COAL IN THE MIDDLE AND EASTERN PARTS OF SAN JUAN COUNTY, NEW MEXICO.

By CLYDE MAX. BAUER and JOHN B. REESIDE, JR.

INTRODUCTION.

From the earliest settlement of southwestern Colorado down to the present time the great coal bed, nearly 50 feet thick, exposed in the canyon of Animas River, 2 miles below Durango, Colo., has attracted general attention. It is true that this bed is not all coal, and attempts to mine it in competition with the better coals lower in the geologic sequence have proved failures. Nevertheless, many persons have speculated regarding its southward extension, and this has led to prospecting in the strip of land lying between the Colorado boundary and San Juan River. The character and size of this and associated beds north of the river have thus been ascertained, but until recently little exact information has been available concerning these beds in the inhospitable region south of San Juan River. In the summers of 1915, 1916, and 1917 the writers procured detailed information regarding the coal beds north of the San Juan, crossed the river, and traced the coal-bearing formation as far as Alamo Arroyo, on the south line of T. 22 N., R. 9 W., where the formation ceases to bear coal beds of commercial value, and thus were able to delimit the field on the west side of the San Juan Basin.

From the Colorado-New Mexico boundary line this field extends through the central and southern parts of San Juan County, which occupies the extreme northwest corner of New Mexico. The outcrop of the coal-bearing Fruitland formation trends southwestward from the State boundary, near the point where it is crossed by La Plata River, to San Juan River. Beyond the San Juan the outcrop parallels Chaco River very closely the entire distance to Alamo Arroyo, near the south side of San Juan County. (See Pl. XVI.) The coal is chiefly of subbituminous rank and is similar to that of the Gallup district, but in the northern part of the field it is good enough to be ranked as bituminous. The beds, numbering from two to six at most localities, range in thickness from a few inches to 40 feet. In the following pages the thickness of various beds at many places is given, and the quality and character of the coal and the inclosing strata are described.

ACCESSIBILITY OF THE FIELD.

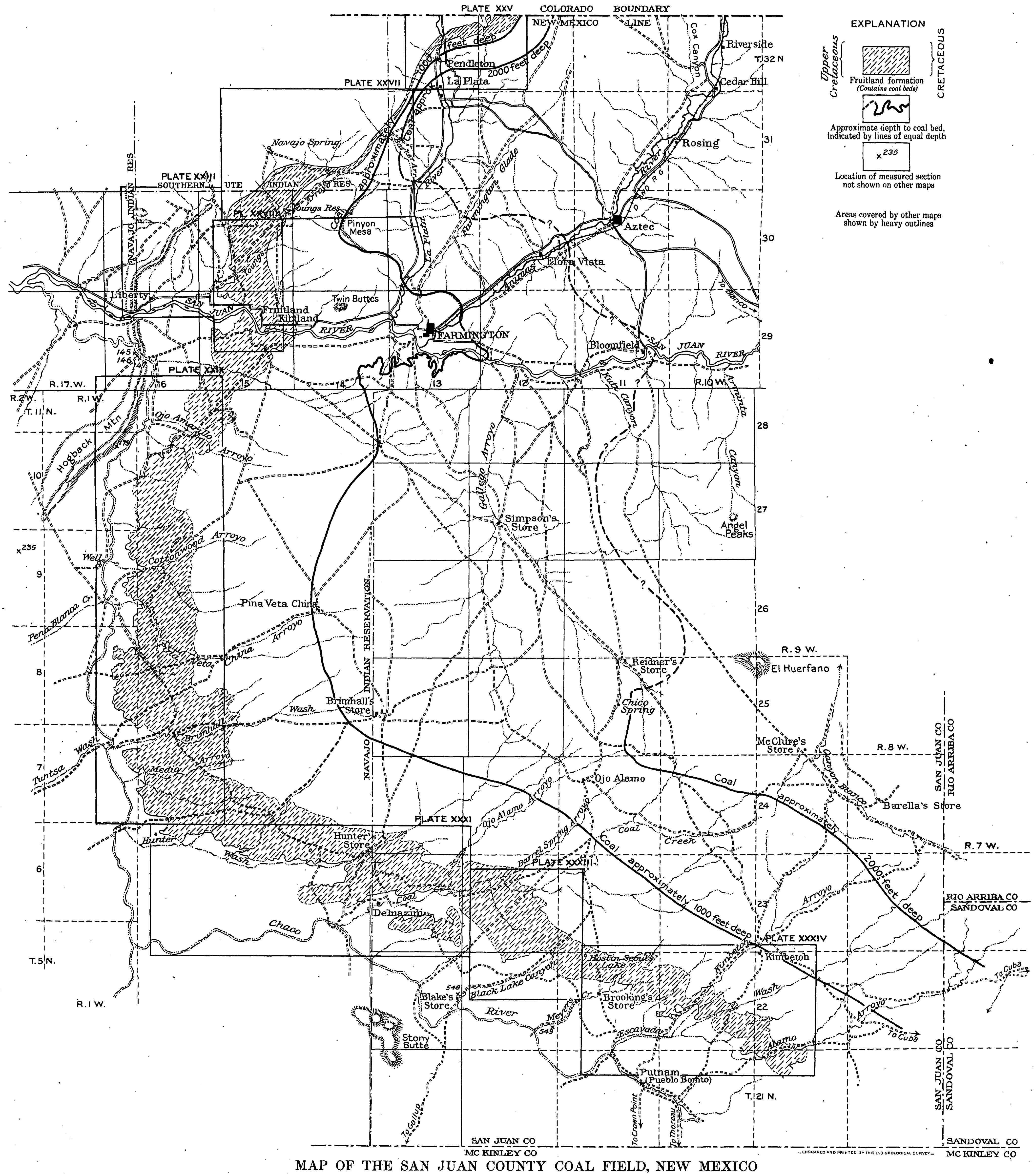
The field may be reached from the north by the Denver & Rio Grande Railroad, a standard-gage branch of which extends from Durango, Colo., to Farmington, N. Mex., on San Juan River in north-central San Juan County. Access to Durango may be had by several routes. Travelers from the west may go from Grand Junction, Colo., on the main line of the Denver & Rio Grande Railroad, by way of Montrose, Vance Junction, and Mancos. The total distance from Grand Junction to Farmington is 300 miles, and the trip requires transshipment of passengers and freight from standard-gage cars to narrow and then from narrow to standard. From the east the traveler may go from Denver and Pueblo, by way of Walsenburg or Salida to Alamosa; thence over the Cumbres Pass (elevation, 10,000 feet) to Durango. The total distance from Denver to Farmington is 496 miles, and two transshipments are required because of changes in track gage. Another route goes from Denver by way of Salida, Marshall Pass (elevation, 10,850 feet), Montrose, Vance Junction, and Mancos. The total distance from Denver by this route is 585 miles, and two transshipments are required. On all these routes grades are heavy, maintenance and operation costs are large, and transportation is therefore relatively slow and expensive.

From the south the field may be reached by wagon from stations on the Atchison, Topeka & Santa Fe Railway. Roads run from Guam, Thoreau, and Baca through several passes in the high ridges that lie a few miles north of the railroad. The trail from Thoreau through Satans Pass as far as the Pueblo Bonito Agency and Indian school at Crownpoint is well kept, but elsewhere the roads are unimproved. The distance from the railroad to the southern edge of the field is 60 miles; to Farmington it is 100 miles. This route requires a hard trip through nearly uninhabited country in which water is available at only a few points, and there are many arroyos to cross—a difficult task when heavy rainstorms or melting snow have supplied enough water to flow or erosion has cut the banks to steep angles.

From Gallup an automobile stage runs northward along a line about 10 miles west of the field, crossing the San Juan at Shiprock, in T. 30 N., R. 18 W., and thence following up the river to Farmington. More direct wagon routes from Gallup to the field are also available but have all the disadvantages of those from other points.

FIELD WORK AND ACKNOWLEDGMENTS.

The field work on which this report is based was done during the summers of 1915, 1916, and 1917. In the absence of a suitable base map, several base lines were measured, from which control points were located by triangulation with plane table and telescopic alidade. From these points detailed mapping was extended through the field.



MAP OF THE SAN JUAN COUNTY COAL FIELD, NEW MEXICO

0 5 10 15 Miles

The field party of 1915, in charge of the senior author, was composed of H. R. Bennett, J. C. Brittain, Royce Brown, and the authors. The party of 1916 included Frank R. Clark, J. E. Heald, J. H. Eiseman, and the junior author, and that of 1917 included Harvey Bassler, K. N. Garard, J. F. Gibbs, and the junior author. Acknowledgment of the efficient aid rendered in the prosecution of the project is due to all these men, particularly Mr. Bassler, who procured all the field data for the region north of T. 30 N., R. 15 W. The authors also wish to thank many residents of San Juan County for hospitality and for courtesies rendered the field parties, and M. R. Campbell for advice and assistance in the field and office work.

SURFACE FEATURES.

LAND FORMS.

This field has a maximum relief of nearly 2,500 feet. The lowest point is on the San Juan near the western edge of the field and is about 5,000 feet above sea level; the highest point is on the southeastern edge of the field and is about 7,500 feet above sea level.

Along the western edge abrupt tilting of resistant rocks and subsequent erosion of the softer materials has formed a striking ridge known as the Great Hogback, Hogback Mountain, or simply the Hogback—a sharp ridge of sandstone whose eastern face is a steep dip slope rising as much as 700 feet above the adjacent country. To the north the Hogback passes into a series of lower parallel ridges and ceases to be a prominent feature.

North of San Juan River the country for some distance east of the Hogback is a fairly even surfaced shale valley, which is known locally as the Meadows. It contains some low sandstone ridges and some badlands. It is unoccupied, though it could probably be successfully cultivated if water were available. Wells drilled for oil in this part of the field have found only salt water.

The remainder of the field is essentially a dissected plateau. (See Pls. XVII and XVIII.) The drainage lines are all intrenched below the upland plain and are separated by flat-topped divides which are clearly parts of a former continuous surface. Here and there isolated remnants stand out prominently—for example, Pinyon Mesa, in T. 30 N., R. 14 W. Along the arroyos there are extensive badlands, which are all cut below the general surface and are invisible from it at relatively short distances. (See Pl. XVIII.)

Sand dunes are abundant on the interstream areas. Sand from the arroyos and dry creek beds is blown in enormous volume out upon the flats and forms large dunes and sand ridges. The surface forms in some parts of the field are much modified in this way. Along the east bank of Chaco River, owing to the prevailing westerly winds, dunes and sand flats are abundant and form a barrier in many places difficult to cross with a team.

Along the large streams, especially the San Juan, there are three or four river terraces, the highest of which is particularly well shown about Farmington and Fruitland. Others are recognizable also at these localities, Farmington itself being built on a terrace 50 feet above the present level of the river.

DRAINAGE AND WATER SUPPLY.[1]

The streams of this field belong to the Pacific drainage system. San Juan River receives all the other streams, and its waters, through Colorado River, reach the Gulf of California. The Continental Divide lies 15 miles southeast of the field represented on the map.

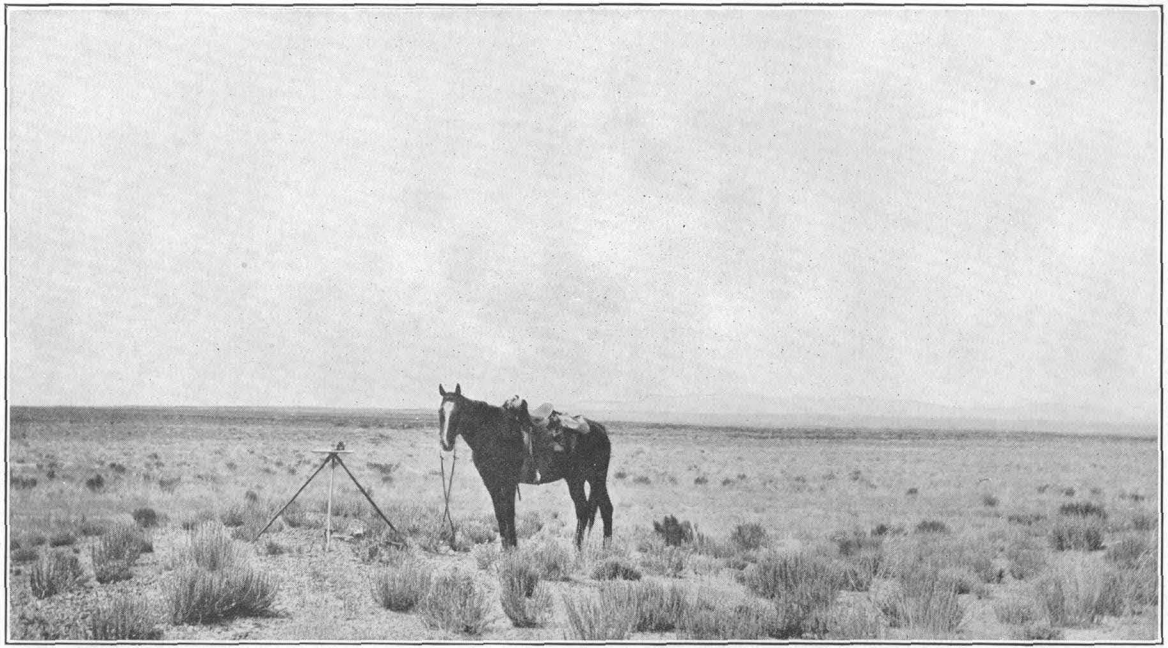
Three perennial streams flow through the region—La Plata, Animas, and San Juan rivers. These streams head in the high mountains of southwestern Colorado and depend for their volume largely on melting snow. The amount of water they carry consequently varies greatly with the season of the year, though it is always enough to permit irrigation of the valleys.

Except in the valleys of these three perennial streams, water is scarce. Even the largest tributaries to these streams contain running water only after the heaviest rains, and Chaco River itself is ordinarily but a wide strip of dry sand. However, water is generally near the surface of the sand in the channels of the arroyos and can be obtained by digging 4 or 5 feet. It varies much in quality but is in general strongly impregnated with mineral salts. Springs, seeps, and other natural watering places are exceedingly rare. The Indians of the region have built a number of reservoirs and sunk shallow wells near the arroyos, which are easy to reach when their location is known and which form the main reliance of the traveler for his water supply. At a few points in Gallego Arroyo wells have been drilled that supply water by pumping. Most of this water carries enough alkali or salt to make it unpalatable.

CLIMATE AND VEGETATION.

This field is part of an arid region whose climate is marked by great variability. Very hot days may be followed by very cool nights; no rain may fall for a month, and then a single shower may bring a normal month's rainfall; the normally rainy months may be absolutely dry and the normally dry months relatively wet. The normal annual precipitation is about 7 inches for the San Juan Valley, though in exceptional years it may rise to nearly 20 inches or fall as low as 3 or 4 inches. For the entire field it is usually under 10 inches. The temperature fluctuates widely—below 0° for the minimum and well above 100° for the maximum. The mean

[1] See also Gregory, H. E., The Navajo country; a geographic and hydrographic reconnaissance of parts of Arizona, New Mexico, and Utah: U. S. Geol. Survey Water-Supply Paper 380, 1916. French, J. A. (State engineer), Surface water supply of New Mexico, 1888–1917, Albuquerque, N. Mex., 1918.



THE PLATEAU SURFACE VIEWED NORTHWESTWARD ACROSS THE VALLEY OF CHACO RIVER, N. MEX., SOUTH OF HUNTER WASH.

annual temperature at Fruitland is 52.6°, and the annual range is about 115°. A daily range of 40° is not uncommon. The summer storms are usually short but violent, with high winds, lightning, and sometimes heavy rain and hail. The winter storms are often accompanied by snow.

The native vegetation is entirely of types adapted to arid conditions of life. The lowest lands bear greasewood (*Sarcobatus*), sagebrush (*Artemisia*), and bunch grasses. Higher lands (up to 6,000 feet) bear rubberweed (*Hymenoxys*), cactus (mainly *Opuntia*), sagebrush, grasses, and scattered juniper (*Juniperus monospermus*) and piñon (*Pinus edulis*). Where very sandy they support a growth of joint fir (*Ephedra*) and redtop grass. Above an elevation of 6,000 feet the chief elements of the flora are juniper and piñon and the minor elements are sagebrush and other shrubby plants, with some jack pine and scrub oak.

By means of irrigation it is possible to raise a number of plants not native to the region. Fruit of various kinds thrives and in most years brings abundant returns. Alfalfa grows well, and some grain, potatoes, tomatoes, and other vegetables are produced. Markets for farm produce are strictly limited by the transportation conditions, and in the best years much more can be raised than there is any possibility of selling.

The Navajo Indians, by means of a system of storm-flood irrigation, succeed in raising fair crops of certain varieties of maize, melons, beans, and a few potatoes in bottom lands, where the soil is rich and gets the benefit of any heavy rains which may fall.

SETTLEMENTS AND ROADS.

Aztec and Farmington are the two main towns of the field. Aztec is the county seat and has a population of 500. Farmington is the terminus of a branch of the Denver & Rio Grande Railroad and has a population of 800. Both are essentially trading centers and supply points for the country about them and are well supplied with stores, banks, and other necessary institutions.

Beside these larger towns there are several scattered settlements on San Juan River, including Blanco, Bloomfield, Kirtland, Fruitland, and Liberty; several on La Plata River, including La Plata and Pendleton; and several on Animas River, including Flora Vista, Inca, and Cedarhill. Most of these are post offices, with one or two stores. South of San Juan River there are a number of isolated trading posts outside of the Navajo Reservation which depend on the Indians for their existence. The location of many of these posts is shown on the map (Pl. XVI). There are very few white settlers outside of the irrigated districts.

Along the perennial streams the roads are kept in good condition and are normally passable for automobiles as well as wagons, but

outside of these districts they are usually mere unimproved wagon trails. These trails are numerous, thanks to the Indian propensity for moving about, though badlands, sand dunes, and rapidly eroding arroyos present many difficulties to the traveler. It is possible to take heavy camp wagons over most of the roads shown on the accompanying maps, but automobiles meet with difficulties in crossing deep arroyos and steep-walled ditches.

Animas and La Plata rivers may be forded at many places, but the San Juan is treacherous and difficult to ford in the spring and summer. The two smaller streams are bridged at a number of places, and the San Juan at Blanco, 20 miles east of Farmington, at Farmington, and at Ship Rock, 35 miles by road west of Farmington. At Bloomfield a ferry operates during periods of high water, and at Fruitland there is a footbridge.

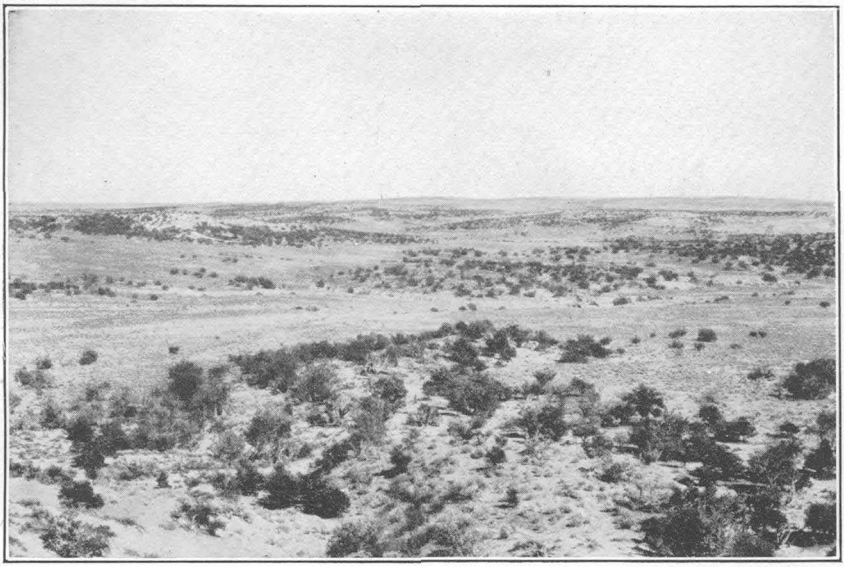
LAND SURVEYS.

The land surveys of parts of the region covered in this report were made in recent years, and the monuments are easily found. Tps. 24 to 28 N., R. 13 W.; part of T. 23 N., Tps. 25 to 28 N., R. 12 W.; Tps. 27 and 28 N., Rs. 11 and 10 W.; and Tps. 29 and 30 N., Rs. 16, 17, and 18 W., were surveyed in 1913. T. 30 N., Rs. 15 and 14 W., was surveyed in 1909. Tps. 21 and 22 N. and part of T. 23 N., R. 13 W., were surveyed in 1893, and although no corners for these townships were found in the field, the geographic details shown on the plats are accurate. The townships between San Juan River and the Colorado-New Mexico State boundary were surveyed mostly during the eighties, and though the corners are not easily found the details shown on the plats are fairly accurate. In the area included in Tps. 21 to 24 N., R. 12 W.; Tps. 21 to 26 N., Rs. 9 to 11 W.; and Tps. 21 to 24 N., Rs. 7 and 8 W., however, no authentic corners were found, and the details shown on the official plats disagree so profoundly with the districts they are supposed to represent that it seems doubtful if the surveys were ever made. The lines shown for this portion of the area mapped are based on relocations of a few corners by local surveyors and the Office of Indian Affairs and must be considered provisional. In the part of the field covered by the net based on the Navajo meridian the lines must also be considered provisional, as little evidence of their position was obtained in the field.

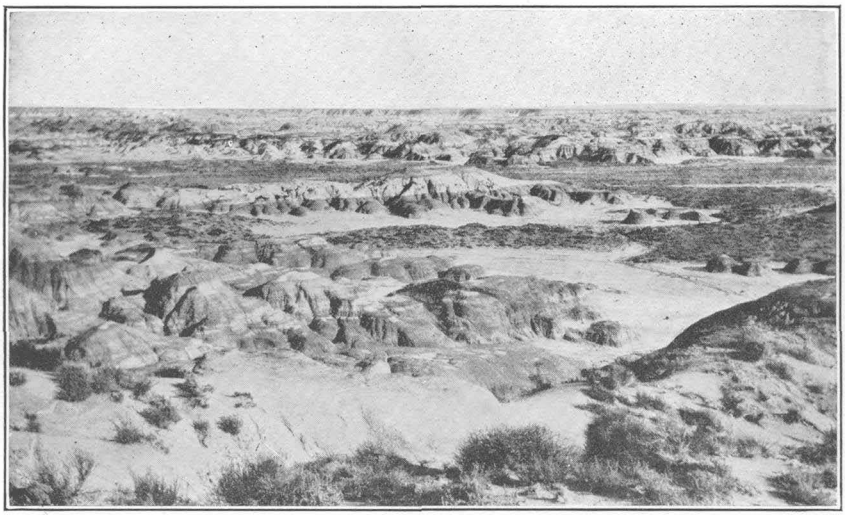
GEOLOGY.

GENERAL FEATURES.

The stratified rocks of this region consist of a succession of sandstone, shale, coal, and conglomerate, laid down originally as marine,



A. CHARACTERISTIC TOPOGRAPHY AND VEGETATION OF THE HIGHEST PART OF THE SAN JUAN COAL FIELD, N. MEX.



B. EXPOSURE OF PUERCO AND TORREJON FORMATIONS MAKING BADLANDS 1½ MILES ABOVE OJO ALAMO STORE, N. MEX.

brackish-water, and fresh-water sediments. The rocks here have been depressed or those in surrounding regions have been uplifted until they lie in the form of an immense basin that stretches from Durango, Colo., on the north, a distance of 125 miles to Gallup, N. Mex., on the south. From the Hogback eastward to Cuba or Gallina, N. Mex., the basin is more than 100 miles across. In the center of the basin the rocks are supposed to be practically flat, but in the rim they are sharply upturned. This is illustrated by a dip of 45° E. in the Great Hogback, which near Liberty post office forms the western rim, dips of only 1° to 3° in the outcrop of the Fruitland formation near by, and dips of 1° or less in the younger beds.

Minor structural features superimposed on this general basin are not numerous in the San Juan County field. Several broad, low anticlines cross the rim at right angles north of San Juan River, but they are noticeable chiefly in the bulges they make in the outcrop lines of the formations. A small, sharper anticline occurs in T. 30 N., R. 15 W., and another in T. 25 N., R. 16 W. (unsurveyed). In T. 30 N., R. 15 W., there is some evidence of a flattening of the dip to form a structural terrace parallel to the basin rim; in T. 29 N., R. 16 W., likewise an obscure structural terrace is observable in the Lewis shale. The only fault large enough to map was seen in T. 22 N., R. 7 W., but it is relatively small.

The Great Hogback is formed by the tilting of the resistant rocks of the Mesaverde group in the sharp monocline known as the San Juan fold. The dip flattens very quickly in the Lewis and Mancos shales, so quickly that at first glance the structure looks as if faulted. However, good exposures show only a rapid but continuous change in the dip. Toward the north the axis of the fold shifts eastward, and in T. 31 N., Rs. 13 and 14 W., and T. 32 N., R. 13 W., the steepest dips are in the Fruitland formation and the Kirtland shale, while the rocks of the Mesaverde group flatten to form the prominent southern extension of the tableland known as Mesa Verde. Farther to the north the fold is not very distinct.

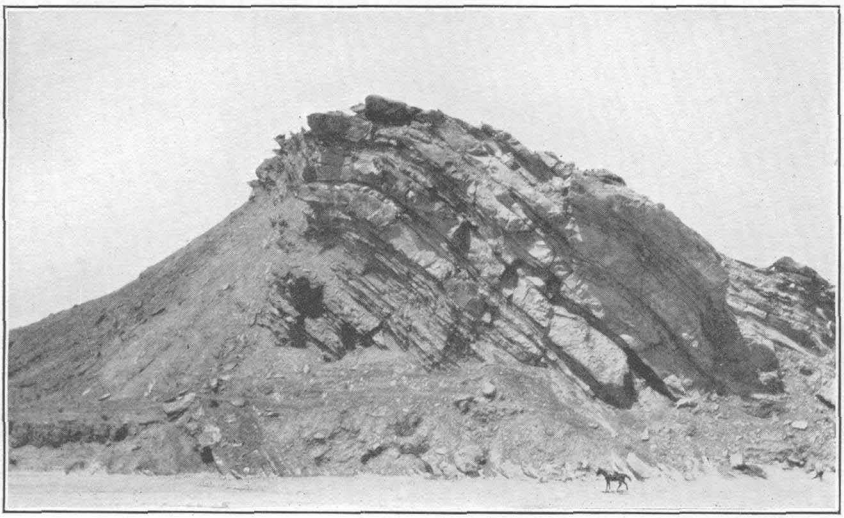
The following table gives the names and thicknesses of the formations and summarizes the stratigraphy:[2]

[2] For a description of the fossils and a discussion of the correlations see Bauer, C. M., and others, Contributions to the geology and paleontology of San Juan County, N. Mex.: U. S. Geol. Survey Prof. Paper 98, pp. 271–353, 1916; Gilmore, C. W., Reptilian faunas of the Torrejon, Puerco, and underlying Cretaceous formations of San Juan County, N. Mex.: U. S. Geol. Survey Prof. Paper 119, 1919; Sinclair, W. J., and Granger, Walter, Paleocene deposits of the San Juan Basin, N. Mex.; Am. Mus. Nat. Hist. Bull., vol. 33, pp. 297–316, 1914; Granger, Walter, Notes on Paleocene and lower Eocene mammal horizons of northern New Mexico and southern Colorado: Am. Mus. Nat. Hist. Bull., vol. 37, pp. 821–830, 1917.

