appears to thin eastward, for it is reported to be 4.5 ft thick in NW¼ sec. 20 and nonexistent in the central part of sec. 21. One drill hole in W½ sec. 22 indicates a thickening of the resources in that section.

A portion of sec. 27 included in this report is considered to contain some thin inferred resources. Data from well drilling in sec. 28 showed little or no coal. Drilling in the southern part of sec. 19 and NW¼ sec. 30 indicates that coal thicknesses in sec. 30 range from 3 to 10 ft and in sec. 29 range from 5 to 10 ft; part of this coal is reported as inferred resources. Old and vaguely described water-well logs from sec. 6, T. 1 S., R. 67 W. and sec. 34, T. 1 N., R. 67 W. imply some resources for sec. 32 and parts of sec. 29, sec. 31, sec. 33, and sec. 34. A thin coal bed at the horizon of coal bed No. 3 was reported from a water well near the center of sec. 33.

Coal bed No. 5 (Middle seam)

Coal bed No. 5 underlies a sizable area in T. 1 N., R. 67 W., but its apparent lack of consistent thickness is such that only comparatively moderately sized areas of coal thicker than 2.5 ft have been delineated. Traces of coal blossom or smut found in NE¼SE¼ sec. 5, NE¼SE¼ sec. 8, and NE¼ sec. 17 were believed to be the result of weathering of the coal bed No. 5 outcrop, where the coal in an upthrown block had been eroded (pl. 6). The total area of coal bed No. 5 more than 2.5 ft thick in this township is more than 3,800 acres and is estimated to contain more than 28,000,000 short tons of original coal resources. Mine maps from the Peerless and Witherbee mines show a mined-out area of about 15 acres that contained about 90,000 short tons of resources; however, records show production of only 9,600 short tons. The appendix gives details of acreage, overburden, and tonnage per section.

The Peerless and Witherbee mines in sec. 4 mined a coal bed herein believed to be coal bed No. 5. The thickness of the coal found in these mines and the thickness of coal reported by drill logs in sec. 5 delineate a considerable acreage of coal in sec. 4 and sec. 5; thicknesses vary from 3 to 6 ft. Logs from drill holes in sec. 7 and sec. 8 show that a large part of this area contains coal varying from 3.4 to 5.3 ft in thickness. Drill holes in sec. 13 and sec. 24, T. 1 N., R. 68 W. and in sec. 18 and sec. 19, T. 1 N., R. 67 W. form the basis for the resources calculated in sec. 18, sec. 19, sec. 20, and sec. 30. Plate 6 shows the area of these resources, and plate 2 shows the thickness of coal and strata of floor, roof, and parting.

Coal bed No. 6 (Upper seam)

Only minor areas and tonnages of resources of coal bed No. 6 are present in T. 1 N., R. 67 W. Only about 6,670,000 short tons of coal are present in an area of just over 1,000 acres. Almost 5,900,000 tons of this coal are presumed to be less than 5.0 ft thick.

The points of observation are drill holes. One drill hole, in SW¼ sec. 34, T. 2 N., R. 67 W., and three holes in the southern half of sec. 4, T. 1 N., R. 67 W., all of which were poorly located and not shown on plate 7, serve to outline some resources in sec. 3, sec. 4, and sec. 9. Drill holes in SW¼ sec. 5 and one in SW¼ sec. 8 serve to outline a small area containing coal bed No. 6. A hole in SE¼ sec. 19 and a poorly located hole in SE¼ sec. 21 (not shown on pl. 1) serve to outline two small areas containing coal more than 2.5 ft thick. Plate 7 shows the thickness and areas of resources of this coal bed, plate 2 shows the thicknesses and strata of roof, floor, and partings, and the appendix shows the acreage, thickness, and amounts of resources.

Coal bed No. 7

Coal bed No. 7 appears to be of only minor importance in T. 1 N., R. 67 W. The total area occupied by this bed is about 270 acres, which contain nearly 1,700,000 short tons of resources. The points of observation are drill holes. Four drill holes in sec. 5 and five in sec. 8 outline two small areas of resources of coal bed No. 7. The inset map on plate 7 shows the thickness and the areas of resources of this coal bed, plate 2 shows the thicknesses and strata of floor, roof and partings, and the appendix shows the overburden, area, and tonnages per section.

OIL AND NATURAL GAS

Oil and natural gas have been produced in the report region, notably in Boulder County, for about 80 yrs. As early as 1901, in NE¼NW¼ sec. 21, T. 1 N., R. 70 W., about 6 mi west of the northwestern corner of the Erie quadrangle, the Boulder Oil Company struck oil in the Hygiene Sandstone Member of the Pierre Shale. Although never large, production from several wells within 2 or 3 mi of the discovery well continued through 1975. Cumulative production was 778,667 bbl of oil from the shale, sandy shale, and shaly sandstone beds in and adjacent to the Hygiene Member of the Pierre Shale, from the so-called barren zone of the Pierre, from the Niobrara Formation, and from a sandstone that is apparently the stratigraphic equivalent of the Codell Sandstone Member of the Carlile Shale. Shows of oil were reported in the Muddy Sandstone of MacKenzie (1965) or the upper part of the Dakota Group of Waage (1955). The trapping mechanisms for the oil and gas were structural in parts of the fields; in other parts, they were probably structural and stratigraphic but largely stratigraphic.

The Wattenberg gasfield, which presently occupies the area from T. 5 N. to T. 2 S. and from R. 68 W. to about midway between R. 64 W. and R. 63 W., was discovered in 1970 and in 1980–81 was producing oil and gas from the "D" sandstone and the "J" sandstone in the South Platte Formation of the Dakota Group of Early Cretaceous age. Twenty-nine oil and gas wells of the Wattenberg field are within the Erie and Frederick quadrangles.

Production from the Terry and Hygiene Sandstone Members of the Pierre Shale began in 1971 in the Spindle field and in 1972 in the Surrey field of the Frederick quadrangle. The names Sussex and Shannon Sandstone Members of the Steele Shale have been applied incorrectly by drillers in the Denver basin to the Terry and the Hygiene, respectively. The Sussex and Shannon are valid names in the Powder River basin of northeastern Wyoming. The Spindle field (528 wells) extends southwest through the Frederick quadrangle and into the Erie quadrangle. The Surrey field comprises 21 wells producing from the Terry Sandstone Member of the Pierre Shale and from the Codell Member of the Carlile Shale (Upper Cretaceous). Some wells have been completed in both sandstones. The field extends into the southeastern part of the Frederick quadrangle in sec. 9, sec. 10, and secs. 15–22, and in secs. 27–34, T 1 N., R. 67 W.

The trapping mechanism for the oil and gas in the area of this report is startigraphic (Matuszczak, 1973, p. 102). That is, it occurs by means of lateral pinchouts of the reservoir sandstones related to facies changes and permeability decrease owing to the increase in siliceous cement in places within the stratigraphic unit.

According to records published by the Colorado State Oil and Gas Conservation Commission (1979), the 528 production wells of the Spindle field in the Erie and Frederick quadrangles (Weld County) produced 2,090,093 bbl of crude oil and 14,421,471 million cubic feet of natural gas in 1979. The cumulative production of the Spindle field in the Erie and Frederick quadrangles to January 1, 1980, was 15,960,985 bbl of crude oil and 74,845,995 million cubic feet of natural gas. The Wattenburg field in Weld County, Erie and Frederick quadrangles, produced 8,210 bbl of crude oil and 1,704,534 million cubic feet of natural gas from 29 wells in 1979. The cumulative production to January 1, 1980, of the Wattenberg field within the Erie and Frederick quadrangles was 76,042 bbl of crude oil and 11,454,007 million cubic feet of natural gas. The total for both fields was 16,126,005 bbl of oil and 86,300,000 million cubic feet of natural gas. The gravity of the crude oil in this area ranges from 41.2 to 62 API, the average being slightly greater than 42 API.

