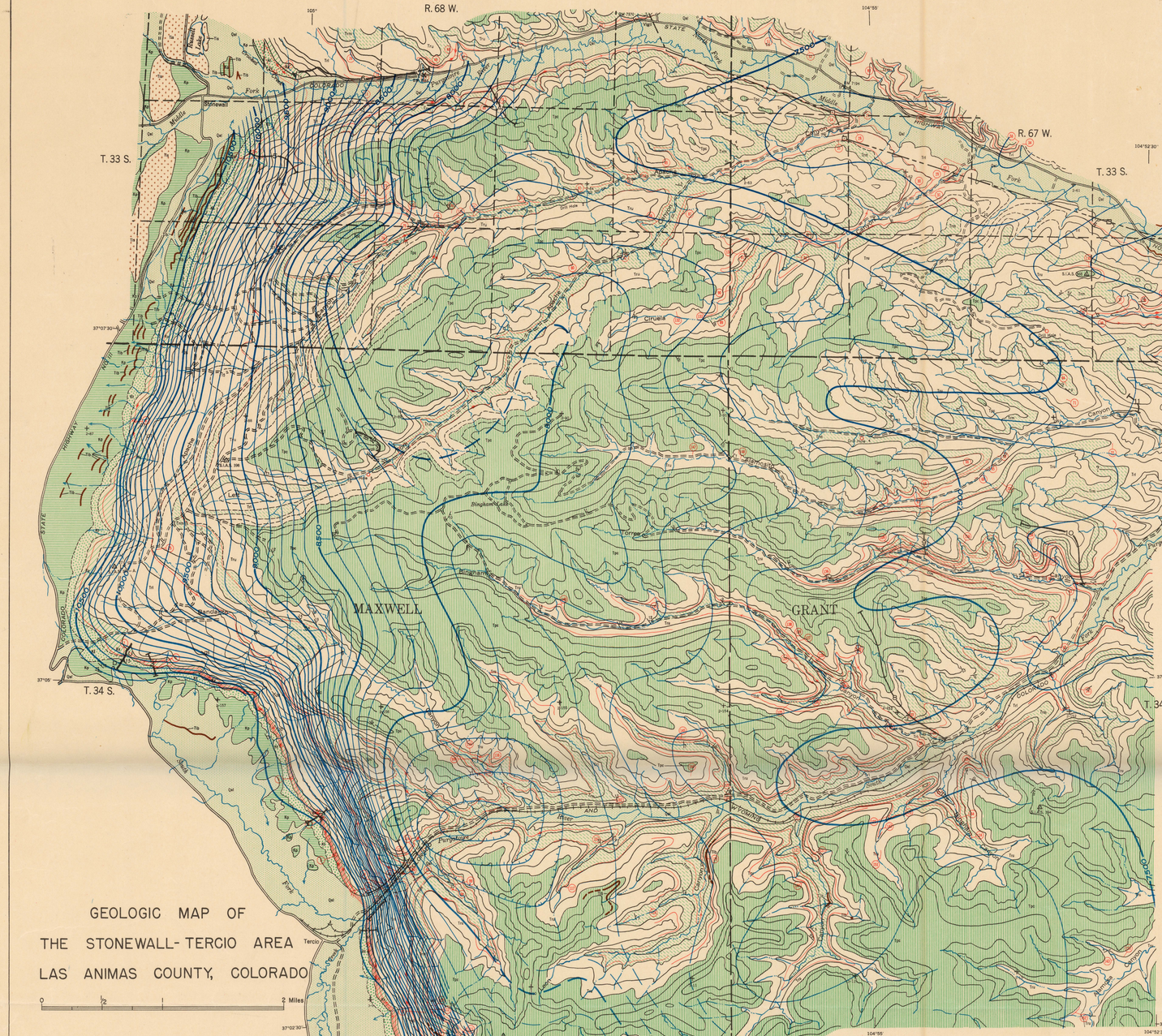
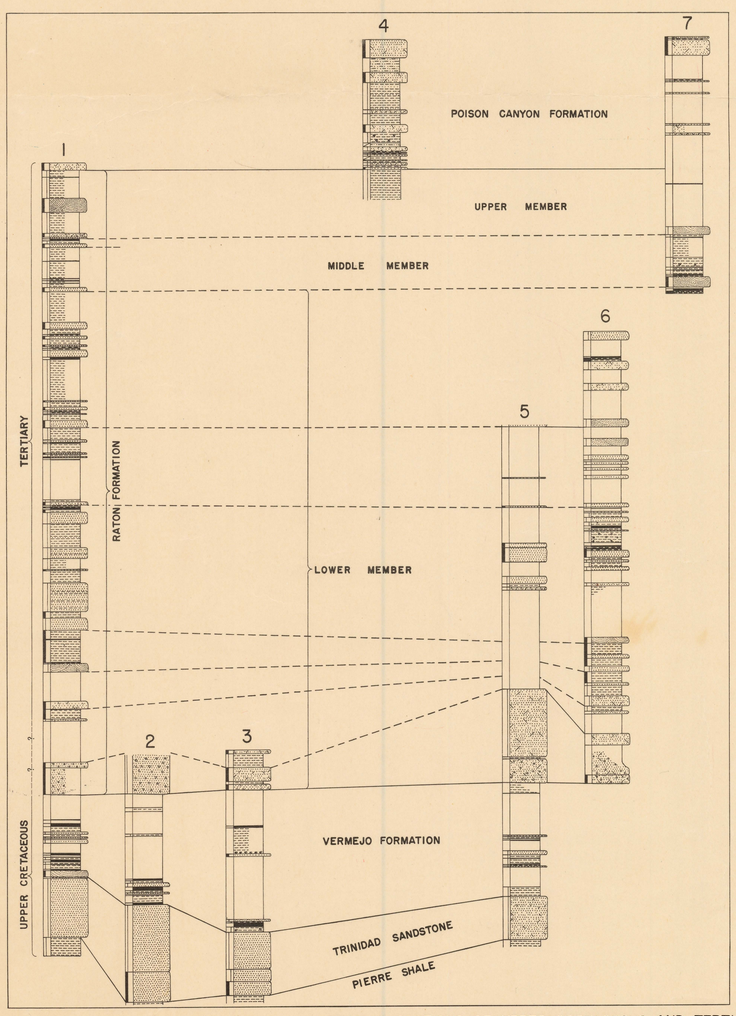
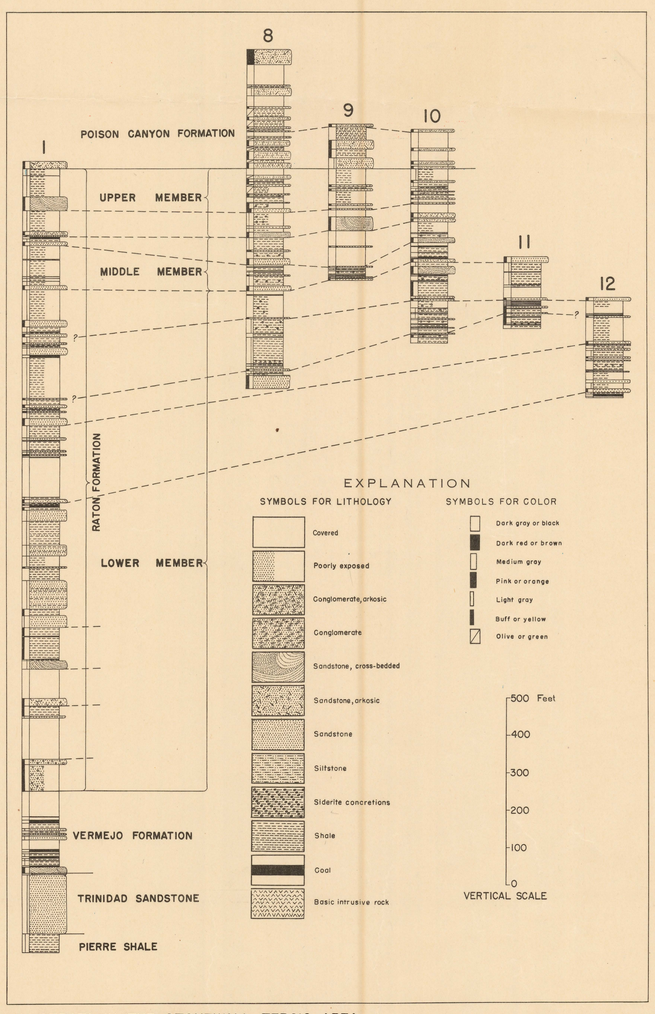
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