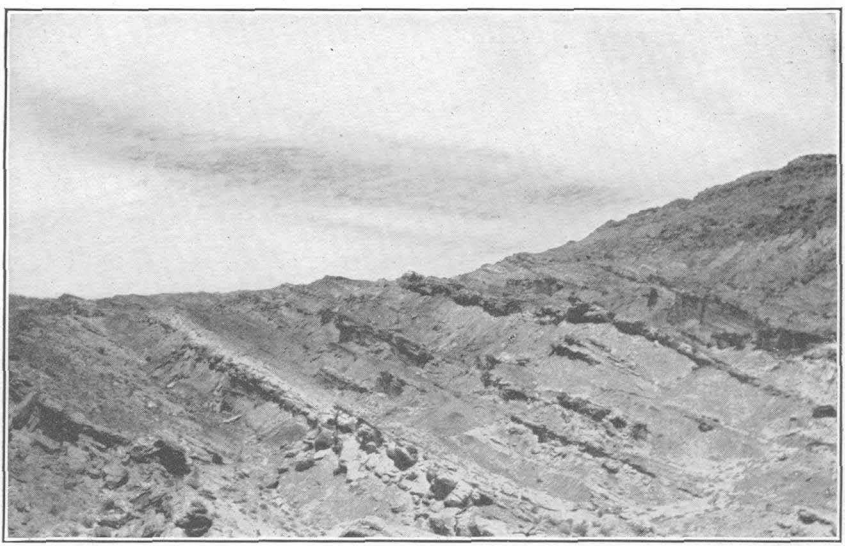
Geologic formations in middle and eastern San Juan County, N. Mex.

Age.	Formation.	Character.	Thickness (feet).[a]		
			1	2	3
Eocene.	Wasatch formation.	Massive buff to yellow conglomeratic sandstone, interbedded with variegated shale; red shale abundant. Fluviatile.	(?)	(?)	(?)
	Formation undetermined.	Light-gray shale with some darker-gray and some red layers and some soft white conglomeratic sandstone. May be part of Wasatch formation. Fluviatile.	(?)	(?)	250
	Torrejon and Puerco formations.	Gray shale and lenticular soft white sandstone with bands of colored shale; yellow firmer sandstones, with concretions. Fluviatile.	1,400	(?)	390–1,140
Upper Cretaceous.	Ojo Alamo sandstone.[c]	White, gray, or brown conglomeratic sandstone containing varicolored shale lenses. Fluviatile.	(?)	400	63–129
	Kirtland shale (including Farmington sandstone member).	Blue-gray shale banded with yellow and brown. Farmington sandstone member, near middle of the Kirtland, made up of a number of channel sandstones. Fluviatile.	950	836	700–1,180
	Fruitland formation.	Gray sandy shale and gray-white cross-bedded sandstone and buff sandstone, with coal beds. Of fresh and brackish water origin.	425	241	230
	Pictured Cliffs sandstone.	Buff to light-yellow and gray sandstone interbedded with thin gray shale. Marine.	210–240	275	50–70
	Lewis shale.	Greenish-gray sandy shale with scattered lenses of buff sandy limestone. Marine.	[b] 1,100–1,710	475	75–140
	Mesaverde group. — Cliff House sandstone.	Mainly buff to copper-red sandstone, with some shale. Some beds massive, cliff forming. Marine.	[b] 390	750	369
	Mesaverde group. — Menefee formation.	Shale with some sandstone and coal. The coal beds are grouped near the top and the bottom of the formation. Of fresh and brackish water origin, with some marine beds.	[b] 356	1,076	(?)
	Mesaverde group. — Point Lookout sandstone.	Massive buff to cream-colored sandstone, with some sandstone; weathers a copper-red. Marine.	[b] 274	300	(?)
	Mancos shale.	Dark-gray and dark-drab shale. Marine.	(?)	(?)	(?)

[a] 1, Northern San Juan County, N. Mex., and southern La Plata County, Colo.; 2, central San Juan County (San Juan River), N. Mex.; 3, southern San Juan County, N. Mex.
[b] Unpublished data collected by Max A. Pishel in Colorado.
[c] See footnote 5a, p. 173.



A. PART OF THE MESAVERDE GROUP IN THE GAP CUT THROUGH THE GREAT HOGBACK BY CHACO RIVER, N. MEX.



B. THE MENEFEE FORMATION IN THE GREAT HOGBACK, 5 MILES NORTH OF SAN JUAN RIVER, N. MEX.

THE FORMATIONS.

MANCOS SHALE.

The Mancos shale, the lowest formation exposed in the field, is a dark-gray to dark-drab marine shale. Its upper part contains a little sandstone, but it is a relatively homogeneous shale. The contact with the overlying Mesaverde group is gradational. No measurements of its thickness were made by the writers, but in the type region to the north it reaches 2,000 feet.

MESAVERDE GROUP.

The rocks of Mesaverde age in this field, though considerably thicker than those farther north, show the same tripartite character as in Mesa Verde National Park, the type locality. Recently Collier[3] has named the formations, in ascending order, the Point Lookout sandstone, the Menefee formation, and the Cliff House sandstone. The Point Lookout is a marine sandstone with some shale, the Menefee formation is chiefly shale but includes some thick sandstone beds and contains both marine and fresh-water faunas and a flora, and the Cliff House consists of sandstone and shale. The thickness and character of these formations are best shown in the sections through the Great Hogback, in T. 29 N., R. 16 W., where it is cut by San Juan River and Chaco River. (See Pl. XIX.) Both are given below:

Section of Mesaverde group on San Juan River.

[Measured by Harvey Bassler.]

	Ft.	in.
Lewis shale.		
Mesaverde group:		
Cliff House sandstone:		
Sandstone, heavy, reddish brown to buff	4	
Shale, gray, sandy, with a few thin beds of sandstone	96	
Sandstone, massive, heavy bedded, reddish brown to buff, with thin layers of shale separating the sandstone beds	330	
Shale and sandstone, interbedded. Sandstone in thin layers and more abundant in upper part of unit; some layers ripple-marked. Both shale and sandstone gray	195	
Concealed; probably sandy shale	73	
Sandstone, soft, buff	8	
Shale, gray, sandy	11	
Sandstone, massive, pisolitic, dark brown on weathered surfaces, gray on fresh surface	33	
	750	

[3] Collier, A. J., Coal south of Mancos, Montezuma County, Colo.: U. S. Geol. Survey Bull. 691, p. 296, 1919.

Mesaverde group—Continued.

Menefee formation:	Ft.	in.
Shale, gray, sandy	6	
Coal	7	6
Shale, sandy, brown, carbonaceous	20	
Bone		6
Shale, carbonaceous	2	6
Coal	1	
Shale, carbonaceous	1	
Coal	1	2
Shale, carbonaceous	4	
Coal		4
Shale, sandy, brown, carbonaceous	28	
Shale, soft, light colored, sandy	6	
Shale, sandy, brown, carbonaceous	12	
Shale containing 18 beds of sandstone. The sandstone layers range in thickness from 3 to 12 feet but average 5 feet	619	
Coal	1	2
Sandstone	15	
Shale	25	
Sandstone	7	
Shale	8	
Sandstone	30	
Shale	125	
Sandstone	35	
Shale	1	
Coal	1	4
Shale	1	2
Coal	1	
Shale and sandstone	10	
Coal	1	1
Shale	26	
Sandstone	12	
Shale	1	
Coal	1	
Shale	20	
Coal	1	1
Shale	2	6
Coal		10
Sandstone		1
Coal	2	2
Shale		2
Coal	2	1
Sandstone and shale	10	
Coal		2
Shale and sandstone	5	
Coal	1	2
Shale	21	
	1,076	

	Ft.	in.
Mesaverde group—Continued.		
Point Lookout sandstone:		
Sandstone	32	
Shale, sandy	16	
Sandstone, with some layers of thin sandy shale	252	
	300	
Total Mesaverde group	2,126	
Mancos shale.		

Section of Mesaverde group in T. 29 N., R. 16 W., where Chaco River cuts the Great Hogback.

[Measured by C. M. Bauer.]

	Ft.	in.
Lewis shale.		
Mesaverde group:		
Cliff House sandstone:		
Shale and sandstone	60	
Sandstone, brown, pitted	18	
Shale, yellow, sandy	8	
Sandstone, light gray, pink in places	6	
Shale, blue and gray	5	
Sandstone, yellow, massive in upper part, carrying a few thin beds of shale; *Halymenites major* in lower part	318	
Shale, sandy, interbedded with yellowish sandstone layers, each 1 foot thick	133	
Sandstone, reddish brown, hard	10	
Shale, blue-gray	40	
Sandstone, massive, thin bedded on top, massive and nearly white below	25	
	623	
Menefee formation:		
Shale, blue and gray, interbedded with lenses of buff sandstone. Shale beds are carbonaceous and contain thin streaks of coal	560	
Sandstone, massive, light gray	20	
Shale, gray; contains beds of sandstone 1 foot thick	30	
Sandstone, light gray, massive	12	
Shale, blue-gray, containing several carbonaceous streaks	92	
Sandstone, massive	20	
Shale, drab	5	
Coal		10
Shale, carbonaceous, black		8
Shale, blue-gray, containing carbonaceous streaks	246	
Sandstone, gray	10	
Shale, gray		8
Coal		8
Shale, gray	7	

	Ft.	in.
Mesaverde group—Continued.		
Menefee formation—Continued.		
Coal (moisture, 11 per cent; ash, 22 per cent)	2	
Shale and sandstone, with thin beds of coal which are burned out	126	
	1,132	10
Point Lookout sandstone:		
Sandstone, light buff and cream-colored, massive	67	
Sandstone, buff to brown, weathering red-brown	158	
Shale and sandstone, thin bedded, yellowish gray	20	
	245	
Total Mesaverde group	2,000	10

Mancos shale.

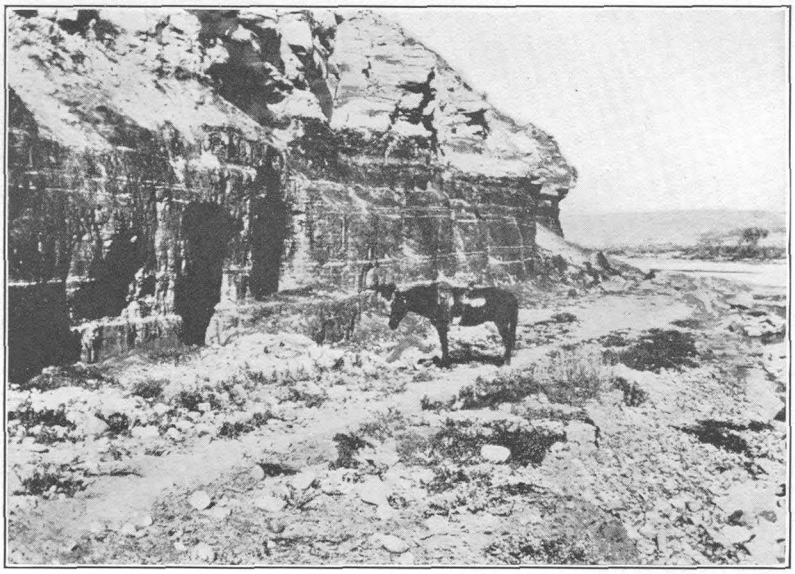
LEWIS SHALE.

The Lewis shale is of marine origin and is very similar to the shale at Fort Lewis, Colo., the type locality.[4] In Colorado this formation reaches a thickness of 2,000 feet, but in New Mexico it is thinner, being 1,100 feet thick 10 miles north of San Juan River, 475 feet thick on San Juan River, and decreasing further in thickness southward as far as Coal Creek, where it is 76 feet thick. It increases again to 103 feet on Meyers Creek and 140 feet on Escavada Wash. The Lewis shale has the same lithologic characteristics throughout the field. It is a greenish-gray sandy shale with local streaks of yellowish calcareous shale. On San Juan River it has also a prominent layer of buff limy concretions about 100 feet above its base.

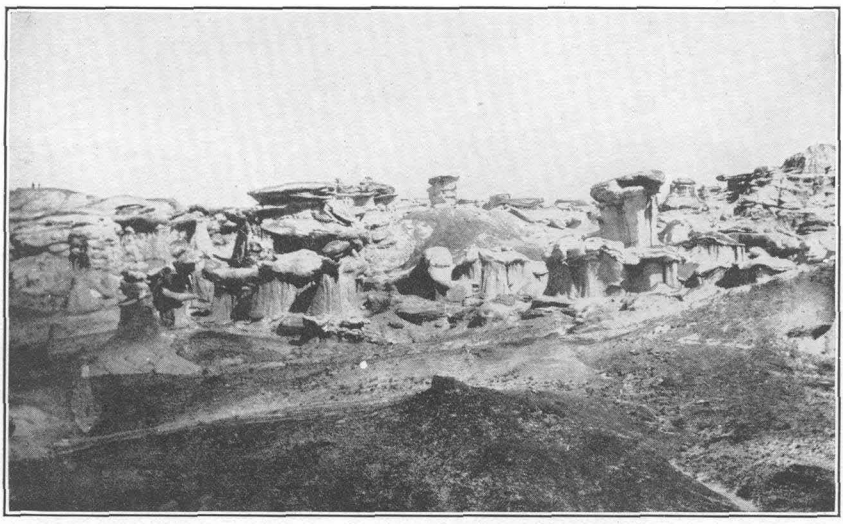
PICTURED CLIFFS SANDSTONE.

Overlying the Lewis shale conformably is the Pictured Cliffs sandstone, of near-shore marine origin. There is no sharp line separating this sandstone from the underlying Lewis shale, but the shale becomes more sandy upward and passes into the sandstone by insensible gradations. Considered in a general way, the Pictured Cliffs sandstone is very different from the beds beneath. As the name indicates, it is a cliff-making sandstone, particularly on San Juan River immediately west of Fruitland, where it forms prominent copper-colored cliffs 20 to 40 feet high. Farther south it is a yellowish to light-gray or brown sandstone and not so massive. The formation is variable in thickness, owing in part to the nature of its boundaries. It is 200 feet thick near the State boundary, 187 feet 6 miles farther south, from 200 to 220 feet 6 miles north of San Juan River, 245 feet on the river, 49 feet on Brimhall Wash, 91 feet on Meyers Creek, and 70 feet on Escavada Wash.

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



A. COAL BED AT LOCATION 140, ON SAN JUAN RIVER HALF A MILE SOUTHWEST OF FRUITLAND, N. MEX.



B. CHARACTERISTIC WEATHERING OF VARIABLE SANDSTONE OF THE FRUITLAND FORMATION, MEYERS CREEK, N. MEX.

FRUITLAND FORMATION.

Conformably above the Pictured Cliffs sandstone lie the brackish and fresh water beds of the coal-bearing Fruitland formation. The contact, like that between the Lewis shale and Pictured Cliffs sandstone, is gradational. The name Fruitland is derived from that of a settlement on San Juan River that is on the outcrop of this formation. The formation consists of sandstone, shale, and coal, very irregularly bedded. In constitution the various beds range from shale to sandstone with every conceivable intermediate phase of sandy shale and shaly sandstone. The marked variation both laterally and vertically is shown in many places by the unequal resistance to weathering and consequent production of fantastic assemblages of pillars, knobs, "mushroom rocks," and other forms. (See Pls. XX and XXI.) This irregularity is most marked in the gray-white sandstone and gray sandy shale, but it affects to some degree the coal beds also. Nevertheless, although the coal beds are lenticular, they are much more persistent than the individual sandstone and shale layers with which they are associated. Some of the coal beds have been traced along their outcrops with considerable certainty for 15 or 20 miles and are of sufficient thickness and good enough quality throughout to be of commercial value when transportation facilities become available. The coal beds are distributed throughout the formation but are more abundant and generally thicker in its lower portion. They are described in detail in the later pages of this report. The Fruitland formation is further characterized by the presence of large concretions of iron carbonate which weather dark brown or black. Many of these concretions have been converted by veins of crystallized barite into large septaria. The Fruitland formation is more sandy than the lower part of the Kirtland shale, from which it is separated by a gradational zone marked in many places by sandstone lenses apparently of river origin. The thickness of the Fruitland formation varies somewhat in this field, ranging from 196 to 415 feet. It is thicker in the northern part of the area than in the southern part. (See sections, Pl. XXII.) The following sections of the Fruitland formation are given to illustrate its character and the thickness and position of the coal beds:

Section of the Fruitland formation on divide between La Plata and San Juan rivers.

	Ft.	in.
Kirtland shale.		
Fruitland formation:		
Shale and sandstone	80	
Sandstone	5	
Shale	20	
Sandstone	10	

Fruitland formation—Continued.	Ft.	in.
Shale, carbonaceous in part	80	
Coal, high in ash	1	6
Shale, carbonaceous	2	6
Coal		3
Shale, carbonaceous		6
Coal		5
Shale, carbonaceous	2	3
Coal	1	2
Shale, carbonaceous		10
Coal		7
Shale, carbonaceous		1
Coal		2
Shale, carbonaceous		9
Coal		7
Shale, carbonaceous	3	
Coal		6
Shale, carbonaceous in part	75	
Coal, with many shale and bone partings (see sec. 32, Pl. XXVI, for details)	14	2
Shale, sandstone, and some concealed intervals	125	
Coal	2	6
Pictured Cliffs sandstone.		
	426	110

Section of Fruitland formation on San Juan River.

Kirtland shale.		
Fruitland formation:	Ft.	in.
Sandstone, gray, fine grained, irregularly bedded	7	
Shale, gray to black; contains fragments of carbonized wood and is streaked with limonite	8	
Shale, light gray to drab, with limonite streaks; sandy in lower portion	11	
Shale, very sandy, light gray to buff	12	
Sandstone, buff, friable; contains concretions of light-gray fine-grained sandstone	15	
Shale, drab, sandy	1	
Shale, brown, carbonaceous; contains plant fragments	2	
Shale, light gray, very sandy, with streaks of pearl-gray calcareous shale and drab platy concretions	14	
Shale, dark brown, carbonaceous; contains plant fragments and gypsum in small flakes	7	
Shale, light gray to drab	10	
Sandstone, platy, fine grained, very light greenish gray	20	
Shale, light gray, sandy, locally carbonaceous	15	
Shale, dark brown, carbonaceous; contains thin lenses of bone	6	
Sandstone, very light gray, fine grained, carbonaceous	18	
Shale, gray to drab, with carbonaceous bands which are burned locally (probably coal beds elsewhere)	30	

PART OF THE FRUITLAND FORMATION NEAR HUNTER'S STORE, IN T. 24 N., R. 13 W., N. MEX.

Fruitland formation—Continued.	Ft.	in.
Sandstone, light gray, fine grained; contains lenses of carbonaceous shale; sandstone is gray to white, cross-bedded, and locally stained brown	25	
Shale, brown to black, carbonaceous	3	
Coal	1	8
Shale, brown, sandy		6
Bone		5
Coal, good	1	
Shale, buff, sandy		5
Coal and bone in thin lenses		9
Shale, carbonaceous, black		½
Coal; contains resin	3	7
Shale, sandy, gray and carbonaceous in places		3
Coal, impure		4
Shale, gray, sandy		1
Bone		6
Shale, gray, sandy		1
Coal, impure	1	4
Shale, gray, sandy		3
Coal, impure	2	11
Bone		4
Shale, gray, sandy		1
Bone		5
Shale, carbonaceous		3
Shale, clayey and carbonaceous	2	3
Bone		3
Shale, brown	5	
Coal		4
Shale, sandy, brown	5	
Shale, light gray, sandy	2	
Sandstone, greenish, cross-bedded	3	6
Shale, brown	1	
Sandstone, nearly white	6	
Coal		6
Sandstone	1	
Coal		6
Pictured Cliffs sandstone.		
	246	6½

Section of Fruitland formation on Cottonwood Arroyo.

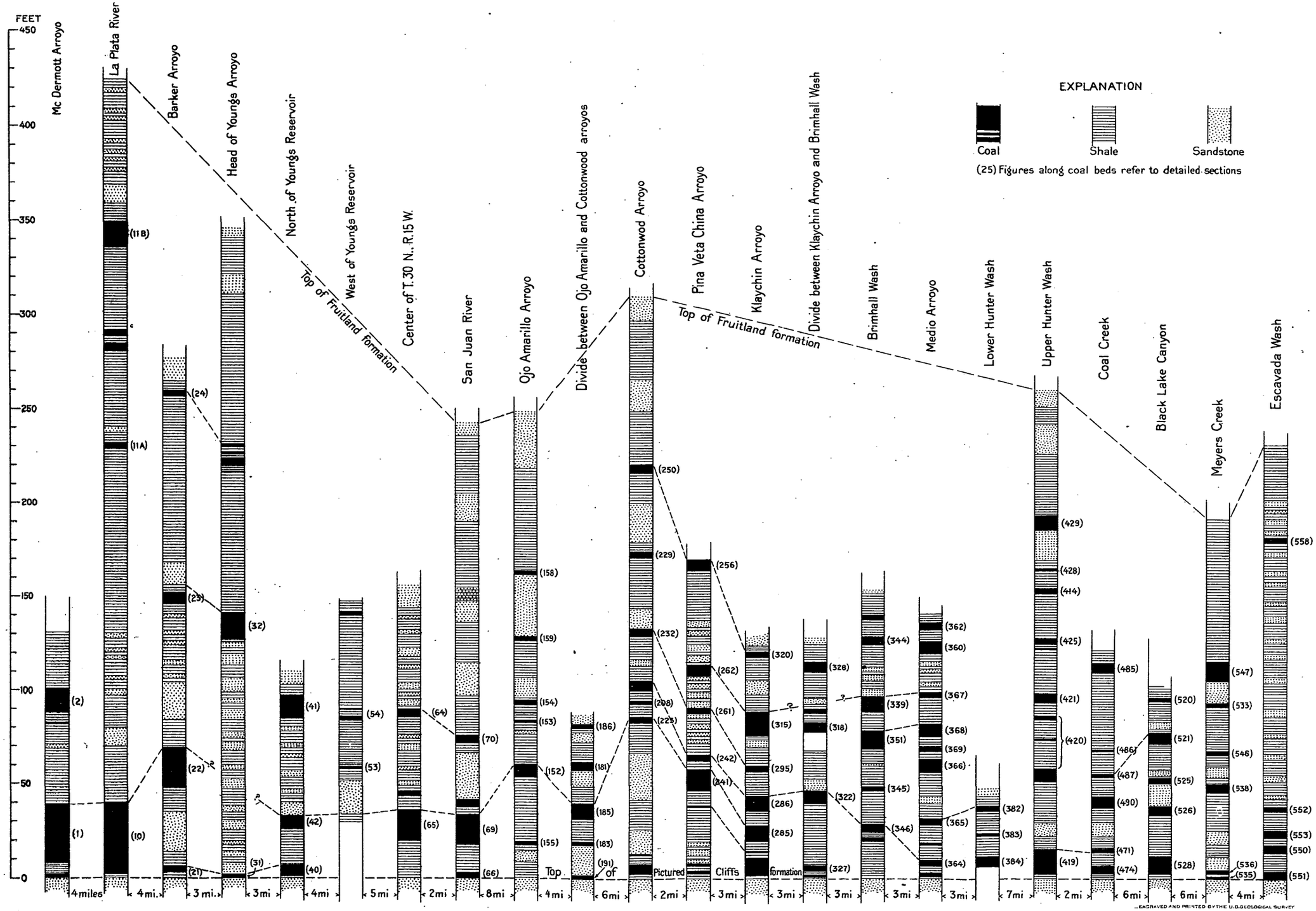
Kirtland shale.		
Fruitland formation:	Ft.	in.
Sandstone, brown, platy	13	
Shale, sandy, gray	31	6
Sandstone, brown, cross-bedded, concretionary	5	
Sandstone; contains concretions of iron carbonate	4	
Sandstone, irregularly bedded and unequally indurated	8	
Shale, gray, sandy, concretionary	28	
Coal		10
Shale, sandy		1
Coal		5
Sandstone, carbonaceous		1

Fruitland formation—Continued.	Ft.	in.
Coal		6
Sandstone, carbonaceous		6
Coal	2	2
Shale, carbonaceous	1	
Shale, gray	15	
Sandstone, buff to gray, cliff-forming	20	
Shale, carbonaceous		10
Shale, gray	35	
Sandstone, gray, easily eroded	11	6
Coal	1	7
Sandstone		3
Coal	2	1
Shale, carbonaceous, brown and gray	12	6
Sandstone, gray; contains lime concretions	4	
Shale, sandy	8	
Shale, brown, carbonaceous		10
Bone		3
Coal, impure		3
Sandstone		1
Coal	3	8
Bone		2
Coal		11
Shale, carbonaceous	6	
Sandstone, nearly white, soft, cross-bedded, streaked with limonite	15	
Shale, gray, sandy	2	
Coal, impure	1	7
Ash (from burned coal)		8
Shale, gray	7	6
Ash (from burned coal)	1	
Shale, bluish gray, sandy	16	
Sandstone, nearly white, soft; contains streaks of limonite ¼ inch thick and in places irregular masses of brown cross-bedded sandstone	25	
Coal		6
Shale, blue-gray, sandy	15	9
Sandstone, shaly in places, light colored, platy	12	
Shale, carbonaceous		4
Coal		8
Shale, sandy	5	4
Coal	2	7
Shale	1	5
Bone		5
Shale, sandy, carbonaceous	3	
Pictured Cliffs sandstone.		
	328	9

Section of Fruitland formation on north fork of Meyers Creek.

Kirtland shale.

Fruitland formation:	Ft.	in.
Sandstone, soft gray at base, capped by hard brown coarse-grained layers	4	
Shale, gray, sandy, streaked with yellow; occasional lenses of sandstone containing iron concretions	42	



COLUMNAR SECTIONS OF THE FRUITLAND FORMATION SHOWING THE POSITIONS OF THE COAL BEDS AND THE THINNING OF THE FORMATION SOUTHWARD

Broken lines connecting coal beds indicate correlations. Numbers in parentheses indicate detailed sections of coal beds on Plates XXVI, XXX, and XXXII

Fruitland formation—Continued.	Ft.	in.
Shale, black, carbonaceous		6
Shale, gray, sandy, banded with yellow, locally a soft gray sandstone, concretionary	10	
Shale, light gray, sandy	25	
Shale, dark brown, carbonaceous		8
Shale, gray, with iron concretions and barite	5	6
Shale, black, carbonaceous		6
Sandstone, yellow, clayey		4
Shale, dark brown, carbonaceous	1	6
Sandstone, clayey, gray, streaked with yellow; contains brown platy concretions of coarser sandstone and some aragonite concretions	12	6
Coal		2
Sandstone, black, carbonaceous		6
Bone	1	
Shale, sandy; contains brown and gray lenses of sandstone and ferruginous concretions with barite and lenses of carbonaceous shale	32	6
Sandstone, soft, gray with brown streaks, cross-bedded and platy at top	6	
Shale, brown, carbonaceous, locally sandy	3	3
Coal, impure		11
Bone		4
Coal, impure	1	2
Bone, sandy		3
Coal		4
Bone, sandy; contains lumps of resin		1
Coal, impure, with resin	1	7
Shale, gray and yellow, sandy	10	6
Shale, gray, sandy, and lenses of yellow sandstone, concretionary	10	
Sandstone, light gray, fine grained, unequally indurated; contains dark-brown sandstone concretions	7	
Shale, dark brown, carbonaceous		6
Shale, dark gray; contains iron concretions locally	5	
Sandstone, light gray, cross-bedded; contains iron concretions with barite; grades laterally into shale	7	6
Bone		6
Coal		7
Bone		5
Coal, impure		2
Shale, black, carbonaceous	2	10
Coal, impure		5
Bone, sandy		1
Pictured Cliffs sandstone.		
	196	1

KIRTLAND SHALE.

The Kirtland shale, named for a post office on San Juan River, lies conformably upon the Fruitland formation. It is composed mostly of gray shale, with some brown and black carbonaceous layers, bluish, greenish, and yellowish shales, easily weathering gray-white sand-

stone, and the brown resistant sandstone of the Farmington member described below. At some points thin beds of purple shale are present near the top of the formation. Barite occurs in concretions and veins in the shales. The Kirtland shale is readily affected by weathering and gives rise to extensive badlands. The formation, so far as known, is of fresh-water origin. It ranges in thickness from 700 feet on Escavada Wash to 950 feet in northern San Juan County and to 1,180 feet on Hunter Wash. It is divided typically into three portions—a lower shale, a middle sandy part named the Farmington sandstone member, and an upper shale.