Table 10 summarizes production in the Erie and Frederick quadrangles.

In Boulder County, Erie quadrangle (T. 2 N., R. 69 W.), one well in Spindle field produced 624 bbl of oil in 1978; cumulative production to January 1, 1980, was 2,097 bbl of oil. The same well produced 602 million cubic feet of gas in 1978; cumulative production to January 1, 1980, was 38,619 milion cubic feet of gas.

Seven gas wells and one oil well are reported in T. 1 N., R. 69 W. and T. 2 N., R. 69 W. These wells were either shut in or not in production as of January 1, 1980.

ENVIRONMENTAL GEOLOGY

The Erie and Frederick quadrangles contain a NE–SW-trending zone of faults traceable from 2 mi SSW of Marshall in the Louisville quadrangle across the southeastern corner of the Niwot quadrangle, the northeastern quarter of the Louisville quadrangle, and the northwestern quarter of the Lafayette quadrangle and northeast across the Erie and Frederick quadrangles where it dies out or is untraceable in the Pierre, Fox Hills, or alluvium along Boulder Creek (fig. 5). The zone is traceable in underground workings and on the surface for a distance of about 20 mi. The width of the zone ranges from about 2 mi in the Louisville quadrangle to as much as 5 mi in the Erie and Frederick quadrangles. The individual faults have variable displacements ranging from 5 to 500 ft. Movement on the faults has been largely dip slip. Where they have been observed, the fault planes are very steep to vertical and of the normal type, but at least one horst border fault (in the Columbine mine) is a high-angle reverse fault. Here coal bed No. 3 was repeated in two drill holes along the fault line. Probably several of the horst border faults are of the reverse type and would appear to converge with depth somewhere in the underlying upper part of the Pierre Shale.

In several places, because of the fracturing of the coal and surrounding rock, along with the usual subsequent increase in the dip of the coals near the faults and the vertical displacement of the coal, the presence of these faults has necessitated a change in the method of mining and locally caused the cessation of mining. Although the faults are inactive, they have played an important part in past mining and are equally important in planning future mining. The fault planes in places also may be important because of channeling or because they act as a barrier in ground-water movement. The southern part of this fault system in the Louisville quadrangle was described by Spencer (1961). In the Erie and Frederick quadrangles, that part of the system was adopted from this author's unpublished notes and maps of 1952–54, which had been modified and shown previously by Laurie (1966) and Colton and Laurie (1973). A 1975 study of coal-mine subsidence and land use in this area (Myers and others, 1975) very adequately described and illustrated the hazards of coal-mine subsidence and its effects on land use. The mined-out areas shown in this study were taken from the author's original maps and revised in 1979 by using the most recent mine maps and information available. There appear to be several discrepancies between maps of the mined-out area in this report and those mentioned previously, but these discrepancies can be attributed to differences in the method and exactness of plotting techniques or to the use of different and later mine maps. Some of these differences are listed by Myers and others (1975, p. V-3), and some are applicable to this report.

Mined-out areas, especially those near the surface, must be considered areas of questionable stability because of the potential for subsidence or lowering of the ground surface owing to the collapse of the roof support of the underground excavations. In the Frederick quadrangle, more than 5,800 acres have been mined out; in the Erie quadrangle, about 4,000 acres have been mined out (pls. 1–7).

Table 10. Oil and gas production in the Erie and Frederick quadrangles, Boulder and Weld Counties, Colorado

No. of wells	1979 Oil production, in barrels	1979 Gas production, in million cubic feet	Cumulative to January 1, 1980 Oil production, in barrels	Cumulative to January 1, 1980 Gas production, in million cubic feet
Weld County, Spindle field (Terry and Hygiene Sandstone Members)				
528	2,090,093	14,421,471	15,960,985	74,845,995
Weld County, Wattenberg field ("D" and "J" sandstones)				
29	8,210	1,704,534	76,042	11,454,007
Total of Spindle and Wattenberg fields				
557	2,098,303	16,126,005	16,037,027	86,300,002

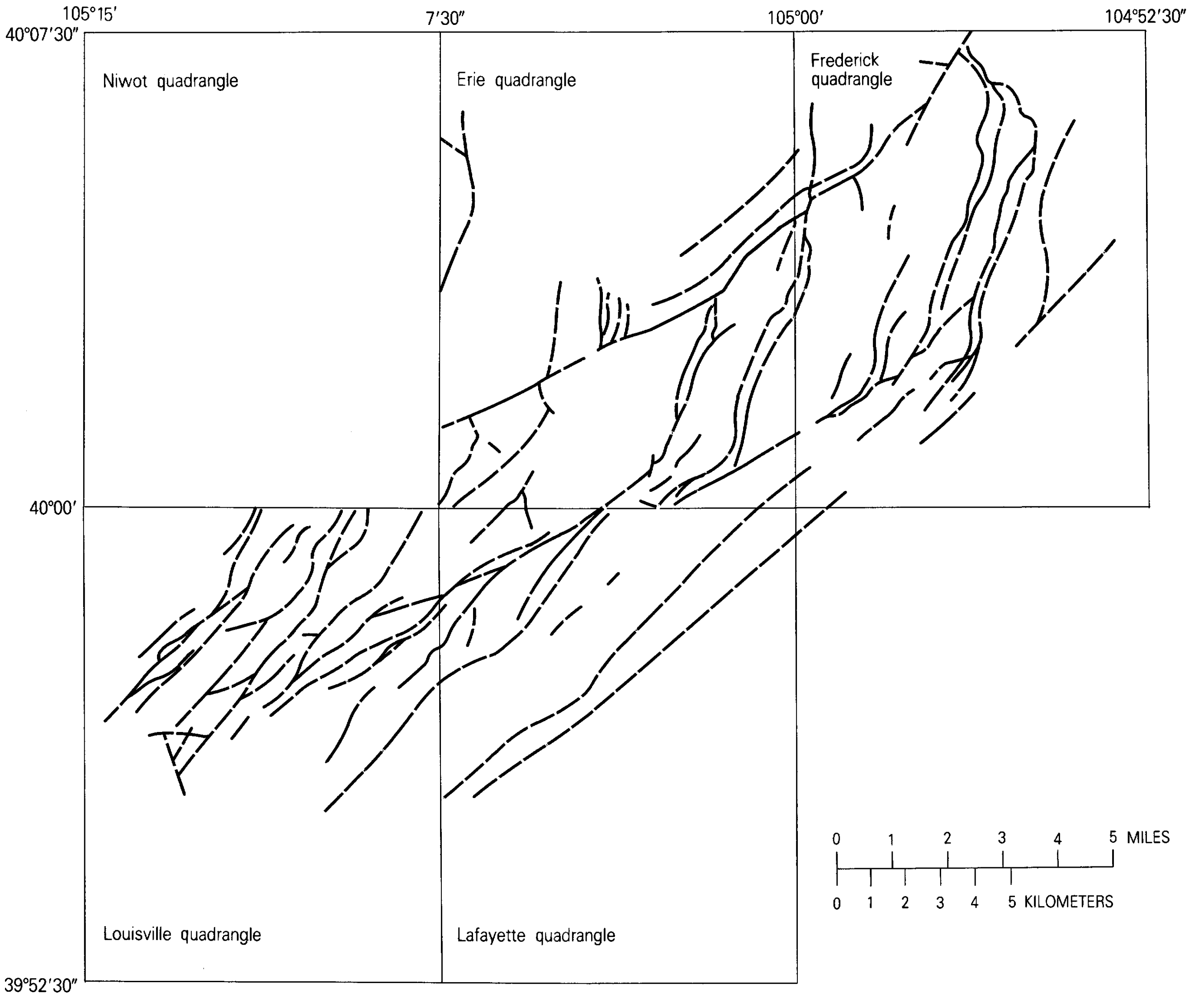

Figure 5. Index map showing the location of the zone of faults in the Boulder-Weld County coal field, Colorado.