COAL INVESTIGATIONS
MAP C 4 (IN 2 SHEETS) SHEET 1

GEOLOGIC MAP OF THE STONEWALL-TERCIO AREA LAS ANIMAS COUNTY, COLORADO







GRAPHIC SECTIONS OF UPPER CRETACEOUS AND TERTIARY STRATA IN THE STONEWALL-TERCIO AREA
(NUMBERS INDICATE LOCATION OF SECTIONS ON GEOLOGIC MAP)

EXPLANATION

SEDIMENTARY ROCKS

- Qal — Alluvium. Valley fill, sand wash, land slides, fan material, and locally soilmantle.
- Tpc — Poison Canyon formation. Yellow shale, and buff to red arkosic sandstone and conglomerate.
- Tru, Tne, Trt — Raton formation. Black to gray carbonaceous and silty shale, coal, buff to green sandstone, and buff to red conglomerate. Includes upper, middle and lower members (Tru, Tm, Trl, respectively). Contact lines shown within formation are bases of sandstone beds (see graphic sections 1-12).
- Kv — Vermejo formation. Dark gray carbonaceous shale, coal, and buff to light gray friable sandstone.
- Kt — Trinidad sandstone. Light gray to buff massive arkosic sandstone.
- Kp — Pierre shale. Gray marine shale, locally silicified; upper 200 ft. is an alternation of thin-bedded buff sandstone and shale.