The sandstone member is well shown in the prominent bluff on San Juan River near Farmington, which it is 455 feet thick. Toward the north this member thickens somewhat, but toward the south it is gradually replaced by shale until on the head of Coal Creek the member disappears as a mapable unit. Still farther south it is represented only by isolated sandstone lenses in the Kirtland shale. The individual sandstone lenses that make up the Farmington member are irregular in thickness, cross-bedded, and composed almost invariably of two parts—at the base an easily eroded yellowish sandstone carrying clay pellets of various sizes and in some lenses sandstone pebbles similar to the matrix and as much as 4 inches in diameter, and above a markedly resistant brownish sandstone, whose upper portion is commonly a dark chocolate-brown on the exposed surface and dark gray on the fresh surface. An individual lens will usually have a maximum thickness of 20 feet and a length of several hundred yards.

The upper part of the Kirtland shale is a thin unit, ranging from 40 to 110 feet in thickness, and is composed of shale and easily weathered gray-white sandstone lenses, very similar to the lower shale unit but carrying in many places relatively high-colored layers of yellow, blue-gray, and purple shale. Its persistence throughout the field is believed to signify a lack of erosion and consequently a small or even no time interval between the deposition of the Kirtland shale and that of the Ojo Alamo sandstone.[4a]

OJO ALAMO SANDSTONE.

The Ojo Alamo sandstone,[5] composed of white, gray, or brown conglomerate sandstone with lenses of soft whitish sandstone and gray or drab shale, overlies the Kirtland shale with apparent conformity. The contact is at many places sharp and well marked, but at other places it is difficult to determine just exactly where in the

[4a] See footnote [5a], p. 173.

[5] For a more complete description of this sandstone see Bauer, C. M., Stratigraphy of a part of the Chaco River valley: U. S. Geol. Survey Prof. Paper 98, pp. 275–276, 1916.

section the formation boundary lies. There does not seem to have been any considerable amount of erosion before the Ojo Alamo sandstone was laid down in the area covered by this report. The Ojo Alamo sandstone is of fluviatile origin. In southern San Juan County it ranges from 60 to 129 feet in thickness. Farther north it increases to nearly 400 feet.

In Colorado the volcanic Animas formation lies above the "Laramie formation" of older authors, which is equivalent to the Pictured Cliffs sandstone, Fruitland formation, and Kirtland shale, inclusive. The relation of the Animas formation to the Ojo Alamo sandstone is not yet known.[5a]

PUERCO AND TORREJON FORMATIONS.

The Puerco and Torrejon formations are very similar lithologically, and their respective faunas are limited to a few narrow but widely separated zones. No mappable plane of separation between them has yet been recognized, and the formations are therefore mapped and considered together. The Puerco formation everywhere rests with uneven base on the Ojo Alamo, and it is believed that the contact is an unconformity, though the amount of erosion was not great.

At the head of Escavada Wash the lower 250 feet of beds is composed of lenticular light and dark gray shales with bands of purplish, bluish, black, and rarely claret-colored shale and of soft gray-white sandstone. This part carries Puerco fossils in its lower strata. It is overlain by 500 feet of lenticular cream-colored to yellow and brown, more indurated sandstone with reddish-brown concretions. The sandstone beds are separated by greenish-gray and lead-gray shales and some soft white sandstone. Fossils are very scarce. The upper 450 feet of beds includes very dark slate-colored shale with two prominent and several fainter red bands and also soft gray-white sandstone. This upper part contains Torrejon fossils.

Near Ojo Alamo the Puerco and Torrejon are only 390 feet thick. The lower 140 feet is composed of much the same material as the lower part on Escavada Wash and carries Puerco fossils near the base. The overlying 250 feet consists of gray shale with bands of brown, greenish-gray, and dark slate-colored shale, soft gray-white sandstone, and some layers of more resistant yellow and brown sand-

[5a] Field work done by the junior author in 1920 has shown that a thinning wedge of the Animas formation extends as far south as San Juan River. The Ojo Alamo sandstone extends northward upon the Animas wedge as far as T. 31 N., R. 13 W., where Puerco or Torrejon beds rest directly on Animas beds. The base of the Animas wedge in New Mexico is apparently conformable, though in Colorado it is clearly unconformable on the Kirtland shale. Southeast of Escavada Wash the Ojo Alamo sandstone is also clearly unconformable on Kirtland shale, and it is likely that both Animas and Ojo Alamo belong with the later rather than with the earlier beds. A full discussion of these new data will be given in a paper now in preparation.

stone. This upper part bears Torrejon fossils. Layers and concretions of dark-green to black manganitic sandstone and concretions of barite occur abundantly in the group, also thin layers of a dense cream-colored flintlike material that is full of plant stems. Silicified wood is common.

On San Juan River at and above Farmington[6] the Ojo Alamo sandstone is overlain by a succession of white to buff, in places rusty-brown sandstones which carry lenses of pebbles and are separated by light-gray, dark-gray, and brown-banded shales. Layers of fine green sandstone and a dense flintlike material are common, as is also silicified wood. The material in many respects is different from that farther south and contains very few fossils. By its position in the section and the fact that it dips eastward under beds containing Torrejon fossils, it is shown to belong to either the Torrejon or the Puerco formation, although direct connection with the southern exposures can not be traced. In the country north of San Juan River the Puerco and Torrejon formations have much the same character as on the river and reach a thickness of 1,400 feet.

The fossils of the Puerco formation and the Torrejon formation differ enough to indicate the lapse of a long period of time during which there may have been erosion, now represented by an unconformity, but there is little indication on the ground of such a break.

FORMATION UNDETERMINED.

In the southern part of San Juan County the beds containing the Torrejon fauna are overlain by a banded deposit, 250 feet thick, of dove-colored shale, lighter-gray sandy shale, and soft white sandstone. A few reddish bands occur near the top, and rarely dark shale is present. One or two more resistant light-gray sandstone lenses carrying pebbles were observed. No fossils were found. The lower boundary of this unit is a clean-cut line with marked irregularities. In its lithology and position the unit suggests strongly the beds in southern Colorado recently described by Granger[7] as the Tiffany beds. These beds at the type locality carry a fauna intermediate in character between those of the Torrejon and Wasatch formations and reach a thickness of at least 300 feet.

In the map by the senior author published as Plate LXIV of United States Geological Survey Professional Paper 98 these beds in the district southeast of Chico Springs are shown as within the

[6] The rocks now referred to the Ojo Alamo sandstone and overlying beds on San Juan River were assigned by the senior author to the Wasatch formation on a map published as Plate 64, U. S. Geol. Survey Prof. Paper 98, 1916. Later and more detailed work farther east has shown that this assignment was in error. It is probable that no true Wasatch beds occur in the territory shown on that map.

[7] Granger, Walter, Notes on Paleocene and lower Eocene mammal horizons of northern New Mexico and southern Colorado: Am. Mus. Nat. Hist. Bull., vol. 27, pp. 821–830, 1917.

Wasatch formation, but later work has suggested the desirability of separating them from the true Wasatch of the region.

WASATCH FORMATION.

At the southeastern extremity of the field the highest rocks observed comprise a very massive, cliff-forming copper-red basal sandstone with lenses of pebbles which is about 50 feet thick, overlain by 150 feet of light-gray and red shales and soft white sandstone, overlain in turn by another prominent cliff-forming sandstone similar to the first. The basal contact of the lower sandstone is not noticeably irregular. No fossils were observed in these beds. The Wasatch formation farther east has been described by different observers as consisting of a basal conglomeratic sandstone overlain by a succession of shales and sandstones with marked coloring. The writers have not traced the horizons, but there would seem to be little doubt that the rocks at the head of Escavada Wash are continuous with the *Coryphodon*-bearing Wasatch of the southeastern part of the San Juan Basin.

AGE OF THE FORMATIONS.[8]

The Mancos shale typically contains invertebrate faunas of Colorado age in the older part and of Montana age in the younger part. Only Montana species were found in the small area of upper Mancos shale examined in this field.

The Mesaverde group has a flora and an invertebrate fauna of Montana age.

The Lewis shale and the Pictured Cliffs sandstone likewise contain invertebrate faunas of Montana age, though with elements not known in the latest Montana faunas, such as that of the typical Fox Hills sandstone.

The Fruitland formation and Kirtland shale contain a homogeneous flora and vertebrate and invertebrate faunas. The flora is of Montana age and closely related to that of the Mesaverde and allied formations of the region. The vertebrate fauna is entirely reptilian and of types known elsewhere only in beds of Montana age. The invertebrate fauna consists of fresh and brackish water forms, in the main of types known elsewhere only in post-Montana beds, though several of the brackish-water species occur only in beds of Montana age and several range from Montana beds into post-Montana beds. It seems most logical, in the light of present knowledge, to consider the Fruitland formation and Kirtland shale as of late Montana age.

The Pictured Cliffs sandstone, the Fruitland formation, and the Kirtland shale together make up the "Laramie formation" of the

[8] For references to literature see footnote, p. 161.

older works dealing with the San Juan Basin. The Ojo Alamo sandstone was also included by some authors. There is still considerable uncertainty as to what part, if any, of the section in San Juan County is equivalent to the typical Laramie of northeastern Colorado.

The Ojo Alamo sandstone has furnished a few poor specimens of plants of little value in correlation and has supplied evidence of a considerable dinosaurian fauna. The only specimen complete enough to identify occurs also in the Kirtland shale. Other specimens are definite enough, however, to be recognized as unlike any known post-Montana species.[9] The abrupt appearance of conglomerate lenses and coarse sandstone in the Ojo Alamo, above the Kirtland shale, has been interpreted as marking a great change in conditions of deposition, considerable lapse of time, and therefore a closer relation of the Ojo Alamo to the later formations than to the earlier, particularly as such a condition exists elsewhere in the general region.[10] However, there is little evidence of an erosional break at the base of the Ojo Alamo sandstone—the persistent thin upper shale of the Kirtland does not show it—and no other evidence of a time break in the succession except the change in lithology. The apparent relationship of the fauna would place the deposition of the Ojo Alamo sandstone in Montana time, though it is not conclusive. This view demands a hiatus between the sandstone and the overlying Puerco formation to account for the interval represented elsewhere by the Laramie formation, which is of post-Montana age but still within the Cretaceous.[10a]

The Puerco and Torrejon formations have furnished a small flora that is interpreted as of Tertiary age and a considerable vertebrate fauna. This fauna consists chiefly of primitive mammals and turtles but no dinosaurs and is unversally regarded as of early Tertiary age. The base of the Puerco formation lies on an irregular surface that shows the effect of some erosion, though not enough in this field to indicate by itself a long time interval. The Puerco elsewhere is said to overlap older formations, and certainly its fauna has nothing in common with those of older formations. The fauna of the Torrejon is of the same type as that of the Puerco but is distinct from it and definitely advanced toward modern mammals.

The Tiffany beds of Sinclair and Granger at their type locality carry a fauna intermediate between that of the Torrejon and Wasatch. The beds in this field that may be equivalent to them occupy the same stratigraphic position and are similar in lithology but yielded no fossils by which to verify the correlation.

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[9] Gilmore, C. W., personal communication.

[10] Lee, W. T., and Knowlton, F. H., Geology and paleontology of the Raton Mesa and other regions in Colorado and New Mexico: U. S. Geol. Survey Prof. Paper 101, p. 55, 1917.

[10a] See footnote [5a], p. 173.

The highest rocks in this field are correlated with the Wasatch of the region on the basis of stratigraphic position and lithologic similarity.

COAL.

DISTRIBUTION.

Coal occurs in the Menefee formation of the Mesaverde group and in the Fruitland formation. There are also local deposits of lignitic material at the base of the Puerco formation, such as that prospected just south of Farmington, and reports are current locally of coal in higher formations. The writer studied in detail the coal of the Menefee formation only in a small area just north of San Juan River, and most of the following description will therefore be devoted to the coal of the Fruitland formation. The coaly material of the younger formations is of very little value in this general region and may be dismissed from consideration.

The coal beds of the Menefee formation are in two groups—one near the top, the other near the bottom of the formation. The beds are lenticular and are variable in purity and thickness. Most of them are relatively thin, but at some places a considerable thickness of minable coal is present.

The coal beds of the Fruitland formation are scattered throughout the formation but are thicker and more persistent in the lower part. The thickest beds lie north of San Juan River, though the total amount of coal is large in some places south of that stream, notably at the mouth of Klaychen Arroyo. Locally extensive burning of the coal beds has taken place and their former positions are marked by red baked shale and clinker. The very thick coal bed low in the Fruitland formation in northern San Juan County has been correlated with that formerly mined at Carbonero Junction, near Durango, Colo.,[11] but extensive correlations are doubtful south of the San Juan. In the extreme southern part of the field the coal beds decrease in number, thickness, and extent, and the coal is of poorer quality than it is in the northern part. Owing to this tendency to deteriorate southward, the coal on Escavada Wash possesses very little economic value.

CHARACTER.

PHYSICAL PROPERTIES.

The coals of the Menefee and Fruitland formations are very similar in character. Both are black with a bright luster and are hard and brittle and break readily in handling. They check and break

[11] Shaler, M. K., A reconnaissance survey of the western part of the Durango-Gallup coal field of Colorado and New Mexico: U. S. Geol. Survey Bull. 316, pp. 392–398, 1906.

on exposure to the air and sun but with some protection may be stored almost indefinitely. The suitability for storage is an important feature in estimating the value of a coal. Resistance to deterioration on exposure is the chief difference between bituminous and subbituminous coal.[12] The chemical differences, though well marked if the two classes are considered as entities, are small between many high-grade subbituminous coals and low-ranking bituminous coals. Subbituminous coal, owing to its larger percentage of moisture, breaks down or "slacks" readily on exposure to weather and must be protected or it will disintegrate to a dust, whereas bituminous coal is relatively unaffected on exposure. South of San Juan River all the coal of the Fruitland formation and that of the Menefee formation away from the Hogback is subbituminous. In the Hogback and north of the San Juan the coal of the Menefee formation is all bituminous. North of the San Juan the coals of the Fruitland formation pass from subbituminous to bituminous in rank, but they are of somewhat poorer quality than the older coals.

All the coals of this field burn to a gray ash without clinker. Nothing is known of their coking qualities, though the higher-grade coals a little farther north, in Colorado, are coked and used at the smelter at Durango.

The coal of the Fruitland formation at many localities contains a considerable amount of the fossil resin wheelerite,[13] in the form of clear brown or yellow grains about the size of a pea. It has been mistaken for sulphur, though in coal sulphur does not occur as such, but in combination with the coal substance or with iron as the brassy minerals marcasite and pyrite (fool's gold). These minerals were not seen in this field.

CHEMICAL CHARACTER.

An analysis of a coal sheds much light on its value, though various properties not indicated by the analysis are important also—for example, resistance to exposure and suitability for storage and shipment without deterioration, behavior in handling and resistance to breakage and production of fine coal, capacity for coking, fusibility of the ash, and presence or absence of clinker. Yet much may be learned of a coal from a knowledge of the percentages of moisture, volatile matter (gases), fixed carbon, ash, and sulphur determined in what is known as a "proximate analysis," the percentages of the actual elements composing the coal determined in an "ultimate analysis," and

[12] For a discussion of the classification of coals see Campbell, M. R., The coal fields of the United States—General introduction: U. S. Geol. Survey Prof. Paper 100, pp. 3–10, 1917 (Prof. Paper 100–A).

[13] U. S. Geol. Surveys W. 100th Mer. Rept., vol. 3, pp. 630–631, 1875.

the heating efficiency expressed in calories or British thermal units.[14] Inasmuch as coal owes its economic value primarily to its ability to produce heat, the heating efficiency is perhaps the most important. As it is in a sense resultant of the chemical composition, the sum of all the other factors of the analysis, it is used (p. 181) as the basis of comparison of the coals of this field with those of other fields.

In the production of heat the volatile matter and the fixed carbon are to be considered as the valuable constituents, and the moisture, ash, and sulphur as injurious constituents. Moisture and ash are inert, absorb part of the heat produced by other constituents, and replace heat-forming substances in such proportion as they are present. Sulphur produces in burning objectionable and harmful gases.

The table on pages 183–187 shows analyses made by the Bureau of Mines of 15 samples of coal from San Juan County and 15 from other fields for comparison. Twelve of the samples from San Juan County were obtained from local mines of the drift type and three from open pits representing the freshest and least-altered coal obtainable. The small amount of adherent moisture—that is, moisture which may be removed by drying—as well as of total water in most of the samples is probably due to the aridity of the climate and consequent low position of the water table during most of the year. The absence of water in and over the coal, however, has the effect of permitting freer access of air and the consequent weathering of the coal much farther back from the outcrop than where the beds are moist the year round. On weathering there is a loss of volatile matter and of heating value, as is shown by the analyses of samples 17750 and 29006, the former from a point 100 feet from the mine mouth, the latter 350 feet from the mine mouth.

All these samples were obtained by the regulation method prescribed by the Geological Survey and the Bureau of Mines, which "involves selecting a representative face of the bed to be sampled; cleaning the face, making a cut across it from roof to floor, and rejecting or including impurities according as these are included or excluded in mining operations; reducing the gross sample, by crushing and quartering, to about 4 pounds; and immediately sealing the sample in an airtight container for shipment to the laboratory."[15]

The four forms of analysis given for each sample are not different determinations but merely four forms of one analysis. Form A is the analysis of the coal exactly as it comes from the bed. Owing to the fact that the original moisture content of a sample is largely a matter of accident and depends partly on the amount of water in and around the place from which it came, it is best for comparisons to use Form B, which is the analysis of the sample air dried under

[14] A calorie is the amount of heat required to raise the temperature of a gram of pure water 1° centigrade at or near 4° C. A British thermal unit is the amount of heat required to raise the temperature of a pound of water 1° Fahrenheit at or near 39° F.

[15] Bur. Mines Bull. 22, p. 8, 1913.

uniform conditions. Form C is the analysis of the sample after all moisture has been theoretically eliminated. Form D is also computed and is the analysis of the sample after all moisture and ash have been theoretically removed. Forms C and D are useful chiefly to engineers.

Five of the analyses represent the coal of the Menefee formation of this field, collected at locations 104 and 548 and at points near Tiznatzin and Putnam (Pueblo Bonito). (See Pl. XVI.) The coal, as represented by analyses 17750 and 29006, is very low in ash and sulphur and relatively high in heating value. Compared with coal mined at Durango, on the north side of the San Juan Basin (analysis 14772), it is lower in fixed carbon and heating value and higher in moisture; compared with that mined at Gallup, on the south side of the basin (analysis 19135), it is higher in heating value and lower in ash. The analyses of samples collected in southern San Juan County show that the coal there is not so good as that in the northern part, being relatively high in ash and sulphur and, as mined, in moisture. It is lower in heating value and about equal to that mined at Gallup.

Ten of the analyses represent the coal of the Fruitland formation, collected at locations 9, 10, 58, 61, 67, 69, 301, and 419. (See maps.) The coal of this formation is low in moisture and sulphur. Two samples show a high sulphur content, which is due possibly to the accidental inclusion of coal with adhering powder residue but possibly also to some local variation in the coal. In ash this coal is uniformly higher than the older coal. The samples collected in the northern part of the field are as high in heating value as the older coal of the same area and higher than the older coal of the southern part. The samples collected in southern San Juan County are about equal to the Gallup coal, though as they come from shallow open pits they may not represent as high-grade coal as that under thicker cover at the same localities.

At present the coals of this field are mined only for local use and consequently come into competition only with that shipped in from Durango, Colo. Should better railroad communication with the north or south, or both, become available the question of competition with other coals of Colorado and New Mexico would become of great importance to one attempting the development of mines in the San Juan field. If a railroad were built into the field from the south any coal mined here would have to compete directly with coal mined in the vicinity of Gallup and indirectly with that of the Raton field, in Colfax County. If better railroad connection were made with the main line of the Denver & Rio Grande Railroad on the north, the local coal would have to compete with the Colorado coals mined near Porter and Hesperus, La Plata County; near Somerset and Crested

Butte, Gunnison County; and near Newcastle and Sunlight, Garfield County; and with the Utah coals mined at Thompson, Sunnyside, and Castlegate. If facilities for shipping coal to the East were improved the local coal would have to compete with coal of the Trinidad and Canon City fields, east of the mountains, and possibly with the subbituminous coal of the Boulder region, which is an important factor in the Denver market. Analyses of representative samples from all these fields are given for comparison on pages 185–187, but the sample from Crested Butte does not represent the highest-ranking coal of that field, for even anthracite is found there.

Other elements entering into value being disregarded, it is of interest to compare the coals of San Juan County and other fields on the basis of their heating value (1) as they come from the mine, (2) air dried, (3) with the deleterious moisture and ash theoretically removed. The first condition is perhaps the nearest to the average coal actually purchased by the consumer; the second avoids the accidental differences due to the local conditions in the mine, drying in storage and shipment, etc.; the third shows how much of the difference in heating value is really due to difference in the pure coal substance. In the following table, for simplicity in comparison, the best coal of San Juan County is taken as having a value of 100, and the heating values of the other coals are expressed in proportionate figures:

Comparative heating values of coals of San Juan County and other fields.

	Analysis No.[a]	As mined.		Air-dried.		Ash and moisture free.	
		British thermal units.	Ratio.	British thermal units.	Ratio.	British thermal units.	Ratio.
SAN JUAN COUNTY.							
1. Menefee formation, northern part	29006	12,010	100	12,270	100	14,020	100
2. Fruitland formation, northern part, bituminous	(b)	11,720	98	12,060	98	14,380	103
3. Fruitland formation, northern part, subbituminous	(c)	11,140	93	11,570	94	13,950	99
4. Fruitland formation, southern part	(d)	10,360	86	11,020	90	13,680	98
5. Menefee formation, southern part	(e)	10,130	83	11,090	90	13,300	95
OTHER FIELDS.							
6. Durango, Colo	14772	13,710	114	13,990	114	15,220	109
7. Crested Butte, Colo	7983	13,430	112	13,620	111	14,960	107
8. Castlegate, Utah	19880	13,060	109	13,200	108	14,430	103
9. Trinidad, Colo	14060	13,000	108	13,080	107	15,270	109
10. Hesperus, Colo	14775	12,670	106	13,170	108	14,550	104
11. Koehler, N. Mex	12338	12,620	105	12,870	105	14,960	107
12. Sunnyside, Utah	12630	12,620	105	12,810	104	14,490	103
13. New Castle, Colo	12327	12,620	105	13,090	107	14,400	103
14. Somerset, Colo	12324	12,430	104	12,650	103	14,600	104
15. Sunlight, Colo	4034	12,420	103	12,810	104	14,470	103
16. Thompson, Utah	17577	11,720	98	11,950	97	14,210	101
17. Canon City, Colo	13395	11,420	95	12,120	99	13,710	98
18. Gallup, N. Mex	19135	11,100	92	11,770	96	13,940	99
19. Lafayette, Colo	15165	9,940	83	11,080	90	13,120	94

[a] See table of analyses on pp. 185–187.
[b] Average of analyses 17749, 29249, 29250.
[c] Average of analyses 22026, 29025, 2464, 22508, 22509.
[d] Average of analyses 22685, 22807.
[e] Average of analyses 3811, 23003, 23004.

From the figures given under "Ash and moisture free" it is apparent that so far as heating power is concerned the best coal intrinsically with which the San Juan coal may compete is that from Trinidad, Colo., but on account of the heavy percentage of ash which that coal contains it is not the most efficient coal as it reaches the consumer. The best coal as it reaches the consumer is that from Durango—in other words, the San Juan coal has its greatest competitor near home.

In the table given above the relative values of these coals are expressed in percentages, but if put on a strict money basis the comparative values might be expressed as follows: If the consumer paid $5 for a ton of the best San Juan coal, delivered as mined, he could afford to pay the following prices per ton for the other coals listed above, as he would receive the same heating value per dollar.

Comparative heating value of San Juan and other coals expressed in value per ton.

1	$5.00	6	$5.70	11	$5.25	16	$4.90
2	4.90	7	5.60	12	5.25	17	4.75
3	4.65	8	5.45	13	5.25	18	4.60
4	4.30	9	5.40	14	5.20	19	4.15
5	4.15	10	5.30	15	5.15		

Analyses of coal samples from the San Juan County coal field, New Mexico, and other fields.

[Made at the Pittsburgh laboratory of the Bureau of Mines; A. C. Fieldner and F. M. Stanton, chemists in charge.]

Coal of the Menefee formation.

Mine and sampler.	Location.				No. on Plate.	Laboratory No.	Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heating value.	
	Quarter.	Section.	T. N.	R. W.					Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
Government mine; Max. A. Pishel, 1913.	SW.	21	30	16	104	17750	1.8	A	10.6	36.7	49.6	3.1	0.64	.....	.....	.....	.....	6,115	11,010
								B	9.0	37.4	50.5	3.1	.65	.....	.....	.....	.....	6,225	11,210
								C	.....	41.1	55.4	3.5	.72	.....	.....	.....	.....	6,840	12,310
								D	.....	42.6	57.4	.....	.75	.....	.....	.....	.....	7,085	12,750
Government mine; Harvey Bassler, 1917.	SW.	21	30	16	104	29006	2.1	A	10.1	39.9	45.8	4.2	.85	.....	.....	.....	.....	6,675	12,010
								B	8.2	40.8	46.8	4.2	.87	.....	.....	.....	.....	6,820	12,270
								C	.....	44.4	50.9	4.7	.95	.....	.....	.....	.....	7,425	13,370
								D	.....	46.6	53.4	.....	1.00	.....	.....	.....	.....	7,790	14,020
Tiznatzin mine; M. K. Shaler, 1906.	(a)	(a)	(a)	(a)	(b)	3811	7.6	A	15.8	35.0	39.8	9.	1.78	5.93	55.74	1.39	25.79	5,540	9,970
								B	8.9	37.9	43.1	10.14	1.93	5.51	60.32	1.51	20.59	5,995	10,790
								C	.....	41.6	47.3	11.13	2.11	4.96	66.19	1.65	13.96	6,580	11,840
								D	.....	46.8	53.2	.....	2.38	5.59	74.48	1.86	15.69	7,400	13,320
Blake's mine; C. M. Bauer, 1915...	.....	13	22	13	548	23003	11.2	A	19.0	32.4	43.2	5.4	.92	.....	.....	.....	.....	5,665	10,190
								B	8.8	36.5	48.6	6.1	1.04	.....	.....	.....	.....	6,380	11,480
								C	.....	40.0	53.3	6.7	1.14	.....	.....	.....	.....	6,990	12,590
								D	.....	42.9	57.1	.....	1.22	.....	.....	.....	.....	7,495	13,490
Pueblo Bonito mine; C. M. Bauer, 1915.	.....	14	21	11	(b)	23004	7.1	A	14.4	34.8	43.3	7.5	1.54	.....	.....	.....	.....	5,680	10,220
								B	7.8	37.5	46.6	8.1	1.66	.....	.....	.....	.....	6,110	11,000
								C	.....	40.7	50.5	8.8	1.80	.....	.....	.....	.....	6,630	11,940
								D	.....	44.6	55.4	.....	1.97	.....	.....	.....	.....	7,270	13,090

a Navajo Indian Reservation.

b Not shown

Analyses of coal samples from the San Juan County coal field, New Mexico, and other fields—Continued.

Coal of the Fruitland formation.