The engineering factors that control such subsidence, the mechanics involved, and the results of coal-mine extraction have been so adequately described and illustrated by Denrud (1976) that the aforementioned mined-out areas in the Erie and Frederick quadrangles should be considered as subsidence risk areas. The report by Amuedo and Ivy (Myers and others, 1975) treats such risks—possible land use and mine subsidence—as completely as possible, given the available information.

Slumping in abandoned coal mines has undesirable effects on at least two activities: (1) mining more coal in the area and (2) surface construction. It may make coal remaining in the same bed or in beds above or below more difficult to recover, if not impossible. If mining were near enough to the surface, it might, in combination with the thickness of the coal mined, the nature of overburden, the method of mining, the length and width of the area mined, and the barriers before each slumping, create an area of roof fall and (or) caving in the mine that could be reflected by the sinking of the ground surface and accompanying surface fractures. Thus, an area characterized by undesirable or dangerous construction conditions would be created. Any previously constructed structures might also be affected.

Three areas of surface subsidence are evident in the Erie quadrangle. The first overlies a 25-acre mined-out area of coal bed No. 3 about 200 ft below the surface in the Old Boulder Valley mine in SE¼ sec. 18, T. 1 N., R. 68 W. The second area involves about 35 acres in NE¼ sec. 18, T. 1 N., R. 68 W. This slumped area is near to but difficult to associate directly with known mining. However, it may overlie old mine workings for which there is no record. The third area of subsidence occupies about 55 acres extending in all directions from the center of sec. 29, T. 1 N., R. 68 W., Weld County. This area is elongated slightly in a SW–NE direction. It is centered on the inactive Columbine mine shaft and overlies part of the old mine workings. Coal mined here from coal bed No. 3, which lay in a horst ranged from 250 to 370 ft below the surface. Coal bed No. 4 in this area was either mined or lost in mining because of its proximity to coal bed No. 3.

In the Frederick quadrangle, another area comprising about 360 acres is marked by potholes. These potholes, which are considered to be good indicators of subsidence, can be seen in T. 2 N., R. 68 W., in a strip along the southern and eastern quarter lines of sec. 27, in most of SW¼ sec. 26, in more than half of NW¼ sec. 35, and in about two-thirds of NE¼ sec. 34. This subsidence has resulted from the old Shamrock mine workings in coal bed No. 5 (Middle seam). The Shamrock operated continuously between 1949 and 1956 but was intermittently productive as early as 1928. The mined-out coal ranges in thickness from 5.0 to 10 ft and lies from 65 to 115 ft below the surface.

From these examples, it should be concluded that all mined-out areas are subject to subsidence risk. Proposed construction projects of any kind should very carefully consider the siting and type of construction planned in these areas.

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Appendix. Coal resources of the Erie and Frederick quadrangles
[Resource values in thousands of short tons]

Section No.	Limits of Over-Burden	Original resources: Area, in acres	Original resources: 2.5-5.0 ft	Original resources: 5.0-10 ft	Original resources: >10 ft	Mined and lost in mining: Area, in acres	Mined and lost in mining: 2.5-5.0 ft	Mined and lost in mining: 5.0-10 ft	Mined and lost in mining: >10 ft	Remaining resources: Area, in	Remaining resources: 2.5-5.0	Remaining resources: 5.0-10	Remaining resources: >10
Measured and indicated—T. 1 N., R. 69 W.—Erie quadrangle													
Coal bed No. 2													
13	125-175	149.8	968.1							149.8	968.1		
24	150-75	229.5	1,487.6							229.5	1,487.6		
24	150-175	22.7		201.0						22.7		201.0	
25	150-175	1.8	8.8							1.8	8.8		
33	50- 60	9.1	47.3							9.1	47.3		
34	50- 60	37.3	189.6							37.3	189.6		
35	250-275	233.9	1,601.2							233.9	1,601.2		
35	250-275	58.2		595.4						58.2		595.4	
36	250-275	26.4	146.6							26.4	146.6		
Total		768.7	4,449.2	796.4						768.7	4,449.2	796.4	
Coal bed No. 3													
11	30- 50	7.2	39.8							7.2	39.8		
12	30- 50	150.1	969.8							150.1	969.8		
12	30- 50	12.7		123.6						12.7		123.6	
13	100-140	330.3	2,367.4			68.9	478.0			261.4	1,889.4		
13	100-140	309.7		3,236.7		101.4		1,134.5		208.3		2,102.2	
14	90-160	213.5	1,396.9			8.2	52.3			205.3	1,344.6		
14	90-160	16.4		159.6						16.4		159.6	
23	50-120	357.6	2,046.4							357.6	2,046.4		
24	140-210	579.6	3,962.7			78.2	622.8			501.4	3,339.9		
24	140-210	60.4		609.3		16.4		159.6		44.0		449.7	
25	180-250	193.5	1,091.2							193.5	1,091.2		
25	180-250	9.1		89.8						9.1		89.8	
26	0-220	557.3	3,470.6							557.3	3,470.6		
27	0-140	396.7	2,569.5			2.7	21.5			394.0	2,548.0		
27	0-140	18.4		179.1		1.8		17.5		16.6		161.6	
28	0- 30	3.6	17.5							3.6	17.5		
33	0-160	68.2	516.1							68.2	516.1		
33	0-160	40.0		368.1						40.0		368.1	
34	50-260	282.0	1,960.5							282.0	1,930.5		
34	50-260	283.4		3,075.6		97.2		1,104.7		186.2		1,970.9	
34[1]	50-260	5.4			124.2					5.4			124.2
35	200-240	335.6	2,417.7			68.2	514.6			267.4	1,903.1		
35	200-240	252.2		2,467.8		251.8		2,463.9		.4		3.9	
35[1]	200-240	38.2				38.2			816.0				
36	100-220	282.6	1,739.6		816.0	14.5	115.4			268.1	1,624.2		
36	100-220	19.9		211.1		5.4		65.2		14.5		145.9	
Total		4,823.6	24,535.7	10,520.7	940.2	752.9	1,804.6	4,945.4	816.0	4,070.7	22,731.1	5,575.3	124.2

[1]Coal beds No. 3 and No. 4 combined.