Pleistocene and Recent; Pliocene; Miocene; Paleocene — QUATERNARY; TERTIARY

Upper Cretaceous — CRETACEOUS

Eocene(?) — TERTIARY

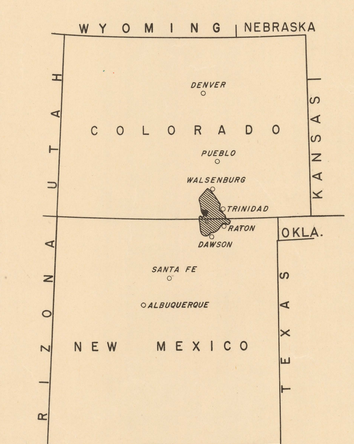
IGNEOUS ROCKS

- Tib — Basic intrusive rocks
- Tis — Silicic intrusive rocks

- Geologic Contact (Dashed where inferred)
- Fault (U, upthrown side. D, downthrown side.)
- Strike and dip of beds.
- Line of graphic section
- Approximate location of coal drill hole
- Mine or prospect

Coal bed
Solid line where correlation and linear extent known, dash and dot line where correlation and linear extent uncertain, dotted line where concealed by alluvium. Coal beds less than 14 inches are not mapped. Arrow points on coal outcrop lines indicate direction of diminishing observed or inferred thickness of coal beds; open arrow points enclose coal more than 28 inches thick, and solid arrow points inclose coal more than 42 inches thick. (1) refers to measured section.

- 8000 — Structure contours. Contours approximate, drawn on base of middle member of the Raton formation. Dashed lines are shown in areas of inadequate control. Contour interval 100-feet. Datum sea level.
- Bench Mark
- S.L.A.S. 396 Triangulation station
- 2-132 Principal or center point of aerial photograph
- Land-grant corner



INDEX MAP OF COLORADO AND NEW MEXICO SHOWING AREA OF THIS REPORT
0 50 100 200 MILES

EXPLANATION
Area of this report
Raton Coal region

Base of geologic map compiled from township plats of the Bureau of Land Management and planimetric maps prepared by the Geological Survey from aerial photographs.

Drafting by M. J. Cowan

GEOLOGY AND COAL RESOURCES OF THE STONEWALL-TERCIO AREA LAS ANIMAS COUNTY, COLORADO

BY
G. H. Wood, R. B. Johnson, D. H. Eargle, R. T. Duffner, and Harald Major
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INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C.

COAL INVESTIGATIONS
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GEOLOGY AND COAL RESOURCES
OF THE STONEWALL-TERCIO AREA,
LAS ANIMAS COUNTY, COLORADO

INTRODUCTION

The Stonewall-Tercio area lies along the western edge of the Trinidad coal field, Colorado, a part of the large Raton Mesa region of Colorado and New Mexico. Coal of Upper Cretaceous and early Tertiary age in that region has been utilized extensively for coking and for domestic heating. Present mining operations are limited, but mining is possible throughout much of the field.

SEDIMENTARY ROCKS

Cretaceous and Tertiary strata crop out over most of the Stonewall-Tercio area. The distribution and stratigraphic sequence of coal beds and rock units are shown on the geologic map, and on the coal sections and the graphic sections. Coal beds equal to or greater than 14 in. in thickness are drawn on the map. Quaternary alluvium occurs in the valley bottoms. Colluvium and soil mantle conceal the underlying geologic units in some of the area.

Upper Cretaceous rocks. Along the western margin of the area, steeply dipping rocks of Upper Cretaceous age crop out as a narrow belt. The Pierre shale is the oldest formation exposed. It is about 1,500 ft thick and consists of gray to dark gray shale interbedded with thin lenses of gray sandstone and gray limestone. These strata contain a marine fauna which includes several species of *Inoceramus, Baculites,* and *Ostrea.* The upper 100 to 200 ft of the formation is a sequence of alternating shale and sandstone beds that have been termed the "transition zone" (Lee and Knowlton, p. 48).

The Trinidad sandstone, 120 to 260 ft thick, conformably overlies and may intertongue with the higher beds of the Pierre shale (Lee and Knowlton, pl. 4). It is a light gray to buff fine- to medium-grained quartzose sandstone that is slightly arkosic in a few places. Cementing materials are clay, calcite, iron oxide, and secondary silica. Beds are usually massive and form cliffs. Abundant casts of *Halymenites major* Lesquereux aid in the identification of the Trinidad sandstone. The belt of outcrop is covered over most of its extent by alluvial and colluvial deposits.

