A RECONNAISSANCE SURVEY OF THE WESTERN PART OF THE DURANGO-GALLUP COAL FIELD OF COLORADO AND NEW MEXICO.[a]

By MILLARD K. SHALER.

INTRODUCTION.

The area of the Durango-Gallup coal field includes 13,500 square miles, of which 1,900 lie in Colorado and the remainder in New Mexico. The total production of coal in this field in 1905[b] was about 660,600 short tons, valued at nearly $1,000,000, exclusive of coke, of which about 12,000 short tons were produced. The entire tonnage of the field is estimated at 80,000,000,000 short tons, by figuring conservatively on a total workable thickness of 6 feet underlying the area, although 10 feet is probably a closer approximation of the average.

The Durango-Gallup coal field extends from the latitude of Durango, Colo., on the north to the latitude of Salt Lake, 70 miles south of Gallup, N. Mex., on the south, a distance of about 200 miles. Chama, Elvado, and the Sierra Nacimiento, in longitude 106° 45′, are situated near the eastern boundary of the field, and its western limit is the New Mexico–Arizona boundary line. The width of the field is about 150 miles. (See Pl. XXII.)

In altitude the surface ranges from 5,000 to 9,000 feet, with an average of about 6,500 feet. The topography is varied, but on the whole the country is an open plateau in which the streams have cut valleys nearly 1,000 feet in depth.

This paper, as may be seen by reference to the map, treats only of that part of the Durango-Gallup field lying west of longitude 107° 30′; hence the remainder of the area will be given no further consideration.[c] The principal towns in Colorado within the region here considered are Durango and Mancos, located on the Denver and Rio

[a] This preliminary report will be followed by a fuller description of the entire field, now in preparation, which will appear at an early date as a publication of the Survey.

[b] Mineral Resources U. S. Figures for 1906 are not yet available.

[c] For a preliminary report on the entire field, but more particularly on the eastern part of it, see Schrader, F. C., The Durango-Gallup coal field: Bull. U. S. Geol. Survey No. 285, 1906, pp. 241-258.

MAP OF WESTERN PART OF DURANGO-GALLUP COAL FIELD, COLORADO AND NEW MEXICO.

Grande Railroad. In New Mexico Gallup, McKinley County, situated on the Atchison, Topeka and Santa Fe Railway, is the only important town in the area.

The coal beds occur in the Upper Cretaceous, and have a maximum thickness of nearly 80 feet, with an average for the workable beds of about 10 feet. The better coals occur in the northern part of the area in the Mesaverde formation.[a] The thicker coal beds occur in the Laramie formation, but they are of poorer quality than those of the Mesaverde. Coal beds also occur in the Mancos and Dakota formations. The character of the coals varies from subbituminous[b] to a good grade of bituminous.

The field work on which this report is based was of a rapid reconnaissance nature throughout and was done mainly during the autumn of 1906. For assistance in the preparation of the report, the writer wishes to acknowledge his indebtedness to Mr. James H. Gardner, who rendered valuable services in both field and office.

GENERAL GEOLOGY.

STRATIGRAPHY.

Fossils collected by this party in 1906 and by Schrader's party during the previous year, which were studied by Stanton and Knowlton, indicate that the several formations observed and mapped in the field have the time values shown in the accompanying table. In classifying the Cretaceous sediments the formation names of Cross[c] are followed as nearly as their limits could be interpreted.

---

[a] Cross, Whitman, Geologic Atlas U. S., La Plata folio (No. 60), U. S. Geol. Survey, 1899.

[b] The term subbituminous has been adopted by the Geological Survey for that class of coal commonly known as "black lignite."

[c] Op. cit.

Stratigraphic succession, age of beds, and tentative correlations in Durango-Gallup coal field, Colorado-New Mexico.

System.	Series.	Formation or group.[a]	Character of strata.			Where exposed.			Thickness.			Economic value.
			North area.	Central area.	South area.	North area.	Central area.	South area.	North area.	Central area.	South area.	
Quaternary.	Recent.		Terrace gravel, alluvial wash, and flood-plain deposits, with chert fragments in central area and hot-spring deposits in south area.			Variably throughout field.			*Feet.* 0–200	*Feet.* (?)	*Feet.* (?)	Residual clays used for brickmaking.
			Unconformity.									
	Pleistocene (?).		Conglomerate; sandy matrix, angular, fine gravels of red quartzite.			Well developed along La Plata River between Laplata and Fruitland, N. Mex.			4–40			
			Unconformity.									
(?)	Eocene or post-Eocene.		Rhyolite, rhyolitic tuff, and dikes of biotite monchiquite.		Basic lavas locally amygdaloidal; amygdules filled with secondary calcite.	Dikes, flows, and isolated necks as in Ship Rock.		Occupies large areas between Zuni and Inscription Rock and farther south.	(b)	200+	0–100+	
			Unconformity.									
Tertiary.	Eocene.	Wasatch(?).	Sandstones, conglomerates, and clay shales.		Unconsolidated pinkish sand, drabmud shale, and conglomerate with pink sandy matrix.	East of Animas River and in Canyon Largo.		Locally present south of Gallup, occupying top of mesa north of Salt Lake.	1,200+		0–500	Shales might be used for brickmaking.
			Unconformity (?).									
		Puerco marl.	Dark-colored marl, unconsolidated sand, thin sandstone and conglomerate beds (fossil mammals and silicified wood).			Along Animas River below Carbon Junction and east and north of Rio Chaco.	East and north of Rio Chaco and capping Choiskai Mountains (may be Wasatch).		900	1,000+		Marl might be used, in part, for brickmaking.
			Unconformity.									
(?)	Post-Laramie.	Animas formation.	Coarse conglomerate, pink sandy matrix, pebbles and bowlders of quartzite and volcanic rock.			From Carbon Junction east and west, and east of McDermott Arroyo.			0–300			

			Unconformity.								
Cretaceous.	Upper Cretaceous.	Laramie formation.	Massive gray sandstone at base, above which are coal beds and alternating sandstone and shale beds.		Basin Mountains; east of McDermott Arroyo in Colorado; east of The Meadows in New Mexico.	East and north of Rio Chaco.		500–1,000	200–800		Contains workable coal beds, above basal massive sandstone. Sandstone excellent for building and some of shale beds might be utilized in brick-making.
		Lewis shale.	Dark-drab clay shale containing limy concretions and thin lenses of limestone.		Forms base of Basin Mountains, covers Fort Lewis Mesa and The Meadows, and crosses San Juan River below Fruitland; outcrops in narrow band east and north of Rio Chaco.			1,600	250–2,000		Could be used, in part, for manufacture of clay products.
		Mesaverde formation.	Consists of two massive sandstones between which occur thin sandstone and shale beds, interstratified and including workable coal beds.	Massive sandstones and interbedded drab shales and coal beds.	Caps Mesa Verde and prominent highlands east, west, and south of Durango; is a prominent escarpment maker.	Occurs in Great Hogback; covered by Tertiary in Choiskai Mountains; surface rock in Gallup Basin, in Nutria monocline and eastward.	In Zuni Basin north of latitude of Nutria.	[c] 750–[d] 1,450	1,500+	1,000+	Contains valuable coal beds, especially in upper and lower parts of formation. Commercially valuable beds of fire clay are mined from formation near Gallup. Sandstone excellent for building purposes.
		Mancos shale.	Dark-drab clay shale, slightly arenaceous; contains limy concretions and lenses irregularly.	Dark-drab clay shale, slightly arenaceous; contains limy concretions and lenses irregularly. Transitional sandstone and shale beds interstratified at top, containing a few coal beds.	East and west of Durango; occupies base of escarpments and valleys; forms base of Mesa Verde.	Underlies hogback and borders field throughout area.	Encircles Zuni Basin on east, south, and west sides.	1,000–1,400	750–1,000	750+	Parts used for brick-making at Durango. Is apparently adapted to manufacture of Portland cement. Contains valuable coal beds in southern part of area.
		Dakota sandstone.	Massive hard quartzose sandstone at top; same at base, locally conglomeratic; dark bituminous shale, containing coal bed, locally workable, between sandstones.		Caps Animas City Mountain; outcrops east and west from Durango; occurs at mouth of Mancos River; underlies Great Hogback, or is contained in it.		Borders Zuni Basin; outcrops north of Santa Fe Railway east of Gallup.	100–300	150–300	150–300	Sandstones are good building stones; coal beds locally mined, but generally dirty.

[a] Formation names follow Cross, W., Geologic Atlas U. S., La Plata folio (No. 60), as nearly as possible.
[b] Surface flows up to 200 feet.
[c] Vicinity of Porter, Colo.
[d] San Juan River.

The Dakota is the basal formation of the Cretaceous in this region. Below it occur the Jurassic-Triassic rocks, whose upper beds range in character from the typical "variegated marl series" of Newberry to massive vermilion or white saccharoidal sandstone. An abrupt change from the prevailing drab and tan colors of the Cretaceous rocks to the red, purple, and white of the underlying Mesozoic marks distinctly the lower limit of the coal-bearing formations of the field.

The Mancos shale, which conformably overlies the Dakota, shows a considerable thinning toward the south. The basal two-thirds of the formation maintains to a remarkable extent the same characteristics that mark the whole formation in the vicinity of Mancos, its type locality, but a pronounced though gradual change occurs in its upper portion. Thin sandstone and coal beds of the upper part of the Mancos, their total thickness comprising 150± feet north of Salt Lake, outcrop over a wide area in the Zuni Basin and gradually grade upward into the Mesaverde. Fossils collected from a sandstone member 20 feet below the lowest coal bed mined between Blackrock and Ramah are beyond doubt of Colorado age. No fossils were found, however, in any bed closely overlying this coal; hence there seem to be possible grounds for believing that it lies within the Mesaverde formation.

Throughout its outcrop the Mesaverde maintains in greater part the same lithologic character as in the vicinity of Durango. As will be seen by a reference to the table, it becomes somewhat thicker to the south and contains a greater number of coal beds. In the part of the field near Durango the coal beds occur near the basal sandstone of the formation; in Mesa Verde and the southern part of the field coal is present near both its upper and lower limits.

The Lewis shale, like the Mancos, though in a greater degree, was observed to thin toward the south from 1,600 feet on San Juan River to 250 feet at the mouth of Coal Creek on Rio Chaco. In the north wall of Chaco Canyon, near the mouth of Coal Creek, fossils were collected near the top of the Mesaverde from a limy sandstone immediately overlying a coal bed. A short distance stratigraphically above this sandstone occurs a shale bed 250 feet thick, having the lithologic characteristics of the Lewis. This shale is succeeded by the massive basal sandstone bed of the Laramie, which is overlain by coal. The same thickness of Lewis shale was noted at several points farther east, up the Chaco, establishing beyond question the notable thinning of this formation from its outcrop along the north side of the field.

The Animas beds outcrop only in a narrow belt along the north border of the field, thinning rapidly both east and west from Animas River. If present at all in the central part of the area, they are hidden by the Puerco marl, which north of Pueblo Alto appar-

ently overlaps the Cretaceous rocks. Unconsolidated white sand, unquestionably of Puerco age, here lies in contact with an irregular surface of Laramie coal immediately overlying the basal sandstone member of that formation. At this place the outcropping Laramie is only about 200 feet thick.

The upper and lower limits of the Puerco marl are difficult to determine in the area of flat-lying beds near Rio Chaco. There is nearly everywhere a marked gradation between these rocks and the Laramie, although the main body of the Puerco is easily distinguished by the presence in it of fossil mammal remains and silicified wood.

STRUCTURE.

The structure of the Durango-Gallup field is comparatively simple. The field consists in a general way of a huge basin, complicated in its southwestern portion (Zuni Basin) by what might be termed a crumpling of its upturned edge. This crumpling produced a syncline with north-south axis, parallel to which minor flexures occur near Gallup, in the middle of the basin thus formed. The structure sections on Pl. XXIII depict in a general way these relations. On account of the intimate association of structure and topographic features, however, it seems well to discuss here the main disturbances of the strata.

The disturbances in the northern part of the area are distinctly traceable to two periods—the close of the Cretaceous and the early Tertiary. The main folding in this part of the area occurred after the close of the Cretaceous period. It was the result of an uplift in the San Juan Mountain region, lying to the north, and was later than the deposition of the Animas beds. This disturbance resulted in two folds of the monoclinal type, trending in general southwestward. These folds are, at the longitude of La Plata River, 20 miles apart; but at Animas River and farther east they coalesce, forming south of Durango a series of sharp-crested hogbacks trending east and west. The northern fold has everywhere upturned the pre-Laramie strata. The fold dies out in the Mesa Verde, but becomes pronounced again to the south, where these rocks are sharply upturned toward the east in the "Great Hogback," near Jewett, and farther south.

On La Plata River near Hesperus the dip of the pre-Laramie is 5° to 10°; but farther south the rocks flatten and descend at an angle only slightly greater than the grade of the river. At a point just north of Pendleton, N. Mex., there is a second monocline which Holmes [a] has called the San Juan fold. A change of dip occurs here, and the Laramie rocks, dipping 10° to 20° SE., cross the river

[a] Holmes, W. H., Geology of the San Juan district: Ninth Ann. Rept. U. S. Geol. and Geog. Survey Terr., 1877, pp. 237-276.

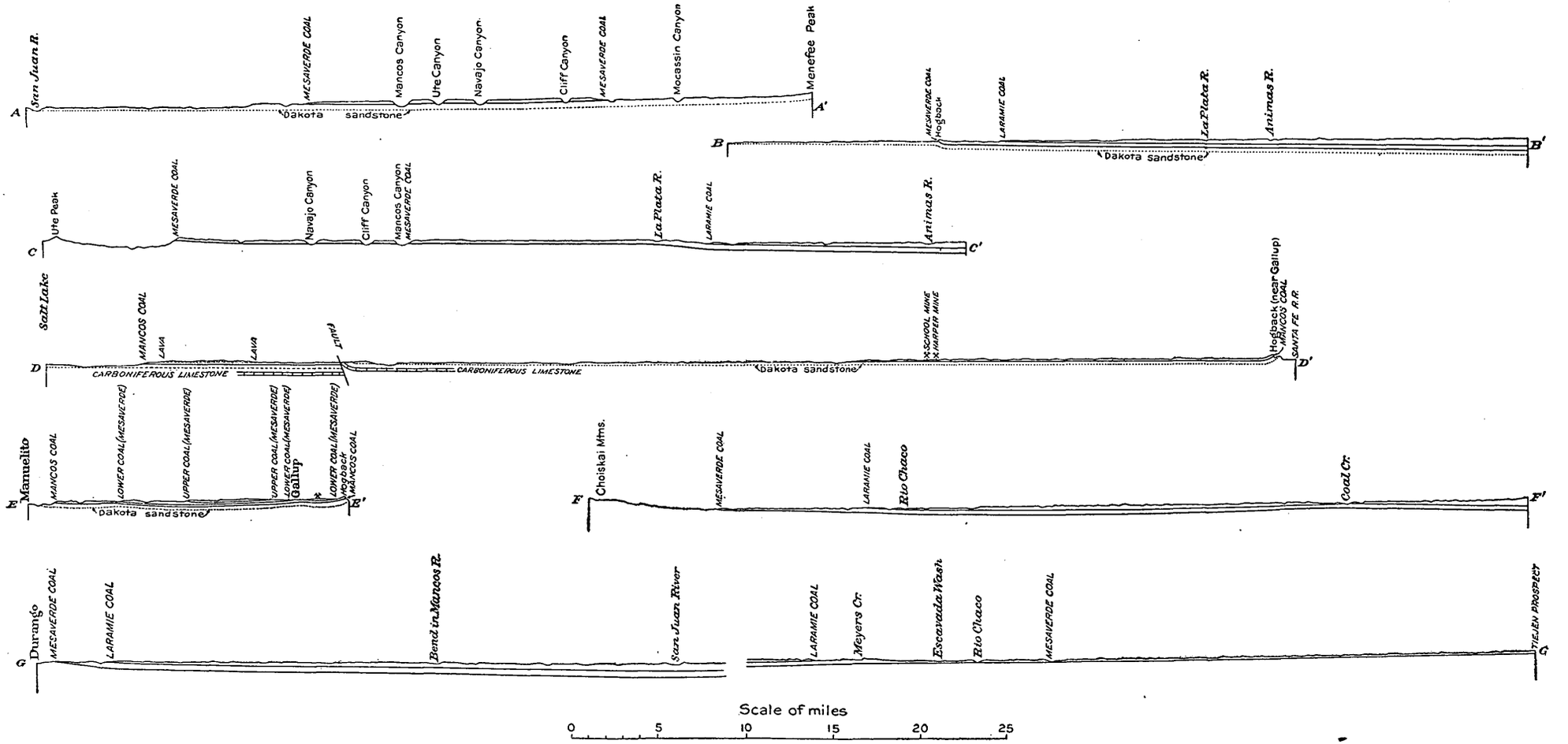
in a low northward-facing hogback. East of McDermott Arroyo the San Juan fold continues northeastward, forming the Basin Mountains, which at longitude 108° swing eastward and cross Animas River at Carbon Junction, where this fold merges with the northern fold. Southwest of La Plata River, trending parallel to the Great Hogback, the San Juan fold presents a westward-facing escarpment of Laramie rocks, which form the eastern boundary of the Vegas, or Meadows. The fold, coalescing with the Great Hogback, crosses San Juan River at Fruitland, the Laramie strata dipping at an angle of less than 2° and flattening toward the south. At Cottonwood Creek they are practically horizontal.