Section No.	Limits of Over-Burden	Original resources: Area, in acres	Original resources: 2.5-5.0 ft	Original resources: 5.0-10 ft	Original resources: >10 ft	Mined and lost in mining: Area, in acres	Mined and lost in mining: 2.5-5.0 ft	Mined and lost in mining: 5.0-10 ft	Mined and lost in mining: >10 ft	Remaining resources: Area, in acres	Remaining resources: 2.5-5.0 ft	Remaining resources: 5.0-10 ft	Remaining resources: >10 ft
Coal bed No. 4													
13	100-140	218.0	1,353.6							218.0	1,353.6		
24	100-150	484.1	3,290.0			34.6	168.4			449.5	3,121.6		
25	100-110	32.7	188.3							32.7	188.3		
27	0-115	72.7	456.3							72.7	456.3		
28	0-115	3.6	25.7							3.6	25.7		
33	0-225	97.2	591.7							97.2	591.7		
34	0-220	176.4	1,032.4							176.4	1,032.4		
35	200-250	222.0	1,525.4							222.0	1,525.4		
35	200-250	248.3		2,707.4						248.3		2,707.4	
36	200-315	51.8	376.4							51.8	376.4		
Total		1,606.8	8,839.8	2,707.4		34.6	168.4			1,527.2	8,671.4	2,707.4	
Coal bed No. 5													
13	30-120	422.0	3,013.6							422.0	3,013.6		
14	30- 70	55.5	323.1							55.5	323.1		
23	30- 80	131.8	766.9							131.8	766.9		
24	45-110	306.5	1,975.1							306.5	1,975.1		
25	80-160	42.7	234.3							42.7	234.3		
26	50-100	319.1	2,034.3							319.1	2,034.3		
27	50- 80	54.6	374.3							54.6	374.3		
33	120-160	36.4	187.2							36.4	187.2		
34	160-200	66.4	388.0							66.4	388.0		
Total		1,435.0	9,296.8							1,435.0	9,296.8		
Coal bed No. 6													
13	35-50	11.8	59.0							11.8	59.0		
27	150-180	7.2	35.0							7.2	35.0		
34	150-180	99.1	500.3							99.1	500.3		
Total		118.1	594.3							118.1	594.3		
Measured and indicated total		8,752.2	47,715.8	14,024.5	940.2	787.5	1,973.0	4,945.4	816.0	7,919.7	45,742.8	9,079.1	124.2
Measured and indicated—T. 2 N., R. 68 W.—Erie quadrangle													
Coal bed No. 3													
33	160-190	23.3	157.7							23.3	157.7		
33	160-190	13.5		147.5						13.5		147.5	
Total		36.8	157.7	147.5						36.8	157.7	147.5	
Coal bed No. 5													
28	100-110	12.8	79.3			6.4	43.0			6.4	36.3		
33	100-170	63.6	422.0							63.6	422.0		
33	100-170	28.1		286.3						28.1		286.3	
Total		104.5	501.3	286.3		6.4	43.0			98.1	458.3	286.3	
Coal bed No. 6													
28	50- 60	8.0	48.7							8.0	48.7		
33	30- 90	95.6	654.7							95.6	654.7		
33	30- 90	182.8	1,910.5			11.7		121.8		171.1		1,788.7	
Total		286.4	703.4	1,910.5		11.7		121.8		274.7	703.4	1,788.7	
Measured and indicated total		427.7	1,362.4	2,344.3		18.1	43.0	121.8		409.6	1,319.4	2,222.5	

Measured and indicated—T. 2 N., R. 68 W.—Frederick quadrangle

Coal bed No. 3													
23	100-110	11.8	57.4							11.8	57.4		
24	70-120	285.9	1,688.6			0.9	7.1			285.0	1,681.5		
24	70-120	15.4		136.2						15.4		136.2	
25	100-200	98.2	646.9			8.2	65.3			90.0	581.6		
25	100-200	208.2		2,683.6		129.1		1,787.3		79.1		896.3	
26	140-150	10.8	62.4							10.8	62.4		
27	140-150	5.4	26.2							5.4	26.2		
33	160-190	6.6	39.9							6.6	39.9		
33	160-190	11.9		132.0						11.9		132.0	
34	130-200	410.9	2,705.6							410.9	2,705.6		
34	130-200	71.1		709.0						71.1		709.0	
35	160-200	187.4	1,237.7							187.4	1,237.7		
35	160-200	84.6		897.2		10.0		100.5		74.6		796.7	
36	200-220	51.0	406.2			20.9	166.4			30.1	239.8		
36	200-220	548.8		7,289.4		516.2		6,897.2		32.6		392.2	
36	200-220	25.5			460.3	22.8			411.6	2.7			48.7
Total		2,033.5	6,870.9	11,847.4	460.3	708.1	238.8	8,785.0	411.6	1,325.4	6,632.1	3,062.4	48.7
Coal bed No. 5													
22	10- 30	0.9	4.3							0.9	4.3		
25	110-140	212.0	1,550.3							212.0	1,550.3		
25	110-140	44.4		475.3						44.4		475.3	
26	0-100	206.4	1,299.8							206.4	1,299.8		
26	0-100	223.8		3,091.3		73.6		1,166.3		150.2		1,925.0	
26	0-100	60.9			1,099.4	36.4			657.1	24.5			442.3
27	0-110	207.5	1,445.3			2.7	21.5			204.8	1,423.8		
27	0-110	298.3		3,642.5		145.4		1,939.7		152.9		1,702.8	
28	100-110	8.2	56.3			1.8	12.8			6.4	43.5		
28	100-110	9.1		88.6		3.6		35.4		5.5		53.2	
33	100-170	19.1	119.9							19.1	119.9		
33	100-170	33.7		343.1						33.7		343.1	
34	100-150	47.2	340.1			8.2	65.3			39.0	274.8		
34	100-150	535.9		6,969.1		335.7		4,610.1		200.2		2,359.0	
34	100-150	46.4			837.7	40.9		738.4		5.5			99.3
35	60-120	83.6	483.1							83.6	483.1		
35	60-120	140.9		2,110.4		68.1		1,037.3		72.8		1,073.1	
35	60-120	27.3			492.8	19.1		344.8		8.2			148.0
36	100-120	306.5	1,810.4							306.5	1,810.4		
36	100-120	0.9		8.7						.9		8.7	
Total		2,513.0	7,109.5	16,729.0	2,429.9	735.5	99.6	8,788.8	1,740.3	1,777.5	7,009.9	7,940.2	689.6
Coal bed No. 6													
27	60- 90	32.7	209.3							32.7	209.3		
27	60- 90	1.8		17.5						1.8		17.5	
28	50- 60	11.8	77.7							11.8	77.7		
28	50- 60	.9		8.8						.9		8.8	
33	30- 90	12.7	83.7							12.7	83.7		
33	30- 90	36.4		373.7						36.4		373.7	
34	60-110	78.2	508.9							78.2	508.9		
34	60-110	5.4		52.5						5.4		52.5	
35	60- 80	221.0	1,521.9							221.0	1,521.9		
36	80-120	351.2	2,359.2							351.2	2,359.2		
Total		752.1	4,760.7	452.5						752.1	4,760.7	452.5	
Township total		5,298.6	18,741.1	29,028.9	2,890.2	1,443.6	338.4	17,573.8	2,151.9	3,855.0	18,402.7	11,455.1	738.3