The coal-bearing Vermejo formation conformably overlies and intertongues with the Trinidad sandstone (Lee and Knowlton, pl. 4). The formation, which ranges from 220 to 380 ft in thickness, consists of buff sandstone, gray shale, and coal beds. The sandstone beds are lenticular, fine-grained, and occasionally cross-bedded. They are moderately cemented, usually friable, and seldom crop out as cliffs or ledges. Sandy carbonaceous shale beds comprise most of the formation. Lenticular coal beds crop out in persistent zones in these shale beds. The basal beds are of Montana age and the higher beds are probably of Laramie age (Brown, p. 82).

Paleocene rocks. Paleocene rocks, deposited in a continental environment, crop out over most of the area. They include the coal-bearing Raton formation and the non-coal-bearing Poison Canyon formation of which only the basal part is exposed. Local intraformational disconformities and angular unconformities are common in these strata. Lines drawn on the bases of a number of lenticular but persistent sandstone beds are shown on the map in the area of outcrop of these formations. The mapped beds are correlated in the graphic sections.

The Raton formation may lie unconformably on the Vermejo formation (Lee and Knowlton, p. 55). However, data bearing on the existence of an unconformity in the Stonewall-Tercio area are indefinite owing to poor exposures and short lateral extent of the outcrops. Elsewhere on the margins of the Raton Mesa region the basal beds of the Raton formation lie unconformably on the Vermejo formation. The Raton formation is mainly Paleocene in age, but an indefinite interval at the base has been assigned to the Upper Cretaceous (Brown, p. 83).

The basal bed of the Raton formation is a cliff-forming granule and pebble conglomerate, 100 to 250 ft thick. Portions of the bed are cross-bedded, however, the conglomerate as a whole is massive. The matrix is of sand ranging in grain size from fine to coarse. The sand grains are angular to sub-rounded with sub-angular grains predominating. The diameters of the granules and the pebbles range from one-eighth of an in. to two in. The degree of rounding varies from well-rounded to sub-angular. Considerable quantities of fresh feldspar occur throughout the conglomerate. Silica and chert are the principal cementing media. These clastics were derived from the pre-Cambrian rocks and from older sedimentary strata.

Above the conglomerate, 450 to 500 ft of sandstone and shale crop out in cliffs, ledges, and slopes. The sandstones are quartzose and arkosic, coarse- to medium-grained, and contain some fresh feldspar. They are lenticular, buff and occasionally cross-bedded. The intervening shales are commonly light gray and somewhat sandy. Interbedded in the shales are several thin and bony coal beds, which are less than 14 in. in thickness.

The overlying beds of the Raton formation include 1,000 to 1,100 ft of alternating beds of graywacke, arkose, shale, and coal. The thicker graywacke or arkosic beds contain weathered feldspars. They are generally lenticular, cross-bedded, ledge-forming, and are buff to olive green. Thin beds of buff to green fine-grained even-bedded graywacke occur with the shale beds. The thicker shale units are generally gray to dark gray. The carbonaceous content of each such unit decreases upward. Coal is intercalated in the shales as thin seams. Channel deposits of arkose form conspicuous ledges and cliffs.

Strata in the interval from 150 to 320 ft below the top of the Raton formation are here included in the middle member of the formation, which is well exposed along the north wall of the canyon of the South Fork of Purgatoire River about 1 mile west of the mouth of Bandarito Canyon. In this locality the middle member of the Raton formation consists from the base upward of the following units: an 11-ft massive bed of medium- to coarse-grained, buff graywacke; 104 ft of interbedded gray to black shales, medium-grained buff and brown sandstone, and thin coal beds; a 10-ft bed of medium- to coarse-grained buff graywacke; and 18 ft of interbedded medium-grained olive sandstone, gray to black shale, and coal beds. A massive bed of coarse-grained arkose, assigned to the upper member of the Raton formation, overlies this sequence on an erosional unconformity. The relief on the erosion surface is approximately 5 ft. The thickness of the middle member near Bandarito Canyon is 143 ft, which is about average for the map area. The lower and upper contacts are drawn on the bases of lenticular beds of graywacke and arkose, which laterally overlap through 50 ft of section. These strata are medium- to coarse-grained, thin- to massive-bedded, and occasionally cross-bedded. Below the beds of the middle member local unconformities are common in the Raton formation and above it they are less common. Beds of the middle member are not individually distinguishable from other strata in the Raton formation. Correlation of the member is, however, possible by lateral tracing of the beds and the member is thus a mappable unit. All of the Raton formation below it is included in the lower member of the formation and the relatively thin part of the formation above it is included in the upper member.