The disturbance of the strata in the northern part of the field after the close of the Cretaceous was followed by a period of quiet, during which a part, or possibly all, of the Tertiary sediments were deposited. Then came a second uplift in the San Juan Mountain region, accompanied and perhaps caused by igneous intrusion. This disturbance resulted in a farther southward tilting of the Cretaceous rocks in the extreme northern part of the area and a consequent tilting of the overlying Tertiary beds. As can be seen from the Animas River structure section (Pl. XXIII), neither of these disturbances affected the beds for any great distance away from the mountains. The folds are sharp, but the strata flatten within a very short distance to the south.

South of San Juan River and north of Zuni Basin the disturbances of the strata are comparatively simple. After the close of Cretaceous time, folding of the monoclinal type occurred, affecting only the pre-Laramie sediments to any considerable degree. The result of this disturbance is shown in the southward extension of the Great Hogback, which, trending west of south from San Juan River, presents a succession of low serrated peaks and sharp-crested ridges to the point where, near Crozier, it disappears under the flat-lying Tertiary sediments of the Choiskai Mountains. This monocline involves the strata of the coal-bearing Mesaverde formation and the upper part of the Mancos. It presents a westward-facing escarpment throughout its length, the strata showing eastward dips of 35° to 50°.

After the deposition of the Tertiary sediments, eruptions of tuffaceous lava and later intrusions of biotitic monchiquite dikes occurred in the region south of San Juan River. Ship Rock, Bennett, and Ford peaks, the dikes radiating therefrom, and the lava flow capping the northern portion of the Choiskai Mountains are results of this volcanic outburst.

The structure of Zuni Basin has already been ascribed to the crumpling of the upturned rim of the major basin. Apparently all of the folding occurred just after the close of Cretaceous time. On the west the basin is bounded by the Defiance monocline, which is the southward extension of the Great Hogback after it reappears east



STRUCTURE SECTIONS OF DURANGO-GALLUP COAL FIELD, COLORADO AND NEW MEXICO.

For location see Pl. XXII (same scale).

of Fort Defiance, Ariz., from beneath the Tertiary covering in the Choiskai Mountains. This fold extends southward and is crossed by the Atchison, Topeka and Santa Fe Railway west of Manuelito; thence it trends in a southerly direction to the latitude of Zuni village, where its axis lies about 2 miles east of Blackrock. On the north the rocks dip steeply eastward, but south of Manuelito the strata flatten until south of Zuni the dip is very low.

As will be seen by reference to the north-south structure section through the basin (Pl. XXIII), the rocks north of Salt Lake dip northward at a very low angle to a fault near the latitude of Ojo Caliente. This fault has an upthrust on the north which at a point about a mile south of Ojo Caliente brings Carboniferous (Aubrey?) limestone in contact with the upper part of the Mancos. The strike of the fault is south of east, but at a distance of a few miles it is obscured beneath the great lava flow that covers a wide area south of Tarche. The Nutria monocline of Gilbert[a] bounds the Zuni Basin on the east. The westward dip of the upturned beds reaches a maximum of 70° near Nutria, but averages about 45° between Gallup and Nutria. Toward the south the strata of the monocline flatten rapidly until at Ramah and beyond the dip is less than 10°. North from the Santa Fe Railway east of Gallup the dip gradually diminishes and its direction changes to northwest. Finally the rocks dip to the north at an angle not exceeding 5°, and their gently upturned edges form the rim of the major basin to and beyond the eastern limit of the area under discussion. The structure of the interior of the basin is shown by the section drawn from Durango southward through Putnam (Pl. XXIII).

Careful lithologic and paleontologic examination of the strata failed to reveal any displacement along either the Great Hogback, its southern extension, the Defiance monocline, or the Nutria monocline.[b] At short distances away from these sharp flexures the strata flatten; hence the basins between the folds are shallow.

In Zuni Basin a period of remarkable volcanic activity followed at apparently a considerable interval after the deposition of the Tertiary sediments. From the eruptive centers, most of them probably some distance east of the coal field, great flows of basic lava were poured westward, covering, as can be seen by a reference to the map (Pl. XXII, p. 376), a large area in this basin. Gilbert[c] describes in detail the remarkable extent of this lava flow, of which only a comparatively small tract lies within the boundaries of the coal field.

[a] Gilbert, G. K., U. S. Geog. Survey W. 100th Mer., vol. 3, 1875, pp. 550–553.

[b] Both Newberry and Dutton, in reports already cited, deduce the existence of a fault of considerable downthrow on the west immediately west of the axis of the abruptly flexed beds in the Nutria monocline. Gilbert and Howell, in vol. 3 of the Wheeler Survey reports, deny the existence of such a fault.

[c] Op. cit., p. 525.

COAL.

COAL-BEARING FORMATIONS.

The coal beds of this field lie at various horizons. In the vicinity of Durango the best coal occurs in the Mesaverde formation. Coal was mined from the thicker Laramie beds some years ago at what is known as the La Plata mine, southeast of Durango, and at the Carbonero mine, on the Denver and Rio Grande Railroad below Durango in Animas Valley. When it was found, however, that the Laramie coals were so much inferior to those of the Mesaverde that they could not compete with them in the market the Laramie mines were abandoned.

On La Plata River near Pendleton and on San Juan River at Fruitland coal has been mined for a number of years for local consumption and to supply the market at Aztec and Farmington. The coal is the Carbonero bed of the Laramie formation. East of Fort Defiance, Ariz., and in New Mexico, coal has been mined since 1894 from beds near the base of the Mesaverde formation.

In the vicinity of Gallup the coals mined are contained in the Mesaverde; they are good grade subbituminous coals and occur in beds up to 8½ feet in thickness. Between Nutria and Blackrock coal has been mined for the last three or four years from two beds about 40 inches thick, occurring in the upper part of the Mancos formation. The coal is a good grade of subbituminous, and is used successfully as fuel at the Indian school at Blackrock and in the construction of a large dam at that place.

At nearly every locality where the Dakota formation outcrops within the area, coal is present. Although generally of poor quality, it becomes locally high-grade bituminous. North of Mancos it is mined on a small scale.

DETAILED DESCRIPTIONS.

For convenience in description, the area under discussion is divided into five districts, which will be described in order of location from north to south.

DURANGO–MESA VERDE DISTRICT.

The Durango–Mesa Verde district includes the Colorado portion of the field, extending westward from Florida River. The largest town in this district is Durango, a county seat having a population of about 4,000. Other towns are Porter, Hesperus, Mancos, and Cortez. The Denver and Rio Grande Railroad furnishes eastern and northern outlets for the district, and its branch line down Animas Valley connects Durango with the rich San Juan Valley country. The Rio Grande Southern Railway connects Durango, by way of Porter, Hesperus, and Mancos, with the mining region about Rico and Telluride.

The coals of this district occur in three formations—the Mesaverde, Laramie, and Dakota, named in the order of the value of their coals. The Dakota coal bed is nearly everywhere dirty and generally is not mined where other coal beds are available. Its maximum observed thickness is about 7 feet, including bony and shaly partings.

The Mesaverde coal is commercially the most valuable, though not the thickest in the district. The maximum observed thickness is 7 feet, but the average for the workable beds is much less than this, being probably about 5 feet. The coal is of excellent quality and in the vicinity of Durango and Porter makes good coke, which is extensively used in the smelters of the region.

The Laramie coal beds are the largest in the district, the maximum observed thickness of an individual bed being about 80 feet, including a considerable number of thin partings in its upper part. The coals are not of so high grade as those of the Mesaverde formation and can not at present compete with them. They are, however, good bituminous coals and undoubtedly will be of great value under better conditions of transportation and market.

The coal beds outcropping between Florida River and the town of Mancos will be given only a cursory treatment here.[a]

Four workable Laramie coal beds occur at the abandoned La Plata mine, 3 miles southeast of Durango. Openings were made in three of the coal beds, which exposed the following section:[b]

Section of coal-bearing strata at La Plata mine, 3 miles southeast of Durango.

	Ft.	in.
Upper or Peacock bed:		
Shale roof.		
Coal	1	8
Sandstone, shaly		2–4
Coal	3	2
Coal, bony		3
Coal		7
Shale		4
Coal	2	7
Fire clay.		
Shale and sandstone	75	
Sandstone, brown	3	
Jumbo bed:		
Coal, with many shale and bone partings	20	
Sandstone and shale	50	
Fairmont bed:		
Coal, with bands of shale and bony coal	15	
Shale and sandstone	100	
Lower bed:		
Coal	4	
	275	10

[a] For a detailed report on this area, see paper by Joseph A. Taff, pp. 321-337 of this bulletin.

[b] At the time of the writer's visit the Fairmont bed had been burning for more than two years, and the entry on the Jumbo bed was filled with water, hence accuracy of measurement was impossible.

Most of the output of the La Plata mine was from the Fairmont bed, which contains an upper bench of coal about 4 feet thick that is free from impurities. The strata dip southeastward at an angle of 28°.

At Carbon Junction, near Animas River, all these beds coalesce, forming the Carbonero bed, which, including several thin bony and shaly partings, attains a total thickness of nearly 100 feet. It is doubtful if more than one-third of this bed can be mined because of the numerous partings. Several benches of clean coal up to 5 feet in thickness are, however, present in this mammoth bed, and probably can be worked economically.

Farther west, at Indian Creek, the Carbonero bed appears to split into several beds as at the La Plata mine. The same condition, but to a less extent, was observed east of "Burned Timber," near the Hesperus–Laplata wagon road. One of the beds is 20 feet thick, including two thin unimportant partings.

The Peacock bed of the Mesaverde formation is mined by the Calumet Fuel Company on Perrine Peak west of Durango. The coal is of excellent quality, and produces a good grade of coke. The area of the present workings is about 12 acres. The following section, measured 1,200 feet in the mine, gives a good idea of the condition of the coal bed:

Section of coal bed in Perrine Peak mine, west of Durango.

	Ft.	in.
Shale roof.		
Coal	6	10¾
Shale		6–8
Coal		3½
Shale floor (?).		
	7	9¼

The coal bed mined at Perrine Peak is locally considered to be the same as the bed mined at Hesperus and the upper bed mined at Porter. Though this coal obtained as far west as Porter cokes in the ordinary beehive oven, tests at Hesperus have not yielded satisfactory results.

The length of the main entry of the Hesperus mine is about 4,800 feet in the direction of the dip, which is to the south at an average angle of 7°. The bed ranges in thickness from 4 feet 10 inches to 6 feet 6 inches and locally a thin parting is present. The following section was measured where the sample was taken for analysis:

Section of coal bed in Hesperus mine.

	Ft.	in.
Coal	3	10
Bone		¼
Coal	1	6
Coal, bony, variable	1	3
Sandstone floor.		
	6	7¼

Along the outcrop of the Mesaverde formation numerous test openings have been made which prove the generally uniform thickness and good character of the coal beds of this formation. Between Spring and Deadman gulches a natural exposure shows the presence of four beds, one of which is 4 feet thick.

In Alkali Gulch on the Crawford ranch a prospect tunnel driven into the east bluff shows one of the Mesaverde coals measuring about 5 feet, which appears to be of the same character as the Hesperus bed. The rocks in Alkali Gulch have a low dip to the south.

A Mesaverde coal bed has recently been opened on the Wiltsey farm in Hay Gulch, by an entry driven on the bed for a distance of 150 feet. A section of the coal is as follows:

Section of coal bed in Wiltsey prospect tunnel.

	Ft.	in.
Sandstone.		
Coal	2	
Coal, bony		4
Coal	4	4
Shale, bituminous.		
	6	8

This coal resembles the Hesperus coal and probably is of equally good quality. The strata in Hay Gulch have a low southeasterly dip, thus making it possible for the coal beds of the Mesaverde to be reached at comparatively slight depth over a wide area lying to the southeast, embracing the greater part of Fort Lewis Mesa.

Seven miles north of Mancos, at the Haller mine, an entry has recently been driven for about 55 feet on a Dakota coal bed. The coal is reported to be a coking coal and to work well in the forge. The following section is exposed in the tunnel:

Section of coal bed in the Haller mine, 7 miles north of Mancos.

	Ft.	in.
Coal		10+
Shale	2	6
Coal	1	3
Shale		6
Coal	1	6
Coal, bony		8
Coal	1	5
Sandstone		½
Coal	1	3
Bony coal floor.		
	9	11½

The same bed has been mined on the east branch of Mud Creek 3½ miles northwest of Mancos. An entry has been driven here for 220 feet, and from it the coal bed has been worked for an equal distance on either side. The coal measures 4 feet 3 inches, including two bony partings of 1 inch each. The roof is bony coal and the floor fire clay. The quality of the coal is apparently the same as at the Haller mine.

MESA VERDE REGION.

South, southeast, and southwest of Mancos the Mesaverde coal beds are exposed in the escarpments of Mesa Verde. This mesa is a high table-land bounded on the north, west, and south by perpendicular cliffs. Its character is shown best by the cross sections (Pl. XXIII, p. 382). Two escarpments formed of massive sandstones of the Mesaverde, underlain by soft clay shale, are prominent features of the mesa cliffs. The lower one forms the base and the upper the top of the Mesaverde formation; they were called by Holmes[a] the Lower Escarpment and Upper Escarpment sandstones.

In Mesa Verde two workable coals, the Upper and Spencer beds, are separated by about 300 feet of shales and sandstones, with several thin coal beds. The Spencer bed outcrops near the mouth of Mancos Canyon, and the Upper bed appears still farther south.

The Wood and Spencer mines are located southeast of the town of Mancos, in sec. 36, T. 36 N., R. 13 W., and sec. 2, T. 35 N., R. 13 W., respectively. At the Spencer mine coal has been taken out for the local market for eighteen years. The coal is 3 feet thick and of excellent quality. The roof is sandstone and the floor shale. About 50 feet below the Spencer is another good coal bed 38 inches thick. The Spencer bed is also worked at the Wood mine, which has been recently opened. A section of the coal bed at this place is as follows:

Section of coal bed in Wood mine, southeast of Mancos.

	Ft.	in.
Shale.		
Coal	1	4
Shale, variable		½–5
Coal	3	
Coal, bony		6
Sandstone, friable.		
	5	1

The rocks at both the Spencer and the Wood mines dip about 3½° S. 30° E. The coal is of excellent quality.

In the following descriptions the numbers refer to localities designated by corresponding numbers on the map (Pl. XXII, p. 376).

No. 18: In sec. 35, T. 35 N., R. 14 W., Fred. Armstrong and others several years ago prospected the Spencer bed, exposing 4½ to 5 feet of excellent coal. The floor is massive sandstone and the roof friable sandy shale. East of the canyon, in sec. 19, T. 35 N., R. 13 W., the same coal bed is reported to lie practically on the surface, and to have a thickness of more than 3 feet.

Nos. 19 and 20: In sec. 19, T. 35 N., R. 14 W., the Spencer bed outcrops in the head of Moccasin Canyon. The Upper bed shows 2½ miles farther south. At neither of these points were the beds examined in detail.

[a] Holmes, W. H., Geology of the San Juan district: Ninth Ann. Rept. U. S. Geol. and Geog. Survey Terr., 1877, p. 254.

No. 21: The Todd mine, in sec. 28, T. 35 N., R. 14 W., has recently been opened on the Spencer bed by Samuel Todd and John Bolster. The rocks dip southward at an angle of 7°. The coal bed ranges in thickness from 28 to 30 inches and lies between beds of firm shale. The coal burns well, leaving a very small amount of white ash. About 300 feet above the Spencer the Upper bed outcrops in two benches, separated by 3 feet of shale, and is underlain by hard carbonaceous shale. The top and bottom benches measure, respectively, 22 and 33 inches. Its quality appears to be poorer than that of the coal at the Wood and Spencer mines.

In the westward-facing escarpment of Mesa Verde, coal beds occur at intervals throughout 400 feet of strata lying between the upper and lower sandstones.

No. 22: In sec. 28, T. 35 N., R. 16 W., the lower or Spencer bed is less than 30 inches thick. The Upper bed is split by a parting into two benches. A natural exposure shows the following section between beds of hard clay shale:

Section of coal bed at location No. 22.

