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COAL RESOURCE OCCURRENCE MAPS AND COAL DEVELOPMENT POTENTIAL MAPS OF THE PRETTY ROCK QUADRANGLE, SAN JUAN COUNTY, NEW MEXICO

[Report includes 22 plates]

by

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PRETTY ROCK 7 1/2-MINUTE QUADRANGLE

INTRODUCTION

Purpose

This text is to be used in conjunction with the Coal Resource Occurrence (CRO) Maps and Coal Development Potential (CDP) Maps of the Pretty Rock quadrangle, San Juan County, New Mexico. These maps were compiled to provide a systematic coal resource inventory of Federal coal lands in Known Recoverable Coal Resource Areas (KRCRA's) in the western United States. The work was performed under contract with the Conservation Division of the U. S. Geological Survey (Contract No. 14-08-0001-17172).

The resource information gathered in this program is in response to the Federal Coal Leasing Amendments Act of 1976 and is a part of the U.S. Geological Survey's coal program. The information provides basic data on coal resources for land-use planning purposes by the Bureau of Land Management, state and local governments, and the public.

Location

The Pretty Rock 7 1/2-minute quadrangle is in southeastern San Juan County, New Mexico. The area is approximately 36 miles (58 km) south of Farmington and 54 miles (87 km) northeast of Gallup, New Mexico.

Accessibility

The area is accessible by light-duty roads which extend from New Mexico State Route 44 which is 14 miles (23 km) to the northeast of the quadrangle. Numerous unimproved dirt roads provide access to remote parts of the quadrangle. The Atchison, Topeka, and Santa Fe Railway operates a route which passes through Gallup 54 miles (87 km) to the southwest.

Physiography

This quadrangle is in the southwestern portion of the Central Basin area (Kelley, 1950) of the larger structural depression known as the San Juan Basin. Elevations range from 5,935 ft (1,809 m) in De-na-zin Wash to 6,360 ft (1,929 m) in the southwest. The topography is, in general, characterized by very gently sloping plains and low relief; the southwest and west-central portions of the quadrangle are areas of higher relief. In the south, intermittent streams have deeply incised the plains and have formed steep-walled canyons. De-na-zin Wash and Coal Creek drain the northern portion of the area; Tsaya Canyon and Ah-shi-sle-pah Wash are the major intermittent streams in the south.

Climate

The climate of the San Juan Basin is arid to semi-arid. Annual precipitation is usually less than 10 inches (25 cm), but varies across the basin due to elevational differences. Rainfall is rare in the early summer;

most precipitation occurs in July and August as intense afternoon thundershowers. Annual temperatures range from below 0°F (-18°C) to above 100°F (38°C). Snowfall may occur from November to April with an average of 18 inches (46 cm) in the southern part of the basin.

Land Status

Approximately 68 percent of the quadrangle is in the southwestern part of the San Juan Basin Known Recoverable Coal Resource Area. The Federal Government owns the coal rights for approximately 88 percent of the KRCRA land as shown on Plate 2 of the Coal Resource Occurrence Maps. Preference Right Lease Applications (NM 3752, NM 3753, NM 3754, NM 3755, NM 3835, NM 3836, NM 3837, and NM 7235) in the north and center cover 53 percent of the quadrangle. A Federal Coal Lease (NM 10931) covers 8 percent of the east-central part of the quadrangle. The Federal Government owns the coal rights for approximately 90 percent of the land outside the KRCRA within the quadrangle.

GENERAL GEOLOGY

Previous Work

Bauer and Reeside (1921) have mapped the Fruitland Formation in the area with emphasis on the outcrops of Fruitland coal beds and clinker. Later, Reeside (1924) mapped the Upper Cretaceous and Tertiary rocks of the San Juan Basin. A more recent publication by Fassett and Hinds (1971) includes subsurface interpretations of the Fruitland Formation coal deposits throughout the San Juan Basin. Shomaker (1971a) has studied in detail the surface occurrences of Fruitland Formation coals in the area and presented coal quality analyses and coal reserve estimates.