The Poison Canyon formation conformably overlies the Raton formation. The lower strata of the Poison Canyon have been traced from previously mapped outcrops to the north (Hills, p. 3) and have been found to intertongue with the upper part of the Raton formation. Approximately 1,700 to 1,800 ft of Poison Canyon strata are reported near the Spanish Peaks (Hills, p. 3). Several hundred feet of the basal part of the formation crop out in the Stonewall-Tercio area. The sandstone beds in it are massive, usually even-bedded, and form cliffs. They are coarse- to medium-grained arkosic sandstones containing much fresh feldspar. Fresh surfaces are buff, gray, or olive, but weathered surfaces are frequently stained red. Pebbles of granite, gneiss, and quartzite are scattered throughout the thicker sandstone beds. The shales are buff, olive, and tan and are slightly carbonaceous. The formation generally is barren of coal, although thin lenses of bony coal are present near the base in Alamosa Canyon.

Quaternary deposits. Quaternary alluvium occurs in the major valleys and in most tributaries. Colluvium and soil mantle were not mapped although these deposits cover some of the slopes and higher areas. Inferred geologic contacts are shown on the map with a dashed line.

IGNEOUS ROCKS

Numerous sills of Eocene (?) age intrude the Pierre shale and, to a lesser degree, the Vermejo and Raton formations. These intrusive rocks are intermediate to basic in composition and dark in color. They are fine grained and range in thickness from several inches to several feet. The alteration of country rock may extend for several feet beyond the contact and in a few localities coal is changed to natural coke and graphitic material. A large sill, silicic to intermediate in composition, intrudes the Pierre shale in T. 33 S., R. 68 W., secs. 20, 29, and 32. The central part of the sill is more silicic and is felsitic in texture. Silicification of shale along the margin of the intrusion may extend several feet beyond the contact. According to a personal communication from C. B. Read the sills were intruded prior to the Eocene folding and eastward thrusting of the Sangre de Cristo Mountains and are genetically related to the intrusives in the Spanish Peaks and Ash Mountain.

STRUCTURE

The Stonewall-Tercio area lies on the western margin of the Great Plains province and on the eastern edge of the Southern Rocky Mountain province. The principal structural feature is the asymmetric Raton Basin which partially lies within the map area. The axis of the folding of the basin trends north approximately at the west edge of the coal field. The western limb and the axis of the basin lie parallel and immediately adjacent to the strike foothills and valleys of the Sangre de Cristo Mountains.

The present trough of the basin is an average distance of 8 to 10 miles east of the axis and is east of the map area about 1 mile east of Weston. The lateral displacement of the trough from the axis may have occurred in the following manner, according to a personal communication from C. B. Read. An over-turned anticline and an underlying overturned syncline developed on the eastern margin of the Sangre de Cristo Mountains during the episode of the Laramide Revolution in which these mountains were thrust eastward. Although portions of the anticline are preserved in the mountains, most of it has been eroded away. The syncline is partially preserved in the Raton Mesa region, and constitutes the Raton Basin.

The eastern limb of the syncline underlies most of the Stonewall-Tercio area. This limb was further deformed or downwarped by compressive forces which folded the syncline and anticline. The trough of the Raton Basin is where the greatest downwarping has occurred.

The northward plunging end of the Tercio anticline enters the southernmost part of T. 34 S., R. 68 W. The structural relief of this anticline was not determined in the course of this work owing to the fact that the southern and western limbs are outside the mapped area. This anticline was folded concurrently with the basin.

Anticlinal noses, with several hundred feet of relief, modify the general eastward dip in the eastern part of the area. The axes trend and plunge eastward at approximately 100 ft per mile. These trends are normal to the strike of the foothills, bogbacks and the trough of the Raton Basin. A small synclinal depression occurs 2 miles northeast of of Tercio in the canyon of the South Fork of Purgatoire River.

Faults are uncommon. One normal fault with a maximum displacement of 35 ft is on the northern limb of the Tercio anticline. Fracturing along this fault took place during the folding of the anticline.

GEOLOGIC HISTORY

Early in the Lower Cretaceous epoch, the Rocky Mountain region was slightly above sea level. Later in the Lower Cretaceous the sea transgressed over a broad area as the result of gradual subsidence. This transgression, although locally initiated during Lower Cretaceous time, did not culminate until early in the Upper Cretaceous. Sand, with lesser quantities of mud, accumulated during the transgression and was eventually indurated into strata of the Dakota sandstone. Limy oozes, mud, and sand were subsequently deposited and consolidated into the Graneros shale, Greenhorn limestone, Carlile shale, Niobrara formation, and Pierre shale.

The initial movements of the Laramide Revolution began in late Pierre time, and resulted in a broad uplifting of the Rocky Mountain region. The Trinidad sandstone was laid down as an off-shore deposit during the regression which accompanied this uplift. Swamps and sluggish streams developed on the emerged surface of the Trinidad; and vegetable matter, sand, and mud accumulated in the swamps and on the flood plains. These sediments were later consolidated into the coal, shale, and sandstone of the Vermejo formation. Mountain building commenced west and southwest of the Stonewall-Tercio area during late Vermejo time. This was the first orogenic phase of the Laramide Revolution. Mountains which formed during this episode were eroded during Late Cretaceous and Paleocene time and contributed the vast amounts of sediments that formed the Raton formation in a slowly subsiding asymmetric basin. These sediments were deposited on piedmonts, flood plains, and in small irregular-shaped swamps in which vegetable matter, now preserved as coal, accumulated. Late in Raton time the mountains were rejuvenated, and sediments that were to form the upper part of the Raton formation were deposited concurrently with the lower strata of the Poison Canyon formation.