	Ft.	in.
Coal	2	4
Coal, bony		6
Shale	2	1
Coal	1	3
	6	2

The rocks dip 7° S. The coal is hard, clean, and apparently of good quality.

No. 23: East of Burnham's ranch, near the southern line of the Southern Ute Indian Reservation, the coal-bearing rocks are not well exposed, but the Upper bed is apparently present and possibly thicker than at location No. 22.

No. 24: In the mesa cliff 2½ miles east of Ute Agency, in sec. 1, T. 33 N., R. 17 W., several coal beds show in outcrop, but only one of these, the Upper bed, is thick enough to be of economic value. It lies between shale beds, has a thickness of 50 inches, and consists of hard, clean coal.

No. 25: In the west wall of Mancos Canyon, in sec. 15, T. 34 N., R. 14 W., the Spencer bed occurs in two benches of 20 inches each, separated by 12 inches of bony coal. The roof is hard, massive sandstone, and the floor shale. The presence of the Upper bed was not determined at this location.

No. 26: One-half mile above the mouth of Fort Lewis Creek, in sec. 31, T. 34 N., R. 14 W., near the level of the canyon floor, the Spencer bed outcrops, showing 4 feet of clean, hard coal. The floor is bony coal and the roof clay shale. The rocks dip south at an angle of 5°.

No. 27: In Cliff Canyon natural exposures in the canyon walls at two points show the general uniformity in occurrence of the Upper and Spencer beds throughout the mesa. Near the mouth of Cliff Canyon, in sec. 3, T. 33 N., R. 15 W., the entire thickness of coal-bearing rocks measures only about 200 feet. The Upper bed shows 44 inches of hard, clean coal. The Spencer bed is represented by 14 inches of coal lying between beds of shale. Between the Upper and Spencer beds two of the intermediate thin beds of other localities in the mesa have locally thickened, one to 20, the other to 30, inches of good coal. The rocks here lie practically flat.

No. 28: Between Spruce Tree House and Spring House forks of Navajo Canyon only the Upper bed is exposed, the Spencer lying at a lower level than the canyon floor. The exposed bed is 5 feet thick, but has a 1-foot shale parting in the middle, which is easily separable from the coal. The roof and floor are hard, firm, clay shale.

No. 29: In Ute Canyon 150 feet of coal-bearing strata are exposed, which includes both the Spencer and Upper as well as several intermediate coal beds that are locally of economic importance. The following section is exposed in the canyon walls:

Section in Ute Canyon.

	Ft.	in.
Shale.		
Coal	1	
Shale, black	4	
Coal	1	
Shale	20	
Coal, Upper	4	9
Shale and thin sandstone	30	
Coal	2	
Shale and thin sandstone	25	
Coal	3	6
Shale and thin sandstone	25	
Coal	4	
Shale (principally)	100	
Coal, Spencer	2	
	222	3

No. 30: In the south cliff of Mancos Canyon, just above the mouth of Navajo Canyon, the following section is exposed, the lowest coal bed of which lies about 400 feet above river level:

Section of coal-bearing rocks at location No. 30, in Mancos Canyon.

	Ft.	in.
Upper sandstone	250	
Shale with coal streaks	30	
Coal, free from partings	3	10
Shale, black	35	
Coal	2	
Shale, black	5	
Sandstone	12	
Shale, black	5	

	Ft.	in.
Coal		6
Shale, black	6	
Coal	1	2
Shale, black	15	
Coal	1	
Shale, black	10	
Coal	1	8
Sandstone		1
Coal	1	4
Shale, black	45	
Coal	1	10
	426	5

Several of the coal beds of the above section are accessible for mining and are of workable thickness and quality.

No. 31: About 1½ miles up the canyon from the locality just described an intrusive body of basic lamprophyre with radiating dikes of the same material occurs in the south canyon wall. Just below this igneous rock a bed of excellent coal outcrops about 20 feet above the river level. The bed is 47 inches thick, without partings, and has a firm shale roof and bony coal floor. It is easily accessible and lies practically horizontal.

No. 32: The subjoined section is exposed in the cliff about 3 miles up Soda Spring Canyon. The section was measured one-half mile above a lamprophyric dike, which, trending north and south, cuts across the canyon, and the same distance below an excellent soda spring.

Section of coal-bearing rocks in Soda Spring Canyon at location No. 32.

	Ft.	in.
Sandstone		6
Coal	1	11
Shale	40	
Shale, carbonaceous	6	
Coal	1	3
Shale, carbonaceous	4	
Coal		10
Shale		4
Coal		6
Shale	20	
Sandstone and shale	14	
Coal	2	2
Coal, bony		1
Coal		5
Sandstone and shale	15	
Coal, variable, bony streak in middle 1 inch thick	4	7
Sandstone and shale	14	
Lenticular band of "Black band" iron ore	1	
Shale	6	

	Ft.	in.
Coal	1	4
Shale, carbonaceous	8	
Coal	2	1
Sandstone		1
Coal	1	8
Shale, carbonaceous	1	6
Coal, dirty	1	2
Shale, carbonaceous		4
Coal	1	2
Fire clay and carbonaceous shale	6	
Coal	1	2
Fire clay	5	
Shale and sandstone	20	
Shale	1	
Coal	2	11
	186	

No. 33: Several coal beds similar in thickness and quality were noted about 2 miles above the exposure just described.

No. 34: Eight miles above the crossing of the Ship Rock-Cortez wagon road the Upper coal bed of the Mesaverde occurs 1,200 feet above river level in the south wall of Mancos Canyon. It is 67 inches thick, is clear of partings, and has a firm shale roof and floor.

Workable coal beds representing the Spencer, Upper, and intermediate beds have been prospected or examined in natural exposures at many other points within Mesa Verde, showing conclusively that their lateral extent, thickness, and quality are more or less uniform throughout the area of the mesa.

LAPLATA–FRUITLAND DISTRICT.

The Laplata–Fruitland district, so named from towns in the area, is located wholly in northwestern New Mexico, north of San Juan River.

The Great Hogback, composed of the upturned Mesaverde formation, rises northward from San Juan River to a height of 500 feet and extends in two parallel unbroken serrated crest lines to a point about midway between Baldwin's store and the State line, where the beds flatten and the fold blends into Mesa Verde. The eastern crest is formed by the upper, and the western, subordinate ridge by the lower sandstone. The coal-bearing strata outcrop in a sag between these ridges. The dip at the river is 40°, but decreases rapidly toward the north, and as a consequence the ridges become more and more separated until the sag develops into a considerable valley. The dip finally falls off to 5° and less, and the various members of the hogback connect with the corresponding members of Mesa Verde.

West of the hogback the Mancos shale, and still farther west the Dakota sandstone, which outcrops just east of the mouth of Mancos River, rise above river level.

East of the Great Hogback a wide, rolling, valley country, the Vegas or Meadows, extends to a northwestward-facing escarpment, the San Juan fold of Holmes, formed of the Laramie sandstones and shales. This valley has been eroded in the nonresistant Lewis shale. The Laramie escarpment presents where it is crossed by La Plata River and for some distance farther south an abrupt northwest face. As the dip of the strata comprising this monocline decreases to the south the escarpment is broken here and there into a series of detached table-lands, whose surfaces slope gently in the direction of the dip. East of this monocline the rocks are chiefly flat-lying marls, capped by sandstones and conglomerates, in which the numerous small tributaries of Animas and La Plata rivers have encountered little resistance to their downward cutting, so that the resulting topography is of the badlands type.

The coals represented in the Laplata–Fruitland district occur in the Mesaverde, Laramie, and Dakota formations. The Dakota coal is mined on San Juan River, a few miles below Ship Rock, for use in the heating plant of the Government Indian school at that town. It is reported to be dirty and not a very satisfactory fuel. A new mine has been opened on the 4½-foot Mesaverde coal bed exposed in the Great Hogback near Jewett, and the coal found to be of excellent quality.

The Mesaverde coals in this district are similar in thickness and quality to those exposed in Mesa Verde. They are not mined at present, but have been prospected and their natural outcrops examined in many places.

The Carbonero bed of the Laramie formation is mined on a small scale in the vicinity of Pendleton on La Plata River and near Fruitland on the San Juan, some of the coal being hauled by wagon to Aztec, Farmington, and other small neighboring towns. The maximum observed thickness of this bed is nearly 50 feet. Other coals are present in the Laramie, both above and below this bed, but generally they are poorer in quality and thinner. The quality of the Laramie coal in this district is better than it is in the vicinity of Durango.

Short prospect entries were driven on each of the three upper Mesaverde coal beds that outcrop in Barker Arroyo, in secs. 5 and 6, T. 22 N., R. 13 W., in the summer of 1905, under the direction of C. W. Fisherdick, of Laplata, for the Arizona and Colorado Railroad. The upper coal varies greatly in the six prospect entries driven on it. The extremes are shown in the subjoined sections, measured in prospects about 1 mile apart on the middle and south branches of the arroyo, respectively. The strata dip at an angle of 15° to 20° S. 70° E.

Sections of upper bed in Fisherdick prospect, Barker Arroyo.

LOCATION No. 35.	Ft.	in.
Sandstone roof.		
Shale		2
Coal	3	8
Sandstone floor.		
	3	10

LOCATION No. 36.	Ft.	in.
Sandy shale roof.		
Coal		8
Shale		1¼
Coal	4	2
Shale floor.		
	4	11¼

The middle one of the three Mesaverde beds is separated from the upper by 85 feet of sandstone and shale. It was mined from 1882 to 1890 in the middle branch of Barker Arroyo (No. 37), and supplied coal for the neighborhood. This mine, known as the Hepler, was abandoned because a fault was encountered in the workings and a bony coal parting 6 inches thick had gradually come in near the middle of the bed. The coal is hard and apparently of good quality, and at the breast of the 100-foot entry still remains hard and unweathered. The bed dips at an angle of 16° S. 70° E., and presents the following section in an open prospect in the north branch of Barker Arroyo:

Section of middle Mesaverde coal bed in north branch of Barker Arroyo, at location No. 38.

	Ft.	in.
Shale, sandy.		
Coal	1	8½
Coal, bony and shale		11
Coal	3	4
Brown carbonaceous shale.		
	5	11½

At a distance of 75 feet below the middle bed the lower coal of the Mesaverde section is exposed as follows in the south branch of Barker Arroyo:

Section of lower Mesaverda coal beds in south branch of Barker Arroyo at location No. 39.

	Ft.	in.
Shale, sandy.		
Coal	2	
Shale, carbonaceous	10	
Coal	1	3
Shale, carbonaceous	3	9
Coal	1	10
Covered.		
	18	10

The strata dip at an angle of 15° S. 15° E.

All of the Mesaverde coal-bearing section in Barker Arroyo immediately underlies the upper sandstone, which is here more than 250 feet thick. The overlying Lewis shale, having the same character as in the Durango–Mesa Verde district, is 2,300 feet thick. It is believed that this represents a local thickening at the crest of the fold, inasmuch as north of the State line and on San Juan River the same formation is only about 1,600 feet thick.

The basal Laramie sandstone, which lies between the Laramie coal-bearing rocks and the Lewis shale, includes some thin intercalated shales and measures 180 feet as exposed in Barker Arroyo. There are three coal beds in the Laramie, the middle or Carbonero bed being the only one mined in the district. The lower and upper beds are generally thin and dirty, and are separated from the Carbonero bed by 60 and 250 feet, respectively, of shale and sandstone.

No. 40: An opening in the Pruitt pasture, known as the Pruitt mine, is located about 25 feet north of the State line in sec. 23, T. 32 N., R. 12 W. This mine is a chamber 25 feet wide, 100 feet long, and high enough for wagons to enter and load direct from the working face. The bed is 36 feet thick, but only 10 feet is mined. It is a good-grade bituminous coal. A section of the entire bed is as follows:

Section of Carbonero bed at Pruitt mine, location No. 40.

		Ft.	in.
	Shale, brown, carbonaceous.		
	Coal	1	
	Sandstone		¼
	Coal	1	6
	Sandstone		¼
	Coal	3	6
	Shale		½
	Coal	1	6
	Coal, bony		1
	Coal	2	
	Sandstone		1
	Coal	2	
	Sandstone		¼
	Coal	1	6
	Shale		2
	Coal	5	
	"Rash"		2
	Coal	2	
	Coal, sandy, bony		1
Part mined.	Coal		10
	Bone		¼
	Coal	1	
	Coal, sandy, bony		4
	Coal		7
	Coal, sandy, bony		1
	Coal, sampled	4	10
	"Rash"		10
	Coal	1	7
	Shale, drab clay		6
	Coal	5	
		36	3½

No. 41: The O'Brien mine, located a short distance east, and the Greer mine, a short distance west of La Plata River, in sec. 15, T. 32 N., R. 13 W., are also on the Carbonero bed. These mines were

closed after they had been taken over two or three years ago by the Phelps-Dodge Mining and Smelting Company. The coal is similar in section and quality to the bed at the Pruitt mine. The rocks dip at an angle of 15° S. 10° E. At the O'Brien mine a slope was driven on the coal for a distance of 800 feet to a point where considerable water and gas were encountered. At the Greer mine a heading was driven for about 350 feet with the rise of the coal, and rooms were worked out from cross entries driven for 200 feet on either side of the main entry. The coal is reported to have excellent steaming but no coking qualities. These mines supplied coal for the New Mexico towns in Animas Valley as well as for the local trade.

Nos. 42 and 43: The Thomas and the Jones mines, located respectively in secs. 22 and 21, T. 32 N., R. 13 W., at present supply practically all of the local and a part of the Aztec and Farmington trade. Both mines are in the Carbonero bed, but their workings are not yet very extensive. The coal section is similar in both of these mines, and roughly corresponds to that exposed at the Pruitt mine. The Thomas mine (No. 42) was opened in 1895, by an entry driven for 275 feet on the strike of the bed, which dips at an angle of 20° S. 53° E. The coal is bituminous in quality. A section of the part of the bed mined is as follows:

Section of the part of the Carbonero bed mined in the Thomas mine, at location No. 42.

	Ft.	in.
Sandstone.		
Coal	4	10
Fire clay		6
Coal	4	6
Sandstone floor.		
	9	10

A coal bed 3½ to 4 feet thick, locally known as the Peacock bed, occurs near the Thomas mine, 250 feet stratigraphically above the Carbonero bed. It has been prospected and appears to be of excellent quality, but wherever exposed to the southwest or northwest it is badly split up by partings.

No. 44: At the Walker mine, about 4 miles south of west from Young's ranch, a slope has been driven for a distance of 100 feet in the Carbonero bed on a dip of 5° S. 65° E. A section of the part of the bed mined is as follows:

Section of Carbonero bed at Walker mine, at location No. 44.

	Ft.	in.
Shale, hard, clay.		
Coal	3	4
Sandstone		1
Coal		9
Sandstone		1½
Coal	2	3
Shale, carbonaceous	2	
Total coal bed	6	6½

No. 45: In sec. 12, T. 31 N., R. 14 W., just west of the eastern boundary line of the Ute reservation, the following section of one of the lower Mesaverde coals is exposed in a small side canyon of Barker Arroyo:

Section of Mesaverde coal bed exposed at location No. 45.

	Ft.	in.
Shale, brown.		
Coal		3
Coal, bony, and shale		5
Coal	6	8
Coal, bony.		
	7	4

The coal bed dips at an angle of 10° SE. It is fairly hard and apparently good bituminous coal.

No. 46: About 5 miles east of north from Young's ranch, in the Ute reservation, the following section is exposed in the canyon walls of a tributary of Coal Creek:

Section of upper Mesaverde coal bed at location No. 46.

	Ft.	in.
Shale roof.		
Coal	2	
Coal, bony		4
Coal	3	
Shale floor.		
	5	4

This bed lies practically horizontal, about 50 feet below the base of the upper sandstone. It outcrops just above the level of the canyon floor, is persistent in thickness and of good quality, and offers a considerable workable area.

No. 47: About 1 mile northeast of Navajo Spring, the upper bed outcrops in the wall of a box canyon at the head of Coal Creek. This bed is about 40 inches thick, lies horizontal, 6 feet below the upper sandstone, and has a firm shale floor and roof. Careful search failed to reveal the existence in workable thickness of any of the other Mesaverde coal beds.

No. 48: In the Great Hogback, 3 miles west of the Walker mine, just below the upper sandstone of the Mesaverde formation, the following coal section is exposed:

Section of coal beds exposed in Great Hogback, at location No. 48.

	Ft.	in.
Sandstone, massive	20+	
Coal	4	4
Shale	10	
Sandstone and shale	40	
Coal	4	8
Shale floor.		
	79	

The strata at this locality dip 15° S. 30° E., and the same beds are exposed at numerous places in each direction along the strike, their thickness and quality being generally uniform.