1984
Frank D. Spencer
Data held by USGS Branch of Coal Resources, Reston, Va.

Section No.	Limits of Over-Burden	Original resources: Area, in acres	Original resources: 2.5-5.0 ft	Original resources: 5.0-10 ft	Original resources: >10 ft	Mined and lost in mining: Area, in acres	Mined and lost in mining: 2.5-5.0 ft	Mined and lost in mining: 5.0-10 ft	Mined and lost in mining: >10 ft	Remaining resources: Area, in acres	Remaining resources: 2.5-5.0 ft	Remaining resources: 5.0-10 ft	Remaining resources: >10 ft
Measured and indicated—T. 1 N., R. 68 W.—Erie quadrangle													
Coal bed No. 2													
18	110-120	1.8	8.8							1.8	8.8		
19	140-210	310.4	1,849.2							310.4	1,849.2		
19	140-210	57.3		567.0						57.3		567.0	
20	190-310	223.9	1,666.0							223.9	1,666.0		
20	190-310	237.5		2,802.9						237.5		2,802.9	
21	180-390	51.8	282.5							51.8	282.5		
29	150-240	110.8	664.1							110.8	664.1		
30	180-240	64.6	380.8							64.6	380.8		
30	180-240	1.8		16.9						1.8		16.9	
Total		1,059.9	4,851.4	3,386.8						1,059.9	4,851.4	3,386.8	
Coal bed No. 3													
4	120-170	98.2	636.1							98.2	636.1		
4	120-170	211.2		2,666.9						211.2		2,666.9	
4	120-170	9.1			169.1					9.1			169.1
7	20-190	53.7	297.6							53.7	297.6		
8	90-200	318.1	2,150.9			46.4	377.3			271.7	1,773.6		
8	90-200	131.9		1,376.6		43.6		492.7		88.3		883.9	
9	130-200	60.8	428.8							60.8	428.8		
9	130-200	531.2		7,107.8		223.9		2,913.4		307.3		4,194.4	
16	20-260	71.8	558.9							71.8	558.9		
16	20-260	516.4		6,113.5		262.2		3,635.6		254.2		2,477.9	
17	40-200	47.2	314.0							47.2	314.0		
17	40-200	393.7		4,954.3		214.5		2,737.8		179.2		2,216.5	
18	30-200	496.6	3,244.1			6.3	46.9			490.3	3,197.2		
18	30-200	40.0		389.4		15.4		149.9		24.6		239.5	
19	80-200	69.1	532.9			10.0	79.6			59.1	453.3		
19	80-200	488.0		4,969.9		126.4		1,260.0		361.6		3,709.9	
20	180-290	27.2	195.7			8.1	62.2			19.1	133.5		
20	180-290	425.1		5,767.6		353.4		4,743.3		71.7		1,024.3	
21	160-450	314.7	2,120.6			3.6	28.6			311.1	2,092.0		
21	160-450	281.9		3,266.1		176.5		1,584.8		105.4		1,681.3	
21	160-450	4.5			79.6	1.8			31.8	2.7			47.8
28	170-550	168.4	1,067.8			5.4	41.4			163.0	1,026.4		
28	170-550	74.6		925.9		23.7		327.7		50.9		598.2	
28	170-550	25.4			487.4	23.6			452.7	1.8			34.7
29	160-410	206.8	1,408.6			111.0	834.1			95.8	574.5		
29	160-410	319.6		4,049.0		307.7		3,930.0		11.9		119.0	
29	160-410	58.2			1,115.0	58.2			1,115.0				
30	130-320	387.3	2,213.6							387.3	2,213.6		
30	130-320	7.3		73.8						7.3		73.8	
31	10-320	385.5	2,643.6			40.0	318.6			345.5	2,325.0		
31	10-320	252.7		2,804.5		54.5		656.5		198.2		2,148.0	
32	40-480	283.7	1,741.2							283.7	1,741.2		
32	40-480	74.5		791.2		8.2		92.6		66.3		698.6	
33	350-520	281.2	1,906.0							281.2	1,906.0		
Measured and indicated total		7,115.6	21,460.4	45,256.5	1,851.1	2,124.4	1,788.7	22,524.3	1,599.5	4,991.2	19,671.7	22,732.2	251.6

Inferred—T. 1 N., R. 68 W.—Erie quadrangle													
Coal bed No. 3													
33	350-520	154.6	1,058.0										
Total										154.6	1,058.0		
inferred		154.6	1,058.0							154.6	1,058.0		
Total measured, indicated, and inferred		7,270.2	22,518.4	45,256.5	1,851.1	2,124.4	1,788.7	22,524.3	1,599.5	5,145.8	20,729.7	22,732.2	251.6
Measured and indicated—T. 1 N., R. 68 W.—Erie quadrangle													
Coal bed No. 4													
17	180-200	2.7	13.3							2.7	13.3		
18	70-200	72.8	390.5							72.8	390.5		
19	35-180	507.1	3,095.0							507.1	3,095.0		
20	170-300	147.4	955.6			54.5	345.9			92.9	609.7		
20	170-300	106.4		1,185.1		46.5		576.0		59.9		609.1	
21	130-400	24.5	160.8			9.1	60.4			15.4	100.4		
28	150-500	111.0	762.7			25.4	171.6			85.6	591.1		
28	150-500	36.4		354.3		17.3		168.4		19.1		185.9	
29	170-260	120.0	767.1			89.0	578.5			31.0	188.6		
29	170-260	188.2		2,449.8		188.2		2,449.8					
29	170-260	25.4			478.5	25.4			478.5				
30	250-270	282.1	1,665.2							282.1	1,665.2		
31	0-380	155.5	1,587.7							155.5	1,587.7		
31	0-380	156.6		1,200.3						156.6		1,200.3	
32	60-350	334.0	2,192.8							334.8	2,192.8		
32	60-350	29.1		283.4						29.1		283.4	
Total		2,299.2	11,590.7	5,472.9	478.5	455.4	1,156.4	3,194.2	478.5	1,844.6	10,434.3	2,278.7	
Coal bed No. 5													
4	80-100	112.7	670.8							112.7	670.8		
4	80-100	3.6		35.0						3.6		35.0	
5	90-100	6.4	31.1							6.4	31.1		
7	80-100	46.3	319.5							46.3	319.5		
7	80.100	10.9		102.2						10.9		102.2	
8	80-100	299.9	1,968.2							299.9	1,968.2		
8	80-100	35.5		333.0						35.5		333.0	
9	100-150	61.3	356.4							61.3	356.4		
16	210-220	4.5	24.2							4.5	24.2		
17	120-220	52.7	305.9							52.7	305.9		
18	120-170	166.5	1,131.9							166.5	1,131.9		
18	120-170	20.9		203.4						20.9		203.4	
19	50-120	270.9	1,702.8							270.9	1,702.8		
19	50-120	138.3		1,379.7						138.3		1,379.7	
20	130-230	292.0	1,848.7							292.0	1,848.7		
21	150-370	60.9	354.3							60.9	354.3		
28	120-410	112.8	689.0							112.8	689.0		
28	120-410	7.3		72.0						7.3		72.0	
29	180-280	151.8	952.4							151.8	952.4		
29	180-280	5.4		53.8						5.4		53.8	
30	110-230	156.4	1,056.9							156.4	1,056.9		
30	110-230	59.2		582.5						59.2		582.5	
31		120-320	49.0	270.9						49.0	270.9		
32	150-400	131.7		809.0						131.7		809.0	
32	150-400	17.6		172.5						17.6		172.5	
33	150-400	1.8	9.8							1.8	9.8		
Total		2,276.3	12,501.8	3,743.1						2,276.3	12,501.8	3,743.1	