The Cuchara and Huerfano formations of Eocene age overlie the the Poison Canyon formation north of the area, and apparently record additional intermittent uplifts. After their deposition, large-scale intrusions of igneous material occurred in the vicinity of the Spanish Peaks and in adjacent parts of New Mexico. The intrusions were followed by a period of intense folding and thrusting in the Sangre de Cristo Mountains, which was coincident with the formation of the Raton basin. This period of mountain building is thought to be a late phase of the Laramide Revolution.

Later Tertiary events are not recorded in the rocks of the Stonewall-Tercio area and are only incompletely recorded in the nearby region. Degradation of the Sangre de Cristo Mountains, the Spanish Peaks, and possibly the rocks of the Raton basin probably began during Oligocene time. The Miocene epoch was a period of igneous intrusion and rejuvenation of the Sangre de Cristo Mountains. The Ogallala formation of Miocene and Pliocene age was deposited on the folded strata of the area, and has since been removed by erosion. Late in Pliocene time large quantities of volcanic material were extruded east of the coal field. These extrusions continued almost to the present. The topography of the Raton basin is the result of erosion which began during the Pliocene.

COAL

The occurrence of high volatile A and B bituminous coking and domestic coal in the Raton Mesa region is well known. The stratigraphy of the coal-bearing formations and the relations of the coal beds has been described in some detail by Richardson (pp. 87-154) and Lee (pp. 66-161). In the Stonewall-Tercio area, inadequate data derived from analyses suggest that coal in the Vermejo and Raton formations is of high volatile A bituminous rank. The data consist of analyses from two beds in the same mine (Analyses of Colorado coal p. 98); therefore, the rank of the coal is largely inferred from analyses in the surrounding portions of the Raton Mesa field where the information is adequate. All large-scale development and mining in the Stonewall-Tercio area has been done by the Colorado Fuel and Iron Corporation. In 1948-1949, no mines were operating.

Coal of the Vermejo Formation

Coal beds of the Vermejo formation crop out in several stratigraphic zones that lie in the lower 150 to 300 ft of the formation. Colluvium conceals most of the Vermejo in the northwestern part of the area and the presence of some of the zones is uncertain. Individual coal beds are lenticular and irregular in thickness and may extend from 3 to 5 miles along the outcrop. (See coal sections 1-10).

The roof of the coal beds is commonly carbonaceous shale. The floor at many places is carbonaceous shale and claystone, containing numerous imperfectly preserved root impressions. In several localities the floor is siliceous shale; in others, sandstone.

The coal is brittle and friable, has a bright luster, platy cleavage, prismatic cleat, and occasionally breaks with a conchoidal fracture. Partings in the coal beds are bony coal and shale. In hand specimens the coal appears to be composed of vitrain with subordinate quantities of durain and fusain. Impurities are pyrite and scattered quartz grains.

Near Tercio a coal bed in the Vermejo formation is approximately 20 ft above a 42 in. sill, basic to intermediate in composition, in the Trinidad sandstone. The lower 2 ft 3 in of the bed is composed of masses of spheroidal coal. These masses are megascopically of pure, hard and bright or glossy coal. Moore states that such a physical characteristic may be caused by nearby igneous intrusions (Moore, pp. 247-250). However, there is no apparent alteration of coal, shale, or sandstone between the sill and the spheroidal coal. The following excerpt concerning spheroidal coal is quoted from a letter written on September 14, 1949 by James M. Schopf to Kirk V. Cammack, both of the U. S. Geological Survey: "They appear limited to coal beds of at least sub-bituminous or higher rank—age or proximity to igneous disturbance seems to be of no consequence. Certainly in the Transvaal or in the Pittsburgh bed there is no particular relation to tectonic disturbance.

"Although some have suggested that rolled balls of pre-coal peat may be involved and others have supposed the spheroidal form is due to plant structures, close examination of the spheroids in place in the coal and study of their sections shows neither of these explanations applies. One common characteristic of this type of spheroidal coal is its more than usually even textured attrital composition. Thin vitrain streaks may be found extending from the spheroids into the surrounding matrix, but such streaks are rather evenly distributed.

"It appears to me the physical make-up of this attrital coal has been responsible, first, for a rather uniform cleating pattern. The spheroids arise by a semi-concentric development of planes of separation within the cleat blocks. These curved planes round off the corners, and deeper planes ultimately become almost concentric. However, there are usually some flatter sides corresponding to sides of the original cube defined by cleating. I think the spheroidal separation is very similar to the planes of regular cleating and that as in cleating, a shrinkage phenomenon is involved."