No. 49: Where San Juan River cuts the Great Hogback at Baldwin's store, the following section of the coal-bearing Mesaverde was measured north of the river:

Section of coal bed exposed in Great Hogback west of Baldwin's store, at location No. 49.

	Ft.	in.
Clay shale.		
Coal	1	8
Shale and shaly sandstone with fossil plants	4	
Coal		6–8
Shale and sandstone	3	
Clay shale	2	
Coal	6	2
Shale	1	
Coal		6
	18	11

Between this section and the upper sandstone is a mass of sandstones and shales about 500 feet thick, containing in the upper part a number of coal beds that may be correlated with the coal beds at location No. 48. Their thicknesses were not determined. The strata dip eastward at an angle of 40°.

No. 50: At the Thurling mine (Bruce mine), in sec. 27, T. 30 N., R. 15 W., between Young's ranch and Jewett, the Carbonero bed, 23 feet thick, was formerly worked, and it is practically all good coal.

No. 51: The Stephens mine (Young mine), in sec. 4, T. 29 N., R. 15 W., was opened several years ago near the Fruitland-Jewett road, 1½ miles northwest of Fruitland. It furnishes the coal used at Fruitland and Jewett, and a considerable quantity is hauled from the mine by wagon to Farmington and the surrounding country. It is opened by a drift 100 feet long, running N. 30° W. on the bed, which lies nearly horizontal. The total thickness of the bed is about 16 feet, including several thin partings in its upper part. The section is as follows:

Section of Carbonero bed at Stephens mine near Fruitland, at location No. 51.

	Ft.	in.
Shale.		
Coal	4	
Coal, bony		6
Coal	5	
Slate, draw		2
Coal	2	
Slate, draw		2½
Coal (mined)	5	
Fire clay.		
	16	10½

Only the lower bench is worked. The quality of the coal is approximately the same as at the Pruitt, Jones, and Thomas mines.

RIO CHACO DISTRICT.

The Rio Chaco district includes that part of the field which lies south of San Juan River and north of the latitude of Fort Defiance, Ariz. Trending southward from the point where it crosses San Juan River, the Great Hogback forms a prominent series of detached, serrated, short ridges along the west border of the field until it disappears beneath the horizontal Tertiary strata of the Choiskai Mountains.

The coal-bearing formations in the Rio Chaco district are the Dakota, Mesaverde, and Laramie. The Dakota coal was not examined nor the formation mapped in this district.

The Mesaverde coal beds vary more in thickness and number than in the northern districts, and the barren rocks between the horizons of the Upper and Spencer beds of Mesa Verde are thicker. As may be seen from the map (Pl. XXII, p. 376), this formation covers a considerable area south of San Juan River, and forms the Great Hogback ridge. This fold becomes less pronounced in the direction of Bennett Peak and the strike of the upper beds swings eastward, paralleling Rio Chaco. The upper standstone forms the walls of Chaco Canyon to Pueblo Alto, above which point the stream has not cut its channel through it. The lower sandstone and along with it the lower part of the coal-bearing rocks continue their southerly trend until, dipping steeply, they disappear near Crozier beneath the unconformable Tertiary strata of the Choiskai Mountains.

The Laramie coal beds, where they are not concealed by unconformable Puerco marl, are of considerable thickness, but they do not compare with the Carbonero bed. It is not possible to correlate the individual coal beds with the beds north of San Juan River, because the Puerco marl prevents their being traced continuously through the district. No openings have been made on any of these coal beds, hence no samples were collected for analysis; but they are apparently of as good grade as the Carbonero bed at Fruitland and are freer from visible impurities.

No. 52: Where Rio Chaco has cut its channel through the Great Hogback about 2 miles south of Baldwin's store, a coal bed outcrops just above the lower sandstone of the Mesaverde. The strata here dip eastward at an angle of 40°. A section of the coal bed follows:

Section of Mesaverde coal bed in Rio Chaco Gap, at location No. 52.

	Ft.	in.
Sandstone, gray.		
Shale, brown, carbonaceous	2	
Coal, clear	5	1
Shale, brown, carbonaceous	3	
Sandstone.		

No. 53: Two miles farther south the following section of a coal bed in the Mesaverde is exposed in the Great Hogback:

Section of Mesaverde coal bed at location No. 53.

	Ft.	in.
Shale, dark, bituminous	10	
Coal	1	2
Shale, dark	5	
Coal	2	11
Shale, brown, carbonaceous.		

This section occurs just below the upper sandstone about 800 feet above the coal bed of location No. 52, described above.

No. 54: Southwest of Fruitland a coal bed is exposed in nearly horizontal Laramie strata with the following section:

Section of Laramie coal bed near Fruitland, at location No. 54.

	Ft.	in.
Clay, shale, dark.		
Coal	4	3
Shale, brown, carbonaceous		4
Coal		5
Shale, brown, carbonaceous.		
	5	

Between this latitude and Cottonwood Arroyo the Laramie coal beds have generally been burned near the surface and no idea of their thickness could be obtained. Six feet of coal, very resinous and breaking with a fracture similar to cannel coal, occurs in Cottonwood Arroyo at location No. 55. The coal bed dips eastward at an angle of 4°.

No. 56: About 4 miles south of the point where Cottonwood Arroyo crosses the Fruitland-Gallup road, 2 miles east of Rio Chaco, the following section of Laramie coal-bearing rocks is exposed about 60 feet stratigraphically above the basal sandstone:

Section of Laramie coal-bearing rocks at location No. 56.

	Ft.	in.
Sandstone, brown, shaly	8	
Shale, drab	3	
Shale, dark	1	
Coal, bony	2	7
Shale, brown, carbonaceous	7	
Coal	7	4
Shale, brown, carbonaceous.		
	28	11

The strata have a low easterly dip and the coal is clean and firm. In the bank of an arroyo about 2 miles northeast of this place, at location No. 57, the same coal bed was observed in like thickness and purity, hence it is probable that there is a considerable area of workable coal between these points.

No. 58: Just south of a tuffaceous lava peak protruding from the Great Hogback west of the mouth of Cottonwood Arroyo three coal beds occur below the upper sandstone of the Mesaverde. From the top downward the beds show, respectively, 7, 4, and 4 feet of clear, hard coal. The strata here dip at an angle of 30° S. 70° E.

No. 59: Two miles farther south these same coal beds appear in the following section:

Section of Mesaverde coal-bearing rocks at location No. 59.

	Ft.	in.
Sandstone, upper.		
Shale, brown, carbonaceous	3	
Coal	5	5
Shale, brown, carbonaceous	2	6
Sandstone	3	
Coal	4	2
Shale, brown, carbonaceous	15	
Coal	2+	
	35+	1

No. 60: In the Great Hogback, about 6 miles east of north of Ford Peak, where the upper strata of the Mesaverde formation begin to flatten and their strike changes to southeast, the following section of coal-bearing rocks is exposed beneath the upper sandstone:

Section of Mesaverde coal-bearing rocks exposed at location No. 60.

	Ft.	in.
Sandstone, massive, brown	20	
Shale, brown, carbonaceous	10	
Coal	1	9
Shale, brown, carbonaceous	2	
Sandstone	4	
Coal	3	6
Shale, brown, carbonaceous	9	
Coal	3	
Shale, brown, carbonaceous	7	
Coal	1	8
Shale, brown, carbonaceous	10	
Covered	10	
Sandstone	20	
Shale, hard, brown, containing fossil plants	3	
Coal	7	
Shale, brown, carbonaceous.		
	111	11

The beds here dip at an angle of 10° N. 75° E.

No. 61: In Captain Tom's Wash, about 1 mile above Crozier, 30 inches of coal is exposed a short distance above the lower sandstone which caps the Two Gray Hills in this vicinity. Coal beds, most of which are either thin or full of partings, were also observed in the Mesaverde strata in the wash both above and below this exposure. The Mesaverde rocks at Crozier dip toward the east at an angle of 5°.

No. 62: Four miles southeast of Sulphur Spring the upper strata of the Mesaverde formation lie practically horizontal and the following coal-bearing section is exposed below the upper sandstone:

Section of upper Mesaverde coal-bearing rocks at location No. 62.

	Ft.	in.
Shale, brown, carbonaceous.		
Coal	4	2
Sandstone and shale	50	
Shale, dark	3	
Coal	1	
Shale, brown	5	
Coal	1	10
Shale, brown, carbonaceous	6	
Sandstone, thin, shaly	12	
Coal	5	4
Shale, brown, carbonaceous	1+	
Sandstone and shale	30	
Coal	3	4
Coal, bony		1
Shale, brown, carbonaceous.		
	122	9

No. 63: About 3½ miles north of east of Crozier, near the Fruitland-Gallup wagon road, a coal bed belonging in the upper part of the Mesaverde formation has a thickness of 3 feet 7 inches. The strata here are practically flat lying. The coal appears to be good subbituminous. To the north, toward location No. 62, and to the south for about the same distance, this coal bed and others near it show a similar thickness and quality.

No. 64: About 2½ miles east of Rio Chaco and 4 miles north of the Crozier–Tiz Natzin wagon road the following coal section is exposed just above the flat-lying basal Laramie sandstone:

Section of Laramie coal bed at location No. 64.

	Ft.	in.
Clay shale.		
Coal	1	6
Shale, black		5
Coal	3	6
Shale		4
Coal	1	2
Shale, brown, carbonaceous.		
	6	11

Between this location and Coal Creek the Laramie formation is in many places hidden by the unconformably overlying Puerco marl, and in others by blown sand to such an extent that none of the coal beds of the formation were observed.

Just east of the northward bend of Rio Chaco the rocks dip north of west at an angle of about 3°, forming the eastern limb of a shallow syncline the axis of which extends southward toward the center of Zuni Basin and is probably coincident with the axis of that fold.

No. 65: In the canyon walls about 2 miles above the bend in Rio Chaco a 3-foot coal bed is exposed just below the upper sandstone of the Mesaverde formation. The strata here dip at an angle of 3° N. 60° W. Much of the coal formerly outcropping in the canyon walls in this vicinity has been burned.

No. 66: In the south wall of Chaco Canyon 3 miles below the mouth of Coal Creek the coal bed shown in the following section underlies the upper sandstone of the Mesaverde formation:

Section of Mesaverde coal bed in Chaco Canyon, at location No. 66.

	Ft.	in.
Shale, brown.		
Coal	1	
Shale	1	
Coal	7	
Coal, bony		6
	9	6

The coal appears to be a good grade of subbituminous, and is hard and blocky. The strata dip at an angle of 3° N. 20° W.

No. 67: On Coal Creek a bed of subbituminous coal near the top of the upper Mesaverde sandstone and above the horizon of any workable coal hitherto described in this formation was opened in 1901 for use at Tiz Natzin, an Indian trading post near by. A slope, subsequently abandoned, was driven for a distance of 25 feet on the coal bed, which dips N. 35° W. at an angle of 4°. The following is a section of the rocks exposed:

Section of upper Mesaverde coal-bearing rocks near Tiz Natzin, on Coal Creek, at location No. 67.

	Ft.	in.
Sandstone, limy, and containing fossil shells	2	
Sandstone, friable	30	
Coal	1	8
Coal, bony		5
Coal	3	2
Fire clay.		
	37	3

The analysis of a sample from the lower bench of this coal indicates a good grade of subbituminous coal. The coal makes a quick, hot fire and leaves a light, white ash.

No. 68: In Chaco Canyon, between the mouth of Coal Creek and Shawver's store, nearly all the coal beds exposed have been burned at their outcrops, but about midway between these localities a bed partially exposed shows a thickness of 4 feet. It lies 40 feet below the bed noted at location No. 67 and at about the horizon of the coal bed described at location No. 66.

Northeast of Shawver's store Laramie coal beds appear at a number of places between Rio Chaco and Coal Creek. Only the lower beds of the formation, including the basal sandstone, are exposed, the upper beds being concealed by overlapping Tertiary strata.

No. 69: This locality is about 3 miles north of the wagon road leading northeastward from Shawver's store. The following section of a coal bed a short distance above the basal Laramie sandstone is exposed in strata dipping N. 30° W. at an angle less than 1°:

Section of Laramie coal bed at location No. 69, 5 miles northeast of Shawver's store.

	Ft.	in.
Sandstone.		
Clay shale	2	
Coal, clear and blocky	3	4
Clay shale.		

No. 70: Two miles north of locality No. 69 and stratigraphically above the coal bed just described, the following coal section was measured:

Section of Laramie coal bed at location No. 70.

	Ft.	in.
Shale, brown, carbonaceous.		
Coal		10
Shale		5
Coal	1	5
Coal, bony, variable		¼
Coal	1	10
Shale, brown, carbonaceous.		
	4	6¼

No. 71: One mile farther north and not more than 50 feet stratigraphically above the exposure at location No. 70, the following coal section is exposed on a branch of Coal Creek:

Section of Laramie coal bed at location No. 71.

	Ft.	in.
Coal, bony, variable.		
Coal, containing fossil resin [a]	3	4
Shale, brown, carbonaceous.		

This coal is evidently of good quality. It is hard and blocky, and its high percentage of wheelerite causes it to ignite readily. The strata are nearly flat lying, and the bed, if persistent, may be mined under a considerable area.

No. 72: Two miles east of location No. 69 and near the same horizon a thick bed of Laramie coal is exposed. The strata are practically flat lying, and the coal is overlain directly by the unconformable Puerco marl. A section of the coal bed is as follows:

Section of Laramie coal bed 1½ miles north of wagon road, at location No. 72.

	Ft.	in.
Sand, unconsolidated.		
Coal		7
Shale, black, carbonaceous	1	3
Coal	1	8
Coal, bony		½
Coal	2	4
Shale		4
Coal	4	
Shale, black, carbonaceous.		
	10	2½

[a] Wheelerite, present in many of the coal beds in this field. For a description, see U. S. Geog. Surveys W. 100th Mer., vol. 3, 1875, pp. 630-631.

The lower bench in the above section is apparently of excellent quality and has the physical characteristics of cannel coal. The same bed is exposed in similar section half a mile farther east.

No. 73: In the north wall of Chaco Canyon, just below the mouth of Meyers Creek, a bed of good, shiny, black, subbituminous coal occurs below the upper sandstone of the Mesaverde formation. The bed is more than 8 feet thick, including a 3-inch bony streak. The strata dip about N. 20° W. at an angle of less than 2°. The coal bed is included in the following section:

Section of upper Mesaverde coal-bearing beds in Chaco Canyon, at location No. 73.

	Ft.	in.
Sandstone, massive	18	
Shale, dark	1	
Coal	1	
Shale, dark	4	
Sandstone, massive	5	
Coal	1	10
Coal, bony, variable		3
Coal	6	1
Shale, brown, carbonaceous.		
	37	2

Between this point and Putnam the coal bed is exposed at several places.

No. 74: The same coal bed is mined at the Pueblo Bonita mine, in the south wall of Chaco Canyon, for use at Putnam post-office and an Indian trading post which is located at the famous Aztec ruins, Pueblo Bonita, 1 mile above. This mine was opened by the Wetherills in 1905, by a 30-foot drift to the rise of the coal bed, a section of which is as follows:

Section of coal bed in Pueblo Bonita mine in Chaco Canyon, 1 mile below Putnam, at location No. 74.

Sandstone, upper.	Ft.	in.
Coal, bony	1	6
Coal	3	8
Coal, bony, and sandstone, variable		4
Coal	2	4
	7	10

The analysis of a sample of coal from this mine indicates a good grade of subbituminous coal, rather high in ash. The coal bed is workable under an extensive area, has an excellent roof and floor, and both benches can be mined, as the parting is easily separable from the coal. The strata dip at an angle of about 2° N. 20° W.

No. 75: Several beds of Laramie coal are exposed in the north branch of Meyers Creek 1½ to 2 miles above the crossing of the Putnam–Ojo Alamo wagon road. The lowest bed overlies the massive

basal sandstone. The following is a section of the rocks exposed in the bed of the arroyo:

Section of Laramie coal-bearing rocks in north branch of Meyers Creek, at location No. 75.

	Ft.	in.
Coal	3+	
Shale, brown, carbonaceous	8	
Coal	1	8
Shale, brown, carbonaceous		4
Coal	2	
Coal, bony	1±	
Sandstone and shale	50	
Sandstone	2	
Coal	3	4
Shale	1±	
Sandstone and shale	15	
Coal	2	8
Parting, variable		½±
Coal	1	4
Shale, brown, carbonaceous	1	
Sandstone and shale	30	
Shale, brown, carbonaceous	1	
Coal	2	9
Shale, brown, carbonaceous.		
	126	1½±

The beds dip N. 20° W. at a low angle and are unconformably overlapped by the Puerco marl, so that they are well exposed only in the stream channels. Apparently these coals can be mined under a large area.