Geologic History

The San Juan Basin, an area of classic transgressive and regressive sedimentation, provided the ideal environment for formation of coals during Late Cretaceous time. At that time a shallow epeiric sea, which trended northwest-southeast, was northeast of the basin. The sea transgressed southwesterly into the basin area and regressed northeasterly numerous times; consequently, sediments from varying environments were deposited across the basin. Paludal (swamp) and stagnant lacustrine and lagoonal environments of deposition resulted in the accumulation of coal in the Late Cretaceous Menefee and Fruitland Formations (Beaumont, 1971). Noncarbonaceous terrestrial deposition predominated during Paleocene and Eocene time.

The first basin-wide retreat of the Late Cretaceous sea is indicated by the nearshore deposits of the Point Lookout Sandstone. These ancient barrier beaches formed a generally northwest-southeast-trending strandline, behind which swamps developed. Organic material accumulated in the swamps and later became coal in the paludal deposits of the lower Menefee Formation. Deposition of materials which formed the coal beds was influenced by the strandline. This is shown by the more consistent thickness and greater lateral extent of the coals parallel to the strandline and also by the lack of continuity perpendicular to it, to the northeast, where the

Menefee and underlying Point Lookout deposits interfinger. Streams which crossed the swamps also influenced deposition of organic matter; stream deposits may terminate even the most continuous coal beds.

During the continued retreat of the sea, the depositional environments in the quadrangle area became more terrestrial. This is evidenced by the transition within the lower Menefee from carbonaceous to noncoal-bearing deposits, in which there is an upward decrease in the occurrence and lateral continuity of the coals. As the sea retreated, the sediments of the Point Lookout Sandstone and overlying Menefee Formation were deposited in successively higher stratigraphic positions to the northeast.

The sea then reversed the direction of movement, and the transgressive sequence of paludal upper Menefee Formation, nearshore Cliff House Sandstone, and marine Lewis Shale was deposited in the quadrangle. Swamps (Menefee) formed southwest (shoreward) of the transgressing beaches (Cliff House). Organic matter deposited in these swamps ultimately formed coal beds in the upper portion of the undifferentiated member and the Hogback Mountain Tongue (Beaumont, 1971) of the Menefee Formation. Subsequently, a thin wedge of beach sands of the La Ventana Tongue (Cliff House Sandstone) was deposited over the Menefee. Another transgressing northwest-southeast-trending strandline is represented in the lithologic record in this quadrangle by the main body of the Chacra Tongue (informal name of local usage) of the Cliff House Sandstone. The marine facies which developed northeast of the strandline as it moved to the southwest is the Lewis Shale. This thick sequence, which thins to the southwest, overlies the Cliff House Sandstone, and marks the last advance of the Late Cretaceous sea.

Evidence of the final retreat of the Late Cretaceous sea are the nearshore regressive Pictured Cliffs Sandstone and the overlying paludal Fruitland Formation which were deposited in successively higher stratigraphic positions to the northeast. Southwest (shoreward) of the beach deposits, swamps, which were dissected by streams, accumulated organic matter which became coals of the Fruitland Formation. Deposition of organic material was influenced by the strandline as shown by both the continuity of the coal beds parallel to the northwest-southeast strandline and their discontinuity perpendicular to it to the northeast.

The brackish-water swamp environment of the Fruitland moved northeast of the quadrangle as the regression continued in that direction. Terrestrial sediments then covered the area as indicated by the lacustrine, channel, and floodplain deposits of the Kirtland Shale. This sequence of events is evidenced by both an upward decrease in occurrence and thickness of Fruitland coals and a gradational change to noncarbonaceous deposits of the Kirtland. Continuous deposition during Late Cretaceous time ended with the Kirtland. The sea then retreated beyond the limits of the quadrangle area, and modern basin structure began to develop.

Terrestrial deposition resumed in the Paleocene as represented by the Ojo Alamo Sandstone and the overlying Nacimiento Formation. The Eocene nonmarine San Jose Formation was subsequently deposited over the Nacimiento erosional surface. Deposition and structural deformation of the basin then ceased, and the warped strata of the San Juan Basin have been exposed to the present time. A significant amount of erosion has occurred, as indicated by the removal of the San Jose Formation, Nacimiento Formation, Ojo Alamo Sandstone, and some of the Kirtland Shale from the area.