Coal of the Raton Formation

Coal occurs in: (1) the lower member of the Raton Formation, (see coal sections 11-72); (2) the middle member (see coal sections 73-128, 155-157); and (3) the upper member (See coal sections 129-154).

Lower member of the Raton formation.--Where exposed, the lower 600 to 750 ft of the Raton formation contains only a few lenticular coal beds, less than 14 in. in thickness. They are bony with carbonaceous shale partings. The coal is banded, brittle, and friable and has a cubic cleat with platy cleavage. Pyrite and scattered quartz grains are common impurities.

A thick extensive coal bed, approximately 700 to 750 ft above the base of the Raton formation and several lenticular coal beds at a lower stratigraphic position underlie a large part of the area. (See coal sections 11-22). On the north wall of the canyon of the Middle Fork of Purgatoire River, the thick bed measures 4 ft. It was prospected in an entry driven by the Colorado Fuel and Iron Corporation on the south wall of the canyon. This company refers to it as the Apache seam. A short distance from the portal, this bed was reported to be 6 ft 2 in. thick and to have a thin sandstone parting. In the canyon of the South Fork of Purgatoire River a bed correlated with the Apache bed is 2 ft thick. Two miles to the south, it is 4 ft 9 in. thick. The floor is a dark-to medium-gray carbonaceous and fossiliferous shale or claystone. The roof is gray-or dark-gray carbonaceous shale. Coal from the Apache bed has a bright luster, prismatic cleat, cubic cleavage, and occasionally breaks with a conchoidal fracture. It is brittle and friable and appears to be composed mainly of vitrain and durain with lesser quantities of fusain. The coal generally is clean.

Thin lenticular coal beds crop out in shales in the interval from 750 to 1,130 ft above the base of the Raton formation. (See coal sections 23-42). Local thickening is common. Individual beds may underlie several square miles. Physical characteristics of these coals are similar to those of the Apache bed. Furthermore, floor and roof conditions are analogous. In Torres and Alamosita Canyons several coal beds contain the spherical masses of pure bright coal. The nearest exposed igneous intrusion is a basic to intermediate sill approximately 2 miles away.

From 1,130 to 1,160 ft above the base of the Raton formation, lenticular coal beds occur in a widespread coal-bearing zone. (See coal sections 44-62). This zone ranges from 40 to 50 ft in thickness. The mapped coal beds average 2 ft 6 in. in thickness. Physical characteristics of coal from this zone are similar to those of the Apache bed. The floors and roofs are generally carbonaceous or sandy shale.

A number of lenticular coal beds crop out in the interval between 1,160 and 1,350 ft above the base of the Raton formation. (See coal sections 63-72). They are in widespread coal zones. The thickness of individual beds is usually less than 14 in. The floors and roofs are carbonaceous shale or claystone. Physical characteristics of coal from this interval are similar to those of the Apache bed.

Middle Member of the Raton formation. Coal beds are interbedded with sandstones and shales of the middle member of the Raton formation. (See coal sections 73-128, 155-157). The base of this member is approximately 1,300 to 1,350 ft above the Vermejo formation. Coal beds occur in two stratigraphic zones which are separated by strata ranging from 50 to 100 ft in thickness. These strata consist usually of a massive sandstone with underlying and overlying shale beds. The massive sandstone is absent in the northern and western parts of the area.

Coal beds of the lower zone of the middle member are lenticular. Individual beds underlie small acreages. They average 1 ft 6 in. in thickness. Beds of the upper zone crop out in a large part of the Stonewall-Tercio area. The Ciruela bed is here named from Ciruela Canyon. It crops out in the upper part of the canyon and is well exposed in some parts of Apache Canyon, where it averages 2 ft in thickness. A number of lenticular coal beds are correlated with the Ciruela bed on the basis of stratigraphic position. The floor and roof of beds in each zone are shale and occasionally sandstone.

The coal has a bright or dull luster. It is friable and brittle, has cubic or prismatic cleat, and sometimes has platy cleavage. It consists, in hand specimens, of approximately equal quantities of vitrain and durain. Impurities are pyrite and scattered quartz grains. Limonite stains are common at several localities.

Upper member of the Raton formation. Two unimportant but relatively widespread coal zones are in the upper member of the Raton formation. (See coal sections 129-154). The zones are separated by 100 to 150 ft of sandstone and shale. Coal beds in these zones are lenticular and underlie small acreages. The maximum measured thickness is 3 ft 1 in. and the average is less than 14 in. Floors are carbonaceous shale or fossiliferous claystone and roofs are carbonaceous shale.