No. 76: In each of the three branches of Escavada Wash, northeast of Putnam, the Laramie coal beds have been burned at the outcrop and the overlying and underlying sandstone baked a brick-red color over a considerable area, so that only one measurable exposure of coal was found. The following coal section is exposed in the south branch of the wash 8 miles above the Putnam–Ojo Alamo wagon road crossing and 3 miles above its juncture with the middle fork:

Section of Laramie coal-bearing rocks in Escavada Wash, at location No. 76.

	Ft.	in.
Sandstone, light gray	5	
Shale, drab	3	
Coal	1	7
Shale, drab	2	3
Coal	4	5
Shale, brown, carbonaceous	2	

The strata dip more to the north than on Meyers Creek, but at about the same angle.

No. 77: Above Putnam the Mesaverde coal beds thin rapidly and partings come in; at a distance of 2 or 3 miles up the canyon no single bench of coal was observed to have a thickness exceeding 37 inches.

An exposure, apparently typical of the upper Mesaverde coal beds east of Putnam, occurs in strata with a low northward dip outcropping in the southward-facing mesa cliff 7 miles south of Pueblo Alto, near the wagon road between Pueblo Alto and the Seven Lakes trading post. The section is as follows:

Section of coal bed near the Pueblo Alto–Seven Lakes wagon road, at location No. 77.

	Ft.	in.
Sandstone, massive	50	
Shale, drab	5	
Coal		6
Shale, dark, carbonaceous	4	
Shale, dark	4	
Coal and bony coal	1	10
Coal	1	11½
Coal, bony		3
	67	6½

No. 78: At a point about 1½ miles farther west the following section of Mesaverde coal is exposed in the same escarpment:

Section of Mesaverde coal bed at location No. 78.

	Ft.	in.
Shale, dark	3	
Coal, bony	1	
Coal	3	1
Shale, brown, carbonaceous	3	1
	10	2

This is the thickest coal bed observed in the upper Mesaverde in the area east of Putnam. The coal is apparently at the horizon of that in the Pueblo Bonita mine and is similar in appearance and quality.

No. 79: About 2½ miles north of Mariana's store, which is situated near the Pueblo Alto ruins, the Laramie coal beds are exposed where the unconformably overlapping Puerco marl has been worn away by stream erosion. One of these beds, occurring a short distance above the basal sandstone of the Laramie, shows over 7 feet of clear coal. Another, a short distance higher, is over 5 feet thick, but the exposures are so poor that nothing definite could be learned of the quality of the coal.

Between location No. 79 and Raton Spring no exposures of Laramie coal beds were observed, on account of a covering of either blown sand or overlapping Puerco marl.

No. 80: At a point about 4 miles southeast of Raton Spring an exposure of Laramie coal shows the following section:

Section of Laramie coal at location No. 80.

	Ft.	in.
Shale, drab, carbonaceous	15	
Coal, with thin shale partings	1	5
Sandstone		1
Coal	3	
Sandstone		½
Coal	2	
Shale, brown, carbonaceous.		
Total coal bed	6	6½

The strata dip northward at an angle of 2°. North and east of Raton Spring Laramie coals were observed, but not examined in detail. They are thick and of good quality.

The Indian trader at Seven Lakes and the postmaster at Cabezon reported to the writer that very thick beds of coal, generally clear of partings and of good quality, occur well toward the head of Arroyo de los Torreones. These beds, though not examined, are undoubtedly in the Laramie formation, as they are in the strike of the beds that outcrop at Raton Spring. Simpson[a] in his "Journal" mentions the occurrence of coal in the head of this arroyo.

Between Chaco Canyon on the north and the latitude of Seven Lakes on the south the rocks are intermediate in the Mesaverde formation and are barren of coal.

No. 81: About 5 miles southwest of Seven Lakes coal beds belonging to the lower Mesaverde outcrop in a tributary of Vacinte Wash. A section including these beds is as follows:

Section of lower Mesaverde coal-bearing rocks at location No. 81.

	Ft.	in.
Shale, drab	5	
Shale, brown, carbonaceous	1	
Coal, containing fossil resin	2	
Shale, drab	30	
Coal	2	11
Shale	1	
Coal	1	
Shale, drab, fissile	8	
Sandstone and shale, red (burned coal bed).		
	50	11

The strata dip to the north at the rate of 100 feet to the mile.

No. 82: Two coal beds in the lower Mesaverde are exposed 5 miles southeast of Togay Springs, where the following section was measured:

[a] Simpson, J. H., Journal of a military reconnaissance from Santa Fe, N. Mex., to the Navajo country, 31st Cong., 1st sess., Senate Ex. Doc. No. 64, 1850, p. 30.

Section of Mesaverde coal-bearing rocks 5 miles southeast of Togay Springs.

	Ft.	in.
Shale, drab.		
Coal	2	5
Shale, carbonaceous	2	
Shale and sandstone	12	
Sandstone	3	
Coal, bony		5
Coal		1
Shale, carbonaceous	3	
Coal	2	5
	25	4

The rocks dip northward at the rate of 200± feet to the mile.

GALLUP DISTRICT.

The Gallup district includes that part of the field which lies between the latitudes of Fort Defiance, Ariz., and Manuelito, N. Mex. The present paper includes a description of only the part of the district lying west of the Continental Divide, which passes in a northeast-southwest direction along a line from the head of Rio Chaco through Hosta Butte.[a]

The topographic features are dependent primarily on structure and secondarily on stream erosion. In the interior of the coal fields the rocks are for the most part flat lying, but in places are sharply folded. The region has been deeply dissected, so as to leave wide valleys, isolated flat-topped table-lands, and here and there low, sharp-crested ridges.

The borders of the coal areas are either prominent escarpments from which the strata dip gently toward the interior or serrated ridges in which they are steeply upturned. Thus a southward-facing escarpment in which the strata dip toward the north at an angle of 2° to 3° forms the border of the field from Hosta Butte westward to the north extremity of the Nutria monocline, where the rocks change in strike from west to south, forming a hogback in which they dip westward at a steep angle. On the west the coal field is limited by the Defiance monocline. In the vicinity of Fort Defiance the rocks in this fold dip steeply to the east, but the dip flattens rapidly toward the south until at the point where the fold is crossed by the Atchison, Topeka and Santa Fe Railway, near Manuelito, it is less than 5°. The strata affected by this fold do not include to any considerable extent the coal-bearing rocks above the Dakota. The Gallup structure section (Pl. XXIII, p. 382) illustrates the nature of the local folding in the vicinity of that town.

[a] For a description of the remainder of this district, see Schrader, F. C., Bull. U. S. Geol. Survey No. 285, 1906, pp. 251-252.

Gallup is the only town of consequence in the district, but Clarkville, Weaver, and Gibson are good-sized coal-mining camps.

The coals of the Gallup district represent three formations—the Dakota, Mancos, and Mesaverde. Those of the Mesaverde are the most valuable and the only ones at present mined. The Dakota coal was examined east of Gallup in the southward-facing escarpment north of the railroad, but was found to be thin and full of partings and consequently not of present commercial value. The position of this coal is not shown on the map.

The Mancos coal occurs in a bed of thin shaly sandstone 50 feet thick at the top of the formation. These beds are present in the Nutria monocline east of Gallup and along the western border of the coal field, but the coal is known to be of commercial value only east of Mariana Lake.

The Mesaverde coal is mined extensively in this district. Beds at both the upper and lower coal horizons are present, separated by 500 feet of barren strata. The beds at both horizons carry a good-grade subbituminous coal and range in thickness up to 8½ feet. Along the southward-facing escarpment that limits the field north of the railroad and east of the Nutria monocline the Mesaverde coal beds occur at the lower horizon. These have not been mined or even prospected, but in the natural exposures examined they appear to be of the same quality as in other parts of the district where they are mined.

No. 83: A typical section of the Mancos coal is exposed in the escarpment south of the entrance to Devils Pass, about 12 miles east of north of Thoreau. The coal compares well in quality with the sample collected in 1905 from the same bed in the Tiejen prospect, 10 miles east of north from Baca. The analysis shows a good subbituminous coal. It contains considerable fossil resin, which causes it to ignite readily. The strata at location No. 83 dip east of north at an angle of 7°. The section of the coal is as follows:

Section of coal bed in Devils Pass at location No. 83.

	Ft.	in.
Shale, drab.		
Coal	2	6
Shale		3
Coal		10
Shale, brown, carbonaceous.		
	3	7

No. 84: About 2 miles north of the locality just described the following section of the lower Mesaverde is exposed in an escarpment on the east side of the pass:

Section of Mesaverde coal beds in Devils Pass 4 miles east of Hosta Butte, at location No. 84.

	Ft.	in
Sandstone, massive.		
Shale	10	
Coal	3	6
Shale and sandstone	25	
Coal	3	6
Sandstone and shale	5	
Coal	3	6
Shale	8	
	58	6

No. 85: North of Mariana Lake, at Dalton's store, on the Guam–Seven Lakes road, a prospect has been opened on one of the lower Mesaverde coal beds. The bed is 3½ feet thick and lies between shale. The dip of the strata is about 3° NNE. The coal is reported to burn well without forming clinkers and to leave a small amount of ash.

No. 86: About 1 mile south of the Navajo Indian Reservation, on the Gallup–Seven Lakes road, 5 miles northwest of Little Togay Spring, the following section of a part of the lower Mesaverde is exposed:

Section of lower Mesaverde rocks at location No. 86.

	Ft.	in.
Sandstone, massive.		
Shale, brown, carbonaceous	1	6
Sandstone and shale	8	
Coal	3	6
Sandstone and shale	15	
Coal	2	6
Shale	8	
Sandstone, massive	15	
Sandstone and shale	17	
Coal, bony	1	
Shale, drab	4	
Coal	2	
Shale	20	
Coal	5	
	102	6

No. 87: North of the divide, about a mile west of the Gallup–Seven Lakes wagon road and about 3 miles northwest of the locality just described, the following section in the Mesaverde formation is exposed. It may represent in part the section of location No. 86.

Section including upper Mesaverde coal beds at location No. 87.

	Ft.	in.
Sandstone	8	
Shale, brown, carbonaceous	4	
Coal	2	6
Shale, brown, carbonaceous	1	
Shale	12	
Coal	3	6
Shale, brown, carbonaceous	3	
Coal	1	6
Shale	4	
Coal	1	2
Shale	5	
Coal	1	
	46	8

No. 88: The coal beds of the Weaver mine, 3 miles north of Gallup, occur in the upper Mesaverde, which is here about 100 feet thick. The section shown below, based in part on drill records obtained from the American Fuel Company, shows six workable coal beds.

Section of upper Mesaverde coal-bearing rocks at the Weaver mine, 3 miles north of Gallup.

	Ft.	in.
Coal	1	
Fire clay	2	
Coal, dirty, No. 1	3	6
Sandstone and shale	14	
Coal		6
Fire clay	7	
Coal, No. 2	4	6
Sandstone and shale	24	
Coal, No. 3	4	
Fire clay	2	
Sandstone	5	
Draw slate	1	6
Coal, No. 3½	6	3
Fire clay	2	6
Sandstone, shale, and thin coal seams	20	
Coal, with many shale partings, No. 4	3	
Sandstone	20	
Coal, No. 5	6	6
	127	3

All these beds have been worked at the Weaver mine, which is the largest producer in the district. At present only one bed—No. 3½—is being mined extensively, although some coal is being taken from bed No. 3. The roof of bed No. 3½ is firm shale and the floor fire clay. A slope has been driven for more than 4,000 feet west of north, on a dip ranging from 4° to 15°. Cross entries have been driven for 800 feet on either side of the main entry and diamond-drill prospecting has been carried a mile ahead of the workings. A number of small

rolls and faults have been encountered in the mine. Analyses show this to be a high-grade subbituminous coal.

No. 89: The Gallup mine is situated at Gibson, near the Weaver mine. Coal beds Nos. 3, 3½, and 5 were worked until early in 1904, when fire closed the mine and it has not yet been reopened. It was operated by a slope driven 5,000 feet on the dip of the coal bed.

No. 90: The Heaton mine, opened by the American Fuel Company in June, 1904, is working bed No. 3½. The mine is operated by a drift, which has been driven for more than 2,500 feet N. 25° W. on the dip of the coal, which ranges from 2° to 15°. The average thickness of the bed is about 3 feet 10 inches, including unimportant thin partings that are locally present. The roof of the coal bed is shale, the floor sandstone.

No. 92: The Otero mine, not now in operation, is located about 3 miles east and 1 mile north of Gallup. The coal beds worked at this mine occur in the lower Mesaverde formation. The section as exposed in the mine is as follows:

Section of lower Mesaverde coal beds in Otero mine, at location No. 92, near Gallup.

	Ft.	in.
Coal, Crown Point bed	3	5
Shale		8
Coal	1	5
Sandstone	11	
Coal, Thatcher bed	4	
Shale and sandstone	6	
Shale	9	
Coal, Black Diamond bed	1	6
Sandstone and shale	88	
Coal	1	2
Shale		9
Coal, Otero bed	3	2
Shale (?).		

Samples were collected from the Crown Point, Thatcher, and Otero beds. The coals are of a good subbituminous grade.

No. 94: The Union mine, situated about 2 miles south of Gallup, is working the Crown Point bed, which has an average thickness of about 6 feet, including a parting 2 feet from the top. The roof is shale and the floor fire clay. The mine is operated by a slope driven for more than 1,000 feet on the dip of the bed, S. 70° W. at an angle of 15°.

No. 95: The Rocky Cliff shaft, 2½ miles from Gallup, is situated a short distance south of Gibson. In it one of the beds of the lower Mesaverde is worked. The shaft is 250 feet deep. The average thickness of the bed is 5 feet.

No. 98: The Clark mine is situated at Clarkville, a mining camp about 4 miles west of Gallup. Diamond-drill borings have shown

the presence here of 5 coal beds of the upper Mesaverde, which in descending order have the following thicknesses:

Thicknesses of coal beds at Clarkville.

	Feet.
First bed	2½
Second bed	3½
Third bed	4½–8½
Fourth bed	5½
Fifth bed	4

Only the third bed is mined at present. The strata vary in dip throughout the mine, ranging from a very low angle to 4½° N. 70° E. Horsebacks and rolls are numerous in the mine. The partings in the bed mined, a section of which is given below, are nearly everywhere present, but vary greatly in thickness and are easily separable from the coal.

Section of upper Mesaverde coal bed in Clark mine, Clarkville, location No. 98.

	Ft.	in.
Shale, carbonaceous, brown and white streaked	1±	
Coal, not mined	3±	
Shale, brownish, sandy	4±	
Coal	2	
Coal, bony	1±	
Coal	2	
Shale, bituminous		3±
Coal	3	3
Fire-clay floor.		

Other mines in the district in which work is at present suspended on account of a decrease in the coal demand are the Rocky Cliff, Thatcher, Catalpa, and Casna.

Near Defiance switch three coal beds of the lower Mesaverde are exposed. The coal-bearing strata have a thickness of about 150 feet, and they dip north of east on the east limb of the local anticline, which trends north and south near Defiance switch and plunges at a steep angle in each direction away from the railroad.

No. 99: About 1¼ miles east of north from Defiance switch, D. M. Smith, a trader, opened a mine and shipped a few cars of coal in 1886. The mine was shortly afterwards abandoned. The coal worked is the lowest bed in the lower Mesaverde. It occurs in strata dipping N. 30° E. at an angle of 4°. The coal appears to be of good quality. A section including it is as follows:

Section of lower Mesaverde coal-bearing beds at abandoned Smith mine near Defiance switch, location No. 99

	Ft.	in.
Sandstone, massive	70	
Shale, carbonaceous	10	
Coal	2	9
Shale, carbonaceous	12	
Coal	4	
Shale, carbonaceous	1	
	99	9

No. 100: About 2 miles west of north from Defiance switch the following coal section is exposed in the lower Mesaverde, about 100 feet stratigraphically above the coal section just given:

Section of lower Mesaverde coal bed at location No. 100.

	Ft.	in.
Sandstone, thin bedded	2	
Shale, carbonaceous	1	
Coal	3	4
Shale, carbonaceous	15	
Coal	2	4
Shale, carbonaceous	5	
Coal	1	6
Shale, dark	3	
	33	2

No. 101: At an abandoned prospect about one-half mile northwest of location No. 100 a 4-foot bed of good subbituminous coal occurs about 60 feet stratigraphically above the section just given. The strata dip N. 70° E. at an angle of 4°.

The coal beds of the Mancos shale are generally thin and probably not of workable thickness anywhere along the western border of the coal field. They occur in a series of thin sandstone and shale beds at the top of the Mancos formation.

No. 102: About 2½ miles northwest of Manuelito, in rocks having a low dip to the west, Mancos coal is exposed as shown in the following section:

Section of Mancos coal 2½ miles north of Manuelito, at location No. 102.