1984
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Section No.	Limits of Over-Burden	Original resources: Area, in acres	Original resources: 2.5-5.0 ft	Original resources: 5.0-10 ft	Original resources: >10 ft	Mined and lost in mining: Area, in acres	Mined and lost in mining: 2.5-5.0 ft	Mined and lost in mining: 5.0-10 ft	Mined and lost in mining: >10 ft	Remaining resources: Area, in acres	Remaining resources: 2.5-5.0 ft	Remaining resources: 5.0-10 ft	Remaining resources: >10 ft
Coal bed No. 6													
4	30- 80	306.7	2,157.8							306.7	2,157.8		
4	30- 80	174.5		1,712.0						174.5		1,712.0	
5	50- 60	21.9	139.9							21.9	139.9		
6	30- 50	37.3	232.2							37.3	232.2		
7	40- 65	169.2	1,123.3							169.2	1,123.3		
8	60-100	192.6	1,128.9			2.7	21.5			189.9	1,107.4		
8	60-100	2.7		24.8						2.7		24.8	
9	70-160	178.2	1,191.9			21.8	173.6			156.4	1,018.3		
9	70-160	364.8		4,327.2		209.8		3,995.2		155.0		332.0	
16	160-200	120.0	790.2			11.8	93.9			108.2	696.3		
16	160-200	109.2		1,215.5		103.7		1,162.0		5.5		53.5	
17	40- 90	169.2	1,031.8							169.2	1,031.8		
17	40- 90	3.6		32.4						3.6		32.4	
18	50-140	123.9	792.8							123.9	792.8		
18	50-140	20.9		208.9						20.9		208.9	
20	100-230	185.7	1,153.1							185.7	1,153.1		
20	100-230	20.9		188.6						20.9		188.6	
21	100-230	80.1	475.0							80.1	475.0		
28	100-150	16.3	96.5							16.3	96.5		
29	50-100	141.0	741.9							141.0	741.9		
30	100-130	9.1	50.5							9.1	50.5		
32	70-100	9.0	51.2							9.0	51.2		
33	100-140	9.0	51.2							9.0	51.2		
Total		2,465.8	11,208.2	7,709.4		349.8	289.0	5,157.2		2,116.0	10,919.2	2,552.2	
Measured and indicated total		15,371.4	62,670.5	64,759.7	2,329.6	2,929.6	3,234.1	30,875.7	2,078.0	12,288.0	59,436.4	33,884.0	251.6
Erie quadrangle total, all coal beds		23,345.5	111,748.7	81,128.5	3,269.8	3,735.6	5,250.1	35,942.9	2,894.0	19,609.9	106,498.6	45,185.6	375.8
Measured and indicated—T. 1 N., R. 68 W.—Frederick quandrangle													
Coal bed No. 1													
13	450-500	80.9	433.5							80.9	433.5		
14	450-500	75.5	397.2							75.5	397.2		
22	500-520	3.6	17.5							3.6	17.5		
23	500-520	18.1	97.6							18.1	97.6		
Total		178.1	945.8							178.1	945.8		
Coal bed No. 3													
1	200-290	635.8		8,938.6		204.1		3,116.7		431.7		5,821.9	
2	180-260	308.9	2,350.8							308.9	2,350.8		
2	180-260	306.8		3,684.2		61.7		928.4		245.1		2,755.8	
2	180-260	11.8			213.0	11.8			213.0				
3	110-230	.9	7.1							.9	7.1		
3	110-230	553.1		7,165.5		346.4		4,577.8		206.7		2,587.7	
4	120-170	51.9		709.5						51.9		709.5	
9	130-200	53.8		749.7						53.8		749.7	
10	0-250	3.6	28.6							3.6	28.6		
10	0-250	380.9		5,741.5		186.2		2,861.7		194.7		2,879.8	
10	0-250	189.9			3,691.0	189.9			3,691.0				
11	250-300	199.3	1,347.8			0.9	7.1			198.4	1,340.7		
11	250-300	191.7		2,035.1		18.1		201.6		173.6		1,833.5	

12	0-300	61.0	433.4							61.0	433.4		
12	0-300	544.3		6,435.8		192.7		2,400.2		351.6		4,035.6	
13	120-320	202.9	1,368.6							202.9	1,368.6		
13	120-320	358.5		4,036.2		24.5		338.3		334.0		3,697.9	
14	50-430	102.7	685.2							102.7	685.2		
14	50-430	385.9		5,158.2		147.4		2,002.2		238.5		3,156.0	
14	50-430	17.3			321.5					17.3			321.5
15	320-390	436.9		6,363.8		388.7		5,783.7		48.2		580.1	
15	320-390	203.1			3,774.6	203.1			3,774.6				
16	20-260	43.7		534.7		13.6		185.7		30.1	349.0		
21	160-450	46.4		572.6		28.2	399.5			18.2		173.1	
22	400-450	20.9	166.4							20.9	166.4		
22	400-450	617.9		9,220.0		343.3		5,621.7		274.6		3,598.3	
23	60-510	12.7	99.4							12.7	99.4		
23	60-510	570.8		8,242.4		221.1	3,169.5			349.7		5,072.9	
23	60-510	39.2			728.5	6.3			117.0	32.9			611.5
24	200-530	93.7	685.0							93.7	685.0		
24	200-530	539.7		6,650.6		35.3	503.6			504.4		6,147.0	
25	450-540	315.9	1,911.5							315.9	1,911.5		
25	450-540	116.5		1,318.0						116.5		1,318.0	
26	60-530	158.2	1,044.5							158.2	1,044.5		
26	60-530	302.0		3,960.4		7.2		113.0		294.8		3,847.4	
26	60-530	1.8			33.4					1.8			33.4
27	90-520	173.9	1,157.3							173.9	1,157.3		
27	90-520	459.0		5,687.3		16.3		209.9		442.7		5,477.4	
28	170-550	44.6	297.2							44.6	297.2		
28	170-550	1.8		17.7						1.8		17.7	
33	350-520	8.2	65.2							8.2	65.2		
34	390-550	94.9	752.6							94.9	752.6		
34	390-550	180.1		1,891.6						180.1		1,891.6	
35	500-540	160.8	1,222.8							160.8	1,222.8		
35	500-540	210.8		2,270.4						210.8		2,270.4	
36	400-580	7.2	35.0							7.2	35.0		
Total		9,421.7	13,658.4	91,383.8	8,762.0	2,646.8	7.1	32,413.5	7,795.6	6,774.9	13,651.3	58,970.3	966.4
Coal bed No. 4													
21	130-400	12.6	67.4							12.6	67.4		
22	350-400	41.9	233.2							41.9	233.2		
Total		54.5	300.6							54.5	300.6		
Coal bed No. 5													
1	180-210	161.1	855.3							161.1	855.3		
2	80-100	92.8	575.4							92.8	575.4		
3	80-130	201.0	1,252.3							201.0	1,252.3		
3	80-130	25.4		296.5						25.4		296.5	
3	80-130	5.4			97.4					5.4			97.4
4	80-100	3.6	18.9							3.6	18.9		
11	170-210	9.9	51.7							9.9	51.7		
12	0-270	72.7	539.6							72.7	539.6		
13	200-370	165.6	1,053.3							165.6	1,053.3		
14	200-320	364.8	2,426.1							364.8	2,426.1		
14	200-320	16.4		159.6						16.4		159.6	
15	200-310	119.1	742.5							119.1	742.5		
15	200-310	0.9		8.2						0.9		8.2	
22	300-400	208.2	1,362.4							208.2	1,362.4		
22	300-400	66.3		695.8						66.3		695.8	
23	330-370	224.6	1,471.8							224.6	1,471.8		
23	330-370	60.9		636.3						60.9		636.3	
24	200-470	170.0	958.0							170.0	958.0		
Total		1,968.7	11,307.3	1,796.4	97.4					1,968.7	11,307.3	1,796.4	97.4

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Frank D. Spencer
Data held by USGS Branch of Coal Resources, Reston, Va.