Stratigraphy

The formations studied in this quadrangle are Late Cretaceous in age. They are, in order from oldest to youngest: (the three formations of the Mesaverde Group), the Point Lookout Sandstone, Menefee Formation, and Cliff House Sandstone; the Lewis Shale, Pictured Cliffs Sandstone, Fruitland Formation, and Kirtland Shale. A composite columnar section on CRO Plate 3 illustrates the stratigraphic relationships of these formations and is accompanied by lithologic descriptions of the individual formations.

The Point Lookout Sandstone, the basal formation of the Mesaverde Group, is a light gray, slightly calcareous, argillaceous sandstone with interstitial kaolinite and interbedded gray shale near the base. It is fairly massive, averaging 150 ft (46 m) thick in this area, and displays a distinctive and consistent character on geophysical logs. This last characteristic was used by the authors to establish the top of the Point Lookout as a lithologic datum for correlation of overlying Menefee Formation coals.

The oldest coal-bearing formation in the quadrangle is the Menefee Formation of the Mesaverde Group. In previous studies the Menefee has been divided, from the base upward, into the Cleary Coal Member, the barren Allison Member, an unnamed upper coal-bearing member (Beaumont and others, 1956), and the Hogback Mountain Tongue (Beaumont, 1971). The first three members are referred as a single undifferentiated member for the purposes of this report only. The undifferentiated member is about 1,140 ft (347 m) thick and consists predominantly of gray, carbonaceous to noncarbonaceous shale with local plant fossils, interbedded light gray to tan, calcareous sandstone, and random coal beds.

The informally named Hogback Mountain Tongue of the Menefee Formation (Beaumont, 1971) is composed of thick paludal coal-bearing sediments deposited shoreward of the massive marine sand of the La Ventana Tongue. It is recognized by the large amount of coal and the stratigraphic equivalence to the La Ventana. The Hogback Mountain Tongue is approximately 550 ft (167 m) thick in the quadrangle area. Similar in lithology to the underlying undifferentiated member, it is composed of gray, carbonaceous shale with local plant fossils, interbedded cream to light gray, calcareous sandstone, and random coal beds.

The Cliff House Sandstone is divided into the La Ventana and Chacra Tongues. The basal or La Ventana Tongue conformably overlies the Hogback Mountain Tongue of the Menefee Formation in this area. Here it is a thin tongue (60 ft [1.8 m]) of sandstone extending into the area from the major La Ventana buildup to the northeast. Lithologically similar to the massive sandstone at the type locality, the La Ventana in the quadrangle area is cream to light gray, friable, calcareous sandstone. The Chacra Tongue (informal name of local usage), which overlies the La Ventana Tongue, extends across the entire quadrangle. It consists of about 350 ft (107 m) of light gray, slightly glauconitic, micaceous sandstone, and interbedded gray shale with plant fossils. This lithology is similar to that at the type section at Chacra Mesa southeast of the quadrangle.

The marine Lewis Shale conformably overlies the Mesaverde Group. In contrast to the underlying Cliff House Sandstone, it is predominantly a gray, flaky, calcareous shale with local plant fossils. The average thickness of the Lewis is 200 ft (61 m) throughout the quadrangle. The upper contact is gradational with the overlying Pictured Cliffs Sandstone and, therefore, is difficult to determine.

The Pictured Cliffs Sandstone consists of light gray to tan, friable sandstone with interstitial kaolinite, commonly interbedded with thin, gray shale near the base of the formation where it grades into the Lewis Shale. The upper contact is more sharply defined than the basal contact, even though intertonguing with overlying Fruitland Formation results in minor variations in the formational top. Since the Pictured Cliffs is present throughout most of the basin and displays a distinctive character on geophysical logs, the authors have used the top of the unit as a lithologic datum for correlation of the overlying Fruitland Formation coals.

The Fruitland Formation is the major coal-bearing unit in the quadrangle. It consists of an average of 260 ft (79 m) of gray to brown, carbonaceous shale with local plant fossils, interbedded gray sandstone, and coal beds of varying thicknesses. The upper contact is gradational from nonmarine lower coastal plain deposits of the Fruitland to upper coastal or alluvial plain deposits of the Kirtland Shale (Molenaar, 1977). Many authors have used various criteria in establishing the upper contact but, in general, for the purposes of this report the uppermost coal was chosen (after Fassett and Hinds, 1971).