	Ft.	in.
Fire clay		8
Coal, bony	2	
Coal		6
Shale		3
Coal		8
Sandstone, argillaceous	3	
Shale, dark		6
Coal, bony toward top	2	8
Shale, carbonaceous	20	
	30	3

No. 103: Six miles northwest of Defiance switch two coals of the lower Mesaverde are exposed. A section including these beds is as follows:

Section of lower Mesaverde coal-bearing rocks at location No. 103.

	Ft.	in.
Sandstone, massive	20	
Shale, drab	12	
Coal	3	5
Coal, bony, variable		1
Coal	2	9
Shale, carbonaceous	2	
Shale and sandstone	8	
Shale, drab		4
Coal	1	3
Coal, bony		6
Coal	1	3
Shale, carbonaceous	1	
	52	7

No. 104: Two miles west of north of location No. 103 the following section of the lower Mesaverde is exposed:

Section of lower Mesaverde coal-bearing rocks at location No. 104.

	Ft.	in.
Shale	25	
Coal, containing fossil resin	1	10
Shale, drab	6	
Coal	1	
Shale, drab	2	
Coal	6	
Sandstone	2	
Shale and sandstone	30	
Coal	1	
Shale, brown	4	
Coal		6
Shale, drab	20	
Coal	4	4
Coal, bony	1	
Coal	1	6
Shale	4	
Coal	1	6
Shale	3	
	114	8

The 6-foot bed near the top of this section is equivalent to the upper bed exposed at location No. 103. A large area in this vicinity is underlain by these coal beds and promises to be a good field for future development.

No. 105: At the St. Michaels mine, near the St. Michaels–Gallup wagon road 5 miles south of east of St. Michaels, Ariz., a coal bed in the lower Mesaverde was opened in 1904 to supply fuel for the mis-

sion school at St. Michaels. A tunnel was driven 35° E. for about 250 feet. The coal compares well with the best coals of the district. It is 53 inches thick and has a good sandstone roof and bony-coal floor.

No. 106: The Agency mine, situated 7 miles southeast of Fort Defiance, Ariz., has during the last ten or twelve years supplied coal for the Navajo Agency and school at Fort Defiance. About 600 tons are mined annually. The bed ranges from 5 to 6 feet in thickness. The roof is sandstone and the floor shale. The strata have a low easterly dip. Apparently the character of the coal is similar to that mined at the St. Michaels and it is probably the same bed. Unquestionably the coal beds are within the lower Mesaverde.

In the vicinity of the St. Michaels and Agency mines several other coal beds contained in the lower Mesaverde outcrop, four or five of them being of workable thickness and good quality. About midway between Fort Defiance and Tohatchi, near the wagon road at the foot of the steep hill, several of these coal beds outcrop, ranging up to 3 feet in thickness. The strata here dip 70° E. at an angle of 10°.

No. 107: A 3-foot bed of coal occurring in the lower Mesaverde outcrops north of the wagon road just mentioned 6 miles southwest of Tohatchi. A short distance north of this locality the Mesaverde formation dips at an angle of 10° and disappears beneath the unconformably overlying Tertiary clay shale of the Choiskai Mountains.

ZUNI DISTRICT.

The Zuni district includes the extreme southern extension of the coal field south of the Gallup district. It occupies a narrow north-south synclinal basin and extends from the latitude of Manuelito on the north to Salt Lake on the south. East and west the coal field of this district is limited by southward continuations of the Nutria and Defiance monoclines, respectively.

Along the western base of the Zuni Mountains the rocks in the Nutria monocline dip steeply away from the mountains. The outcropping edges of the hard rocks form sharp-crested ridges, between which are narrow valleys that have been cut in the softer sandstones and yielding shales. South of Ramah the fold is less pronounced and the coal-bearing rocks dip gently toward the interior of the basin. A short distance south of Manuelito the rocks in the Defiance monocline become less steeply tilted until in the latitude of Zuni village the coal-bearing rocks dip gently to the east toward the center of the district.

North of Zuni River the interior of the coal field is a wide piñon-covered table-land. Its surface is broken here and there by projecting, isolated buttes and by canyons. The Zuni plateau, which

includes the coal field south of Zuni River, is bounded on the east by an extensive lava flow, a tongue of which crosses the coal field south of Tarche in a wide belt and extends as far as the Arizona line. This lava flow forms a prominent table-land throughout its extent and, in connection with a fault of considerable magnitude which was observed 1 mile south of Ojo Caliente trending south of east, isolates the coal field in the southern part of the plateau. This part of the district will hereafter be designated the Salt Lake region. The relations of the lava flow, the coal rocks, and the fault are shown on the map (Pl. XXII) and in the structure sections (Pl. XXIII).

The workable coal beds of this district occur presumably in the Mancos formation. Fossils were collected north of Salt Lake in limy sandstone 35 feet below the lowest coal bed of the district and were determined by Stanton to be of Colorado age. As has already been stated, however, it is possible that the contact between the Mancos and Mesaverde formations lies between this fossil horizon and the coal beds, and if this is true the coals would be correlated with the lower Mesaverde. No bed of clear coal was observed of greater thickness than 4 feet. Since in the Salt Lake region the coal-bearing rocks are overlain in large areas by lava and unconformable Tertiary(?) strata, a determination of the presence of workable coal beds can be accomplished only by prospecting.

No. 108: In the monocline, about 4 miles east of south from Nutria, the following coal section is exposed in beds of the Mancos formation, which dip S. 40° W. at an angle of 16°.

Section of Mancos coal bed at location No. 108.

	Ft.	in.
Sandstone, coarse-grained	6	
Shale, dark, carbonaceous	1	
Coal	3	9
Shale, carbonaceous	10	
Shale and sandstone	12	
Coal		10
	33	7

The same bed, 40 inches thick, was observed to outcrop at a point about 1 mile south of this locality.

Nos. 109 and 110: Near the Nutria-Zuni road, midway between these towns, two mines were opened recently on coal beds of the Mancos formation. These mines supply fuel for the Zuni school and for use in the construction of a large dam at Blackrock. At the Harper mine (No. 109) the lowest of three beds outcropping in the vicinity has been opened by a 300-foot slope on the dip of the bed, which is N. 60° E. at an angle of 3°. The coal, as shown in the subjoined section, is full of partings. It is of inferior quality, though the 11-inch bench is an excellent blacksmith's coal.

Section of Mancos coal bed in Harper mine, at location No. 108.

	Ft.	in.
Shale roof.		
Coal, bony		4
Coal		5
Coal, bony		5
Coal	1	2
Coal, bony		5
Coal		11
Coal, bony		5
Coal		9
Fire clay.	4	10

The School mine (No. 110), situated about one-half mile northwest of the Harper mine, is in a bed of coal about 50 feet stratigraphically above the section just given. At the time visited this mine had just been opened by a short entry. An analysis of a sample taken at the working face shows the coal to be a good-grade subbituminous, although rather high in ash. The bed is 40 inches thick and lies between a shale roof and a fire-clay floor. About 7 feet above this coal occurs another bed which shows 34 inches of good, clear coal. The roof and floor are massive sandstone, each separated from the coal by about 2 inches of clay shale.

No. 111: Near the top of the mesa, about 10 miles east of Zuni village, the following section of a Mancos coal bed was measured in strata dipping eastward at a low angle:

Section of Mancos coal at location No. 111.

	Ft.	in.
Shale, gray, sandy	2	
Coal, bony	1	
Coal, bony at top	2	6
Coal, bony		2
Coal	2	6
Shale, drab.	8	2

No. 112: About 6 miles northeast of the Miller ranch, underlying a massive pinkish sandstone which is a prominent horizon marker in this vicinity, a Mancos coal bed 3 feet 2 inches thick, with shale roof and floor, is exposed in strata dipping to the north at a low angle. The same coal bed was observed at a point 1½ miles farther west and about 1 mile north of the Miller ranch.

In the head of Carrizo Valley, in the Salt Lake region, coal beds are exposed in the Mancos formation at numerous places. The maximum observed thickness of these beds is about 4 feet of clear coal.

No. 113: West of the Salt Lake–Tarche wagon road about 6 miles north of Papalota, where a Mexican store is located, the subjoined section of the Mancos coal beds is exposed in the mesa cliff. The

strata dip northward at a low angle beneath unconformably overlying Tertiary sediments.

Section of Mancos coal beds at location No. 113.

	Ft.	in.
Shale, drab	6	
Coal	2	8
Shale, black	1	
Shale, drab	20	
Coal, bony	1	
Shale	2	
Coal, with variable sandstone parting	2	
Shale	2	
Coal	1	
Coal, bony		1
Shale, sandy	14	
	51	9

No. 114: One mile east of the Salt Lake–Tarche wagon road and 6 miles east of north of Papalota, the following coal section occurs in Mancos strata, which dip S. 70° W. at an angle of 2°:

Section of Mancos coal bed at location No. 114.

	Ft.	in.
Shale, drab	3	
Shale, carbonaceous	1	
Coal	2	8
Shale, carbonaceous	1	
Coal	2	2
Shale, dark	1	2
	11	

At a point 1 mile farther south the lower bench of this coal bed is 26 inches thick and the parting measures nearly 1 foot, the upper bench remaining the same thickness.

No. 115: Two miles southeast of location No. 114 the following section of Mancos coal is exposed in flat-lying strata:

Section of Mancos coal bed at location No. 115.

	Ft.	in.
Shale, dark	1	
Coal	1	11
Coal, bony		10
Coal		11
Coal, bony		2
Coal	1	2
Coal, bony		5
Coal		10
Coal, bony		4
Shale, carbonaceous	5	
Total coal bed	6	7

No. 116: About 4½ miles north of east of Papalota a bed of Mancos coal outcrops in the escarpments of a wide, low mesa. The bed has

a thickness ranging from 30 to 36 inches and is free from partings The roof is sandstone and the floor carbonaceous shale. This bed can be mined under a considerable area in this vicinity.

No. 117: Eight miles north of Salt Lake, near the Provencer ranch, prospectors from Silver City, N. Mex., about ten years ago drove an entry for 30 feet in a Mancos coal bed. It is reported that $1,000 was spent by these people in prospecting the coal beds of this vicinity and that 30 coal entries were filed on but never proved up. The entry just referred to shows the following section:

Section of Mancos coal at Provencer prospect, location No. 117.

	Ft.	in.
Shale.		
Coal	2	
Coal, bony, sandy		½
Coal	1	
Coal, bony, sandy		½
Coal	1	
Shale, brown, carbonaceous.	4	1

No. 118: About 2 miles north of west of location No. 117 the Mancos coal-bearing rocks show the following section, which includes the thickest and best coal beds observed in this vicinity:

Section of Mancos coal beds at location No. 118.

	Ft.	in.
Shale.		
Coal	4	
Shale	6	
Coal	3	6
Shale.	13	6

This section occurs about 80 feet above the limy sandstone mentioned on page 380, in which fossils of Colorado age were collected.

CHARACTER OF COAL.

Throughout the Durango-Gallup field the coals have a bright luster and are clean to handle. When freshly mined they are hard but brittle and break badly with handling, thus producing a high percentage of fine coal. This fine coal or slack is in the greater part of the area waste, as the coals, except those in the Durango region, do not coke. In the Gallup district this waste amounts to nearly 20 per cent of the run-of-mine coal. In the vicinity of Durango, however, the fine coal is coked and the product used in the smelters of the region. The coke gives excellent satisfaction, but is reported not to bear shipment well, being somewhat brittle.

In the Gallup district the coals have a low specific gravity and give the best satisfaction under stationary boilers, as unburned fragments of the coal blow out of the stacks of locomotives on account of high forced draft. Throughout the field the coals are good domestic and steam-producing coals.

During the present work samples representative of the various coal beds were collected from mines and prospects in the coal field. Each sample was taken with great care and is thought to be representative of the bed in the opening in which it was taken. With two or three exceptions, all the samples were taken by making a cut across a fresh working face, including all the coal mined and excluding such partings as in practice are rejected. This material was pulverized and quartered in the mine and sent in sealed cans to the United States Geological Survey fuel-testing plant, where the analyses given in the following tables were made by F. M. Stanton.

Proximate analyses of coals from Durango-Gallup field, Colorado-New Mexico.

	Location.	Formation.	Name of coal bed.	Thickness of coal.		Sampler.
				Ft.	*in.*	
1	8 miles north of Mancos, Colo	Dakota		2	9	J. A. Taff. C. D. Smith.
2	Porter Colo	Mesaverde		3	7½	J. A. Taff.
3	do	do		2	2	Do.
4	Near Durango, Colo	do		5	6	J. A. Taff. C. D. Smith.
5	Porter, Colo	do		2	7½	J. A. Taff.
6	do	do	Porter No. 3	3	0	M. R. Campbell.
7	Hesperus, Colo	do		5	0	J. A. Taff.
8	Near Durango, Colo	do		6	10¾	M. K. Shaler
9	Hesperus, Colo	do		5	4	Do.
10	5 miles northeast of Pendleton, N. Mex.	Laramie	Carbonero	4	10	Do
11	Mancos, Colo	Mesaverde	Spencer	4	4	J. A. Taff.
12	do	do	do	3	0	J. A. Taff. C. D. Smith.
13	1½ miles northwest of Pendleton, N. Mex.	Laramie	Carbonero	7	0	F. C. Schrader. M. K. Shaler.
14	Mancos, Colo	Mesaverde	Spencer	3	0	J. H. Gardner.
15	1 mile west of Putnam, N. Mex	do		6	2	M. K. Shaler.
16	3 miles north of Gallup, N. Mex	do	Weaver No. 3	4	1	M. R. Campbell.
17	1½ miles east of Gallup, N. Mex	do	Otero	5	1	Do.
18	South of Cortez, Colo	do	Spencer	2	5	J. H. Gardner.
19	7 miles east of St. Michaels, Ariz	do		4	5	M. K. Shaler.
20	1½ miles northwest of Fruitland, N Mex.	Laramie	Carbonero	5	0	F. C. Schrader. M. K. Shaler.
21	Clarkville, N. Mex	Mesaverde		8	6	M. K. Shaler.
22	10 miles northeast of Blackrock, N. Mex.	Mancos		3	4	Do.
23	1½ miles east of Gallup, N. Mex	Mesaverde	Thatcher	4	0	M. R. Campbell.
24	3 miles north of Gallup, N. Mex	do	No. 3½	6	9	Do.
25	1½ miles east of Gallup, N. Mex	do	Crown Point	5	6	Do.
26	3 miles north of Gallup, N. Mex	do	No. 3½	6	9	Do.
27	30 miles west of Putnam, N. Mex	do		3	2	M. K. Shaler.
28	17 miles northeast of Thoreau, N. Mex.	Mancos		4	9	F. C. Schrader.

Proximate analyses of coals from Durango-Gallup field, Colorado-New Mexico—Cont'd.

	Laboratory No.	Analysis of sample as received.				Air-drying loss.	Analysis of air-dried sample.				Sulphur.	Fixed carbon+Volatile matter $+H_2O$.
		Moisture.	Volatile matter.	Fixed carbon.	Ash.		Moisture.	Volatile matter.	Fixed carbon.	Ash.		
1	3993	1.54	31.26	53.80	13.40	0.60	0.95	31.45	54.13	13.47	1.02	1.67
2	3996	2.57	32.92	55.27	9.24	1.10	1.49	33.39	55.87	9.35	.73	1.60
3	3997	2.02	34.92	55.89	7.17	.90	1.13	35.24	56.40	7.23	.48	1.55
4	3994	2.87	35.60	54.37	7.16	1.00	1.89	35.96	54.92	7.23	2.31	1.45
5	3995	3.33	34.85	52.68	9.14	1.90	1.45	35.52	53.70	9.22	1.15	1.45
6	2092	2.73	36.05	54.48	6.74	1.30	1.44	36.52	55.20	6.83	.54	1.44
7	3950	5.71	36.16	52.78	5.35	2.70	3.10	37.16	54.24	5.50	.67	1.35
8	3552	3.64	37.79	53.35	5.22	1.60	2.07	38.40	54.22	5.31	1.38	1.34
9	3573	5.55	36.23	52.53	5.69	2.30	3.33	37.08	53.77	5.82	.66	1.33
10	3639	7.14	33.54	46.73	12.59	3.00	4.27	34.58	48.18	12.97	.57	1.25
11	3991	6.12	35.86	49.44	8.58	2.50	3.71	36.67	50.82	8.80	.64	1.25
12	3992	5.42	38.14	51.29	5.15	2.00	3.48	38.94	52.33	5.25	.80	1.23
13	2465	8.30	35.56	47.89	8.25	4.60	3.88	37.28	50.19	8.65	.69	1.22
14	4225	5.44	38.71	50.10	5.75	2.00	3.51	39.50	51.12	5.87	1.03	1.19
15	3823	17.46	32.92	41.26	8.36	9.70	8.59	36.46	45.69	9.26	2.44	1.01
16	1023 1024	11.77	41.85	43.11	3.26							
17	1038	10.80	40.35	42.77	6.08							
18	4226	20.92	31.37	41.26	6.45	9.40	12.72	34.62	45.54	7.12	.47	.96
19	4112	14.49	37.08	44.58	3.85	5.10	9.89	39.07	46.98	4.05	.42	.96
20	2464	9.89	38.44	41.48	10.19	4.50	5.65	40.25	43.43	10.67	.67	.95
21	2434	13.95	38.43	42.12	5.50	9.30	5.12	42.37	46.45	6.06	.59	.95
22	3952	7.76	37.60	38.66	15.98	3.90	4.01	39.12	40.22	12.62	1.54	.93
23	1028	9.68	41.42	40.82	8.08							
24	102b	11.00	42.63	42.44	3.93							
25	1027	9.13	40.77	40.23	9.87							
26	1025	10.92	42.63	42.35	4.10							
27	3811	15.79	34.99	39.85	9.37	7.60	8.86	37.86	43.13	10.14	1.92	.92
28	2361	15.03	37.26	41.97	5.74	5.20	10.37	39.30	44.27	6.06	.60	.90

Ultimate analyses of selected coal samples from Durango-Gallup coal field, Colorado-New Mexico.