Mine and sampler.	Location.				No. on Plate.	Laboratory No.	Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heating value.	
	Quarter.	Section.	T. N.	R. W.					Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
New Mexico mine; Max. A. Pishel, 1913.	.....	7	32	12	3	17749	1.6	A	6.6	35.4	44.9	13.1	0.66	.....	.....	.....	.....	6,380	11,490
								B	5.1	36.0	45.6	13.3	.67	.....	.....	.....	.....	6,485	11,680
								C	.....	37.9	48.0	14.1	.71	.....	.....	.....	.....	6,835	12,300
								D	.....	44.1	55.9	.....	.83	.....	.....	.....	.....	7,950	14,310
Bill Thomas mine; Harvey Bassler, 1917.	NW.	22	32	13	9	29249	2.9	A	5.9	39.1	44.0	11.0	.63	.....	.....	.....	.....	6,695	12,050
								B	3.2	40.2	45.3	11.3	.65	.....	.....	.....	.....	6,890	12,410
								C	.....	41.5	46.8	11.7	.67	.....	.....	.....	.....	7,120	12,810
								D	.....	47.0	53.0	.....	.76	.....	.....	.....	.....	8,060	14,510
Jones mine; Harvey Bassler, 1917.	SE.	21	32	13	10	29250	3.3	A	6.9	38.1	43.1	11.9	1.32	.....	.....	.....	.....	6,460	11,630
								B	3.7	39.4	44.6	12.3	1.37	.....	.....	.....	.....	6,685	12,030
								C	.....	41.0	46.2	12.8	1.42	.....	.....	.....	.....	6,940	12,500
								D	.....	47.0	53.0	.....	1.63	.....	.....	.....	.....	7,960	14,330
Prospect drift; J. B. Reeside, jr., 1917.	NW.	16	30	15	58	29026	1.4	A	9.6	37.2	40.5	12.7	2.36	.....	.....	.....	.....	5,850	10,530
								B	8.3	37.7	41.1	12.9	2.39	.....	.....	.....	.....	5,935	10,690
								C	.....	41.2	44.8	14.0	2.61	.....	.....	.....	.....	6,475	11,660
								D	.....	47.9	52.1	.....	3.04	.....	.....	.....	.....	7,530	13,560
Marcelius mine; J. B. Reeside, jr., 1917.	SW.	28	30	15	61	29025	1.4	A	8.8	41.7	41.2	8.3	.62	.....	.....	.....	.....	6,475	11,660
								B	7.4	42.3	41.9	8.4	.63	.....	.....	.....	.....	6,570	11,820
								C	.....	45.7	45.2	9.1	.68	.....	.....	.....	.....	7,095	12,770
								D	.....	50.3	49.7	.....	.75	.....	.....	.....	.....	7,810	14,060
Black Diamond mine; Schrader and Shaler, 1905.	SW.	4	29	15	67	2464	4.5	A	9.9	38.4	41.5	10.2	.64	.....	.....	.....	.....	6,275	11,300
								B	5.6	40.3	43.4	10.7	.67	.....	.....	.....	.....	6,570	11,830
								C	.....	42.7	46.0	11.3	.71	.....	.....	.....	.....	6,965	12,540
								D	.....	48.1	51.9	.....	.80	.....	.....	.....	.....	7,855	14,140
Black Diamond mine; C. M. Bauer, 1915.	SW.	4	29	15	67	22508	6.2	A	11.6	38.6	39.9	9.9	.60	.....	.....	.....	.....	6,105	10,990
								B	5.7	41.1	42.6	10.6	.64	.....	.....	.....	.....	6,510	11,720
								C	.....	43.6	45.2	11.2	.68	.....	.....	.....	.....	6,905	12,430
								D	.....	49.2	50.8	.....	.77	.....	.....	.....	.....	7,775	14,000

L. W. Henderickson mine; C. M. Bauer, 1915.	SW.	3	29	15	69	22509	5.1	A	10.5	38.6	41.7	9.2	.60	.....	.....	.....	.....	6,230	11,210
								B	5.7	40.6	43.9	9.8	.63	.....	.....	.....	.....	6,560	11,810
								C	.....	43.1	46.6	10.3	.67	.....	.....	.....	.....	6,960	12,530
								D	.....	48.0	52.0	.....	.75	.....	.....	.....	.....	7,760	13,970
Local pit; C. M. Bauer, 1915.....	(a)	(a)	(a)	(a)	301	22685	6.1	A	16.1	36.2	40.7	7.0	.69	.....	.....	.....	.....	5,855	10,540
								B	10.6	38.5	43.4	7.5	.73	.....	.....	.....	.....	6,235	11,230
								C	.....	43.1	48.5	8.4	.82	.....	.....	.....	.....	6,980	12,560
								D	.....	47.1	52.9	.....	.89	.....	.....	.....	.....	7,615	13,710
Do.....	(a)	(a)	(a)	(a)	419	22807	5.8	A	19.1	33.0	41.7	6.2	.43	.....	.....	.....	.....	5,660	10,180
								B	14.1	35.0	44.3	6.6	.46	.....	.....	.....	.....	6,010	10,810
								C	.....	40.7	51.6	7.7	.53	.....	.....	.....	.....	6,995	12,600
								D	.....	44.1	55.9	.....	.57	.....	.....	.....	.....	7,580	13,640

[a] Navajo Indian Reservation.

Possibly competing coals in Colorado.

Durango, La Plata County.....	.....	.....	.....	.....	.....	14772	2.0	A	3.0	34.8	55.3	6.91	0.74	5.50	76.36	1.50	8.99	7,620	13,710
								B	1.0	35.5	56.4	7.05	.76	5.39	77.92	1.53	7.35	7,775	13,990
								C	.....	35.9	57.0	7.12	.76	5.33	78.73	1.55	6.51	7,855	14,140
								D	.....	38.6	61.4	.....	.82	5.74	84.77	1.67	7.00	8,455	15,220
Hesperus, La Plata County.....	.....	.....	.....	.....	.....	14775	3.8	A	7.1	38.1	49.0	5.85	.60	5.68	70.85	1.47	15.55	7,040	12,670
								B	3.4	39.6	50.9	6.08	.62	5.47	73.65	1.53	12.65	7,320	13,170
								C	.....	41.0	52.7	6.30	.65	5.26	76.25	1.58	9.96	7,575	13,640
								D	.....	43.8	56.2	.....	.69	5.61	81.37	1.69	10.64	8,085	14,550
Crested Butte, Gunnison County..	.....	.....	.....	.....	.....	7983	1.4	A	3.0	33.6	56.2	7.24	.39	5.39	74.46	1.52	11.00	7,460	13,430
								B	1.6	34.1	57.0	7.34	.40	5.30	75.52	1.54	9.90	7,565	13,620
								C	.....	34.6	57.9	7.46	.40	5.22	76.75	1.57	8.60	7,690	13,840
								D	.....	37.4	62.6	.....	.43	5.64	82.94	1.70	9.29	8,310	14,960
Somerset, Gunnison County.....	.....	.....	.....	.....	.....	12324	1.7	A	5.6	37.6	47.6	9.22	.43	5.31	69.68	1.40	13.96	6,910	12,430
								B	4.0	38.2	48.4	9.38	.44	5.21	70.89	1.42	12.66	7,025	12,650
								C	.....	39.8	50.4	9.77	.46	4.97	73.82	1.48	9.50	7,320	13,170
								D	.....	44.1	55.9	.....	.51	5.51	81.81	1.64	10.53	8,110	14,600
Newcastle, Garfield County.....	.....	.....	.....	.....	.....	12327	3.6	A	7.1	40.8	46.9	5.19	.45	5.65	70.77	1.56	16.38	7,010	12,620
								B	3.6	42.3	48.7	5.38	.47	5.45	73.41	1.62	13.67	7,275	13,090
								C	.....	43.9	50.5	5.59	.48	5.23	76.20	1.68	10.82	7,550	13,590
								D	.....	46.5	53.5	.....	.51	5.54	80.71	1.79	11.46	7,995	14,400
Sunlight, Garfield County.....	.....	.....	.....	.....	.....	4034	3.0	A	5.3	36.3	49.6	8.79	.76	5.26	67.76	1.58	15.85	6,900	12,420
								B	2.4	37.4	51.1	9.06	.78	5.08	69.86	1.63	13.59	7,115	12,810
								C	.....	38.3	52.4	9.28	.80	4.93	71.57	1.67	11.75	7,290	13,120
								D	.....	42.2	57.8	.....	.88	5.44	78.89	1.84	12.95	8,035	14,470

Analyses of coal samples from the San Juan County coal field, New Mexico, and other fields—Continued.

Possibly competing coals in Colorado—Continued.

Mine and sampler.	Location.				No. on Plate.	Laboratory No.	Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heating value.	
	Quarter.	Section.	T. N.	R. W.					Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
Trinidad, Las Animas County	.....	.....	.....	.....	.....	14060	0.6	A	1.5	30.8	54.4	13.32	0.53	4.98	73.10	1.71	6.36	7,220	13,000
								B	0.9	31.0	54.7	13.40	.53	4.94	73.54	1.74	5.87	7,265	13,080
								C	.....	31.3	55.2	13.53	.54	4.88	74.23	1.74	5.08	7,335	13,200
								D	.....	36.2	63.8	.....	.62	5.64	85.85	2.01	5.88	8,480	15,270
Canon City, Fremont County	.....	.....	.....	.....	.....	13395	5.8	A	10.3	38.2	45.0	6.49	.42	5.38	65.45	1.08	21.18	6,340	11,420
								B	4.7	40.6	47.8	6.89	.45	5.03	69.48	1.15	17.00	6,730	12,120
								C	.....	42.6	50.2	7.23	.47	4.74	72.94	1.20	13.42	7,070	12,720
								D	.....	46.0	54.0	.....	.51	5.11	78.62	1.29	14.47	7,620	13,710
Lafayette, Boulder County	.....	.....	.....	.....	.....	15165	10.3	A	20.7	31.8	44.0	3.49	.45	6.04	57.80	1.20	31.02	5,525	9,094
								B	11.6	35.5	49.0	3.89	.50	5.46	64.44	1.34	24.37	6,150	11,080
								C	.....	40.1	55.5	4.40	.57	4.72	72.90	1.51	15.90	6,965	12,540
								D	.....	42.0	58.0	.....	.60	4.94	76.25	1.58	16.63	7,285	13,120
Possibly competing coals in New Mexico.																			
Gallup, McKinley County	.....	.....	.....	.....	.....	19135	5.7	A	13.2	39.1	40.5	7.21	0.45	6.04	62.73	1.13	22.44	6,165	11,100
								B	7.9	41.5	42.9	7.65	.48	5.74	66.51	1.20	18.42	6,535	11,770
								C	.....	45.1	46.6	8.31	.52	5.26	72.26	1.30	12.35	7,100	12,780
								D	.....	49.2	50.8	.....	.57	5.74	78.81	1.42	13.46	7,745	13,940
Koehler, Colfax County	.....	.....	.....	.....	.....	12338	1.9	A	3.6	36.1	48.3	12.00	.70	5.25	69.76	1.31	10.98	7,015	12,620
								B	1.8	36.8	49.2	12.23	.71	5.14	71.11	1.34	9.47	7,150	12,870
								C	.....	37.5	50.1	12.45	.73	5.03	72.40	1.36	8.03	7,280	13,100
								D	.....	42.8	57.2	.....	.83	5.75	82.70	1.55	9.17	8,315	14,960

Possibly competing coals in Utah.

Thompson, Grand County						17577	2.0	A	7.1	37.1	45.4	10.44	0.66	5.59	65.98	1.45	15.88	6,510	11,720
								B	5.3	37.8	46.3	10.65	.67	5.48	67.29	1.48	14.43	6,640	11,950
								C	.....	39.9	48.9	11.24	.71	5.17	71.05	1.56	10.27	7,010	12,620
								D	.....	44.9	55.1	.....	.80	5.82	80.04	1.76	11.52	7,895	14,210
Sunnyside, Carbon County						12630	1.5	A	5.1	38.4	48.7	7.81	.51	5.54	70.72	1.58	13.84	7,010	12,620
								B	3.6	39.1	49.4	7.93	.52	5.45	71.80	1.60	12.70	7,120	12,810
								C	.....	40.5	51.3	8.23	.54	5.25	74.49	1.66	9.83	7,385	13,290
								D	.....	44.1	55.9	.....	.59	5.72	81.17	1.81	10.71	8,045	14,490
Castlegate, Carbon County						19880	1.0	A	3.3	42.5	48.0	6.19	.40	5.60	73.22	1.35	13.24	7,260	13,060
								B	2.3	43.0	48.5	6.25	.40	5.54	73.99	1.36	12.46	7,335	13,200
								C	.....	44.0	49.6	6.40	.41	5.41	75.72	1.40	10.66	7,505	13,510
								D	.....	47.0	53.0	.....	.44	5.78	80.90	1.50	11.38	8,020	14,430

The sections of the coal beds at the points sampled, except those shown below, are given in the plates of graphic sections, and the parts included in the sample are marked by an asterisk.

Section of coal beds in Tiznatzin mine, on Coal Creek 2 miles above mouth, in T. 23 N., R. 14 W., unsurveyed.

[Analysis 3811.]

	Ft.	in.
Sandstone.		
Coal	1	8
Bone		5
Coal*	3	2
Shale.		
	5	3

Section of coal beds in Pueblo Bonito mine, 1 mile southwest of Putnam (Pueblo Bonito), in T. 21 N., R. 11 W.

[Analysis 23004.]

	Ft.	in.
Sandstone.		
Bone		2
Coal*	2	8
Bone, sandy		6
Coal*	1	7
Shale, carbonaceous	2	6
Coal, impure	2	4
Shale.		
	9	9

Section of coal beds in Blake's mine, sec. 13, T. 22 N., R. 13 W.

[Analysis 23003.]

	Ft.	in.
Sandstone.		
Coal*	1	7
Shale, carbonaceous	1	1
Coal	1	5
Sandstone.		
	4	1

ASH TESTS.

Tests were made in the field of the ash content of samples from a number of beds, and at the same time note was made of the air-drying loss. The tests were made with a small portable outfit, devised by C. E. Lesher.[16] Samples collected at locations 140, 145, 154, 155, 230, 235, and 545 represented beds or benches of coal whose purity was uncertain and whose value the geologist wished to know in the field. The other samples were tested as representative of the coal at the outcrop. Each sample for the ash test was taken from a clean

[16] Lesher, C. E., Field apparatus for determining ash in coal: U. S. Geol. Survey Bull. 621, pp. 1–12, 1915.

face of the bed by picking off, as nearly as possible, an even amount from all parts of the face so as to obtain a fair representation of the character of the bed.

The high ash content of samples from locations 153, 167, 224, and 231, as compared with that of samples from mines, would seem to indicate the presence of some foreign material in the weathered part of the coal bed, possibly mineral salts deposited by the evaporation of ground water.

Ash tests of coal from the Menefee formation.

Location 145.

Section.		Ash (per cent).	Moisture (per cent).
	Ft. in.		
Shale.			
Coal	2	22.2	11.1
Shale.			

Location 235.

Shale.			
Coal, bony	1 7	21.5	10.6
Bone	4		
Shale.	1 11		

Ash tests of coal from the Fruitland formation.

Location 140, Navajo mine, south side of San Juan River.

Section.		Ash (per cent).	Moisture (per cent).
	Ft. in.		
Shale, carbonaceous.			
Coal, bony	1 8	16.6	6.3
Shale, sandy	6		
Bone	5		
Coal	0	11.6	2.2
Shale	1 5		
Coal and bone	9		
Shale, carbonaceous	½		
Coal, impure	3 7	20.2	2.6
Shale, sandy	3		
Coal, impure	4		
Shale, sandy	1		
Bone	6		
Coal	1 4		
Shale, sandy	3		
Coal, impure	2 11	27.5	1.7
Bone	4		
Shale	1		
Bone	5		
Shale.			
	14 10½		

Location 154.

Shale, carbonaceous.			
Bone	2 5	33.2	10.4
Shale, carbonaceous.			

Ash tests of coal from the Fruitland formation—Continued.

Location 155.

Section.	Ft.	in.	Ash (per cent).	Moisture (per cent).
Shale, black, carbonaceous.				
Bone		2		
Coal		3		
Bone		8		
Shale		½		
Coal, impure	2	9½	27.0	11.3
Shale		2		
Coal		11		
Shale		½		
Bone		6½	34.5	10.2
Coal		6		
Bone		2		
Coal		10		
Shale.				
	7	0		

Location 230.

Shale, carbonaceous.				
Coal	1	8		
Bone		1		
Sandstone		3		
Coal, bony; contains wheelerite	2	3	28.5	8.8
Shale.				
	4	3		

Location 545.

Sandstone.				
Coal, impure		7		
Shale		3		
Bone	1	10		
Sandstone		5		
Coal, bony	1	2	28.5	7.4
Shale	1	4		
Coal, bony	2	10	31.0	8.7
Shale.				
	8	5		

Location 153.

Shale, carbonaceous.				
Coal	1	2	16.2	12.4
Shale.				

Location 167.

Shale.				
Bone		7		
Coal, impure	3	8	17.2	6.3
Bone		1		
Sandstone		1		
Bone		1		
Coal		3		
Bone and shale		3		
Coal	2	2		
Shale		1		
Coal	1	0		
Bone		2		
Shale.				
	8	5		

Ash tests of coal from the Fruitland formation—Continued.

Location 224.

Section.	Ft.	in.	Ash (per cent).	Moisture (per cent).
Shale, carbonaceous.				
Coal, impure	2	7	21.5	5.5
Shale, carbonaceous	1	5		
Bone		5		
Shale.				
	4	5		

Location 231.

Shale, carbonaceous.				
Bone		3		
Coal, impure		3		
Sandstone		1		
Coal, impure	3	8	17.7	3.8
Bone		2		
Coal		11		
Shale.				
	5	4		

QUANTITY OF COAL IN THE FRUITLAND FORMATION.

By assuming that the average conditions at the outcrop of a coal-bearing formation persist in depth it is possible to estimate the amount of coal present. The value of the estimate of course depends on the amount and character of the information available. Where good contour maps of the field exist and the position, dip, and thickness of the coal beds and overlying strata are known, fairly accurate estimates may be made. Where less detailed information is at hand, more assumptions are necessary, and the result is of course less exact. The method used depends on the character of the coal beds, their attitude with reference to the surface, and the topography of the field.

In estimating the amount of coal in the Fruitland formation of San Juan County only the area under which the coal is not deeper than 1,000 feet was considered. This area was divided into a number of narrow strips running perpendicular to the outcrop, the total thickness of coal at the outcrop and the area were obtained for each strip, and on the assumption that an acre-foot contains 1,800 tons of coal the tonnage was calculated for each strip. The sum of these amounts gives the coal beneath 1,000 feet or less of cover as 16,288,000,000 tons and the total area underlain as 747 square miles.

It must be remembered, however, that these figures represent the total amount of coal and not necessarily the amount that may be mined. The recoverable amount is variable, depending upon mining practice and the care exercised in extracting the coal. As it is probable that the percentage of recovery will constantly tend to get

nearer and nearer 100, it is not thought wise to make an estimate on that basis.

Another estimate was made by taking an average of the total thickness of coal exposed at a number of places on the outcrop, the figure for each place being weighted by multiplying it by the sum of half the distances to the two adjacent places. The average thickness thus obtained (21 feet) was then multiplied by the total area underlain by the coal beds and the product reduced to tons. The resulting figure was 18,069,000,000 tons. This method does not take into account the relatively small size of the area underlain, within the depth limit, by the thick coal beds of the northern part of the field, and the estimate is therefore larger than that obtained by the first method.

The figures given above include all the coal beds observed. As some beds undoubtedly are not exposed and escaped observation, the estimate is not unwarrantedly high for the total coal content. Perhaps one-third of the coal represented in the estimates is in beds less than 14 inches thick and is therefore of small value under present economic conditions. Furthermore, no account was taken of partings, which in some parts of the field considerably reduce the value of the thicker beds. Locally the partings make up a third or more of the total thickness, but on the average they are very much less than that amount. If a tenth is allowed, however, for these partings the amount of usable coal at a depth of less than 1,000 feet is still nearly 10,000,000,000 tons.

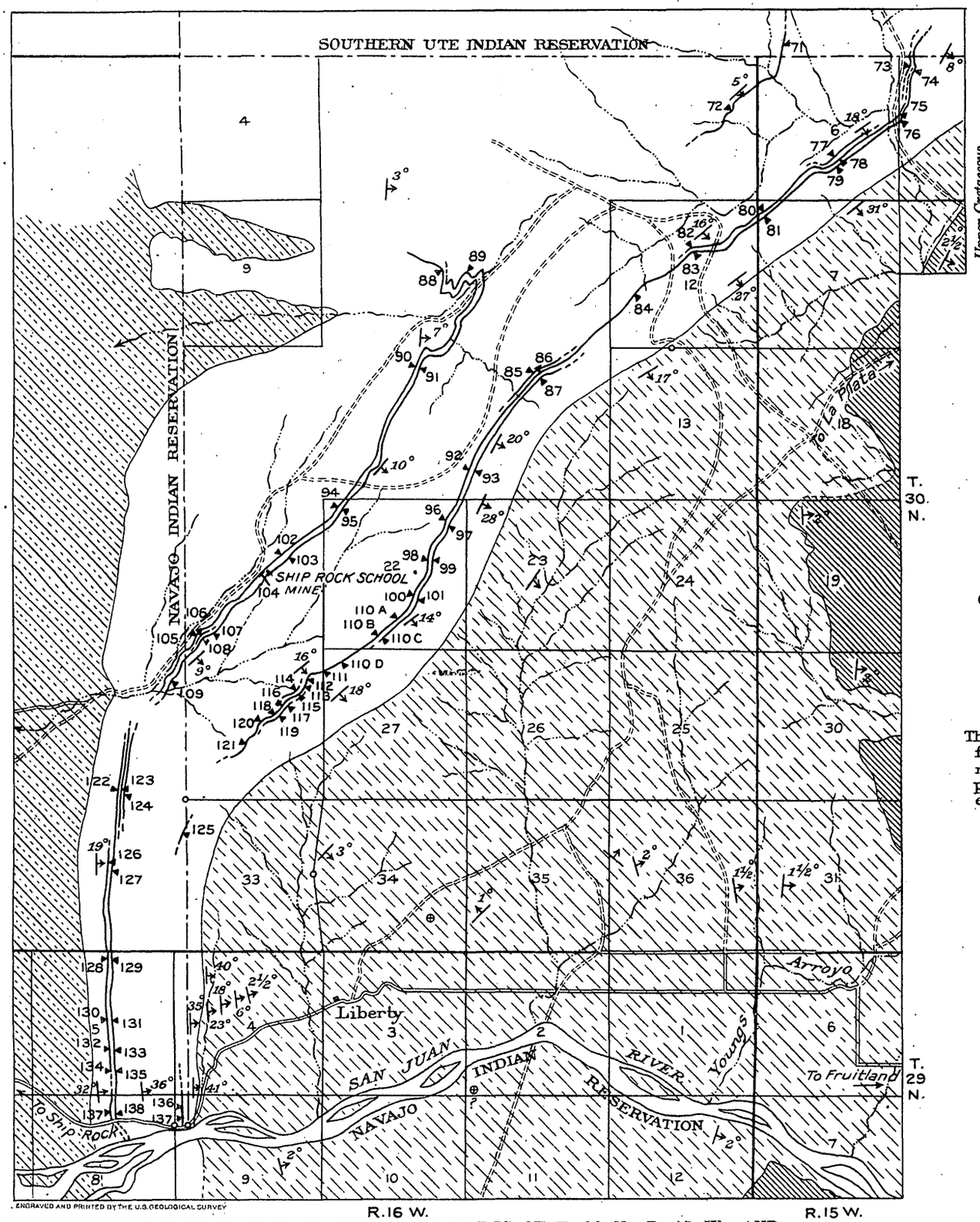
Sufficient data are not yet available concerning the area in which the coal lies deeper than 1,000 feet to estimate the quantity, but it is probable that between the depths of 1,000 and 2,000 feet at least as much coal is present as there is at a depth of less than 1,000 feet.

COAL IN THE MENEFEE FORMATION OF THE MESAVERDE GROUP.

The Mesaverde group was examined in detail only in T. 30 N., R. 16 W., and small adjoining tracts to the east and south. Its upper boundary is elsewhere the limit of the field studied. However, sections of coal beds were measured at several places south of San Juan River, samples of the coal were obtained for analysis (see table, p. 183), and where Chaco River cuts through the Great Hogback a section through the entire group was examined. These data are considered below.

COAL IN T. 30 N., R. 16 W., AND ADJACENT TRACTS.

The coal beds of the Menefee formation in T. 30 N., R. 16 W. (Pl. XXIII), are in two groups, one near the top and the other near the base. This grouping is well shown in the section on San Juan River. (See p. 163.) Individual beds in both groups are lenticclar, though



EXPLANATION

- Pictured Cliffs sandstone
- Lewis shale
- Mesaverde group *(Contains coal beds)*
- Mancos shale

Upper Cretaceous — CRETACEOUS

- Strike and dip
- Horizontal bed
- Outcrop of coal bed and location of measured section
- Land corner found

The top and base of the Menefee formation are not shown on the map but occupy the approximate position of the highest and lowest coal beds, respectively

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

MAP OF T. 30 N., R. 16 W., AND PARTS OF T. 30 N., R. 15 W., AND T. 29 N., RS. 15 AND 16 W., SAN JUAN COUNTY, NEW MEXICO

SHOWING OUTCROPS OF COAL BEDS IN THE MESAVERDE GROUP

0 1 2 3 Miles

some may be traced for several miles along the outcrop, and one was followed for nearly 6 miles. Some beds show in places a considerable thickness of clear coal, the maximum observed being 11 feet 6 inches, though as a whole partings are numerous and the value of the beds is thereby lessened.

The only mine in the township is that at location 104 (see Pl. XXIII), which supplies the Indian school and agency at Ship Rock. Production is limited to the needs of this institution. The coal bed mined here is 6 feet 2 inches thick and without partings.

The lower group of coal beds includes at most points two major beds, also some short lenses and locally a number of thin beds of small value.

Near the north side of T. 30 N., R. 16 W., and in R. 15 W. two sections were measured on a short but valuable lens of coal. At location 71 it is 3 feet 6 inches thick with a streak of coal above and another below it, and at location 72 it is 7 feet 8 inches thick. (See Pl. XXIV.) The bed thins out north and south of these locations.

In sec. 10 two beds crop out which may be traced southwestward into sec. 29. The lower of these beds is represented by sections at locations 88, 90, 94, 102, and 105. (See Pl. XXIV.) It has numerous partings and is not of high value. A short lens of small value 5 feet above the last-mentioned bed is represented by the section at location 106. The higher of the two beds, 20 to 25 feet above the lower, was examined at locations 89, 91, 95, 103, 104, 107, 108, and 109. The sections are shown on Plate XXIV. At location 89 this bed is split by 5 feet of shale into two thin beds, but the shale thins southward and disappears, and at locations 95, 103, and 104 there is over 6 feet of clear coal. Location 104 is the mine of the Ship Rock Indian Agency, from which two samples have been taken for analysis. (See table, p. 183.) Farther south, at locations 108 and 109, the bed pinches down to about 2 feet of coal and is overlain by a thin, valueless lens. Neither of these beds can be traced farther south, though they may be connected with those shown in the section at location 122.

Above the higher bed represented by the sections at locations 91 and 95 a number of thin beds of small lateral extent are present. These are described in the following stratigraphic sections but are not shown on the map:

Section of strata above the higher bed at location 91.