The freshwater deposits of the Kirtland Shale are the youngest Cretaceous strata in the area. They consist of gray siltstone with local plant fossils, and interbedded gray silty shale. The formation has previously been divided into several members by various authors; however, for the purposes of this report it was not necessary to distinguish between the individual members.

A total of five formations crop out within the quadrangle. The outcrop pattern trends in a general northwest-southeast direction, with the formations becoming successively younger to the northeast. The oldest formation exposed is the Chacra Tongue (informal name of local usage) of the Cliff House Sandstone which crops out as resistant sandstone beds along the Chaco River in the southwestern part of the quadrangle. The entire sections of the Lewis Shale, Pictured Cliffs Sandstone, and Fruitland Formation crop out consecutively in a northeasterly direction. The lowermost beds of the Kirtland Shale, the youngest formation within the area, are exposed in the extreme northeastern corner of the quadrangle.

Structure

The axis of the San Juan Basin is about 43 miles (69 km) north of the Pretty Rock quadrangle area and trends in an arcuate pattern across the northern portion of the Central Basin area (Baltz, 1967). Regional dip within the quadrangle was measured as 1° 5' to 2° to the northeast by Reeside (1924).

COAL GEOLOGY

Individual coal beds are not continuous across the San Juan Basin because the coal related strata are progressively younger from southwest to northeast; the strata rise in steps due to minor transgressions which occurred during the overall retreat of the sea. However, for the exclusive purpose of reserve and reserve base calculations, the Fruitland 1 coal bed has been correlated and mapped as if it was a single bed, continuous throughout the basin.

A lithologic datum was used for correlation of the coals (CRO Plate 3). The primarily marine sandstone units (Point Lookout, Pictured Cliffs) which underlie the coal-bearing formations (Menefee, Fruitland) were used as datums since they represent a more laterally continuous boundary than any of the overlying paludal, fluvial, and lacustrine deposits of the coal-bearing formations. Also, the sandstone units are generally more easily recognized on geophysical logs. As shown on CRO Plate 3, the tops of the sandstone units have been used as datums for the drill holes, and the coals have been plotted in the column and correlatd based upon their position relative to the datum. In this quadrangle, the Fruitland-Pictured Cliffs contact from geologic maps (Bauer and Reeside, 1921) was used for determining Fruitland coal correlations.

One coal zone (Fruitland) and two coal beds (Fruitland 1, Fruitland zone B) were mapped on the surface, and a coal zone (Menefee) and a coal bed (Fruitland zone A) were mapped in the subsurface of this quadrangle (CRO Plate 1). the Menefee Formation coal beds are designated as the Menefee coal zone (Me zone), which extends from the top of the La Ventana Tongue to the base of the Menefee Formation. These coal beds are generally noncorrelative and less than reserve base thickness (5 ft [1.5 m]) as specified by the U.S. Geological Survey.

Menefee Formation coal beds in the southern part of the San Juan Basin are considered subbituminous A in rank. The rank has been determined on a moist, mineral-matter-free basis with calorific values averaging 10,817 Btu's per pound (25,160 kj/kg) (Amer. Soc. for Testing and Materials, 1977). The coal is hard, brittle, and black with a bright luster. The coal readily slakes with exposure to weather; however, it stocks fairly well when protected. The "as received" analyses indicate moisture content varying from 14.4 to 19.1 percent, ash content ranging from 5.4 to 10.2 percent, sulfur content of one percent or less, and heating values on the average of 9,913 Btu's per pound (23,058 kj/kg). Analyses of several Menefee Formation coal beds are given in Table 1 (Bauer and Reeside, 1921; Dane, 1936; Lease, 1971; Shomaker, 1971b).

The Fruitland 1 (Fr 1) is defined by the authors as the lowermost coal of the Fruitland Formation; it is generally directly above the Pictured Cliffs Sandstone. The coal bed crops out in the central portion of the quadrangle, extending from west to east. The trace of the outcrop has been modified from the original data source to conform with modern topographic maps. Above the Fruitland 1 coal bed is the Fruitland coal zone (Fr zone), extending from the top of the Fruitland Formation to the lowermost coal which is designated on CRO Plate 3 as a Fruitland zone coal bed. The Fruitland zone consists of several coal beds which are generally noncorrelative and less than reserve base thickness (5 ft [1.5 m]). Several beds of the Fruitland zone crop out in the northwest part of the quadrangle (CRO Plate 1). The traces of these outcrops have been modified from the original data source to conform with modern topographic maps. Within the Fruitland zone there are two locally thick accumulations of coal which have been designated by the authors as the Fruitland zone A and the Fruitland zone B.