	Near Durango, Colo.	Hesperus, Colo.	Mancos, Colo.	7 miles east of St. Michaels, Ariz.	10 miles northeast of Blackrock, N. Mex.	3 miles northwest of Gallup, N. Mex.	1½ miles east of Gallup, N. Mex.	30 miles west of Putnam, N. Mex.
Laboratory No.	3552.	3573.	4225.	4112.	3952.	1278.	1307.	3811.
Analysis of sample as received:								
Prox. Moisture	3.64	5.55	5.44	14.49	7.76	12.29	10.79	15.79
Prox. Volatile matter	37.79	36.23	38.71	37.08	37.60	34.58	33.82	34.99
Prox. Fixed carbon	53.35	52.53	50.10	44.58	38.66	46.14	36.73	39.85
Prox. Ash	5.22	5.69	5.75	3.85	15.98	6.99	18.66	9.37
Ult. Sulphur	1.36	.64	1.01	.41	1.48	.63	1.26	1.78
Ult. Hydrogen	5.39	5.46	5.80	6.02	5.67	5.82	5.22	5.93
Ult. Carbon	75.40	72.70	72.26	63.41	60.55	63.31	55.07	55.74
Ult. Nitrogen	1.48	1.37	1.47	1.23	.99	1.03	.95	1.39
Ult. Oxygen	11.15	14.14	13.71	25.08	15.33	22.22	18.84	25.79
Calorific value determined:								
Calories	7,553	7,289	7,170	6,371	6,248	6,251	5,504	5,539
British thermal units	13,595	13,120	12,906	11,468	11,246	11,252	9,907	9,970
Loss of moisture on air drying	1.60	2.30	2.00	5.10	3.90	1.60	2.90	7.60
Analysis of air-dried sample:								
Prox. Moisture	2.07	3.33	3.51	9.89	4.01	10.86	8.13	8.86
Prox. Volatile matter	38.40	37.08	39.50	39.07	39.12	35.14	34.82	37.87
Prox. Fixed carbon	54.22	53.77	51.12	46.95	40.22	46.90	37.83	43.13
Prox. Ash	5.31	5.82	5.87	4.05	16.62	7.10	19.22	10.14
Ult. Sulphur	1.38	.66	1.03	.42	1.54	.64	1.30	1.92
Ult. Hydrogen	5.29	5.32	5.69	5.75	5.45	5.73	5.05	5.50
Ult. Carbon	76.63	74.41	73.73	66.81	63.00	64.34	56.71	60.32
Ult. Nitrogen	1.50	1.40	1.50	1.28	1.03	1.05	.98	1.51
Ult. Oxygen	9.89	12.39	12.18	21.69	12.36	21.14	16.74	20.61
Calorific value determined:								
Calories	7,676	7,461	7,316	6,723	6,500	6,353	5,668	5,994
British thermal units	13,816	13,429	13,163	12,083	11,702	11,435	10,202	10,790
Carbon-hydrogen ratio	14.48	13.99	12.96	11.60	11.56	11.23	11.23	11.00

The ultimate analyses given in the second of these tables and the physical character of the coals show that they may be classified as ranging in quality from high-grade bituminous to high-grade subbituminous coals. According to the carbon-hydrogen ratio of classification proposed in 1905 by M. R. Campbell,[a] these coals fall into the following groups:

The Perrine Peak coal of the Mesaverde formation falls into group G, which includes high-grade bituminous coals of the Appalachian field from West Virginia, Pennsylvania, Kentucky, Alabama, etc. All the Mesaverde coals of the Durango-Porter region likewise fall into this group.

The coals from Hesperus and Mancos fall into group H, which includes the best bituminous coals of the eastern and western interior coal fields from Indian Territory, Kansas, Illinois, Kentucky, Iowa, Missouri, etc.

The coals from the neighborhood of St. Michaels, Ariz., and of Blackrock, N. Mex., fall into group I, which includes lower-grade bituminous coals from Iowa, Illinois, Indiana, Wyoming, Montana, etc.

The Mesaverde coals from the Chaco region and from the Gallup district fall into group J, which includes subbituminous coals and lignites from Texas, Colorado, North Dakota, and Wyoming.

According to the analyses made at the United States Geological Survey fuel-testing plant of samples of coal collected during 1906 by various members of the Survey in different coal fields of the West, given elsewhere in this volume, the high-grade bituminous coals of the Durango region are as good as the best bituminous coals in any other of these western fields. The Laramie coal of the Durango-La Plata region has a higher fuel value than any other coals of that age in the West except those of the Grand River and Book Cliffs fields of Colorado and eastern Utah.

A classification based on proximate analyses is very satisfactory for the comparison of coals of a similar grade in any one area. As will be seen by reference to the first of the two foregoing tables, in which the analyses are arranged in the order of their relative fuel values according to the ratio $\frac{\text{Fixed carbon}}{\text{Volatile matter} + \text{water}}$, the coals of the Durango-Hesperus-Laplata region are the best in the field; the Mesa Verde coals, except that of the Todd mine, are second, and the coals of the area south of San Juan River are the poorest in quality.

Ash being left out of consideration, it is thus plain that the quality of the coals in this field is in a general way not dependent on geologic age, but on the degree of metamorphism that they have suffered. Very evidently the proximity of the coals of the northern part of the

[a] Classification of coals: Trans. Am. Inst. Min. Eng., Washington meeting, May 1, 1905.

area to the great San Juan uplift had a controlling influence over this greater degree of metamorphic change.

Were it not for the high percentage of ash and water present in the coals of Laramie age, in the northern part of the field, their fuel values would be equal to those of the Mesaverde coals of that region.

DEVELOPMENT AND MARKETS.

The earliest development of the coal resources of this field, outside of small workings to supply a limited domestic demand, began with the advent of the railroads. The Denver and Rio Grande Railroad reached Durango in 1881. It was late in the eighties, however, before any great activity in coal mining began in the northern part of the field. In the vicinity of Gallup, coal mining began late in 1881 or early in 1882, at about the time the Atlantic and Pacific Railroad (Atchison, Topeka and Sante Fe) reached Gallup from the East. The Rio Grande Southern Railway was built northwestward from Durango in 1892.

The total coal production to date in that part of the Durango-Gallup field under consideration is 10,000,000 short tons, valued at the mines at approximately $15,000,000. The output since 1901 has been about 650,000 tons[a] yearly, without any considerable variation from year to year during that period. Coke has been produced in the Durango region to the value of about $30,000 yearly since the advent of the Rio Grande Southern Railway.

The greatest development has taken place in the Gallup district, where the output since 1900 has trebled that of the remainder of the field. That the development in this district is not greater is due to a single factor—lack of demand for the product. The demand for Gallup coal is kept at its present status partly on account of the substitution of oil from California and Texas for coal as fuel on the railways of the West and Southwest, and partly on account of the lack of direct railway connection with the mining region of southern Arizona and the absence of railway competition which might lessen freight rates. Aside from the Gallup district most of the development of the coal resources of this field has been in the Durango-Mancos district. The market for this part of the field is the mining camps of the San Juan region and the Denver and Rio Grande and Rio Grande Southern railways.

The development in this coal field has been entirely dependent on railway facilities. There are good markets for coal and coke which could be economically reached from any part of the field if railway connections were established and freight rates were rendered more reasonable by competition.

[a] This figure includes coal made into coke.

Throughout the field the conditions for economical mining are favorable so far as topography is concerned. Railways with light grades, to which the coal beds of the area would be easily accessible, could be constructed almost anywhere through the field. In the northern, western, and southern parts timber available for mining purposes is at hand, but the country in the vicinity of Rio Chaco is barren of forests. In the interior of the field water in quantity can undoubtedly be obtained at moderate depths by boring. This has already been proved in the Gallup district, where an ample supply of artesian water has been obtained at a depth of about 1,000 feet. In the northern part of the field the streams carry an abundant water supply throughout the year.

THE UNA DEL GATO COAL FIELD, SANDOVAL COUNTY, N. MEX.

By Marius R. Campbell.

General description.—The Una del Gato coal field is located in Sandoval County, N. Mex., about 15 miles south of Los Cerrillos and 14 miles east of a stopping place on the Santa Fe Railway known as Algodones. (See fig. 4.) It lies in a depression between the Ortiz Mountains on the east and the north end of the Sandia Range on the southwest. The coal is best developed in T. 13 N., R. 6 E., but it is known to extend to the north into T. 14 N., R. 6 E., and to the east into T. 13 N., R. 7 E. It is probably connected with the Cerrillos coal field, but the intervening country is so deeply covered with gravel that the indurated rocks are largely concealed, and hence the exact relationship is unknown.

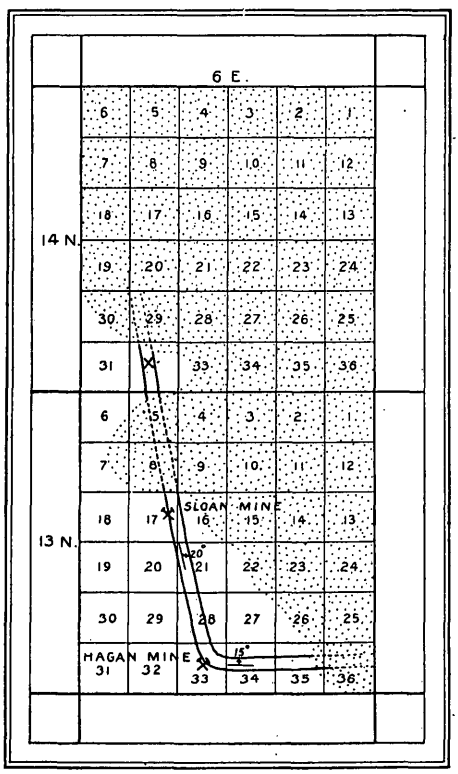


FIG. 4.—Map of Una del Gato coal field, New Mexico.

The field is not yet developed on a commercial scale, as it has no railroad connection. The most work has been done at the south end, in what is known as the Hagan field. This is mainly comprised in secs. 33 and 34, T. 13 N., R. 6 E. Another point of development is in sec. 17, in what is known as the Sloan field. The northern extremity has been extensively worked in the past and is known as the Pina Vititos field.

In the hasty visit which the writer paid to this field no opportunity was afforded for determining the age of the coal-bearing rocks, but it is highly probable that they are Laramie, corresponding to the coal-bearing beds of the Cerrillos field. In the Una del Gato field the coal beds occur in a formation composed largely of sandstone. Its character is well shown by the following section, measured by Charles R. Keyes,[a] near the Sloan mine:

Section of coal-bearing rocks at Sloan mine.

	Ft.	in.
Sandstone, massive, yellow	20	
Shale, drab	4	
Coal	2	
Shale, sandy	6	
Coal	2	
Clay		6
Coal	2	
Shale, drab	5	
Coal	1	
Sandstone, soft, yellow	5	
Coal	4	
Shale, sandy	4	
Sandstone, yellow	3	
Shale, variegated	20	
Sandstone, yellow	2	
Shale, light	10	
Coal, impure on outcrop	5	
Shale, with 6 inches of gypsum	11	
Sandstone, shaly	3	
Shale, drab	5	
Coal	1	
Shale, light	8	
Coal	1	
Sandstone, generally massive	116	
	240	6

The country between the mountain ranges has been reduced to a peneplain and then deeply covered with gravel. On account of this covering the coal beds are visible only where the gravel cap has been removed. The rocks are thus exposed throughout secs. 33 and 34, T. 13 N., R. 6 E., striking east and west and dipping about 15° N. Near the center of sec. 33 the rim of the basin turns to the north almost at right angles and the rocks are well exposed for a distance of 3 miles to the Sloan mine. Throughout this course the strike is nearly north and south and the dip about 20° E. North of the Sloan mine the mesa is not dissected for about 2 miles and consequently the rocks do not appear, but they are again well exposed in sec. 32, T. 14 N., R. 6 E., in what is known as the Pina Vititos field, where a small stream has cut across the rim of the basin, exposing all of the beds.

[a] Unpublished private report.

Hagan mine.—This is the most important mine in the field. It is located near the center of sec. 33, T. 13 N., R. 6 E., at the point where the rim of the basin turns abruptly from an east-west to a north-south course. The coal mined is known locally as the Hopewell bed. It outcrops near the base of the cliffs and the mine has been driven down on the dip (about 15°) for more than 700 feet. In that distance the coal bed holds remarkably constant, ranging from a little less than 4 feet to 4 feet 3½ inches in thickness. Generally it is free from shale or clay partings, but near the mouth of the mine a small parting is present. The roof and floor are both composed of massive sandstone, which makes mining comparatively simple. Although the mine is located at the point where the strike changes abruptly, the coal does not appear to be materially disturbed by faults or minor folds.

The coal is of excellent appearance, hard and bright, and evidently belongs to the bituminous class.

Other coal beds occur in the same section, but they are either too small or too impure for commercial use.

Sloan mine.—This mine is located near the middle of sec. 17, T. 13 N., R. 6 E. The rocks are considerably disturbed by faults which cut them in various directions. Much of the exploratory work at this place has been wasted on account of failure to recognize these faults, and any permanent mine work to be successful must be so planned as not to be affected by them. Several coal beds are exposed, but no attempt was made to determine the total number. The most prominent, supposed to be the same as the Hopewell bed at the Hagan mine, has the following section:

Section of coal bed at Sloan mine.

	Ft.	in.
Coal	1	9
Shale		8½
Coal	1	3
	3	8½

Pina Vititos field.—Apparently the same beds are exposed in the Pina Vititos field as were seen at the Sloan and Hagan mines. The Hopewell bed has been extensively mined in the past and seems to run about 4 feet in thickness. A bed 12 or 15 feet below the Hopewell has the following section:

Section of coal bed in Pina Vititos field.

	Ft.	in.
Coal	1	1½
Shale	1	3½
Coal		7½
Shale		11½
Coal	1	6
	5	6

Analyses.—The chemical composition of the Hopewell coal is shown by the following analyses made from samples collected by the writer in the south end and in the middle of the field:

Analyses of coal from Una del Gato field.

[E. E. Somermeier, analyst.]

	South end of field.	Middle of field.
Laboratory No	1012	1013
Moisture	7.81	9.68
Volatile matter	44.72	42.32
Fixed carbon	41.80	41.36
Ash	5.67	6.64
Sulphur	.69	.66

It has also been tested by the owners, who report the following analyses, made at the Pittsburg Testing Laboratory (Limited).[a] The writer has no knowledge of how the sampling was done, nor of how the samples were handled afterwards. The analyses are given merely for what they are worth:

Analyses of coals from the Una del Gato field.

	Hagan mine.	Sloan mine.	Pina Vititos mine.
Moisture	6.25	7.28	9.03
Volatile matter	40.40	42.49	42.35
Fixed carbon	47.56	43.60	44.17
Ash	5.78	6.63	4.45
Sulphur	.62	.67	.66

[a] Unpublished private report of Charles R. Keyes.

COAL IN THE VICINITY OF FORT STANTON RESERVATION, LINCOLN COUNTY, N. MEX.

By MARIUS R. CAMPBELL.

During the past year the writer made a hurried examination of the Fort Stanton Public Health and Marine-Hospital Service Reservation and immediate vicinity in search of coal. Although the work was rapidly done and only a small area examined, certain facts regarding the occurrence of coal in that field were determined which seem to be of sufficient importance to justify publication.