The coal is friable and soft with prismatic or cubic cleat and platy cleavage. Conchoidal fracture is common. The coal is banded and generally consists of durain with subordinate quantities of vitrain and fusain. The luster is usually dull. Impurities are common and consist of pyrite, scattered quartz grains, and abundant sulphur and limonite stains; however, the coal is clean in many localities.

COAL RESERVES

The original reserves of coal in the Stonewall-Tercio area are estimated to have been 490,969,000 tons, all but a small part of which still remains in the ground. This estimate is based upon many measured thicknesses of coal beds at the outcrop, obtained during the course of the field work in the area, and shown graphically in the accompanying coal sections. The locations at which the measurements were made are also indicated on the map.

Classes of reserves. In order to give the total estimate additional significance, the accompanying table has been prepared to show the coal reserves of the Stonewall-Tercio area in categories according to township, geologic formation, thickness of bed, and reliability of the information upon which the estimate was based.

As shown on the table, the reserves are classified according to the thickness of the coal into the following three categories: 14 to 28 inches, 28 to 42 inches, and more than 42 inches. To obtain the tonnage estimate for each category, maps showing isopach intervals corresponding to these three ranges in thickness were constructed for all coal beds. The areal extent and average thickness of the coal within each isopach interval were determined for individual beds, and from these data, the estimated tonnage of coal by beds was calculated.

The reserves in the Stonewall-Tercio area are further classified in the table in two categories, *measured* and *indicated* and *inferred*, depending upon the reliability of the information that was available concerning the presence of coal at a distance from points of positive information. This classification was based upon an original division of the reserves into three categories, *measured, indicated,* and *inferred.* Measured reserves were computed from dimensions revealed in outcrops, trenches, and mine workings. The points of observation were no more than one-fourth mile apart. Indicated reserves were computed partly from specific measurements, and partly from the projection of visible data for a reasonable distance on geologic evidence. The points of observation were from one-fourth to one mile apart. Inferred reserves were based largely on knowledge of the character of the beds gained during the course of field work, and on an assumed continuity of coal for which there is geologic evidence. All coal included in inferred reserves lies more than one mile from the outcrop. Measured reserves in the Stonewall-Tercio area are small because there has been little mining or development of the coal except at the outcrop. In preparing the reserve table, therefore, measured reserves were combined with indicated reserves in a single category, including all coal 1 mile or less from the outcrop.

In general, reserve estimates are further classified according to the thickness of the overburden above the coal beds. In the Stonewall-Tercio area, however, most of the reserves lie under less than 1,000 feet of overburden, and only a small amount in the Vermejo formation and the lower part of the Raton formation lie under more than 1,000 feet of overburden. No attempt was made, therefore, to separate the reserves into categories according to overburden.

The reserve table shows that 133,414,000 tons, or approximately 30 percent of the total estimated coal in the Stonewall-Tercio area, is classified as measured and indicated reserves in beds at least 28 inches thick. An additional 189,719,000 tons, or approximately 40 percent of the estimated coal, is shown as inferred reserves in beds at least 28 inches thick. As has already been pointed out, the percentage of measured reserves is very small because there has been little development of the coal in the area. With the expansion of mining and drilling programs in the future, however, a considerable part of the coal classed as indicated and inferred reserves should be transferred to measured reserves.

Past mining. The amount of mining in the Stonewall-Tercio area has been small. From 1902 to 1915, about 1,530,000 tons of coal were mined from beds A and C at the Colorado Fuel and Iron Corporation's Las Vegs mine (coal section no. 4) near Tercio in T. 34 S., R. 68 W. During 1919 and 1920, about 1,000 tons of coal were mined by the same company at the Cornell mine, T. 34 S., R. 68 W. A number of other small mines or prospects are located on the map, but the extent of these operations and the tonnage of coal mined are unknown. It can be stated with assurance, however, that no more than 2 million tons have been mined from the area.

Recoverable reserves. No data were available to the writers on the relative amounts of coal recovered and lost in mining in the Stonewall-Tercio area. Elsewhere in the western United States, however, recoverability in mining averages about half of the coal originally present in the ground. On this basis, the amount of coal mined and lost in mining in the area to January 1, 1950, is two times the amount mined, or about 4,000,000 tons; the remaining reserves in beds more than 28 inches thick are 319,133,000 tons: and the recoverable reserves in beds more than 28 inches thick are 159,566,500 tons.

Future development. Large scale development and mining of coal is possible in the Stonewall-Tercio area in the lower beds of the Vermejo formation and in the Apache bed in the lower member of the Raton formation. Calculations based on outcrop data indicate that the reserves in these beds are sufficient to permit mining for a considerable length of time. Prior to the development of any mining program, however, it would be advisable to outline the areal extent of the individual coal beds by drilling. In the central and eastern parts of the area, the beds in the Vermejo formation can be mined by deep shafts. In the western part of the area, the beds in the Vermejo formation and the Apache bed can be mined by deep shafts or slopes.

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