Section No.	Limits of Over-Burden	Original resources: Area, in acres	Original resources: 2.5-5.0 ft	Original resources: 5.0-10 ft	Original resources: >10 ft	Mined and lost in mining: Area, in acres	Mined and lost in mining: 2.5-5.0 ft	Mined and lost in mining: 5.0-10 ft	Mined and lost in mining: >10 ft	Remaining resources: Area, in acres	Remaining resources: 2.5-5.0 ft	Remaining resources: 5.0-10 ft	Remaining resources: >10 ft
Coal bed No. 6													
1	100-125	164.7	1,118.3							164.7	1,118.3		
2	80-100	115.5	741.1							115.5	741.1		
3	80-100	8.2		76.9						8.2		76.9	
3	80-100	111.9	670.4							111.9	670.4		
3	0-100	9.1		89.7						9.1		89.7	
4	30-80	40.0	268.5							40.0	268.5		
4	30-80	9.1		93.4						9.1		93.4	
9	70 160	19.1	126.0							19.1	126.0		
9	70-160	30.0		345.4		10.9		133.7		19.1		211.7	
10	40- 80	28.2	180.1							28.2	180.1		
10	40- 80	26.4		274.6						26.4		274.6	
11	140-180	68.2	357.6							68.2	357.6		
12	290-310	13.5	74.0							13.5	74.0		
13	60-310	290.1	1,449.5							290.1	1,449.5		
14	300-310	130.9	757.7							130.9	757.7		
14	300-310	19.1		210.9						19.1		210.9	
Total		1,084.0	5,743.2	1,090.9		10.9		133.7		1,073.1	5,743.2	957.2	
Coal bed No. 7													
22	180-220	10.9	53.0							10.9	53.0		
23	200-225	5.4	26.2							5.4	26.2		
Total		16.3	79.2							16.3	79.2		
Township total		12,723.3	32,034.5	94,271.1	8,859.4	2,657.7	7.1	32,547.2	7,795.6	10,065.6	32,027.4	61,723.9	1,063.8
Inferred—T. 1 N., R. 68 W.—Frederick quadrangle													
Coal bed No. 3													
33	350-520	29.1	206.1							29.1	206.1		
34	390-550	226.8	1,533.8							226.8	1,533.8		
35	500-540	258.6	1,700.4							258.6	1,700.4		
36	400-580	22.7	110.4							22.7	110.4		
Township total		537.2	3,550.7							537.2	3,550.7		
Township total, measured, indicated, and inferred		13,260.5	35,585.2	94,271.1	8,859.4	2,657.7	7.1	32,547.2	7,795.6	10,602.8	35,578.1	61,723.9	1,063.8
Measured and indicated—T. 2 N., R. 67 W.—Frederick quadrangle													
Coal bed No. 3													
19	60-160	7.2	42.5							7.2	42.5		
19	60-160	241.9		3,233.8		231.4		3,113.0		10.5		120.8	
19	60-160	11.8			215.1	11.8			215.1				
20	100-200	69.1	432.7			14.5	107.4			54.6	325.3		
20	100-200	163.0		1,821.8		152.1		1,711.0		10.9		110.8	
21	140-300	230.1	1,188.8							230.1	1,188.8		
27	300-400	59.2	471.5							59.2	471.5		
27	300-400	216.0		1,911.6						216.0		1,911.6	
28	300-410	234.6	1,339.2							234.6	1,339.2		
29	30-270	106.5	664.8			4.5	35.8			102.0	629.0		
29	30-270	319.7		3,719.8		215.9		2,466.5		103.8		1,253.3	
30	70-250	8.1	58.4							8.1	58.4		
30	70-250	427.8		5,178.3		278.5		3,547.0		149.3		1,631.3	
31	200-300	432.1		5,447.1		331.2		4,181.7		100.9		1,265.4	

31	200-300	8.2			150.9					8.2			150.9
32	0-310	38.2	256.6							38.2	256.6		
32	0-310	378.4		5,089.4		21.8		340.8		356.6		4,748.6	
32	0-310	52.3			994.4	35.4			678.4	16.9			316.0
33	130-380	280.9	1,181.1							280.9	1,181.1		
33	130-380	63.6		619.1						63.6		619.1	
34	415-480	121.7	845.9							121.7	845.9		
34	415-480	242.9		2,149.6						242.9		2,149.6	
Total		3,713.3	6,481.5	29,170.5	1,360.4	1,297.1	143.2	15,360.0	893.5	2,416.2	6,338.3	13,810.5	466.9
Inferred—T.2 N., R. 67 W.—Frederick quadrangle													
Coal bed. No. 3													
21	300-310	14.6	81.8							14.6	81.8		
22	320-340	134.9	802.8							134.9	802.8		
27	200-360	68.1	518.2							68.1	518.2		
27	300-360	14.5		128.3						14.5		128.3	
28	300-410	5.5	34.0							5.5	34.0		
Township total, inferred		237.6	1,436.8	128.3						237.6	1,436.8	128.3	
Measured and indicated—T. 2., R. 67 W.—Frederick quadrangle													
Coal bed No. 4													
32	250-300	63.7	395.8							63.7	395.8		
32	250-300	28.9		339.5						28.9		339.5	
33	320-350	11.8	57.4							11.8	57.4		
Total		104.4	453.2	339.5						104.4	453.2	339.5	
Coal bed No. 5													
19	130-150	79.1	455.4							79.1	455.4		
20	70-130	296.5	1,958.9							296.5	1,958.9		
21	70-100	101.9	636.5							101.9	636.5		
29	70-100	570.5	4,156.7							570.5	4,156.7		
30	80-150	141.0	895.4							141.0	895.4		
30	80-150	171.1		2,195.0						171.1		2,195.0	
31	140-210	82.7	527.8							82.7	527.8		
31	140-210	15.4		149.9						15.4		149.9	
32	200-320	406.6	2,765.0							406.6	2,765.0		
32	200-320	49.1		483.0						49.1		483.0	
33	160-330	206.4	1,202.3							206.4	1,202.3		
34	300-330	107.4	669.9							107.4	669.9		
Total		2,227.7	13,267.9	2,827.9						2,227.7	13,67.9	2,827.9	
Coal bed No. 6													
19	40- 50	8.2	39.9							8.2	39.9		
30	90-100	4.5	21.9							4.5	21.9		
31	90-180	7.2	36.1							7.2	36.1		
32	90-180	33.6	172.5							33.6	172.5		
33	150-250	81.8	481.1							81.8	481.1		
34	150-250	93.7	568.5							93.7	568.5		
Total		229.0	1,320.0							229.0	1,320.0		