The Fort Stanton Reservation is located about 6 miles west of Lincoln, the county seat of Lincoln County, N. Mex. It occupies the valley of Bonito Creek, which heads in the White Mountains to the southwest, and it extends northward nearly to the foothills of the Capitan Range. Access to the reservation is had by wagon road from Roswell, on Pecos River, 50 miles to the east, or by a branch line of the El Paso and Southwestern System from Carrizozo on the west. This branch railroad was originally built to develop the coal mines at Capitan, but since the mines as well as the railroad have passed into the hands of the El Paso and Southwestern System, mining has been abandoned and train service has been all but discontinued. According to report, mining was stopped on account of the great number of dikes encountered and because the coal could not compete with that from the Dawson mines in Colfax County, which were acquired by the same company.

The geologic relations in the Capitan coal field are not easily made out, as the country is seamed and cut by dikes in all directions and by at least one fault of considerable proportions. The coal-bearing rocks of the field have been called Laramie, but apparently on no evidence except that they are probably Cretaceous in age and lie above the Benton (Colorado) shale. Fossils are not abundant in the coal field, but the writer made a small collection of fossil leaves from a sandstone bed closely underlying the coal at an abandoned mine about a mile west of the village of Capitan. The material was not sufficient for a final determination, but according to the following report of F. H. Knowlton is classed as probably of Laramie age:

From this small but interesting collection I have been able to identify the following forms with a considerable degree of certainty: *Cinnamomum affine* Lesq., *Platanus*

Raynoldsii? Newby, *Populus* sp.? cf. *P. melanarioides* Lesq. The most abundant form in the collection is the *Cinnamomum*, which appears to be the *C. affine* of Lesquereux, but the leaves are rather smaller than the normal leaves of that species and not all of them quite agree with the types. It may be that it is a new but closely related species, though if correctly determined—and I believe it is—it would indicate a Laramie age for the beds. The specimen identified with *Platanus Raynoldsii* is a mere fragment from the base of the leaf, but it can hardly be another species. The *Populus* is a smaller leaf than the type specimen of *P. melanarioides*, but is otherwise indistinguishable. My opinion is that the beds in question are Laramie in age.

The extent of these beds could not be determined, but from their widespread distribution on the summit northwest of Capitan and along Bonito Creek it seems that they must have a thickness of many hundreds of feet, possibly approaching 1,000 feet. In general they consist of sandstone and shale, the former buff or yellowish white, and the latter variegated in color, with reds and greens of common occurrence. Coal beds are present in this formation, but most of them seem to be small, having a thickness of only a few inches.

In the vicinity of Capitan there is at least one coal bed of workable thickness, which has been prospected along the outcrop from a point about 1½ miles southwest of the village northward for a distance of 2 or 3 miles. Many openings have been made and coal has been mined at various places along this line of outcrop. The two principal mines were known as Capitan Nos. 1 and 2. Mine No. 1 is located in sec. 4, T. 9 S., R. 14 E., and mine No. 2 in the E. ½ NE. ¼ sec. 8, T. 9 S., R. 14 E. All work is now abandoned except in mine No. 1, which is leased by local residents and in which a small amount of coal is being mined for home consumption.

The coal is bright and hard enough to stand transportation. No chemical analyses are available by which to determine its characteristics, but from physical appearance it should be classed undoubtedly as a bituminous coal. No measurements were made of the thickness of the bed in mine No. 1, but near the mouth of mine No. 2 the coal has the following section:

Section of Capitan coal bed in mine No. 2.

	Ft.	in.
Sandstone roof.		
Coal	1	7
Shale		4
Coal	3	6
	5	5

The fossil plants noted above were obtained from the vicinity of this mine. Both Nos. 1 and 2 are slope mines, the coal bed dipping about 4° to 8° SW.

As shown by the accompanying sketch map (fig. 5), the coal outcrops in a nearly north-south direction, approximately along the line between secs. 4–5 and 8–9. To the north it probably passes into

T. 8 S., R. 14 E., but its outcrop was not definitely located. South of mine No. 2 the outcrop can be followed for a distance of about a mile to a point where it is cut off abruptly by a fault which extends at least across parts of three tiers of townships. This fault passes about half a mile west of Capitan in a nearly north-south direction. A little south of the village it swings to the west and passes about 800 feet west of the west corner (No. 47) of the Fort Stanton Reservation. From this point it trends nearly southward for 2 miles and then swings to the southwest, crossing Bonito Creek just above the main road, about 2 miles east of Angus. From this point on Bonito Creek the

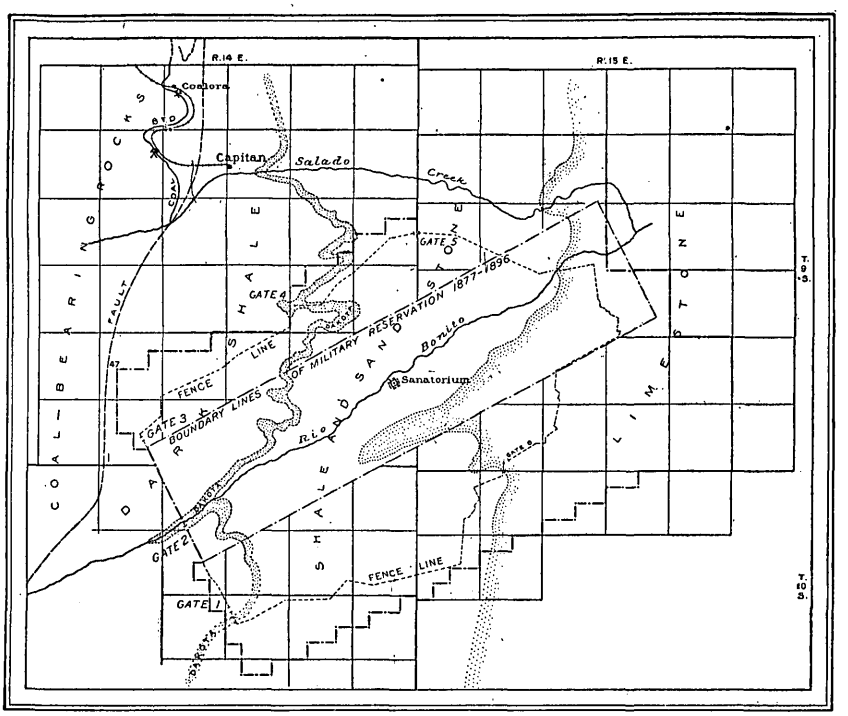


FIG. 5.—Geologic sketch map of Fort Stanton Reservation and vicinity, New Mexico.

fault trends to the southwest in the direction of Ruidoso, where coal of workable thickness is reported. It seems possible that the Capitan coal bed reappears near Ruidoso and that in the intermediate area it is so far below the surface as to be beyond reach.

Time did not permit an extended reconnaissance to determine the relation of the rocks on the two sides of this fault, but enough was seen to warrant the belief that the beds on the east side have been raised relative to the coal-bearing rocks on the west side. The amount of displacement could not be determined. It seems probable, however, that it is not great, and that in the vicinity of Capitan it may be less than 200 feet.

The rocks exposed east of the fault show the following section, the thicknesses being estimated:

Geologic section in Fort Stanton Reservation.

	Feet.
1. Sandstone, massive, yellowish brown; highest rock east of fault; caps mesa southwest of Capitan, possibly base of Laramie	100
2. Shale, mainly dark, almost black at base (fossiliferous)	500
3. Sandstone, massive, traces of plant stems	100
4. Shale and sandstone, the former variegated	300
5. Limestone, gray (sparingly fossiliferous)	700
6. Shale, variegated.	

The only fossil found in No. 1 is an oyster, which is not distinctive, but, according to T. W. Stanton, may be of Montana age. A few fossils were found at the base of No. 2, at the southwest corner of sec. 22, T. 9 S., R. 14 E., and also near the upper (No. 2) gate of the reservation in the SW. ¼ sec. 9, T. 10 S., R. 14 E. Doctor Stanton reports on these as follows:

> The lot from near the upper gate of the Fort Stanton Reservation consists of dark calcareous shale, with many specimens of *Inoceramus labiatus* Schloth. and some imperfect imprints of two species of ammonites, probably belonging to the genus *Prionotropis*. The horizon is in the Benton group.

The dark shale identified by Doctor Stanton as Benton rests directly upon a massive sandstone, supposed to be Dakota, that is well exposed in the gorge of Salado Creek, one-half mile east of Capitan, where it dips to the west and passes under the dark shale forming the valley in which the village is located. From its outcrop on Salado Creek the sandstone swings to the south and enters the reservation in the vicinity of gate No. 4. It is not well exposed on the road from Fort Stanton to gate No. 4, but can be seen in every side ravine entering Bonito Creek from the west above the sanatorium. This bed crosses Bonito Creek about a mile below gate No. 2 and then passes out of the reservation between gate No. 2 and the south corner.

Traces of coal were found in this sandstone, but nothing of economic importance. Toward the base the massive sandstone is replaced by thinner-bedded sandstones accompanied by shale. At the time of the visit these lower beds were regarded as part of the same formation, but on comparison with other sections in the Territory it seems probable that the beds below this massive sandstone are of Morrison age, and consequently are not directly related to the Dakota sandstone.

The shale and sandstone beds of the supposed Morrison formation rest upon a great mass of gray limestone, which covers the eastern half of the reservation and which is supposed to be of Carboniferous age, although no fossils were obtained by which to determine this point. The limestone is apparently underlain by reddish shale, but the writer had no opportunity of examining this part of the sections, and consequently knows little regarding it, except what could be seen from a distance.

COAL OF STONE CANYON, MONTEREY COUNTY, CAL.

By MARIUS R. CAMPBELL.

In Contributions to Economic Geology for 1905, Ralph Arnold published a brief account [a] of the coal bed showing in Stone Canyon, in the southeast corner of Monterey County, Cal. From his description the coal appears to be exceptionally good for this region; and so the writer, during the last year, made a brief examination of the mine and sampled the coal for chemical analysis.

As noted by Arnold, the coal is unique as regards its geologic age, but the presence a few feet above the coal bed of a richly fossiliferous sandstone fixes its age as Lower Miocene beyond the possibility of a doubt.

The coal bed lies very close to the contact between the Miocene sandstone and the Franciscan chert and serpentine. The younger beds rest in a syncline upon the older rocks, and considerable time and money have been spent searching for the outcrop of this coal bed on the other limb of the syncline, along the contact of what has always been supposed to be the same formations. The chief value of Arnold's contribution is that he has shown conclusively that the coal-bearing sandstones are overlain unconformably by the Upper Miocene sandstones and shales, and that it is the latter rocks which are in contact with the Franciscan on the northeastern limb of the trough. According to this determination the horizon of the coal bed is not present in that region, and consequently search for it in the past has been unrewarded, and in the future will yield only negative results.

At the time of Arnold's visit it was supposed that the clay which lies below the coal and which is commonly regarded as forming the foot wall was residual clay, resulting from the decay of the serpentine rocks (Franciscan). Since t hat time, however, a crosscut or tunnel has been driven from the coal bed for a distance of 50 feet toward the Franciscan; but the only rocks cut in this tunnel are clay and greenish sandstones closely resembling the Lower Miocene sandstone as seen in the canyon just above the mine. Not only do these rocks appear to be part of the coal-bearing Miocene, but, so far as the writer could determine, they do not show any evidence of

[a] Coal in the Mount Diablo Range, Monterey County, Cal.: Bull. U. S. Geol. Survey No. 285, 1906, pp. 223-225.

shore conditions and material directly derived from the Franciscan rocks. In view of this development the coal bed can not be regarded as resting directly upon the Franciscan, nor can the contact between the two rock masses be regarded as undoubtedly that of nonconformity, due to overlap.

This conclusion is of the utmost importance in the commercial development of the mine, for the reason that if the coal was deposited upon the uneven floor of the old Franciscan land mass the coal bed would be subject to abrupt and extreme variations in thickness, and consequently would be irregular in its geographic extent. If, however, at least 50 feet of material was laid down before the coal was deposited, the latter is likely to be fairly regular in thickness, and mining operations can be carried on with the prospect of finding the bed of workable thickness over a rather large area.

The coal bed is developed by a mine in sec. 14, T. 22 S., R. 13 E., which consists of two openings—one a slope 350 feet in depth going down toward the northeast nearly on the coal bed, which dips at an angle of 63°, and the other a drift southeast of the creek, where the coal bed stands nearly vertical. The mouth of this drift is 1,500 feet southeast of the slope and it has been driven in on the coal bed in a southeasterly direction for a distance of 3,000 feet. From the bottom of the slope gangways have been driven for about 2,000 feet and a drill has been sunk on the bed for a distance of 250 feet below the floor of the gangway. Throughout the extent of the developed mine the coal bed holds a fairly uniform thickness, but accurate measurements were difficult to obtain, as the lower part of the bed was not always removed. The gangways are in general from 10 to 12 feet wide, and they rarely reach both the top and bottom of the bed. Tests at various places in the mine have shown from 14 to 18 feet of coal with an average thickness of about 15 feet.

On the surface the coal is exposed at only a few places, but extensive prospecting has showed, according to the owners, that the coal bed extends in a northwest-southeast direction for a distance of nearly 8 miles. The prospect pits are now caved, so that it is impossible to verify this statement. Actual mining has extended for a distance of about 5,000 feet, and in that distance there is no indication of material variation in the thickness of the bed.

Two samples, A and B, were taken for chemical analysis. Sample A represents the coal where it is slightly damp and sample B where it is exceedingly dry.

Analyses of coal from Stone Canyon.

[F. M. Stanton, analyst.]

	As received.		Air dried.	
	A.	B.	A.	B.
Laboratory No	3772.	3773.	3772.	3773.
Air-drying loss	3.50	2.20	.....	.....
Moisture	7.13	6.95	3.76	4.86
Volatile matter	44.47	46.69	46.08	47.74
Fixed carbon	37.03	40.13	38.37	41.03
Ash	11.37	6.23	11.79	6.37
Sulphur	4.60	4.17	4.77	4.26
Hydrogen	.....	6.28	.....	6.18
Carbon	.....	66.01	.....	67.50
Nitrogen	.....	1.17	.....	1.19
Oxygen	.....	16.14	.....	14.50
British thermal units	.....	12,447	.....	12,727

This part of Monterey County is semiarid, and the coal, so far as the bed has been followed, carries very little water. This is especially true of the drift, which is drained below into the 300-foot level of the slope. In this opening the coal is as dry and brittle as if it had been kiln dried, but in the slope there is a small amount of water.

The coal is hard and generally of a dull luster, but there are scattered bands of bright coal. Cleavage is not extensively developed in the coal, but as a rule the large blocks are bounded by joint planes. The coal has a brown streak, and on this account has generally been classed as a lignite. The writer, however, is not disposed to regard this characteristic as distinctive of lignite, for the reason that many coals which give such a streak are to all intents and purposes bituminous coals. So far as the writer has observed, weathering is a better criterion for distinguishing between bituminous and subbituminous[a] coals. One of the distinguishing features of all lignites and subbituminous coals is the breaking up of the coal and loss of moisture on drying. In the lower grades of lignite this is so pronounced that lumps go to pieces in a few days or even hours, in much the same manner as the slaking of lime. In this breaking up the fractures are very irregular, with no tendency to follow certain planes, as is the case with bituminous coal. The latter may break into as fine fragments as the lignites, but all the particles are rudely prismatic, due to the cleavage developed in the coal.

The Stone Canyon coal does not show the characteristic slaking of lignite, nor does it weather readily on exposure to the atmosphere. At present the mine has no railroad connection, and it is kept in operation on a small scale pending such connection. Several hundred tons of lump coal have been corded up near the engine house, and, according to report, have been standing in this position for two or three years without showing any appreciable tendency to disintegrate. Minute

[a] The name subbituminous has been adopted by the United States Geological Survey for the class of coals generally called "black lignites," or "lignitic coals" to distinguish them from the true, brown, woody lignites.

checks resembling lignite fractures appear on many of the blocks, but they have not developed sufficiently to cause the blocks to crumble. On chemical composition alone it is impossible to classify this coal satisfactorily by any of the schemes so far proposed, but on physical properties alone the writer regards it as a bituminous coal.

The most striking characteristic of the coal as shown by chemical analyses is the heavy percentage of volatile matter as compared with the fixed carbon. This indicates a rich gas-making coal, and, were it not for the heavy percentage of sulphur, it could doubtless be used to advantage in the manufacture of illuminating gas. The heating properties of the coal are excellent, running as high as 12,727 British thermal units in the air-dried sample. This is considerably better than most of the subbituminous coals of the Pacific coast or even some of the better grades of coal of Wyoming.

The hardness and the freedom from slaking make this an excellent shipping coal, and, so far as the writer's experience goes, it is the best grade of coal on the Pacific coast south of Washington.