	Ft.	In.
Sandstone	15	
Shale, carbonaceous	10	
Coal		4
Shale, carbonaceous	3	6
Coal	3	6

	Ft.	in.
Shale, carbonaceous	14	
Coal	3	8
Shale, carbonaceous	4	
Coal		5
Bone		6
Coal		4
Shale, carbonaceous	1	6
Coal	1	8
Shale, carbonaceous	10	
Sandstone	8	
Shale, carbonaceous	6	
Coal bed of section 91, Plate XXIV.		
Total section	82	5
Total coal	9	11

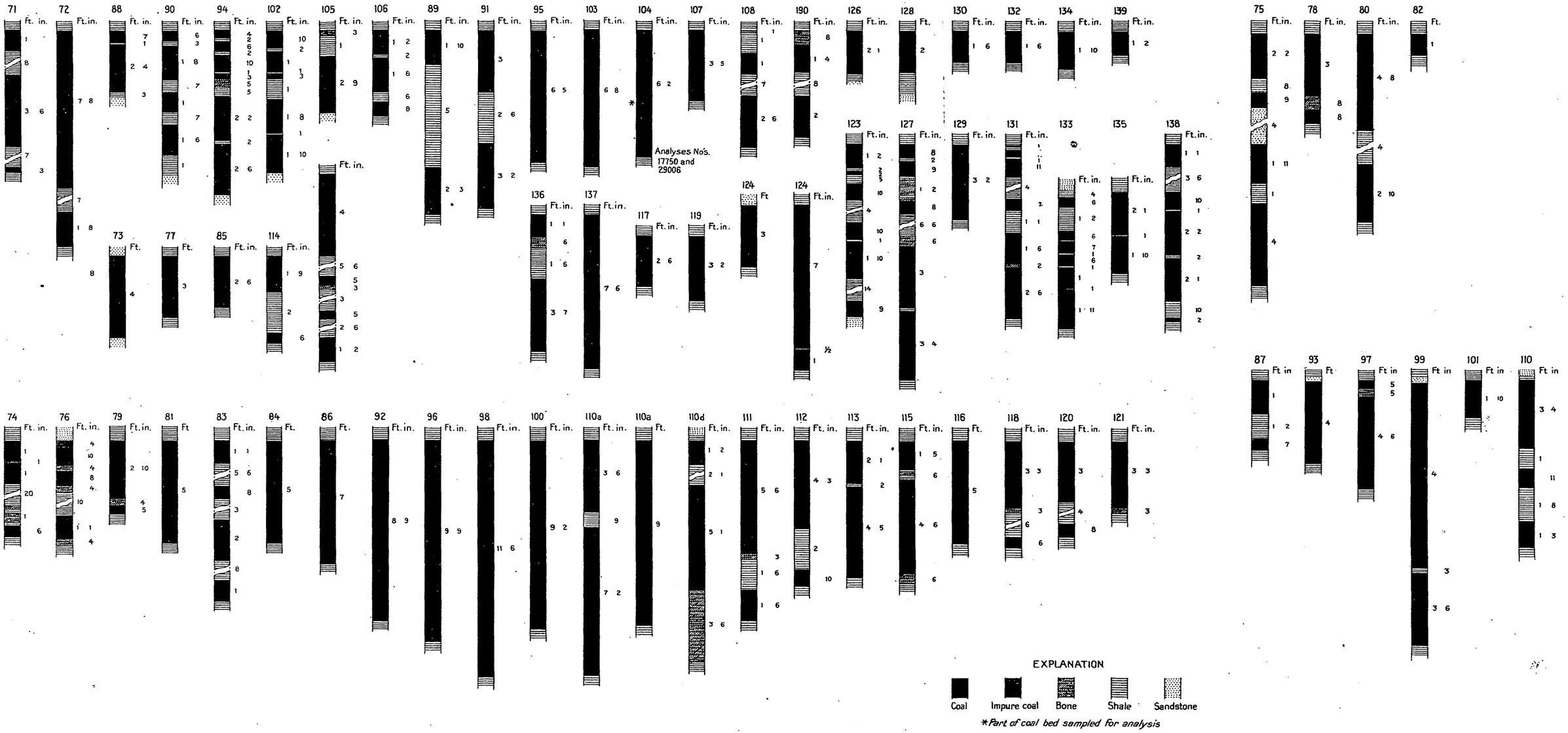
Section of strata above the higher bed at location 95.

	Ft.	in.
Sandstone and shale, yellow	15	
Shale, carbonaceous	4	
Coal		6
Shale, carbonaceous	1	
Coal	1	1
Shale and sandstone	10	
Coal	1	
Shale and sandstone	30	
Coal	1	3
Shale and sandstone	15	
Coal		6
Shale and sandstone	10	
Coal bed of section 95, Plate XXIV.		
Total section	89	4
Total coal	4	4

A coal bed crops out in sec. 29 which may be traced southward to San Juan River. It is shown in sections at locations 122, 127, 129, 131, 133, 135, and 138. (See Pl. XXIV). It is variable in thickness and purity, though locally, as at location 138, it reaches 5 feet in thickness and has few partings. At locations 122, 127, 131, and 138 it is overlain at a distance ranging from 4 to 6 feet by a thin bed of small value.

Beneath the bed represented by sections 122 and 138, and separated from it by 5 to 10 feet of shale, is a thin bed of coal which was examined at locations 128, 130, 132, 134, and 139. It is less than 2 feet thick in most of the sections. (See Pl. XXIV.)

In sec. 29 the coal bed of section 122 is overlain by two lenses. The main bed at location 123 is separated by 12 feet of shale and sandstone from the first bed above, which is 8 feet thick. (See Pl. XXIV). At 30 feet higher is the second lens, which is shown in the section at location 124 and is 3 feet thick at that point. These lenses can be traced laterally only a short distance.



SECTIONS OF COAL BEDS OF THE MENEFEE FORMATION IN T. 30 N., R. 16 W., SAN JUAN COUNTY, NEW MEXICO

—ENGRAVED AND PRINTED BY THE U.S.GEOLOGICAL SURVEY—

Above the higher bed of section 138 at the same locality several thin lenses are present, which are shown in the following section:

Section of strata above the higher bed at location 138.

	Ft.	in.
Shale.		
Coal	1	2
Shale and sandstone	246	
Coal		4
Shale, carbonaceous	1	2
Coal	1	
Shale and sandstone	10	
Coal	1	1
Shale	26	
Sandstone	12	
Shale	1	
Coal	1	
Shale	20	
Coal bed of section 138, Plate XXIV.		
Total section	320	9
Total coal	4	7

The upper group of coal beds contains one rather persistent bed overlain and underlain by lenses of varying extent. In sec. 32, T. 30 N., and sec. 4, T. 29 N., practically no workable coal was observed in the upper part of the Menefee formation, though the exposures are very good.

The persistent coal bed of the upper group is represented on Plate XXIV by sections made at locations 74, 76, 79, 81, 83, 84, 86, 92, 96, 98, 100, 110–A, 110–B, 110–D, 111, 112, 113, 115, 116, 118, 120, and 121. It is the thickest and most valuable coal bed of the township. At location 74 it is either absent or represented by a layer of coal 6 inches thick. At location 76 it is 1 foot 1 inch thick; at location 79, 2 feet 10 inches; at location 81, 5 feet; at location 83 it thins to 2 feet. From this point it increases toward location 98, where it is 11 feet 6 inches thick and free from partings. Southward from location 98 it decreases in thickness and value, and at location 121 it is 3 feet 3 inches thick. Beyond this point it vanishes.

In sec. 5, T. 30 N., R. 15 W., the persistent bed is underlain by a lens which at location 73 is 4 feet thick, its maximum. (See Pl. XXIV.) The intervening strata are 28 feet thick.

In sec. 6, T. 30 N., R. 15 W., the persistent bed is underlain by two lenticular beds, which were mapped, and several minor lenses. The lower bed, measured at location 77 (see Pl. XXIV), is of small extent and 3 feet thick at its maximum. Ten feet above it lies the second lens, examined at locations 75, 78, 80, and 82. This bed increases from 2 feet 2 inches in thickness at location 75 to 4 feet 8 inches at location 80 and decreases to 1 foot at location 82. At location 75, between the bed shown in section 77 and that in section

75, a lens about 200 feet long is 12 feet thick at the middle but thins out within 100 feet on each side of the point of maximum thickness, and there is also a thin bed not shown on the map. At location 80 a thin bed of small extent likewise underlies the bed shown in section 80. The sections of these lenses are given graphically on Plate XXIV. The upper lens mapped is from 20 to 30 feet beneath the persistent bed.

In sec. 14, T. 30 N., R. 16 W., the persistent bed is underlain by a short lens examined at location 85. It is 2 feet 6 inches thick at its maximum and lies 10 feet beneath the persistent bed.

In sec. 28 a short lens was mapped which is shown by the section at location 114. (See Pl. XXIV.)

Above the persistent bed two lenses were mapped. One is shown by the sections at locations 87, 93, 97, 99, 101, and 110–C. It reaches a maximum thickness of 9 feet at location 99 and thins in either direction from that point. It lies from 15 to 20 feet above the persistent bed. The second lens was examined at locations 117 and 119. It is a little over 3 feet in thickness at both points and is separated from the persistent bed by 20 to 30 feet of shale and sandstone.

At location 125 a section (see Pl. XXIV) was measured which contains a coal bed 4 feet thick, and in addition three beds too thin to be of value. None of them can be traced very far laterally.

At locations 136 and 137 occurs a lens which increases from 3 feet 7 inches to 7 feet 6 inches in thickness within a very short distance. It can not be traced southward because of alluvial cover, but, to judge by other very variable beds, it is probably not extensive. Twenty feet below this bed at location 137 the following section was measured:

Section of lenticular coal bed at location 137.

	Ft.	in.
Shale, carbonaceous, sandy.		
Bone	6	0
Shale, carbonaceous	2	6
Coal	1	0
Shale, carbonaceous	1	0
Coal	1	2
Shale, carbonaceous	4	
Coal		4
Shale, carbonaceous, sandy.		
Total section	16	0
Total coal	2	6

COAL SOUTH OF SAN JUAN RIVER.

A section of the Mesaverde group where Chaco River cuts through the Great Hogback is given on page 165. This section exhibits very little coal. Only three thin beds are exposed, at locations 145, 146,

and 147, in the zone covered by the lower group of beds. It seems possible that, owing to the abrupt folding of the strata, any coal beds present in the upper part of the Menefee formation have been squeezed out, though it is true that at some places north of the San Juan no coal can be found even where exposures are unusually good. The lowest coal bed at location 145 shows 2 feet of coal (moisture 11 per cent, ash 22 per cent). At location 146 there is 8 inches of coal, and at location 147 the coal bed is 10 inches thick. At all three of these locations the coal is overlain and underlain by shale.

Sections of coal beds and inclosing strata of the Menefee formation at other places are given below. They all fall within the zone of the upper group of beds.

Section of coal beds at location 179, 1½ miles southeast of mouth of Ojo Amarillo Arroyo.

	Ft.	in.
Sandstone, nearly white, easily weathered	45	
Sandstone, buff, fine grained	18	
Shale, light gray and yellow, sandy	18	
Sandstone, buff, massive	56	
Shale		2
Coal	3	5
Shale, brown, carbonaceous	2	2
Coal	3	4
Shale, blue-gray, with thin streaks of coal	26	
Coal	3	5
Shale, blue-gray, with streaks of coal	18	6
Coal	3	7
Shale	12	
Sandstone, massive.		
Total section	209	7
Total coal	13	9

Section of coal beds at location 235, 5 miles west of mouth of Cottonwood Arroyo.

	Ft.	in.
Sandstone, massive, light yellow, weathering pink	65	
Shale, gray, carbonaceous	15	
Shale, gray	12	
Coal	1	7
Bone		4
Shale, carbonaceous	2	3
Coal, weathered	3	8
Shale, carbonaceous	8	
Sandstone	4	
Shale	6	
Coal	2	8
Shale, gray	16	
Sandstone, hard, platy	4	6
Shale, carbonaceous	3	

	Ft.	in.
Sandstone, forming cliff	22	
Shale, carbonaceous	3	
Coal	1	
Shale, carbonaceous	2	
Sandstone, pink	14	
Shale, gray, sandy	10	
Shale, dark gray, containing several 3-inch beds of coal	5	6
Shale, black, carbonaceous	4	6
Coal		10
Shale, dark gray	61	
Coal		3
Shale, carbonaceous	2	
Coal		5
Shale, dark gray	18	
Coal		10
Shale	12	
Sandstone	15	
Shale, gray, with carbonaceous streaks	21	
Coal	1	5
Shale, carbonaceous	3	
Sandstone	3	
Shale, carbonaceous	4	
Coal	1	2
Shale, carbonaceous	35	
Sandstone	5	
Shale, dark, carbonaceous	87	
Shale and sandstone in alternating thin beds	195+	
Total section	661+	
Total coal	13	10

Section of coal bed at Tiznatzin mine, on Coal Creek 2 miles above mouth.

[Highest coal bed of Mesaverde group.]

Sandstone.	Ft.	in.
Coal	1	8
Bone		5
Coal, sampled	3	2
Shale.		
	5	3

(See analysis 3811, p. 183.)

Section of coal bed at location 548, at Blake's store.

Sandstone.	Ft.	in.
Coal, sampled	1	7
Shale, carbonaceous	1	1
Coal, sampled	1	5
Sandstone.		
	4	1

(See analysis 23003, p. 183.)

Section of strata at location 549, on Meyers Creek 1 mile above mouth.

	Ft.	in.
Cliff House sandstone	369	
Menefee formation:		
Shale, brown, carbonaceous	14	
Coal, impure	1	6
Shale, brown, carbonaceous	40	
Sandstone, brown	15	
Shale, carbonaceous	12+	
	451+	

Section of coal bed at Pueblo Bonito mine, 1 mile west of store at Pueblo Bonito.

[Highest coal bed of Mesaverde group.]

Sandstone.	Ft.	in.
Bone		2
Coal, sampled	2	8
Bone, sandy		6
Coal, sampled	1	7
Shale, carbonaceous	2	6
Coal, impure	2	4
Shale.		
	9	9

(See analysis 23004, p. 183.)

Another section of the bed represented by the last section, taken at a different point in the same mine, shows the following:

Section of coal bed at Pueblo Bonito mine.

Sandstone.	Ft.	in.
Bone	1	6
Coal, sampled	3	8
Bone		4
Coal, sampled	2	4
Shale.		
	7	10

COAL IN THE FRUITLAND FORMATION.

GENERAL FEATURES.

In the following description of the coal of the Fruitland formation the field will be treated arbitrarily as a number of districts suggested by the surface features or by the continuity of exposures of the beds themselves. These districts are not distinct divisions, and their boundaries are therefore in large part indefinable. They are selected simply for convenience in presenting details that could not be set forth so readily if the field were treated as a whole.

Certain general features of interest, however, may be noted concerning the coals of the Fruitland formation. The outcrop, as shown

on Plate XVI, is confined to a narrow belt running from the boundary between Colorado and New Mexico at first southwestward, then westward, then southward to San Juan River. From the San Juan it runs parallel to Chaco River as far as the south boundary of San Juan County. The beds dip southeastward in the northern part of the field, eastward in the central part, and northeastward in the southern part to relatively slight depths beneath the overlying rocks. This surface distribution and attitude are, of course, to be expected, inasmuch as the field is part of a great structural basin. (See p. 161.) The Fruitland formation continues beyond the limits of this field and completes a great circuit, of which the part here described forms nearly the western half. The exposures are best in the arroyos. The thickest and most valuable beds of coal are in the northern part of the field, though there is considerable coal in the middle part. In the southern part the beds are thin and very lenticular and the coal is poor. (See Pl. XXII.)

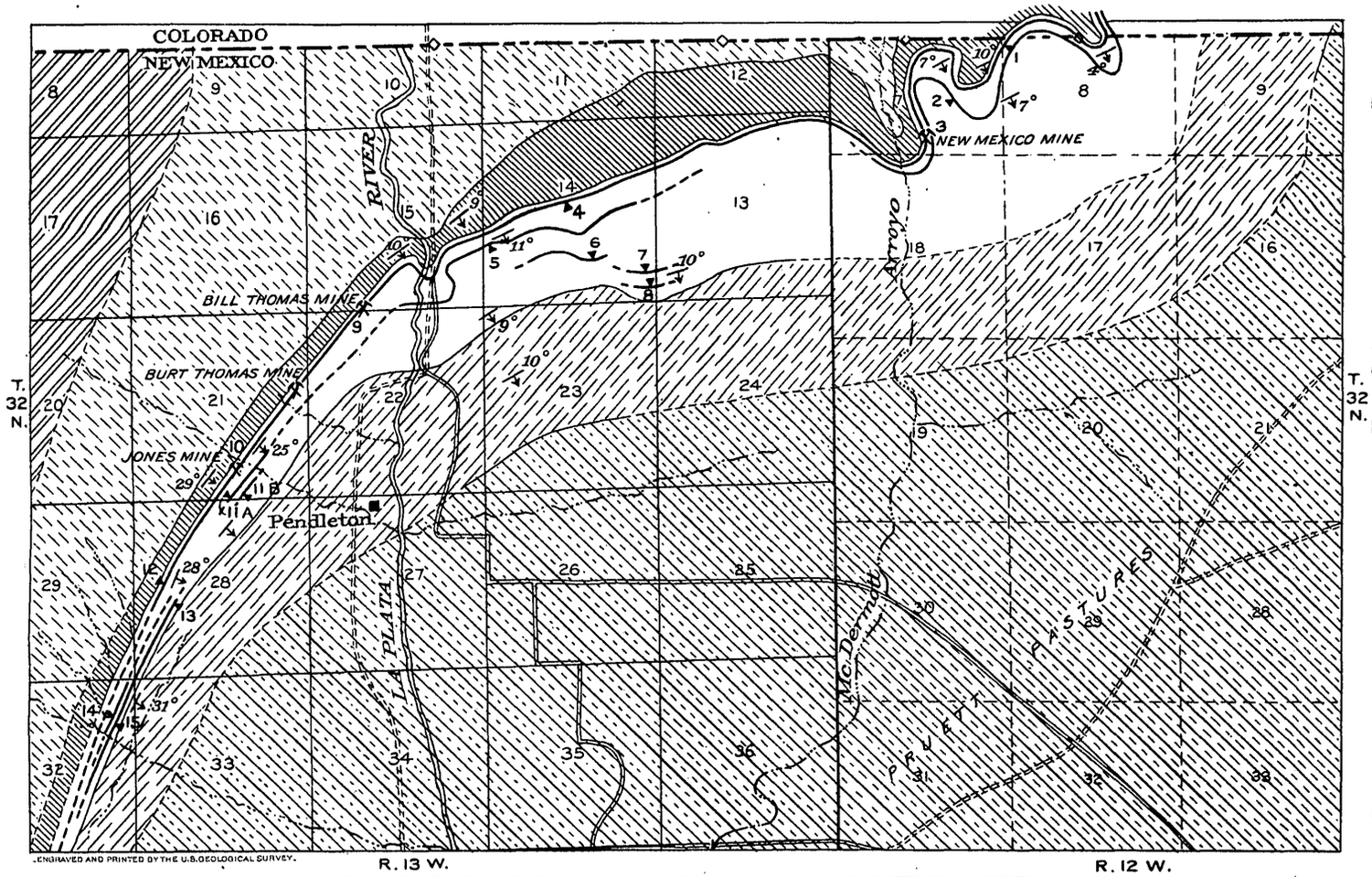
LA PLATA VALLEY.

The coal in the La Plata Valley district, which extends from location 1 to location 15 (see Pl. XXV), occurs in two main beds with a number of minor lenses. At location 1 a lens of coal 2 feet thick rests directly upon the Pictured Cliffs sandstone. It was not noted elsewhere in the district. From 6 to 30 feet above this horizon lies the bed which was examined at locations 1, 3, 4, 9, 10, and 12. It is from 23 to 38 feet in total thickness, being thus the largest observed in the whole field, and has been correlated with the Carbonero[17] bed, formerly mined at Carbon Junction, near Durango, Colo. Whether this correlation is valid or not, the bed is certainly thick and valuable in the district just north of the State boundary line. Its character is shown in the sections on Plate XXVI. Parts of it are being mined at five places in this district, from three of which samples have been obtained for analysis. (See p. 184.) The product from the bed is used entirely for local consumption.

From 100 to 125 feet above the Carbonero bed lies another bed which was measured at location 2. It is extensively developed to the north, in Colorado. In this district it is much split by partings and can not be traced very far. The section is given graphically on Plate XXVI.

Farther south a lenticular bed about 180 feet above the Carbonero bed can be traced for some distance, but it is of small value except at location 5 because of partings. The section is given on Plate XXVI. At location 11–A it shows the following section:

[17] Shaler, M. K., A reconnaissance survey of the western part of the Durango-Gallup coal field of Colorado and New Mexico: U. S. Geol. Survey Bull. 316, pp. 392–398, 1906.



MAP OF DISTRICT NEAR LA PLATA RIVER, SAN JUAN COUNTY, NEW MEXICO

0 1 2 3 Miles

EXPLANATION

TERTIARY

Eocene

Eocene formations and Ojo Alamo sandstone (Upper Cretaceous)

CRETACEOUS

Upper Cretaceous

Kirtland shale

Fruitland formation *(Contains coal beds)*

Pictured Cliffs sandstone

Lewis shale

Mesaverde group

Strike and dip

Outcrop of coal bed and location of measured section

Section of coal bed at location 11–A.

	Ft.	in.
Shale.		
Coal		2
Shale, carbonaceous		4
Coal	1	5
Shale, carbonaceous		6
Coal		3
Shale, carbonaceous		1
Coal		5
Shale		1
Coal		1
Shale.		
Total section	3	4
Total coal	2	4

Beneath the bed examined at location 5 there are several unmapped lenses of coal whose value is small because of thinness or partings. The character of these beds is indicated in the following section:

Section of coal beds beneath that examined at location 5.

	Ft.	in.
Sandstone	10	
Shale	2	
Coal bed of location 5 (see Pl. XXVI)	5	7
Shale	40	
Sandstone	2	
Shale	40	
Coal and bone	1	6
Shale	2	6
Coal	1	3
Shale	5	
Coal	1	
Shale		9
Coal		9
Shale		1
Coal		3
Shale		1
Coal		2
Shale		½
Bone		1
Shale		6
Coal		4
Bone		3
Coal		5
Shale		9
Bone		2
Coal		3
Shale	15	
Coal	2	
Shale	5	
Total section	137	8½
Total coal	12	8

At location 11–B a thick coal bed is exposed, but it is of short lateral extent and much cut up by partings. The section is shown on Plate XXVI.

Between the coal bed of location 11–A and that of location 11–B several lenses are present, which are shown in the following section:

Section of coal beds between locations 11–A and 11–B.

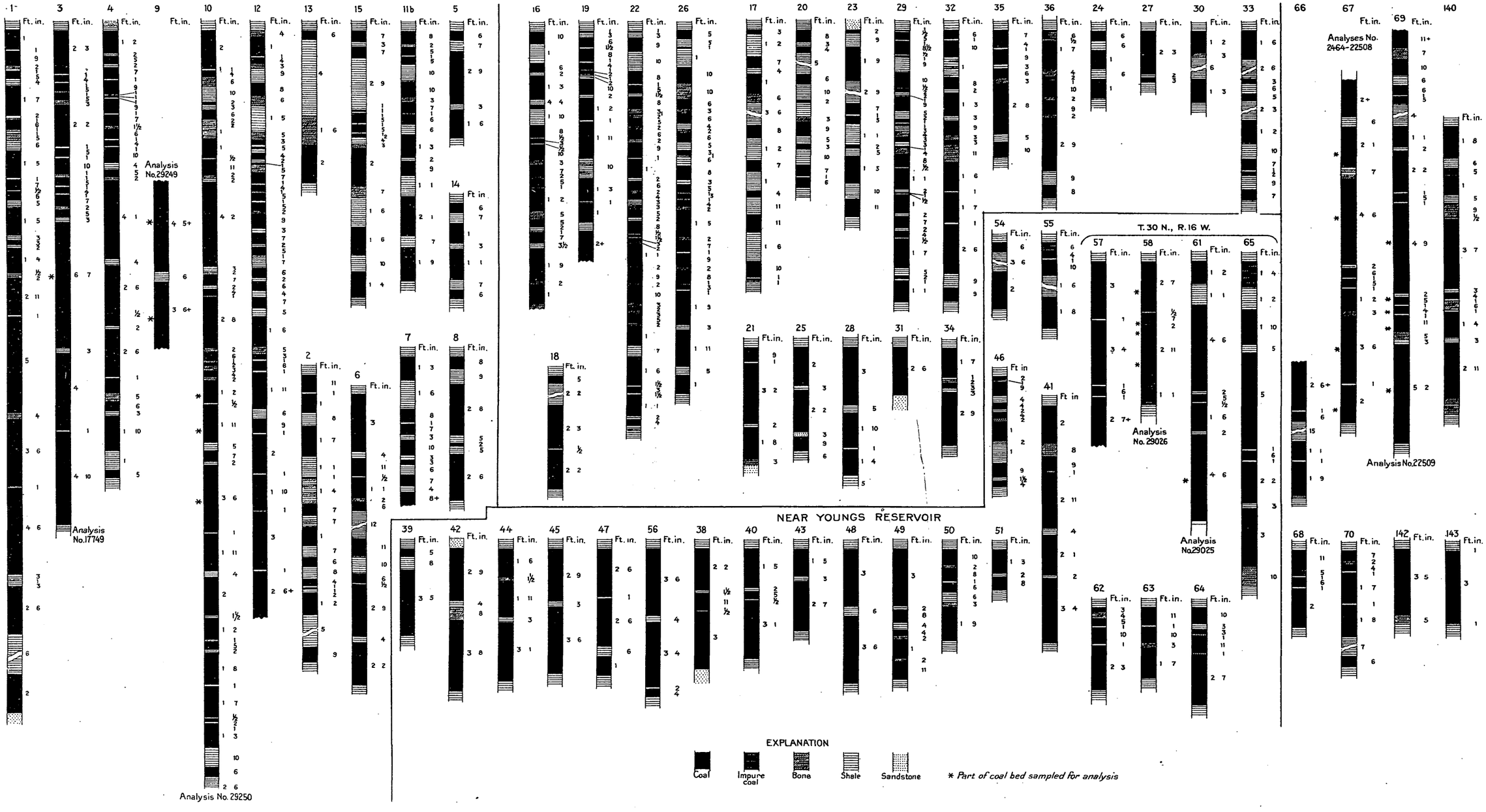
	Ft.	in.
Shale.		
Coal bed of location 11–B (see Pl. XXVI).		
Shale, carbonaceous	4	
Sandstone		10
Shale, carbonaceous	40	
Coal		10
Shale		9
Coal	1	9
Coal, impure	1	
Shale, carbonaceous	4	
Coal		9
Bone and shale		8
Coal		5
Shale		4
Bone and bony coal		8
Shale		3
Bone		6
Shale, carbonaceous	37	
Sandstone	5	
Shale	5	
Coal bed of location 11–A (see p. 201).		
Total section	103	9
Total coal	4	9

At locality 6 two lenses are present close together at about the middle of the Fruitland formation. At locations 7 and 8 two lenses in the upper part of the Fruitland formation about 100 feet apart are shown. None of these lenses are extensive enough to be of great value. The sections are all shown on Plate XXVI.

A short lens is represented by the section obtained at location 14. (See Pl. XXVI.) At 12 feet above this lens is another one, unmapped. Its character is shown by the following section:

Section of coal lens between locations 14 and 15.

	Ft.	in.
Shale, carbonaceous.		
Bone		1
Shale		3
Coal		6
Shale		5
Coal		9
Shale	1	



SECTIONS OF COAL BEDS OF THE FRUITLAND FORMATION IN NORTHERN SAN JUAN COUNTY, NEW MEXICO

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

	Ft.	in.
Shale, carbonaceous—Continued.		
Coal		10
Coal, bony		2
Coal		7
Shale.		
Total section	4	7
Total coal	2	10

At locations 13 and 15 a lens was examined which has but small value because of numerous partings. The sections are shown on Plate XXVI. It lies about 70 feet above the bed shown at location 14 and may be the same as the bed at location 11–B.

LA PLATA-SAN JUAN DIVIDE.

Along the La Plata-San Juan divide, from location 16 to location 37 (see Pl. XXVII), the lowest coal-bearing bed rests immediately upon the Pictured Cliffs sandstone. Higher up in the Fruitland formation there are three other fairly persistent beds and some minor lenses. Between locations 36 and 37 an abnormal development of sandstone occurs and little coal can be found, though the exposures are favorable.

The basal bed was examined at locations 21, 25, 28, 31, 34, and 37. It is variable in thickness and character, as the sections on Plate XXVI show. At location 37 the bed is only 1 foot thick.

The Carbonero bed in this district can not be directly connected with that in the district to the north, but the covered interval is short, and there is little doubt as to their identity. The bed was examined at locations 16, 19, 22, and 26. It lies from 30 to 50 feet above the Pictured Cliffs sandstone, and though some of the sections are incomplete it evidently decreases in thickness southward. For some miles southwest of location 26 no sections of it were obtained. Near location 37, in the zone where it ought to be found, only a little bone and dark shale are present, and it very probably thins out between locations 26 and 37.

From 100 to 120 feet above the Carbonero bed a higher bed was measured at locations 17, 20, 23, 29, 32, 35, and 36. It is of considerable thickness but much cut up by partings and consequently of small value.

From 75 to 100 feet above the last-mentioned bed occurs another bed which was measured at locations 24, 27, 30, and 33. It is thin and split by partings.

At location 18, 85 feet above the bed of location 17, a lens is present which may represent the horizon of the bed at location 24. It contains 4 feet 5 inches of coal with one thin parting. The section is shown on Plate XXVI.

DISTRICT ADJACENT TO YOUNGS RESERVOIR.