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Section No.	Limits of Over-Burden	Original resources: Area, in acres	Original resources: 2.5-5.0 ft	Original resources: 5.0-10 ft	Original resources: >10 ft	Mined and lost in mining: Area, in acres	Mined and lost in mining	Mined and lost in mining: 5.0-10 ft	Mined and lost in mining: >10 ft	Remaining resources: Area, in acres	Remaining resources: 2.5-5.0 ft	Remaining resources: 5.0-10 ft	Remaining resources: >10 ft
Coal bed No. 7													
29	90-100	2.4	12.0							2.4	12.0		
31	90-100	7.2	40.1							7.2	40.1		
32	70- 90	59.1	372.8							59.1	372.8		
32	70- 90	16.3		165.3						16.3		165.3	
Total		85.0	424.9	165.3						85.0	424.9	165.3	
Measured and indicated.		6,359.4	21,947.5	32,503.2	1,360.4	1,297.1	143.2	15,360.0	893.5	5,062.3	21,804.3	17,143.2	466.9
Measured, indicated, and inferred.		6,597.0	23,384.3	32,631.5	1,360.4	1,297.1	143.2	15,360.0	893.5	5,299.9	23,241.1	17,271.5	466.9
Measured and indicated—T. 1 N., R. 67 W.—Frederick quadrangle													
Coal bed No. 3													
3	400-440	229.4	1,304.5							229.4	1,304.5		
4	130-390	240.1	1,440.6	79.7						240.1	1,440.6		
4	130-390	8.2								8.2		79.7	
5	0-350	11.3	90.0							11.3	90.0		
5	0-350	369.9		5,509.3	2,273.9					369.9		5,509.3	
5	0-350	127.2								127.2			2,273.9
6	220-400	446.8		5,955.8		429.5			5,719.8	17.3		236.0	
7	320-350	430.5		6,258.2		235.7			3,347.7	194.8		2,910.5	
7	320-350	32.7			612.5					32.7			612.5
8	0-400	28.2	224.7							28.2	224.7		
8	0-400	413.1		6,090.0						413.1		6,090.0	
8	0-400	115.5			2,150.2					115.5			2,150.2
9	260-500	93.8	617.2							93.8	617.2		
15	400-480	77.2	527.2							77.2	527.2		
16	60-520	114.7	655.9							114.7	655.9		
17	40-500	64.6	485.6							64.6	485.6		
17	40-500	470.5		6,266.4		56.4		949.3		414.1		5,317.6	
17	40-500	85.5			1,627.6	13.7			250.3	71.8			1,377.3
18	270-520	303.9		4,564.7		61.9		1,234.5		242.0		3,330.2	
18	270-520	246.6			4,684.3	114.7			2,098.4	131.9			2,585.9
19	420-530	452.3		6,897.8		190.2		3,019.2		262.1		3,878.6	
19	420-530	187.5			3,507.9	92.8			1,723.4	94.7			1,784.5
20	450-540	268.4	1,959.3							268.4	1,959.3		
20	450-540	368.5		4,264.2						368.5		4,264.2	
20	450-540	1.8			33.0					1.8			33.0
21	400-430	280.3	1,470.6							280.3	1,470.6		
22	420-500	349.3	2,481.1							349.3	2,481.1		
27	430-590	40.9	267.8							40.9	267.8		
28	440-550	154.7	854.4							154.7	854.4		
29	420-520	71.0	565.3							71.0	565.3		
29	420-520	307.5		3,777.1						307.5		3,777.1	
30	510-550	193.8	1,363.5							193.8	1,363.5		
30	510-550	382.1		4,561.4						382.1		4,561.4	
31	540-630	23.6	141.7							23.6	141.7		
34	570-690	254.7	1,439.7							254.7	1,439.7		
Total		7,246.1	15,889.1	54,224.6	14,889.4	1,194.9		14,270.5	4,072.1	6,051.2	15,889.1	39,954.6	10,817.3

Inferred—T. 1 N., R. 67 W.—Frederick quadrangle

Coal bed No. 3

3	400-440	32.8	159.6							32.8	159.6		
9	260-500	41.0	249.1							41.0	249.1		
10	380-550	86.5	439.1							86.5	439.1		
15	400-480	232.1	1,402.8							232.1	1,402.8		
16	220-460	116.5	721.5							116.5	721.5		
27	430-590	207.4	1,083.1							207.4	1,083.1		
28	440-550	151.9	817.0							151.9	817.0		
29	420-520	61.9	463.9							61.9	463.9		
29	420-520	190.2		2,194.4						190.2		2,194.4	
30	510-550	.9	7.1							.9	7.1		
30	510-550	55.4		646.8						55.4		646.8	
31	540-630	389.4	2,641.4							389.4	2,641.4		
31	540-630	149.1		1,527.0						149.1		1,527.0	
32	540-650	412.6	2,939.3							412.6	2,939.3		
32	540-650	227.4		2,331.9						227.4		2,331.9	
33	520-700	232.9	1,219.3							232.9	1,219.3		
34	570-700	57.3	278.9							57.3	278.9		
Inferred resources		2,645.3	12,422.1	6,700.1						2,645.3	12,422.1	6,700.1	
Total No. 3.		9,891.4	28,311.2	60,924.7	14,889.4	1,194.9		14,270.5	4,072.1	8,696.5	28,311.2	46,654.7	10,817.3

Measured and indicated—T. 1N., R. 67 W.—Frederick quadrangle

Coal bed No. 5

3	300-330	20.8	109.5							20.8	109.5		
4	160-250	140.9	790.8				15.5	90.4		125.4	700.4		
5	0-300	375.8	2,598.9							375.8	2,598.9		
5	0-300	65.5		649.1						65.5		649.1	
6	250-260	7.2	35.0							7.2	35.0		
7	240-370	246.5	1,689.4							246.5	1,689.4		
7	240-370	159.3		1,493.9						159.3		1,493.9	
8	300-330	353.0	2,449.4							353.0	2,449.4		
8	300-330	.9		8.2						.9		8.2	
16	360-410	18.3	114.0							18.3	114.0		
16	360-410	5.4		55.4						5.4		55.4	
17	40-390	211.0	1,322.7							211.0	1,322.7		
17	40-390	6.4		63.0						6.4		63.0	
18	170-410	454.1	3,311.2							454.1	3,311.2		
18	170-410	24.6		221.8						24.6		221.8	
19	310-420	377.6	2,544.9							377.6	2,544.9		
19	310-420	96.5		904.9						96.5		904.9	
20	350-440	325.7	1,200.2							325.7	2,200.2		
20	350-440	217.5		2,284.1						217.5		2,284.1	
21	300-430	289.4	1,720.0							289.4	1,720.0		
21	300-430	93.7		947.4						93.7		947.4	
22	430-450	4.5	22.1							4.5	22.1		
28	400-410	100.9	651.0							100.9	651.0		
28	400-410	10.0		974.4						10.0		974.4	
29	400-410	131.0	780.3							131.0	780.3		
29	400-410	10.0		97.4						10.0		97.4	
30	280-400	135.5	841.5							135.5	841.5		
Total		3,882.0	21,180.9	7,699.6		15.5	90.4			3,866.5	21,090.5	7,699.6	

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Measured and indicated—T. 1 N., R. 67 W.—Frederick quadrangle

Coal bed No. 6													
3	150-250	59.9	360.9							59.9	360.9		
4	150-220	415.7	2,524.4							415.7	2,524.4		
5	200-300	38.1	203.4							38.1	203.4		
7	311-410	.9	4.3							.9	4.3		
8	120-200	5.4	27.4							5.4	27.4		
9	260-320	40.1	213.3							40.1	213.3		
16	240-320	13.6	68.0							13.6	68.0		
17	180-240	183.8	1,135.9							183.8	1,135.9		
17	180-240	34.6		381.6						34.6		381.6	
18	260-300	68.2	368.4							68.2	368.4		
19	280-340	31.8	171.9							31.8	171.9		
20	310-350	118.8	734.0							118.8	734.0		
20	310-350	37.2		397.0						37.2		397.0	
21	350-375	10.0	48.7							10.0	48.7		
28	350-375	1.8	8.8							1.8	8.8		
29	400-420	.9	4.4							.9	4.4		
30	400-410	3.6	17.7							3.6	17.7		
Total		1,064.4	5,891.5	778.6						1,064.4	5,891.5	778.6	
Coal bed No. 7													
5	130-200	90.0	523.3							90.0	523.3		
8	150-210	143.7	903.2							143.7	903.2		
8	150-210	21.8		196.7						21.8		196.7	
19	400-430	10.9	53.0							10.9	53.0		
30	400-430	2.7	13.1							2.7	13.1		
Total		269.1	1,492.6	196.7						269.1	1,492.6	196.7	
Measured and indicated total		12,461.6	44,454.1	62,899.5	14,889.4	1,210.4	90.4	14,270.5	4,072.1	11,251.2	44,363.7	48,629.5	10,817.3
Measured, indicated, and inferred total		15,106.9	56,876.2	69,599.6	14,889.4	1,210.4	90.4	14,270.5	4,072.1	13,896.5	56,785.8	55,329.6	10,817.3
Quadrange grand total		40,263.0	134,586.8	225,711.1	27,999.4	6,608.8	579.1	79,751.5	14,913.1	33,654.2	134,007.7	145,780.1	13,086.3

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