The district adjacent to Youngs Reservoir extends from location 39 to location 56. (See Pl. XXVII.) Between location 37 and location 39 a stretch of perhaps half a mile yields little evidence of coal beds. However, the basal coal bed is present in the district, coal is found at the horizon of the Carbonero bed, and a number of isolated lenses occur.

The basal coal was examined at locations 38, 40, and 43. It ranges in thickness from 4 feet 3 inches to 6 feet 2 inches with some partings. The sections are shown on Plate XXVI.

The Carbonero bed in this district is about 30 feet above the basal bed. It was measured at locations 39, 42, 44, 45, 47, and 56. At location 53 its presence is shown by "smut." Relatively the bed is thin, but it is the best in the district, as is shown by the sections (Pl. XXVI).

At location 41 and also at location 46 there is a short lens of coal about 85 feet above the base of the Fruitland formation. The first is thick and of some value; the second is much split by partings. At location 48 a section of a lens 17 feet above the Carbonero bed was measured. It is 7 feet thick with one parting. (See Pl. XXVI.)

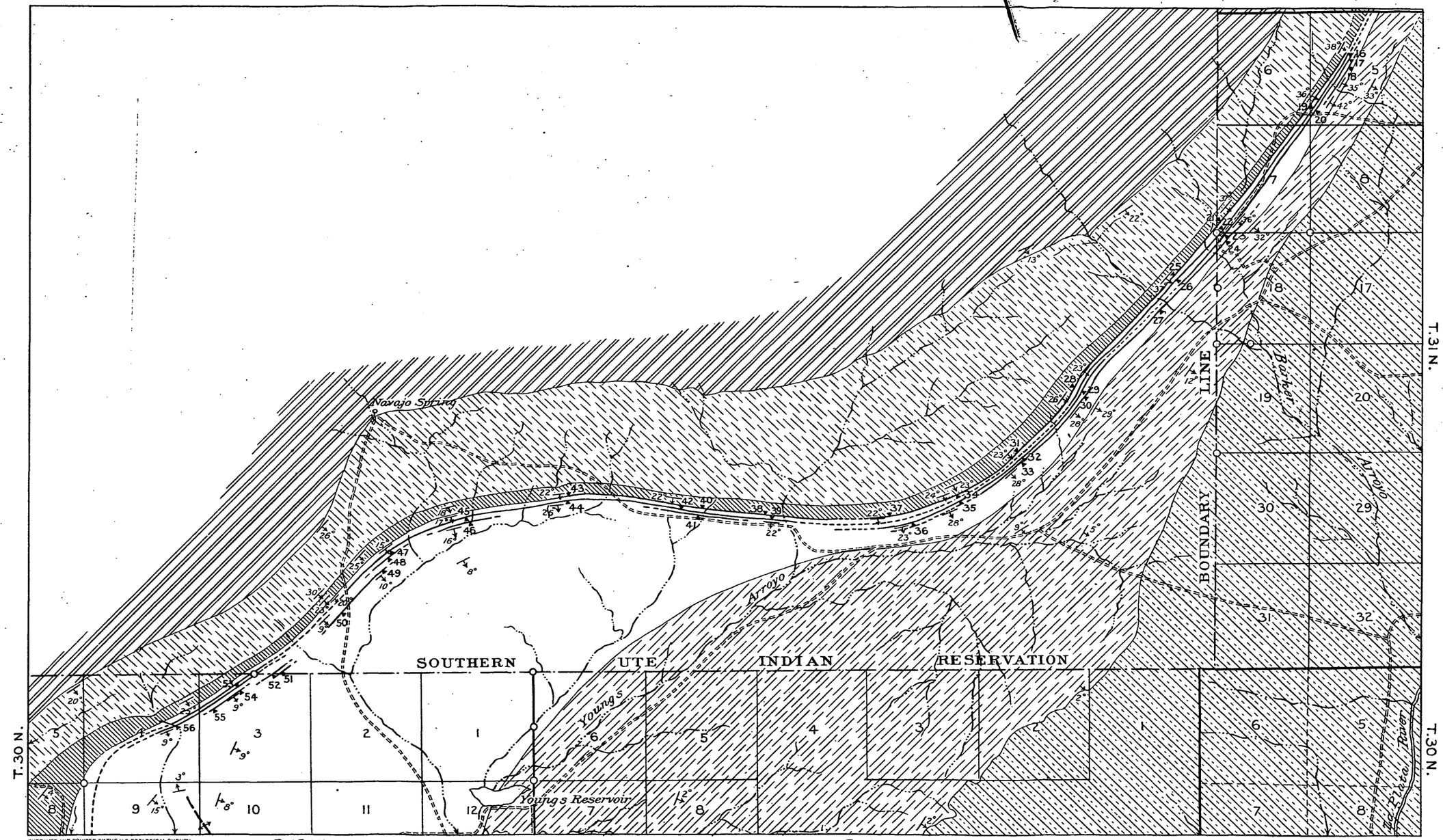
Sections were measured at locations 49 and 50 on a bed about 75 feet above the Carbonero bed. These sections are given on Plate XXVI. The bed is not of great value because of partings.

Sections at locations 51, 52, and 53 show small, thin lenses. The first is shown on Plate XXVI; the second has a little bone and 1 foot 1 inch of coal; the third, a little bone and 1 foot of coal.

Sections at locations 54 and 55 (Pl. XXVI) show the character of a short lens about 50 feet above the horizon of the Carbonero bed. It is of small value.

CENTRAL PART OF T. 30 N., R. 15 W.

The coal of the central part of T. 30 N., R. 15 W. (see Pl. XXVIII), is in two beds, the lower of which is at the horizon of the Carbonero bed, 20 to 30 feet above the base of the Fruitland formation. Sections were obtained of this bed at locations 57, 58, 61, and 65 and are shown on Plate XXVI. At location 59 a well sunk in prospecting for oil is reported to have passed through "15 feet of coal." At location 60 another well passed through "16 feet of coal." A prospect at location 58 shows the upper part of the bed and supplied a sample for analysis (No. 29026, p. 184). At locality 61 a mine known locally as the Marcelius mine, not now in operation, supplied a sample for analysis from the lower part of the bed (No. 29025, p. 184). A mine was opened some years ago at location 65, but the workings were not extensive, and it is now abandoned and badly caved in.



EXPLANATION

Eocene formations and Ojo Alamo sandstone (Upper Cretaceous)

Kirtland shale

Fruitland formation (*Contains coal beds*)

Pictured Cliffs sandstone

Lewis shale

Mesaverde group

Strike and dip

Anticlinal axis

Outcrop of coal bed and location of measured section

Land corner found

Eocene — TERTIARY

Upper Cretaceous — CRETACEOUS

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY.

MAP OF DISTRICT BETWEEN BARKER ARROYO AND YOUNGS RESERVOIR, SAN JUAN COUNTY, NEW MEXICO

0 1 2 3 Miles

Another bed 50 feet above the Carbonero bed was examined at locations 62, 63, and 64. The sections are shown on Plate XXVI. It is of small value.

At location 58 a lens 2 feet 6 inches thick occurs 8 feet above the Carbonero bed. It could not be traced far laterally.

SAN JUAN RIVER.

The district near San Juan River (see Pl. XXVIII) produces a large share of the coal mined in the field, though the developments are not extensive and the product is all consumed locally. Two mines are in operation north of the river, both of which were sampled for analysis (Nos. 2464, 22508, and 22509, p. 184). An open pit on the south bank of the river opposite Fruitland furnishes the Navajo Indians with fuel. The two beds found in the district to the north are present here.

The lower bed was examined at locations 66, 67, 69, 140, and 144 (Pl. XXVI). At location 67, at the Black Diamond mine, northwest of Fruitland, the bed is over 15 feet thick and contains a number of partings. At location 69, at the Hendrickson mine, the bed is 16 feet thick, contains partings, and is overlain by another bed, 4 feet higher in the section, which is so split by partings as to have little value. At location 140, the open pit south of the river (see Pl. XX, *A*), the bed is much poorer in quality and more cut up by partings. No further exposures of this zone are met until location 144 is reached, but here only a small amount of coal is to be found at the horizon of the Carbonero.

At locations 68, 70, 141, 142, and 143 a bed 30 to 50 feet above the Carbonero bed was examined. It is from 3 to 4 feet in thickness but at some points contains many partings. At location 141 the coal bed is partly burned and the best section obtainable is probably unreliable on that account.

Section of coal bed at location 141.

	Ft.	In.
Sandstone.		
Coal		6
Sandstone		1
Coal		6
Sandstone.		
	1	1

At location 66 a thin coal bed rests upon the Pictured Cliffs sandstone, and at location 140 the same horizon shows coaly material of no value.

South of this district a stretch of several miles is so deeply covered with wind-blown sand and river-terrace materials that exposures are rare, and though coal is probably present, it is not exposed and correlations of the beds are uncertain.

OJO AMARILLO ARROYO.

The coal in and near Ojo Amarillo Arroyo (see Pl. XXIX) occurs in six beds, none of which can be definitely correlated with the beds on San Juan River, though they lie largely in the lower part of the same formation. The lowest bed, about 15 feet above the Pictured Cliffs sandstone, was measured at location 155 as follows:

Section of coal bed at location 155.

	Ft.	in.
Shale.		
Shale containing gypsum	1	1
Shale		1
Bone		3
Shale.		
	1	5

This bed pinches out both to the north and to the south in a distance of several hundred yards. A similar lens appears at about the same horizon a mile farther south, at location 166, where 1 foot 9 inches of coal is exposed. Overlying it and separated from it by 34 feet of shale is a coal bed which was mapped for several miles and was measured at locations 149, 150, 152, 156, 161, 168, 172, and 175, in the vicinity of Ojo Amarillo Canyon. The bed is best developed south of the arroyo, where an upper bench averages about 4 feet thick. North of the arroyo the bed is split by numerous partings, as shown by sections 149 and 150. The measurements of this bed are shown graphically on Plate XXX.

The next higher bed of coal in the section is represented by measurements at locations 148, 151, 153, and 162. At location 148, about 2 miles north of the arroyo, it shows the following section:

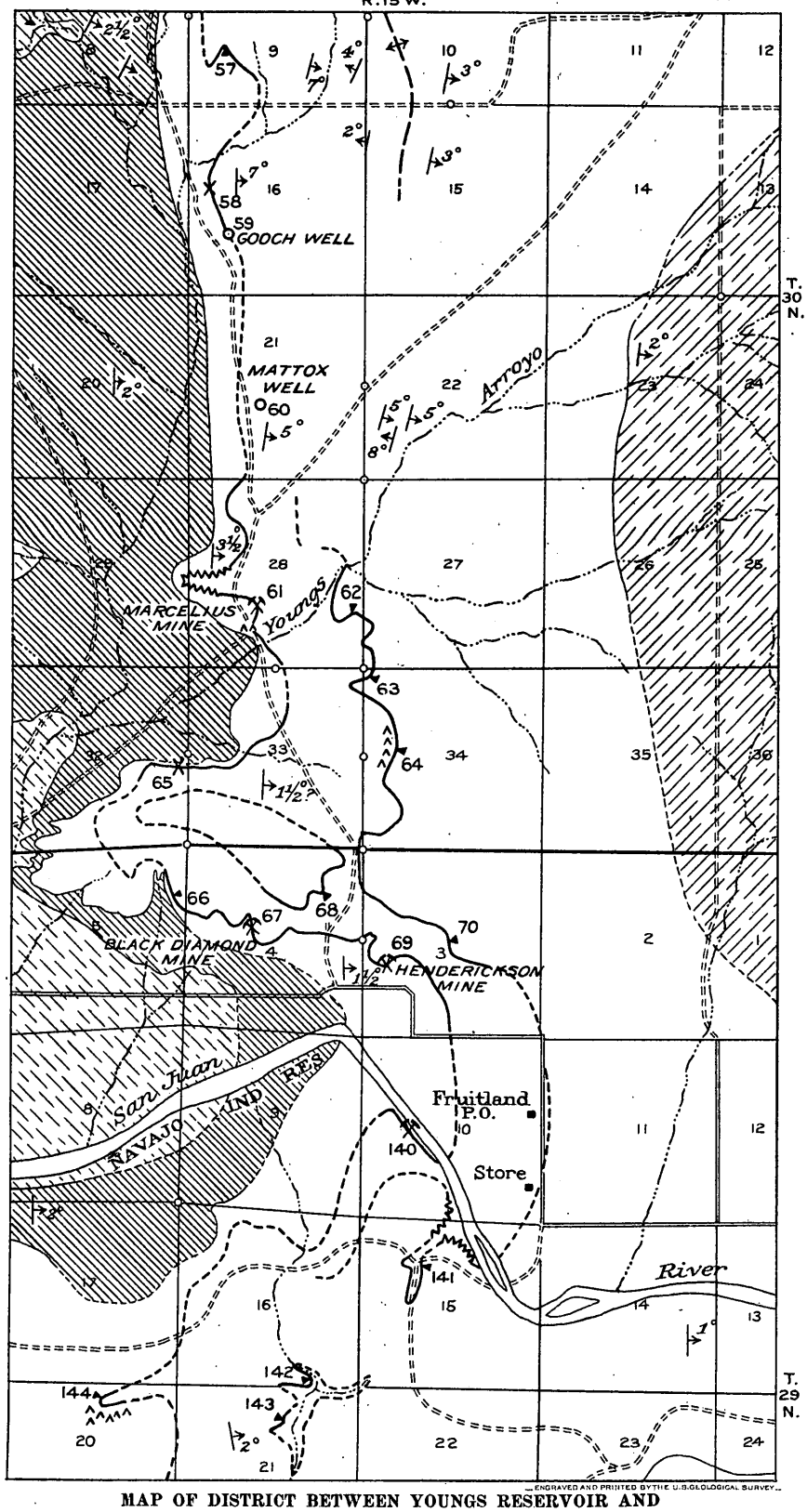
Section of coal bed at location 148.

	Ft.	in.
Shale.		
Coal	1	9
Bone		4
Shale.		
	2	1

The bed thins southward to 11 inches at location 149 and to 14 inches at location 153, on the north side of the arroyo. A field test here shows that the coal is impure, containing 16.2 per cent of ash. South of the arroyo, at location 162, the bed is 13 inches thick, and farther south it thins out and disappears.

Separated from the bed just mentioned by 10 to 20 feet of sandstone and sandy shale is another bed, whose average thickness is less than 3 feet and which was measured at locations 154, 163, and 170. The sections are shown on Plate XXX, except section 163, which contains only 1 foot 6 inches of coal.

South of the arroyo two higher beds which are not present on the north side were examined and measured. One of these was meas-



EXPLANATION

Upper Cretaceous — CRETACEOUS

- Kirtland shale
- Fruitland formation (*Contains coal beds*)
- Pictured Cliffs sandstone
- Lewis shale
- Strike and dip
- Anticlinal axis
- Outcrop of coal bed and location of measured section
- Burned coal bed
- Clinker-covered hills
- Land corner found
- Well

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

MAP OF DISTRICT BETWEEN YOUNGS RESERVOIR AND SAN JUAN RIVER, SAN JUAN COUNTY, NEW MEXICO

0 1 2 Miles

ured at locations 159, 164, 167, 169, 171, 174, 176, and 178. The bed is variable in thickness and is split by many partings. It lies 30 feet above the bed of section 154, just mentioned. All the sections are given on Plate XXX except those at locations 159, 164, and 174, which are given below.

Section of coal bed at location 164.

	Ft.	in.
Shale, brown.		
Coal		3
Bone		3
Coal		3
Bone		7
Shale		½
Coal		10
Shale	1	
Sandstone	1	
Coal	1	1
Shale.		
Total section	5	3½
Total coal	2	5

Section of coal bed at location 159.

	Ft.	in.
Shale, carbonaceous.		
Coal		6
Shale, carbonaceous		5
Coal		10
Shale, carbonaceous.		
	1	9

Section of coal bed at location 174.

	Ft.	in.
Shale, carbonaceous.		
Bone	1	1
Coal, impure		6
Shale		2
Coal		11
Shale.		
	2	8

The highest bed of coal exposed in this locality is a lens whose thickness was obtained at locations 158, 160, 165. It lies about 30 feet above the bed last described. The fact that this is a lens is shown by the middle measurement being 3 feet 10 inches, the northern 2 feet 11 inches (see Pl. XXX), and the southern 1 foot 11 inches.

DIVIDE BETWEEN OJO AMARILLO AND COTTONWOOD ARROYOS.

On the divide between Ojo Amarillo and Cottonwood arroyos, from location 180 to location 206, inclusive (see Pl. XXIX), the coal beds crop out in the bluff facing Chaco River. Two beds are generally of sufficient thickness to be mapped across this district; other

beds are lenticular and are thick enough to warrant mapping only locally.

The lowest lenses mapped lie at the base of the Fruitland formation, and although they are not continuous they occur at the same horizon throughout this portion of the field. These lenses are represented by measurements obtained at locations 191, 194, and 201. At location 191 1 foot 8 inches of coal overlies 10 inches of bone, at location 194 there is 2 feet 2 inches of coal, and at location 201 there is 1 foot 6 inches. These lenses are overlain by 10 to 15 feet of light-yellow sandstone very much like the Pictured Cliffs sandstone below, but because of the presence of coal and the brackish-water fossils similar to those of the Fruitland formation at location 191 these rocks are included in the Fruitland. Above this sandstone is a lens of coal which is very irregular in thickness. At location 180 8 inches of coal overlies 6 inches of bone; at location 183 the same lens contains over 4 feet of good coal. (See Pl. XXX.) This lens is separated by a few feet of gray sandstone and shale from another coal bed which is represented by sections at locations 185, 188, 190, 192, 193, 195, 196, 198, 202, 203, and 206. These sections, except Nos. 196, 202, and 206, are shown on Plate XXX. The bed is very irregular in thickness and in some places is split by many partings. However, it averages over 3 feet of coal. Measurements at locations 196, 202, and 206 are given below:

Section of coal bed at location 196.

	Ft.	in.
Shale.		
Coal	1	5
Shale.		

Section of coal bed at location 202.

	Ft.	in.
Shale, carbonaceous.		
Coal, dirty	1	0
Shale		½
Coal		2
Shale.		
	1	2½

Section of coal bed at location 206.

	Ft.	in.
Shale, carbonaceous.		
Coal	1	10
Bone		3
Shale, carbonaceous.		
	2	1

From 16 to 18 feet higher is a bed of coal that is more regular and perhaps more persistent than any other bed in this part of the field. It was measured at locations 181, 182, 184, 187, 189, 197, 200, and probably also 204. The sections of this bed show an average thickness of 3½ to 4 feet of coal. They are all given on Plate XXX

R.17 W. R.16 W. R.15 W.

T. 29 N. T. 11 N. T. 10 N. T. 9 N. T. 8 N. T. 7 N.

MOUNTAIN HOGBACK CHACO RIVER Ojo Amarillo To Fruitland Arroyo Dip about 1° Dip about 0°30' To Farmington Cottonwood Arroyo Pina Vetta Chiquita Ojo Dip about 0°30' Brimhall Wash To Brimhall's store Medio Arroyo To Hunter's store

EXPLANATION

Upper Cretaceous — CRETACEOUS

- Kirtland shale
- Fruitland formation (*Contains coal beds*)
- Pictured Cliffs sandstone
- Lewis shale
- Mesaverde group
- Mancos shale
- Strike and dip
- Outcrop of coal bed and location of measured section
- Burned coal bed
- Clinker-covered hills

ENGRAVED AND PRINTED BY THE U.S.GEOLOGICAL SURVEY.

MAP OF CENTRAL PART OF SAN JUAN COUNTY COAL FIELD, NEW MEXICO

0 1 2 3 Miles

except No. 204, which shows only 1 foot of coal, and No. 181, which is given below.

Section of coal bed at location 181.

	Ft.	in.
Shale, carbonaceous.		
Coal, containing resin	1	2
Shale, carbonaceous	1	
Bone		6
Shale		2
Coal, containing resin		5
Shale, carbonaceous.		
Total section	3	3
Total coal	1	7

This bed is supposed to be the same as the bed at location 178, in the district immediately to the north.

Lenses of coal higher in the formation were measured at locations 186, 199, and 205, representing probably one horizon. Sections 186 and 205 are given on Plate XXX, and 199 is given below:

Section of coal bed at location 199.

	Ft.	in.
Shale, carbonaceous.		
Coal		5
Shale		1
Coal		11
Shale, carbonaceous.		
	1	5

COTTONWOOD ARROYO.

In the Cottonwood Arroyo district there are five coal beds that crop out more or less continuously. These were examined at locations 207 to 251, inclusive. (See Pl. XXIX.) The lowest is at the base of the Fruitland formation and rests directly on the Pictured Cliffs sandstone. Sections of it were measured at locations 209, 212, 216, 224, 225, 234, and 236. With the exception of Nos. 212, 225, and 234, these sections are given graphically on Plate XXX. At location 212 an incomplete section shows more than 1 foot of bony coal; at location 225 the bed contains 1 foot of good coal; and at location 234 it shows 1 foot 3 inches of impure coal. The bed is thickest at location 236, where it consists of a lower bench 3 feet 2 inches thick and a higher one 1 foot 10 inches thick, separated by 3 feet of shale. Farther south these benches are more widely separated and are therefore considered as two distinct beds, though they are mapped as one, owing to the proximity of their outcrops.

Between 40 and 50 feet of cross-bedded gray-white sandstone and gray shale separate this coal bed from the one next above. This upper bed was measured at locations 215, 217, 223, 226, and 237. Sections at locations 217, 223, and 237 are shown on Plate XXX, and those at locations 215 and 226 are given on page 210.

Section of coal bed at location 215.

	Ft.	in.
Shale.		
Bone	1	
Shale	1	2
Coal, containing resin	1	2
Shale		3
Bone		4
Shale, carbonaceous.		
Total section	3	11
Total coal	1	2

Section of coal bed at location 226.

	Ft.	in.
Shale, carbonaceous.		
Coal		9
Shale, carbonaceous		3
Sandstone, gray	3	
Shale, carbonaceous	1	1
Coal		8
Bone		6
Shale, carbonaceous.		
Total section	6	3
Total coal	1	5

As can be seen from the sections on Plate XXX, the bed averages over 3 feet in thickness near Cottonwood Arroyo but is split by partings at the north and south sides of this district.

Between the bed described above and the next bed of importance higher in the section there is about 15 feet of sandy shale. Near the top of this shale a thin lens of coal crops out for a short distance north of Cottonwood Arroyo, with the thickness and character shown in the following section:

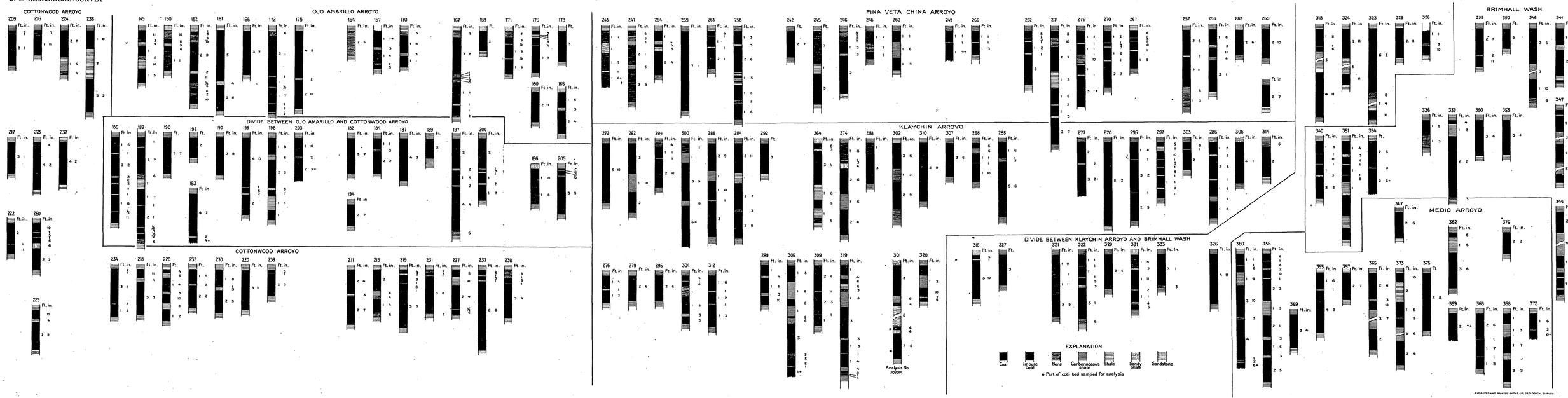
Section of coal bed at location 208.

	Ft.	in.
Shale.		
Coal	1	2
Sandstone		1
Coal		3
Bone		4
Coal		9
Shale, carbonaceous.		
Total section	2	7
Total coal	2	2

Section of coal bed at location 210.

	Ft.	in.
Shale, carbonaceous.		
Coal	1	3
Shale.		

A few feet above this lens lies a bed which has an extensive distribution in this district and the districts to the south. Sections of it obtained at locations 211, 213, 219, 227, 231, 233, and 238 are shown



SECTIONS OF COAL BEDS OF THE FRUITLAND FORMATION IN CENTRAL SAN JUAN COUNTY, NEW MEXICO

ENGRAVED AND PRINTED BY THE U.S.GEOLOGICAL SURVEY

on Plate XXX; at location 207 it contains only 1 foot 10 inches of coal. It averages 3½ feet in thickness, and it is exceptionally pure at location 233, where it contains over 6½ feet of clean coal.

Another bed of coal which also averages about 3½ feet in thickness lies 30 feet higher in the section. Measurements of it were obtained at locations 214, 218, 220, 228, 230, 232, and 239. These are shown graphically on Plate XXX.

About 70 feet higher lies the highest coal bed of importance in this district. Sections of it at locations 221, 222, 250, and 251 show many partings. As a whole, the bed consists of very impure coal. With the exception of section 221, these measurements are given on Plate XXX.

Section of coal bed at location 221.

	Ft.	in.
Shale, carbonaceous.		
Bone		8
Shale, carbonaceous, with streaks of bone	1	6
Shale, gray		6
Bone	1	7
Shale		1
Bone		3
Shale		1
Bone		3
Shale, sandy		1
Coal		8
Shale		2
Coal, containing resin		8
Shale, carbonaceous		3
Coal	1	2
Shale		½
Coal		8
Shale.		
Total section	8	7½
Total coal	3	2

A lens with a lateral extent of only a few hundred yards occurs midway between this bed and the next one beneath at location 229, where its maximum observed thickness is about 3½ feet. (See Pl. XXX.)

PINA VETA CHINA ARROYO.

Five coal beds exposed at the mouth of Pina Veta China Arroyo are correlated directly with the five beds in the district immediately to the north, and a new bed is present. These beds were examined at locations 240 to 283, inclusive. (See Pl. XXIX.) The lowest bed in Cottonwood Arroyo, as mentioned above, is here a group of two beds and several benches separated by 3 to 15 feet of sandy shale. The two principal beds of the group are thin and irregular, and the coal varies in quality and is commonly high in ash. Measure-

ments of the group obtained at locations 240 and 244 are given below.

Section of coal bed at location 240.

	Ft.	in.
Shale, carbonaceous.		
Coal, much weathered	1	0
Shale, carbonaceous	3	4
Coal	1	1
Shale, carbonaceous.		
Total section	5	5
Total coal	2	1

Section of coal bed at location 244.

	Ft.	in.
Shale, carbonaceous.		
Coal, impure	1	4
Shale, carbonaceous	1	8
Coal	1	3
Shale, carbonaceous	5	5
Coal, impure	1	3
Bone		10
Total section	11	9
Total coal	3	10

Only one bench of coal 1 foot 6 inches thick was observed at location 252, and one 1 foot 8 inches thick at location 253.

The next coal bed, 35 feet higher in the section, was measured at locations 241, 243, 247, 254, 258, 259, and 263, as shown on Plate XXX. In these sections it averages about 4 feet in thickness, but at location 241, as shown below, it has one bench over 4 feet thick and two other benches which are separated by thick partings.

Section of coal bed at location 241.

	Ft.	in.
Shale, carbonaceous.		
Coal	4	10
Shale	1	3
Bone		6
Coal	1	6
Shale	1	8
Bone		2
Coal, impure	1	2
Shale.		
Total section	11	1
Total coal	7	6

This bed contains a large quantity of coal, its maximum thickness (at location 259) being 7 feet 10 inches.

About 15 feet above the coal bed just described is the bed which is thought to be the same as the one measured at location 238, in the district to the north. Measurements of this bed were obtained at

locations 242, 245, 246, 248, 255, and 260 and are shown graphically on Plate XXX. The bed is very irregular, its minimum observed thickness, at location 248, being 2 feet 9 inches, of which 10 inches is bone and shale, and its maximum observed thickness, at location 245, being 6 feet 2 inches of coal. However, the upper bench at location 245 contains a high percentage of ash.

The next higher coal bed in the section is the same as the one measured at location 239, in the district immediately to the north. Measurements of it were obtained at locations 249, 261, and 266. This bed averages 2½ feet, but at location 261 it is split into two benches by a parting which is over 4 feet thick, as shown in the following section:

Section of coal beds at location 261.

	Ft.	in.
Shale.		
Coal		11
Sandstone		1
Shale, carbonaceous		5
Shale	3	9
Coal	1	3
Total section	6	5
Total coal	2	2

The other sections of this bed are shown on Plate XXX.

Near location 261 a bed of coal appears midway between the bed just described and the highest bed in the section. It was measured at locations 262, 271, 275, 267, and 270 and was found to contain many partings, as shown in the sections on Plate XXX.

The highest bed in this district is the same as that measured at location 251, in the district to the north. Measurements of it at locations 256, 257, 283, and 269 are given on Plate XXX; at location 268 it contains 2 feet 1 inch of good coal. This bed averages nearly 4 feet in thickness.

KLAYCHIN ARROYO.

Very good exposures of the Pictured Cliffs and Fruitland formations are to be found on Klaychin Arroyo between locations 264 and 314 (see Pl. XXIX), and the coal beds can be measured in considerable detail except where they have burned along their outcrops and are now covered with red baked shale or clinker. The following section extending from location 284 to location 287 gives the thickness and character of most of the coal beds, as well as the intervening sandstone and shale, and indicates the great amount of coal here present in the Fruitland formation:

Section on Klaychin Arroyo, compiled from sections 284, 285, 286, 287, 315, and 320.

	Ft.	in.
Sandstone, gray.		
Shale, brown	3	
Highest or seventh bed:		
Coal	1	
Shale, brown, carbonaceous	1	3
Coal		10
Sandstone, yellow		2
Coal		4
Shale, brown and gray	12	
Sandstone	8	
Shale, drab, sandy	7	
Shale, brown, carbonaceous	2	
Sixth bed:		
Coal	1	10
Shale, brown, carbonaceous	1	6
Coal		10
Sandstone, gray, carbonaceous		4
Coal, impure		3
Shale, brown, sandy	1	
Coal		3
Sandstone, brown, carbonaceous		6
Coal, with resin	2	7
Shale, carbonaceous		3
Coal	1	6
Shale, black, carbonaceous		1
Coal, with resin	1	6
Sandstone, gray, carbonaceous		4
Coal		6
Shale, brown	1	6
Sandstone, platy, brown		4
Shale, burned red and white	10	
Fifth bed:		
Ash (from burned coal bed)		6
Shale, banded brown and gray	5	
Sandstone, buff, platy, lenticular	1	
Shale, greenish gray, sandy	7	
Fourth bed:		
Coal	1	3
Shale, sandy		2
Coal	2	3
Shale, brown, carbonaceous		½
Coal	1	8
Shale, brown		5
Coal, containing resin	1	8
Shale, brown, sandy	7	
Shale, black, carbonaceous	1	6
Third bed:		
Coal	1	6
Bone		1
Shale, brown, very sandy		3
Coal, containing much resin	5	6

	Ft.	in.
Shale, brown, carbonaceous	2	
Sandstone, brown, platy	2	
Shale, brown, carbonaceous	1	
Second bed:		
Coal	1	3
Shale, brown	2	6
Lowest bed:		
Coal	2	11
Shale, brown	1	
Coal	2	7
Bone		3
Coal	2	8
Shale, brown, carbonaceous	2	
Pictured Cliffs sandstone.		
Total thickness	121	4
Total coal	34	8

The lowest bed of coal is the same as the lowest one in Pina Veta China Arroyo. It measured at locations 272, 273, 278, 282, 284, 292, 293, 294, and 300. The sections at locations 273, 278, and 293 are given below; others are shown on Plate XXX. Its variability in thickness and character is marked.

Section of coal bed at location 273.

Shale.	Ft.	in.
Coal	1	9
Shale.		

Section of coal bed at location 278.

Shale.	Ft.	in.
Coal	2	4
Shale	1	6
Coal	2	8
Shale	3	4
Coal	1	10
Shale.		
Total section	11	8
Total coal	6	10

Section of coal bed at location 293.

Shale.	Ft.	in.
Coal	1	9
Shale.		

The second bed, as shown in the section on this page, is 1 foot 3 inches thick and only 2½ feet above the lowest bed at location 284. Apparently it is a thin lens which extends only a short distance.

The third bed averages nearly 4 feet in thickness and is correlated with that measured at location 263, in the district immediately to the north. Measurements of it were obtained at locations 264, 274, 281, 285, 290, 291, 298, 307, 302, and 310. Except the sections at locations 290 and 291 these are given on Plate XXX. At location 290 all the

beds are burned and their outcrops are covered with baked shale and clinker, and at location 291 the bed contains only 1 foot 3 inches of coal. South of this point this bed is thin and does not warrant mapping.

The fourth coal bed is split by many partings, as shown particularly at location 297. It is represented by sections at locations 277, 280, 286, 296, 297, 303, 306, 311, 313, and 314. With the exception of those at locations 311 and 313, all are shown on Plate XXX. Although sections 311 and 313 are separated by less than a quarter of a mile they differ much and illustrate the great variability of some of the coal beds of the Fruitland formation. At location 311 the bed contains only 1 foot 9 inches of coal, but at location 313 it contains 5 feet 6 inches of coal of fair quality, though considerably weathered where measured. The other measurements show an average thickness of about 4 feet for this bed.

The fifth coal bed, which is 12 to 15 feet higher than the one last mentioned, was measured at locations 276, 279, 287, 295, 299, 304, 308, and 312. The sections not shown on Plate XXX are given below.

Section of coal bed at location 299.

	Ft.	in.
Shale, brown, sandy.		
Coal	1	9
Shale, carbonaceous.		

Section of coal bed at location 308.

	Ft.	in.
Shale.		
Coal, weathered	1	0
Shale.		

At location 287 the bed has been burned and is represented by a 6-inch bed of ash.

The next higher coal bed in the section was measured at locations 289, 305, 309, 315, and 319. It averages over 4 feet of coal. These sections are given on Plate XXX, except the one which follows.

Section of coal bed at location 315.

	Ft.	in.
Shale, carbonaceous.		
Coal, good	1	10
Shale, carbonaceous	1	6
Coal		10
Sandstone, gray		4
Coal, impure		3
Shale, sandy	1	
Coal		3
Sandstone		6
Coal; contains much resin	2	7
Shale, carbonaceous		3
Coal	1	6
Shale, black		1

Shale, carbonaceous—Continued.	Ft.	in.
Coal; contains resin	1	6
Sandstone, gray		4
Coal, good		6
Shale, carbonaceous.		
Total section	13	3
Total coal	9	2

The seventh or highest coal bed in the Fruitland formation in this locality is correlated with the highest coal bed in Pina Veta China Arroyo, which was measured at location 283. This bed is mined on a small scale by stripping at location 301, where it contains an upper bench 3 feet thick and a lower bench 2½ feet thick. Technically these two benches are distinct beds, for they are separated by about 7 feet of shale. However, they are worked together at this place and are parts of the same bed to the north and to the south. A sample was obtained from the lower bed at this location, and an analysis of it is given on page 185 (No. 22685). The bed is only about 2 feet thick at location 320, as shown in section on Plate XXX.

DIVIDE BETWEEN KLAYCHIN ARROYO AND BRIMHALL WASH.

On the divide between Klaychin Arroyo and Brimhall Wash the lower coal beds crop out in a low bluff extending in a nearly north-south direction. The higher beds, on the other hand, are concealed in the broad, low divide and can be seen only about low hills or in "blowouts" where the wind has removed the loose surface material. The district extends from location 316 to location 333. (See Pl. XXIX.)

The lowest coal bed is at nearly the same horizon as the lowest in the district immediately to the north. It is represented by a series of lenses and was measured at locations 316, 327, and 332. Between these three localities the bed is less than 1 foot thick. Sections at locations 316 and 327 are shown on Plate XXX, and that at location 332 is given here:

Section of coal bed at location 332.

Shale, sandy.	Ft.	in.
Coal	1	2
Shale, carbonaceous.		

The coal bed next higher in the section is the same as the one measured at location 314. Sections of it at locations 321, 322, 329, 331, and 333 are given on Plate XXX; at location 317 the bed is burned and shows 1 foot of ash. The average thickness of this coal bed in this district is nearly 4 feet.

The third bed of importance in this district is represented by sections at locations 318, 323, 324, 325, 328, and 330. In the north-

ern part of the district it is in reality two beds, the parts being separated by 5 feet of shale, but each bench is thick enough to be valuable. The sections are all given on Plate XXX, except that at location 330, which is given here.

Section of coal bed at location 330.

	Ft.	in.
Shale, carbonaceous.		
Coal, impure		10
Bone, sandy		1
Coal, impure		8
Shale, carbonaceous		1
Coal		4
Bone		4
Coal	1	4
Bone		2
Coal	1	3
Bone		2
Coal, impure		11
Shale, black		3
Coal, impure		7
Bone		4
Coal, impure		4
Shale, carbonaceous.		
Total section	7	8
Total coal	6	3

About 6 feet below this section is a lens containing 1 foot 6 inches of coal. Also, 15 feet higher than the bed just described, at location 326, a lens crops out which contains nearly 5 feet of coal, but it thins within a short distance to the north and south of this point.

Two coal beds which are present in the district to the north are believed to be present in this district also, but owing to the evenness of the surface of the divide they are not exposed. It is believed, however, that they crop out on Brimhall Wash, and they will be considered in the following description of that district.

BRIMHALL WASH.

The exposures in Brimhall Wash are not as good as those in Klaychin Arroyo, to the north, but the horizons of the coal beds can be followed between outcrops by the occasional clinker hills and by weathered coal thrown out from gopher holes.

Five coal beds were mapped in this part of the field, which extends from location 334 to location 344. (See Pl. XXIX.) The lowest bed in the section was measured at locations 334, 335, 337, 341, 342, 343, 346, 348, and 350. It contains on the average about 2½ feet of coal, and its thickest observed section is at location 346, where it contains 3½ feet of coal, as well as a lens 3 feet lower carrying 1 foot 10 inches of coal. Sections at locations 335, 341, 346, and 350 are shown on Plate XXX; the others are given on page 219.

Section of coal bed at location 334.

	Ft.	In.
Shale, carbonaceous.		
Bone and ash	1	3
Shale, carbonaceous.		

Section of coal bed at location 337.

	Ft.	In.
Shale, carbonaceous.		
Coal	1	6
Shale, carbonaceous.		

Section of coal beds at location 342.

	Ft.	In.
Shale.		
Coal		6
Bone		1
Coal		10
Bone		5
Shale, sandy	15	
Coal	1	
Clay		6
Coal	1	1
Shale	4	9
Coal		6
Bone	1	6
Shale	1	2
Coal	2	
Shale.		
Total section	29	4
Total coal	5	11

Section of coal beds at location 343.

	Ft.	In.
Shale, carbonaceous.		
Coal	1	4
Bone	1	5
Shale, carbonaceous	6	
Coal, good	1	1
Bone		4
Coal		4
Shale, carbonaceous.		
Total section	10	6
Total coal	2	9

Section of coal bed at location 348.

	Ft.	In.
Shale.		
Coal; contains resin	1	6
Shale.		

Above this bed and separated from it by about 18 feet of sandy shale is a coal bed which is correlated with that measured at location 330. Measurements of it in this district were obtained at locations 345, 347, and 349. The upper part of the section at location 342 (see above) may also represent this horizon, though the connection is not

traceable. This bed is thinner here than in the district to the north, and at location 347 it is associated with two lenses of coal, as shown on Plate XXX. At location 345 it contains 1 foot 6 inches of coal, and at location 349 there is 1 foot 8 inches of coal overlain by 5 inches of bone.

About 20 feet higher in the section is a coal bed represented by sections 340, 351, and 354, which are shown on Plate XXX. Its average thickness in this district is about 5½ feet.

The bed last mentioned is separated by about 10 feet of shale from the next higher one, which was measured at locations 336, 339, 352, and 353. This bed averages 3½ feet in thickness, as shown by the sections on Plate XXX.

The highest traceable coal bed on Brimhall Wash is represented only by section 344 (Pl. XXX), though a thin lens containing about 1 foot of coal mapped half a mile east of location 339 may be correlated with it. Its horizon at some points is marked by clinker.

A coal bed observed at location 338 has a thickness of 1 foot 2 inches but is of very small lateral extent. Its horizon is well up in the Fruitland formation, above the other coal beds.

MEDIO ARROYO.

In the Medio Arroyo district, extending from location 355 to location 375, the coal beds, instead of having the usual eastward dip, are affected by a local syncline and anticline. As shown on the map (Pl. XXIX), the dips are low, mainly less than 2°. Nevertheless the outcrop and attitude of the beds are modified by this structure. The syncline is oval and has a northeasterly axis about 5 miles in length and a shorter axis about 3½ miles long. Calculations from elevations on the eastern limb of the syncline give a westward dip of 80 feet to the mile. Other dips are shown on Plate XXIX.

The lowest coal bed in the section was measured at locations 355, 357, 365, 373, and 375. The bed is the same as the lowest coal on Brimhall Wash. At locations 365 and 373 a lower bench is separated from the upper by 3 feet 7 inches and 2 feet 6 inches respectively of shale, but at location 375 there is no shale parting. The sections are given graphically on Plate XXX.

The next higher bed of coal was measured at locations 364, 366, 370, and 374. These measurements are given below.

Section of coal bed at location 366.

	Ft.	In.
Shale, carbonaceous.		
Coal; contains resin	1	11
Shale.		

Section of coal bed at location 370.

	Ft.	in.
Shale, brown.		
Coal; contains resin	1	5
Shale, brown		10
Coal		8
Shale.		
	2	11

Section of coal bed at location 374.

	Ft.	in.
Shale, brown.		
Coal	1	11
Bone		3
Shale, drab.		
	2	2

Section of coal bed at location 364.

	Ft.	in.
Shale, carbonaceous.		
Coal	1	7
Shale		3
Coal		8
Shale.		
	2	6

An isolated coal outcrop occurs in a butte at location 356, and another around a butte at location 358. These outcrops are about 25 feet above the bed last described and are apparently at the same horizon, though the thickness is very different in the two localities. Section 356 is given on Plate XXX, and section 358 is given below:

Section of coal bed at location 358.

	Ft.	in.
Shale, carbonaceous.		
Coal; contains resin	1	11
Bone		6
Coal, impure		3
Shale.		
	2	8

A lens of coal probably a few feet above the horizon just described was measured at location 369, where it contains 3 feet 4 inches of impure coal.

The next coal bed lies 5 feet above this one and is represented by sections at locations 359, 363, 368, and 372. These are shown on Plate XXX. The bed averages about 3½ inches in thickness.

Another coal bed from 5 to 15 feet higher is represented by sections at locations 361, 367, and 371:

Section of coal bed at location 361.

	Ft.	in.
Shale.		
Coal	1	11
Shale.		

Section of coal bed at location 367.

	Ft.	in.
Shale.		
Coal	2	6
Shale, carbonaceous.		

Section of coal bed at location 371.

	Ft.	in.
Shale.		
Coal, dirty		6
Shale, carbonaceous	1	8
Coal	1	3
Shale.		
	3	5

The outcrops as well as the mass of the two beds just mentioned are close together at some points, and it is probable that the two beds could be worked at the same time in a number of places.

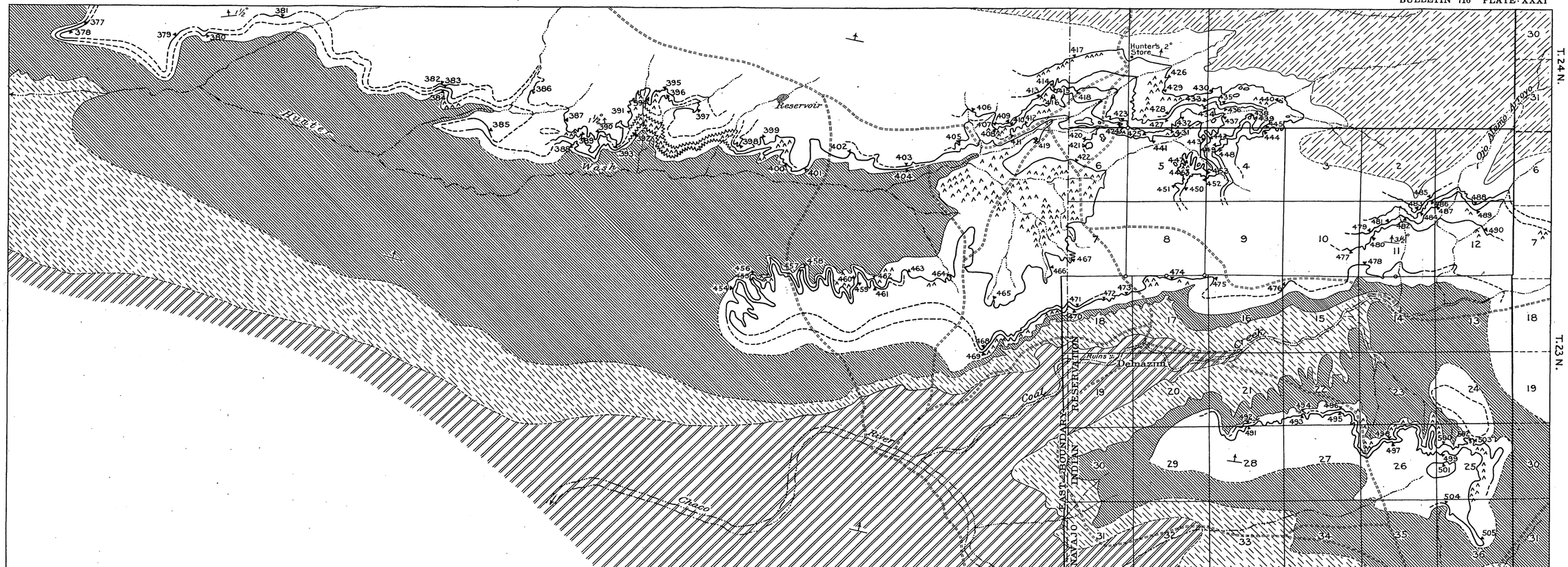
Another pair of coal beds occurs about 20 feet higher. The lower one of the two was measured at location 360, and the section is given on Plate XXX. The bed at this place shows over 7 feet of good coal but is a comparatively short lens and thins within short distances to the north and to the south. The higher bed was measured at location 362, where it contains 3 feet 6 inches of coal. From its outcrop it also is believed to be lenticular, though exposures of it to the south are not good. Measurements obtained at location 376, giving 1 foot 3 inches of coal separated by 6½ feet of shale from 2 feet 2 inches of coal below, may represent the two beds last described, though the correlation is not certain.

LOWER HUNTER WASH.

Along Hunter Wash from location 277 to location 404 (see Pl. XXXI) the coal crops out on the north side of the arroyo and strikes about S. 80° E. The dip is N. 10° E., about 1½° throughout the district. Two valuable coal beds were observed and mapped most of the distance of 12 miles. The correlations between outcrops were based largely on the stratigraphic position. Between these beds in several localities are one or two lenses which extend only for short distances along the outcrop.

The lowest coal bed has in this district an average thickness of about 5 feet. Measurements of it at locations 377, 380, 384, 385, 388, 400, 401, 402, and 404 are given on Plate XXXII; at location 392 the bed contains only 1 foot 10 inches of coal.

A higher bed, which is very persistent and has a distribution almost equal to that of the lowest bed, was measured at locations 378, 379, 381, 382, 386, 387, 390, 391, 394, 395, and possibly 403. Between locations 395 and 403 the connection can not be traced, but the horizon of the coal is the same at both places. The bed is regular in thickness compared with the other coal beds of the field, although its average is less than 3 feet. If the coal at location 403 is the same bed it is much thicker farther east and south. Sections at locations 378, 394, 395, and 403 are given below; the others are shown on Plate XXXII.



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MAP OF DISTRICT ON HUNTER WASH AND COAL CREEK, SAN JUAN COUNTY, NEW MEXICO

Section of coal bed at location 378.

	Ft.	In.
Shale, carbonaceous.		
Coal	1	10
Shale, carbonaceous.		

Section of coal bed at location 394.

	Ft.	In.
Shale.		
Coal	1	6
Shale.		

Section of coal bed at location 395.

	Ft.	In.
Shale.		
Coal	1	6
Shale, sandy.		

Section of coal bed at location 403.

	Ft.	In.
Shale, carbonaceous.		
Coal	2	4
Shale		1
Coal	1	9
Sandstone.		
	4	2

In the breaks south and southwest of the reservoir shown on Plate XXXI three coal lenses or beds, which have only a small length of outcrop, appear between the two beds just described. Sections of these lenses were obtained at locations 383, 389, 396, 397, 398, and 399. At location 383 1 foot 2 inches of coal was found, and at location 389 the same thickness was exposed. The other sections are given graphically on Plate XXXII.

UPPER HUNTER WASH.

The upper Hunter Wash district is continuous with that just described, but owing to the excellence of its exposures it is treated by itself. (See Pl. XXXI.) The district is a much dissected badland with very little vegetation and affords an excellent opportunity to examine the coal in considerable detail. It seems probable that the divide between Hunter Wash and Medio Creek contains beneath its flat sandy surface at least some of the higher beds which crop out in the Hunter Wash badlands and that these should be correlated with those high up on Medio Arroyo. Nevertheless, because of the lack of exposures on the gently sloping surface of the divide, due in part to the quantity of wind-blown sand on it, no correlation will be attempted. It is known, however, that several of the coal beds mapped on Hunter Wash do not extend beneath the divide with a thickness worth considering. These are indicated by the measured sections.

Six coal beds and two small lenses thicker than 14 inches were mapped in this district. The lowest one has a maximum observed

thickness of 12 feet 9 inches at location 419, where a sample was also taken for analysis (No. 22807, p. 185). Sections of this bed were obtained at locations 403, 419, 422, 454, 456, 458, 460, 462, 463, 464, 465, 466, and 467, all of which are shown on Plate XXXII. This bed has been burned throughout an area of about 2 square miles just south of Hunter Wash, and an enormous mass of red and varicolored clinker flanks the arroyos. In some places the clinker is 40 to 50 feet thick and shows the effect of great heat.

At locations 405, 411, 412, and 420 measurements were taken of thin, irregular beds 30 to 60 feet higher stratigraphically, which, owing to the discontinuity of the outcrop and the variable thickness, can not be correlated with certainty and are therefore called lenses, though they occur near the same horizon. Sections at locations 405 and 411 showing 2 feet and 2 feet 4 inches of coal, respectively, are given on Plate XXXII. Sections at locations 412 and 420 are given below:

Section of coal bed at location 412.

	Ft.	in.
Shale, carbonaceous.		
Coal, very impure		5
Coal, with resin	1	
Shale.		
	1	5

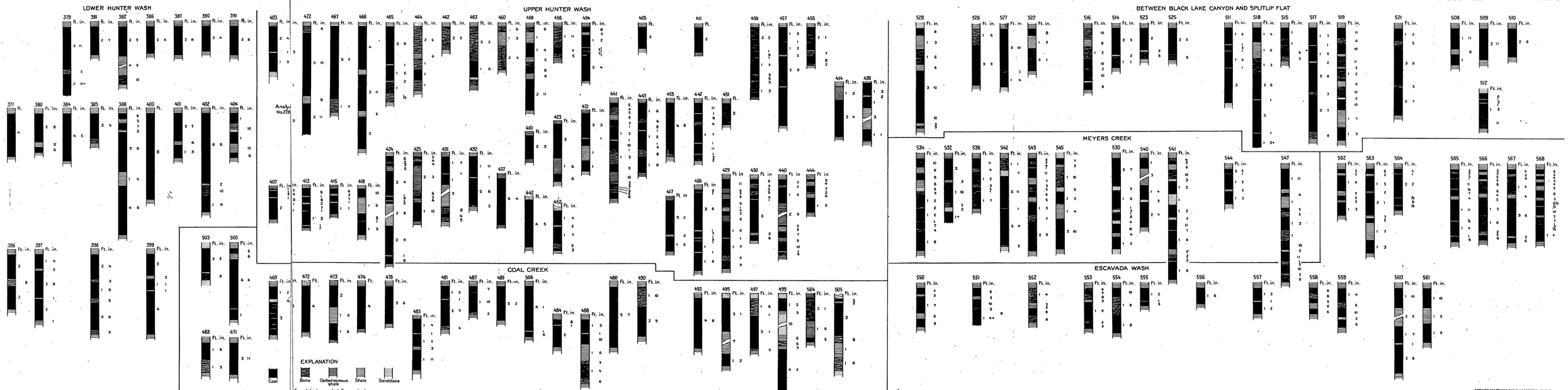
Section of coal bed at location 420.

	Ft.	in.
Shale.		
Bone		2
Coal		6
Bone		5
Coal		5
Sandstone, gray, clayey	10	6
Coal		8
Shale, gray	14	6
Coal		11
Sandstone, gray-white.		
Total section	28	1
Total coal	2	6

A bed measured at locations 455, 457, 459, and 461 crops out on the divide on the south side of Hunter Wash and probably is very near the horizon of the lenses just described. The sections shown on Plate XXXII and the one given below indicate its variable character and the large number of partings it contains.

Section of coal bed at location 461.

	Ft.	in.
Shale, carbonaceous.		
Bone		8
Shale	1	3
Coal, impure	1	2
Bone		4
Shale.		
	3	5



SECTIONS OF COAL BEDS OF THE FRUITLAND FORMATION IN SOUTHERN SAN JUAN COUNTY, NEW MEXICO

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Another coal bed about 80 feet above the lowest bed was measured at locations 406, 408, 410, 416, 421, 423, 441, 443, 447, 453, and 451. The bed averages about 4½ feet in thickness but contains many partings, which in places make it practically worthless. With the exception of those at locations 406, 408, and 416, the sections are given graphically on Plate XXXII.

Section of coal bed at location 406.

	Ft.	in.
Sandstone.		
Coal		10
Shale		1
Coal, impure		8
Shale, sandy		3
Coal	1	3
Shale.		
Total section	3	1
Total coal	2	9

Section of coal bed at location 408.

	Ft.	in.
Shale.		
Coal		8
Shale.		

Section of coal bed at location 416.

	Ft.	in.
Shale, carbonaceous.		
Coal		8
Bone		1
Coal		11
Shale.		
	1	8

Separated from this bed by about 15 feet of shale and sandy shale is a coal bed which was measured at locations 407, 409, 413, 415, 418, 424, 425, 431, 432, 437, 442, 446, 450, and 452. This bed also is very impure and filled with many shale and bone partings. The only locality at which it shows no partings is in the vicinity of locations 437 and 442, where it contains over 4 feet of clear coal. Sections at locations 446 and 450 are given here; the other sections are shown on Plate XXXII.

Section of coal bed at location 446.

	Ft.	in.
Sandstone.		
Coal	2	6
Shale, carbonaceous	5	
Coal		6
Shale.		
Total section	8	
Total coal	3	

Section of coal bed at location 450.

	Ft.	in.
Shale, carbonaceous.		
Coal, impure		8
Shale		5
Coal		5
Shale		½
Coal	1	8
Shale.		
Total section	3	2½
Total coal	2	9

A thin but persistent coal bed about 25 feet higher in the section was measured at locations 414, 427, 434, 436, 439, and 449. The thickest portion of the bed observed is at location 414, where it contains 3 feet 4 inches of coal. At location 427 it contains 1 foot 3 inches of coal; at 434, 1 foot 7 inches; at 436, 1 foot 3 inches; and at 449, 1 foot 7 inches. Sections 414 and 439 are shown on Plate XXXII.

A bed that crops out on the south fork of Hunter Wash about 10 feet above the bed just described was measured at locations 428, 433, 435, 438, 445, and 448. The bed averages less than 2 feet in thickness, and therefore the sections are all given in the text.

Section of coal bed at location 428.

	Ft.	in.
Shale, carbonaceous.		
Coal; contains resin	1	
Sandstone		2
Coal; contains resin	1	
Shale.		
	2	2

Section of coal bed at location 433.

	Ft.	in.
Shale, carbonaceous.		
Coal; contains resin	1	
Sandstone		2
Coal; contains resin		10
Shale, carbonaceous.		
	2	

Section of coal bed at location 435.

	Ft.	in.
Shale, carbonaceous.		
Coal		8
Sandstone		2
Coal; contains resin		10
Shale, carbonaceous.		
	1	8

Section of coal bed at location 438.

	Ft.	in.
Shale, sandy.		
Coal		3
Shale, carbonaceous		4
Coal		10
Shale		1

Shale, sandy—Continued.	Ft.	in.
Coal; contains resin	1	7
Bone		9
Coal; contains resin	1	1
Bone		5
Shale.		
Total section	5	4
Total coal	3	9

Section of coal bed at location 445.

Shale, carbonaceous.	Ft.	in.
Coal	1	8
Sandstone		2
Coal		9
Shale.		
	2	7

Section of coal bed at location 448.

Shale, carbonaceous.	Ft.	in.
Coal		10
Sandstone		2
Coal	1	3
Shale.		
	2	3

The highest coal bed of value on Hunter Wash has an average thickness of about 3½ feet, though the upper and lower portions of the bed contain many partings of shale and bone. Measurements of it were obtained at locations 417, 426, 429, 430, 440, and 444, all of which are given graphically on Plate XXXII.

COAL CREEK.

The coal on Coal Creek is neither so abundant nor so well exposed as it is on Hunter Wash. (See Pl. XXXI.) The beds, with the exception of the two lower ones, can not be correlated certainly with those that crop out on Hunter Wash. These two lower beds, however, are believed to be continuous with the corresponding beds in the district to the north. The lowest coal bed is the best one in this district, having an average thickness of 4 feet. It was measured at locations 469, 470, 472, 473, 474, 475, 476, and 478. With the exception of the sections given below the measurements are shown graphically on Plate XXXII.

Section of coal bed at location 475.

Shale, carbonaceous.	Ft.	in.
Coal	1	3
Shale.		

Section of coal bed at location 476.

Shale, carbonaceous.	Ft.	in.
Coal, impure	1	6
Bone	1	2
Shale.		
	2	8

Separated from this bed by 5 to 20 feet of sandy shale is a higher coal correlated with the second bed on Hunter Wash. It is thin and variable here also, as shown by sections 468 and 471 on Plate XXXII. It was noted east of location 471 at several points but is less than a foot thick.

Four coal beds higher in the section were measured on Ojo Alamo Arroyo near the point where it joins Coal Creek. The lowest one of these was measured at locations 477, 480, and 490. This bed is very pure in the vicinity of location 480, where it contains 5 feet 7 inches of clear coal. However, it does not persist very far along the outcrop, and to the south it is concealed in the flat valley of Coal Creek. Sections 480 and 490 are shown on Plate XXXII.

Section of coal bed at location 477.

	Ft.	in.
Shale, carbonaceous.		
Bone	1	4
Coal, weathered	1	2
Shale, carbonaceous	6	
Coal		6
Shale		6
Coal		8
Shale, brown		1
Coal, impure	1	6
Shale, brown.		
Total section	11	9
Total coal	3	10

The next higher bed was measured at locations 479, 481, 482, 487, and 489. It is believed to continue southward across Coal Creek and is correlated with the bed at location 506. It averages about 3 feet in thickness, as shown by the sections on Plate XXXII and those given below. At location 479 only 6 inches of coal is exposed, but at location 482 over 6 feet was found.

Section of coal bed at location 482.

	Ft.	in.
Top eroded.		
Coal, weathered	1	1
Shale		1
Coal	1	4
Shale		1
Coal	2	3
Shale, brown	1	8
Coal	1	
Shale		6
Coal		11
Shale		½
Coal		10
Shale		6
Coal		10
Shale.		
Total section	11	1½
Total coal	8	3

Sections at locations 484, 486, and 488 represent the coal bed next above. At location 486 the bed contains 1 foot 2 inches of coal. The other sections are shown on Plate XXXII.

The highest coal bed could be traced for only a short distance. Section 483, on Plate XXXII, shows three benches, each a little over 1 foot thick, separated by thin shale partings.

Three coal beds crop out in an isolated tract on the south side of Coal Creek. They probably correspond with the lower three beds on the north side of the creek, but the correlation is not certain, as the beds are known to be lenticular. The lowest bed was measured at locations 492, 494, 496, 498, 500, 503. Its greatest thickness is at location 500, where it contains 5½ feet of coal. The section at location 492 shows only 1 foot; at 494, 1 foot 2 inches; and at 496, only 10 inches. Sections at locations 500 and 503 are shown on Plate XXXII.

Section of coal bed at location 498.

	Ft.	in.
Sandstone, gray.		
Bone	1	2
Coal	1	4
Shale.		
	2	6

The thickness of the second coal bed, which is about 15 feet higher, was obtained at locations 491, 493, 495, 497, 499, 502, 504, and 505. This bed averages about 4½ feet of coal. The measurements at locations 491 and 502 are given below; the others are shown on Plate XXXII.

Section of coal bed at location 491.

	Ft.	in.
Shale.		
Coal		11
Shale, sandy.		

Section of coal bed at location 502.

	Ft.	in.
Shale.		
Bone		6
Sandstone		3
Coal	3	11
Shale, sandy.		
	4	8

The bed when visited in September, 1915, was burning at a point a short distance east of location 493. Although little smoke was noticed, gases were issuing from crevices over the outcrop, and many slumps of the overlying beds had taken place recently. Red clinker or baked sandstone and shale are abundant at this locality. The highest portion of this outlier contains a small area (see Pl. XXXI) underlain by another bed, which was measured at location 501.

Section of coal bed at location 501.

	Ft.	in.
Shale, brown.		
Coal		8
Shale, brown		8
Coal	1	6
Shale, brown.		
	2	10

BETWEEN BLACK LAKE CANYON AND SPLITLIP FLAT.

In this district between Black Lake Canyon and Splitlip Flat (see Pl. XXXIII) several coal beds are exposed, but owing to the lack of continuous exposures it is very difficult to correlate the beds at different horizons. The most probable correlation of outcrops gives five beds, with a possibility of six.

In the beds of Black Lake and several other small intermittent lakes in this vicinity there are deposits of black material buried beneath several feet of sand and clay. These deposits were described at considerable length a few years ago.[18] In the writers' opinion this substance is a peat and may represent a period when these lakes were permanent throughout the year.

The lowest bed of the Fruitland formation crops out in a bluff just north of Black Lake Canyon, 2 miles west of Black Lake. It was measured at location 528, where it contains about 5 feet of coal. (See Pl. XXXII.)

The second bed crops out in the same bluff about 20 feet higher and was measured at locations 522, 526, and 527. It is probably much more extensive than is indicated by the outcrop line on Plate XXXIII, but it is concealed in the broad flats by soil and wind-blown sand. Its thickness averages nearly 4 feet where observed, as shown by the sections on Plate XXXII.

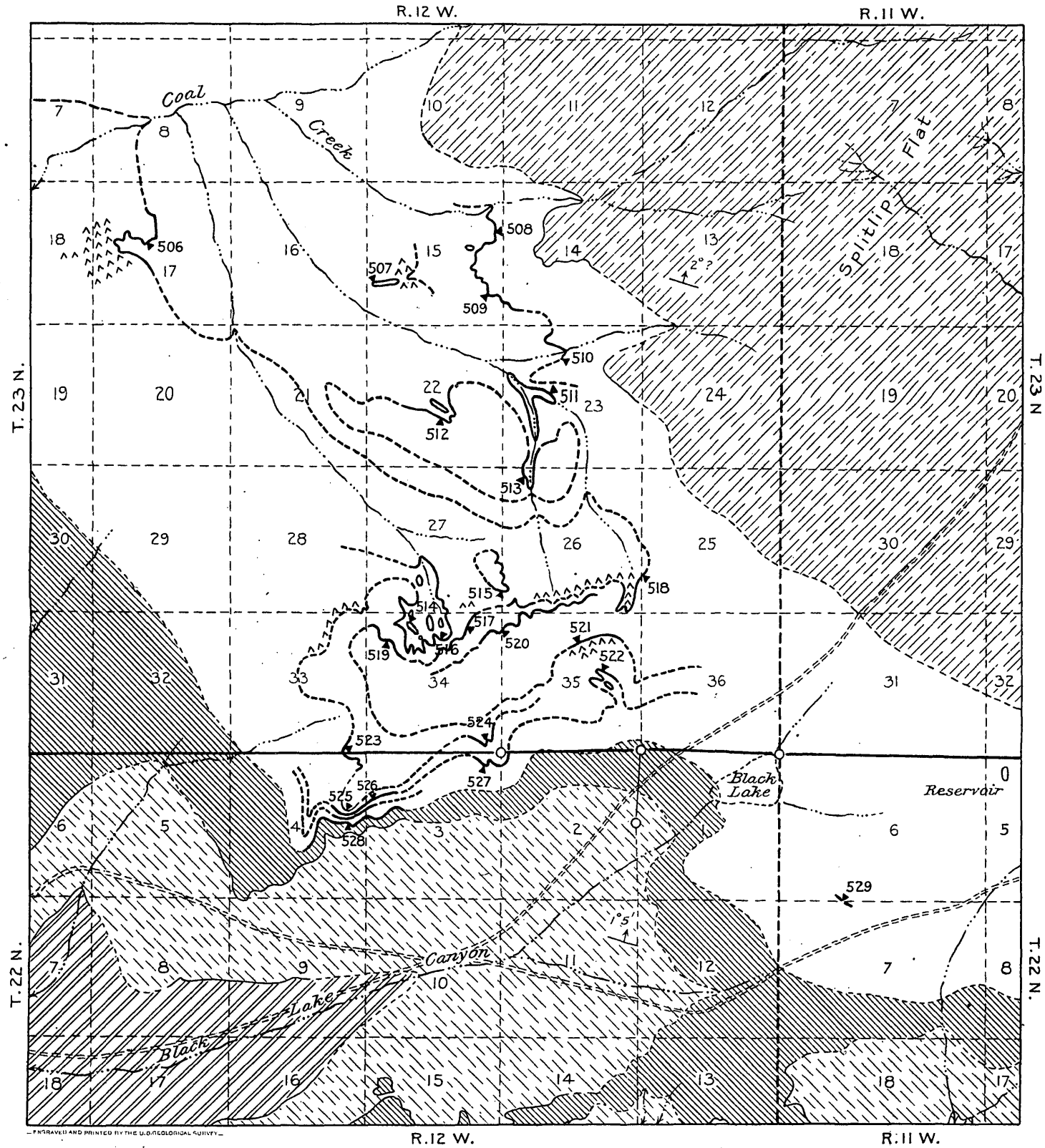
The next higher coal bed was measured at locations 514, 516, 523, 524, and 525. The average thickness of this bed is nearly 3 feet. The section at location 524 is given below; the other measurements are shown on Plate XXXII.

Section of coal bed at location 524.

	Ft.	in.
Sandstone, yellow.		
Coal, impure		11
Shale, carbonaceous		3
Bone		5
Shale, carbonaceous.		
	1	7

A coal bed from 15 to 20 feet higher than the one just described is correlated with the bed measured at location 506. This bed was measured at locations 511, 515, 517, 518, 519, and 521. (See Pl.

[18] Foster, William, Remarkable carbonaceous deposit near Putnam, N. Mex.: Econ. Geology, vol. 8, p. 360, 1913.



EXPLANATION

- Kirtland shale
- Fruitland formation *(Contains coal beds)*
- Pictured Cliffs sandstone
- Lewis shale
- Mesaverde group

Upper Cretaceous — CRETACEOUS

- Strike and dip
- Outcrop of coal bed and location of measured section
- Clinker-covered hills
- Land corner found

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

MAP OF DISTRICT BETWEEN BLACK LAKE CANYON AND SPLITLIP FLAT, SAN JUAN COUNTY, NEW MEXICO

0 1 2 3 Miles

XXXII.) Although this bed averages more than 5 feet of coal, it is split by many partings, and in only a few localities are there benches of clean coal as thick as 3 feet. A lens at about the same horizon was measured at location 507, where it contains 1 foot 4 inches of coal.

Sections of another coal bed 25 feet higher were obtained at locations 508, 509, 510, 512, and 513. Those at locations 508, 509, and 510 are given on Plate XXXII; the other two are given here:

Section of coal bed at location 512.

	Ft.	In.
Sandstone.		
Coal		6
Bone		1
Coal		3
Bone		½
Coal	1	3
Coal, impure		11
Shale.		
Total section	3	½
Total coal	2	11

Section of coal bed at location 513.

	Ft.	In.
Shale, sandy.		
Bone		4
Coal, good	1	6
Shale, carbonaceous.		
	1	10

A measurement obtained at location 520, showing 1 foot 6 inches of coal, apparently represents a lens at the same horizon as the bed just described.

An isolated exposure about 1 mile south of Black Lake, at location 529, shows 8 inches of impure coal. The surface of the divide is very flat, and owing to the great amount of wind-blown sand drainage is imperfect and natural reservoirs have been formed in several places. By the use of short dirt dams the Indians have been able to conserve in these reservoirs a considerable supply of water.

MEYERS CREEK.

Meyers Creek has cut a rather sharp valley into the plain to a depth of about 100 feet. In this valley the Fruitland formation is well exposed. The dip of the beds is N. 15° E., about 100 feet to the mile.

Five coal horizons are recognized on upper Meyers Creek (see Pl. XXXIV), all of little value because of partings and variability. At two of these horizons there are poor, lenticular beds; the beds at the other three vary much laterally and are everywhere split by many thin partings of shale and bone. The lowest coal bed of

the Fruitland formation lies immediately on the Pictured Cliffs sandstone and was measured at locations 535, 537, 539, and 544. This bed is thin and variable, as shown by the following sections:

Section of coal bed at location 535.

	Ft.	in.
Shale, carbonaceous.		
Coal		11
Shale, carbonaceous		4
Coal, impure		4
Shale, carbonaceous.		
	1	7

Section of coal bed at location 537.

	Ft.	in.
Shale, carbonaceous, black.		
Coal		7
Shale	1	5
Coal, impure		6
Sandstone, gray.		
	2	6

Section of coal bed at location 538.

	Ft.	in.
Shale, carbonaceous, black.		
Coal, impure		4
Sandstone, yellow.		

Section of coal bed at location 541.

	Ft.	in.
Shale, carbonaceous, black.		
Coal		5
Sandstone		1
Coal, impure	1	5
Shale		2
Coal	1	2
Sandstone.		
	3	3

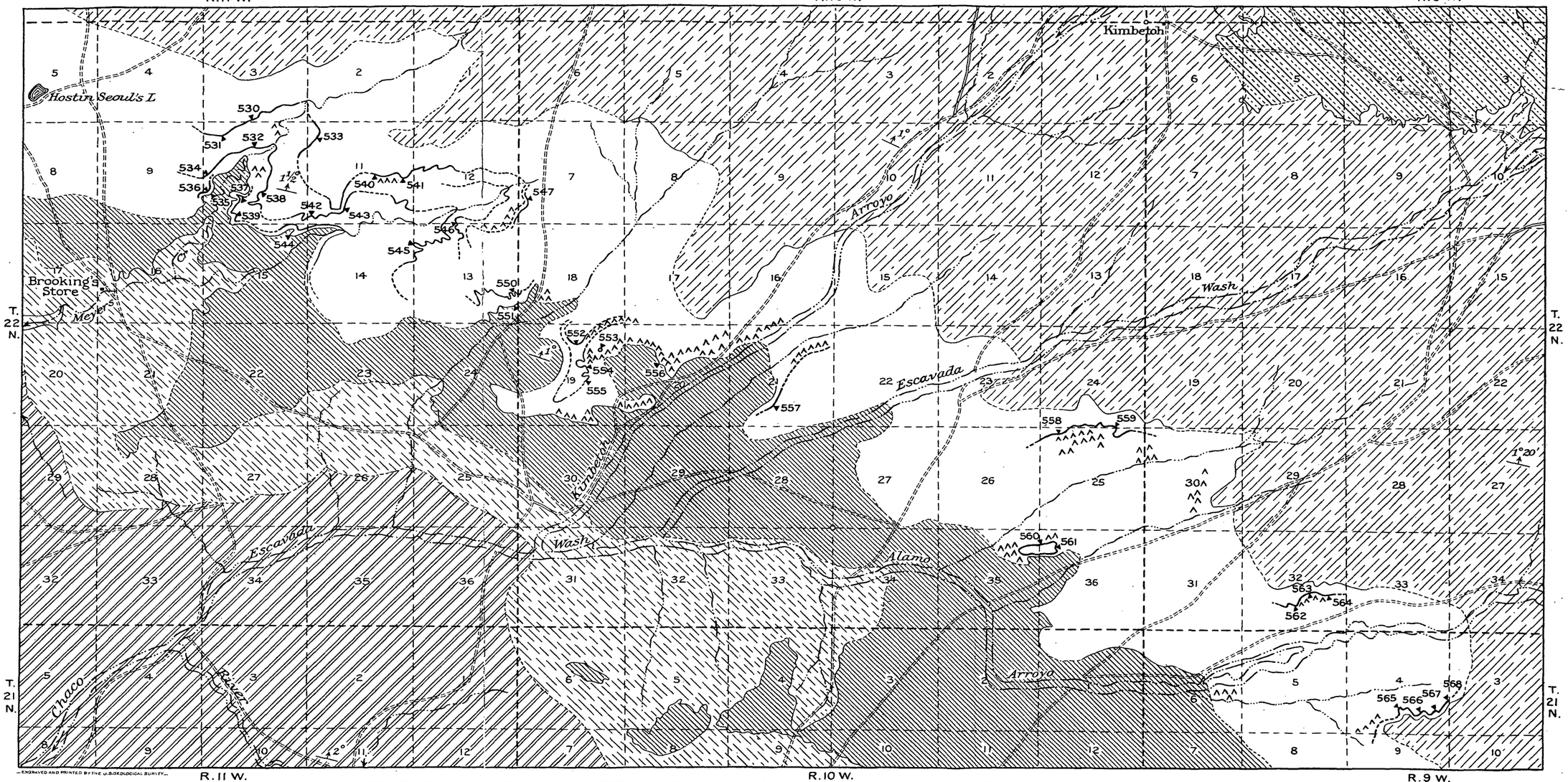
About 6 feet above this bed a short lens at location 536 shows 3 inches of coal.

The second coal bed is separated from the lowest one by 40 feet of sandy shale and was measured at locations 532, 534, 538, 542, 543, and 545. As shown by these sections, which are all given on Plate XXXII, the bed averages more than 5 feet in thickness, though it is split by many thin partings of shale and bone, and many of the benches of coal are impure.

On the south fork of Meyers Creek a bed of coal comes in 15 feet above the one just described, and a section of it was obtained at location 546.

Section of coal bed at location 546.

	Ft.	in.
Shale, carbonaceous.		
Coal	1	
Shale, carbonaceous, black		8
Coal, impure	1	2
Shale, carbonaceous.		
	2	10



EXPLANATION

TERTIARY

Eocene

Eocene formations and Ojo Alamo sandstone (Upper Cretaceous)

CRETACEOUS

Upper Cretaceous

Kirtland shale

Fruitland formation *(Contains coal beds)*

Pictured Cliffs sandstone

Lewis shale

Mesaverde group

Strike and dip

Outcrop of coal bed and location of measured section

Clinker-covered hills

Land corner found

ENGRAVED AND PRINTED BY THE U.S.GEOLOGICAL SURVEY

MAP OF DISTRICT BETWEEN MEYERS CREEK AND ALAMO ARROYO, SAN JUAN COUNTY, NEW MEXICO

0 1 2 3 Miles

A higher coal bed occurs on the south fork of Meyers Creek 15 to 20 feet above the lens just mentioned and also crops out on the north fork. Measurements of it were obtained at locations 530, 533, 540, and 541. This bed averages about 6 feet in total thickness but is split into many benches by partings of shale, sandstone, and bone. The section at location 533 is given below; the other measurements are given on Plate XXXII.

Section of coal bed at location 533.

	Ft.	in.
Shale, brown.		
Coal, impure	1	3
Shale, carbonaceous, black		3
Bone	1	4
Shale, carbonaceous, black.		
	2	10

A bed of coal 10 feet higher than the one last mentioned was measured at location 547. It is very thin north of this point but may continue for some distance to the southeast. The section is given on Plate XXXII.

BRANCHES OF ESCAVADA WASH.

The Fruitland formation is fairly well exposed on Kimbetoh Arroyo and Alamo Arroyo but less so on Escavada Wash. (See Pl. XXXIV.) On these arroyos considerable burning has occurred, particularly north of Kimbetoh Arroyo, and the resulting clinker is heavy enough to suggest the presence of thick beds of good coal. However, only thin lenticular beds with many partings are exposed. The visible variation laterally in the coal beds and the inclosing shale and sandstone is so great in even short exposures that there is little justification for attempting correlations between them where the concealed intervals are large.

On a small arroyo branching northeastward from Kimbetoh Arroyo two beds of coal are exposed. A nearly complete section of the lower bed, which rests on the Pictured Cliffs sandstone, measured at location 551, is as follows:

Section of coal bed at location 551.

	Ft.	in.
Shale, carbonaceous.		
Coal, with resin		9
Shale, black, carbonaceous		3
Coal, with resin		10
Bone, sandy		3
Coal, with resin	1	4+
Total section	3	5+
Total coal	2	11+

Ten feet above this bed, at location 550, the second bed was measured, as follows:

Section of coal bed at location 550.

	Ft.	in.
Shale, carbonaceous.		
Coal		7
Shale, carbonaceous		2
Coal, with resin	1	7
Shale, carbonaceous		6
Coal		9
Shale, carbonaceous.		
Total section	3	7
Total coal	2	11

North of Kimbetoh Arroyo much clinker occurs and there are three horizons at which coal is exposed. The lowest bed rests on the Pictured Cliffs sandstone, and a section measured at location 556 is given below. At 20 feet above this bed occurs another lens which was measured at locations 553, 554, and 555. At 10 feet above this second lens is a stratum of baked rock thick enough to suggest the presence of much more coal than that which shows at the only point available for a section of the bed (location 552). These sections are given below:

Section of coal bed at location 556.

	Ft.	in.
Sandstone, carbonaceous.		
Coal, with resin	1	6
Shale, carbonaceous		6
Sandstone, Pictured Cliffs.		
	2	

Section of coal bed at location 553.

	Ft.	in.
Shale, carbonaceous.		
Bone		4
Coal		3
Bone		6
Bone, very sandy		3
Coal, with resin	1	9
Bone		2
Coal		6
Shale, carbonaceous.		
Total section	3	9
Total coal	2	6

Section of coal bed at location 554.

	Ft.	in.
Shale, sandy.		
Coal, with resin		10
Bone, with resin	1	8
Coal, with resin	1	8
Shale, carbonaceous.		
Total section	4	2
Total coal	2	6

Section of coal bed at location 555.

	Ft.	in.
Shale, carbonaceous.		
Coal, with resin	1	2
Bone, with resin		1
Coal, with resin		5
Shale, carbonaceous.		
Total section	1	8
Total coal	1	7

Section of coal bed at location 552.

	Ft.	in.
Shale, carbonaceous.		
Bone, with resin	1	4
Sandstone, carbonaceous		3
Shale, carbonaceous		3
Coal, with resin		8
Bone, with resin		8
Shale, carbonaceous.		
Total section	3	2
Total coal		8

On the south side of Kimbetoh Arroyo exposures are poor, but some clinker shows and a small bed of coal was measured at location 557. The horizon is about 12 feet above the top of the Pictured Cliffs sandstone.

Section of coal bed measured at location 557.

	Ft.	in.
Shale, carbonaceous.		
Coal, containing resin	1	2
Shale, carbonaceous		2
Coal, containing resin	1	2
Shale, carbonaceous.		
Total section	2	5
Total coal	2	4

Between Escavada Wash and Alamo Arroyo there are several small nameless arroyos branching northeastward from Alamo Arroyo. These have eroded extensive badlands, exposing the Fruitland and Kirtland formations, and all the coal present in the Fruitland is visible or indicated by burns. There is evidence of only two coal horizons—one near the base and the other near the top of the Fruitland—neither of which extends very far laterally. The lower coal is exposed in an outlier and was measured at locations 560 and 561, about 1,000 feet apart horizontally. The upper coal was measured at locations 558 and 559.

Section of coal bed at location 560.

	Ft.	in.
Shale, carbonaceous.		
Coal, containing resin	1	10
Shale, carbonaceous	2	2
Coal, containing resin	1	7

	Ft.	in.
Shale, carbonaceous		1
Coal, containing resin	2	8
Shale, carbonaceous.		
Total section	8	4
Total coal	6	1

Section of coal bed at location 561.

Shale, carbonaceous.	Ft.	in.
Coal, containing resin and some shale laminae	1	10
Shale, carbonaceous	1	5
Coal, containing resin	1	9
Shale, carbonaceous.		
Total section	5	
Total coal	3	7

Section of coal bed at location 558.

Shale, carbonaceous.	Ft.	in.
Coal, high in ash		6
Bone		6
Coal, containing resin		5
Shale, carbonaceous		6
Coal, high in ash		6
Shale, carbonaceous.		
Total section	2	5
Total coal	1	5

Section of coal bed at location 559.

Shale, carbonaceous.	Ft.	in.
Coal, containing resin	1	4
Bone		6
Coal, containing resin		6
Sandstone, carbonaceous		3
Coal, containing resin		9
Shale, carbonaceous.		
Total section	3	8
Total coal	2	11

On the north side of Alamo Arroyo a short exposure of a single bed of coal in the upper part of the Fruitland formation was measured at locations 562, 563, and 564. This bed is split by many shale partings, as is shown on Plate XXXII.

On the south side of Alamo Arroyo another exposure of a single bed at very nearly the same horizon was measured at locations 565, 566, 567, and 568. These sections also show many partings. (See Pl. XXXII.)

The lower part of the Fruitland formation is largely concealed in Alamo Arroyo, but baked rock shows the former presence of some coal.

A reconnaissance of the area underlain by the Fruitland formation 7 or 8 miles southeastward from Alamo Arroyo furnished little evidence of coal. Much of the area is covered, but where exposures are available very little coal is seen.

SOUTHEAST OF ESCAVADA WASH, IN McKINLEY COUNTY.

An inspection of the maps and sections of coal beds shows that in the Hunter Wash district the coal beds have more partings than those farther west and north. From the Hunter Wash district southeastward the coal beds progressively decrease in number, extent, and thickness, and the coal deteriorates in quality. There are fewer and less valuable beds in Black Lake Canyon than in Coal Creek; fewer in Meyers Creek than in Black Lake Canyon. In the Escavada Wash district only thin scattered lenses of impure coal are present. This very noticeable deterioration probably continues for some distance beyond the limit of the field considered in this paper, and the presence of valuable coal beds to the southeast in the Fruitland formation is very unlikely, though such beds have been reported to occur within the next 25 miles by Shaler and Gardner,[19] who made a rapid reconnaissance of the district. At a number of other places where this preliminary work records the presence of valuable coal beds the detailed survey has failed to find them or has shown that they really are so filled with partings as to have only small value, and it is possible that this is true also in the districts not yet surveyed in detail. Gardner[20] reports that east of R. 5 W. the Fruitland formation (his Laramie formation) is barren of coal.

[19] Shaler, M. K., A reconnaissance survey of the western part of the Durango-Gallup coal fields of Colorado and New Mexico: U. S. Geol. Survey Bull. 316, pp. 376–426, 1907. Gardner, J. H., The coal fields between Gallina and Raton Spring, N. Mex., in the San Juan coal region: U. S. Geol. Survey Bull. 341, pp. 335–351, 1909.

[20] Gardner, J. H., op. cit., p. 347.