Fruitland Formation coal beds in the southern part of the San Juan Basin are considered high volatile C bituminous in rank, although the coals vary from subbituminous C to high volatile B bituminous. The rank of the coal has been determined on a moist, mineral-matter-free basis with calorific values ranging from 9,375 to 13,092 Btu's per pound (21,806-30,452 kj/kg)

TABLE 1

Analyses of coal samples from the Menefee Formation

(Form of analysis: A, as received; B, moisture free; C, moisture and ash free)

U.S. Bureau Mines Lab No.	Well or Other Source	Location			Approx. Depth Interval of Sample (ft.)	Form of Analysis	Proximate, percent					Heating Value (Btu)	Remarks
		Section	T.N.	R.W.			Mois-ture	Volatile matter	Fixed Carbon	Ash	Sulfur		
J-57562	Pit Sample	SW¼ 11	22	13	------------	A	14.4	32.6	42.8	10.2	0.9	9,870	
						B	----	38.1	50.0	11.9	1.0	11,530	
						C	----	43.3	56.7	----	1.2	13,090	
23003	Mine Sample Blake's Mine	13	22	13	________	A	19.0	32.4	43.2	5.4	0.92	10,190	
						B	----	40.0	53.3	6.7	1.14	12,590	
						C	----	42.9	57.1	----	1.22	13,490	
J-51245	Channel, Open Pit	NW¼ 9	22	14	________	A	19.1	33.4	40.7	6.8	0.9	9,280	Probably weathered
						B	----	41.3	50.3	8.4	1.2	11,470	
						C	----	45.1	54.9	----	1.3	12,520	
J-51246	Channel, Open Pit	NE¼ 2	22	16	________	A	15.3	33.9	42.7	8.1	1.0	10,310	
						B	----	40.1	50.3	9.6	1.1	12,180	
						C	----	44.3	55.7	----	1.3	13,470	

To convert Btu's/lb to kj/kg, multiply Btu's/lb by 2.326.

(Amer. Soc. for Testing and Materials, 1977). The coal is hard, brittle, and black with a bright luster. It readily slakes with exposure to weather; however, the coal stocks fairly well when protected. The "as received" analyses indicate moisture content varying from 4.98 to 19.4 percent, ash content ranging from 16.0 to 24.23 percent, sulfur content less than one percent, and heating values ranging from 7,420 to 10,222 Btu's per pound (17,259-23,776 kj/kg). Analyses of several Fruitland Formation coal beds are given in Table 2 (Bauer and Reeside, 1921; Dane, 1936; Shomaker, 1971a).

Menefee Coal Zone

The Menefee coal zone extends from the top of the La Ventana Tongue to the base of the Menefee Formation. The La Ventana deposits to the northeast of this quadrangle are contemporaneous with the coal-bearing Hogback Mountain Tongue of the Menefee Formation (Beaumont, 1971) and exhibit a distinctive character on geophysical logs. Therefore, it portrays the upper boundary of the coal-bearing Menefee zone more consistently than the randomly occurring uppermost Menefee coal. This correlation of the top of the La Ventana with the top of the Menefee zone was extended into this quadrangle for consistency.

The structure contour map of the Menefee coal zone (CRO Plate 5) was drawn using the top of the La Ventana Tongue. This map shows the dip of the Menefee coal zone varies from less than 1° to approximately 2.5° to the northeast. Due to topography and dip, overburden (CRO Plate 6) varies from less than 200 ft (61 m) in the southwest to greater than 1,200 ft (366 m) in the northeast. Also shown on CRO Plate 6 is the total amount of interburden

TABLE 2

Analyses of coal samples from the Fruitland Formation

(Form of analysis: A, as received; B, moisture free; C, moisture and ash free)

U.S. Bureau Mines Lab No.	Well or Other Source	Location Section	T.N.	R.W.	Approx. Depth Interval of Sample (ft.)	Form of Analysis	Proximate, percent Moisture	Volatile matter	Fixed Carbon	Ash	Sulfur	Heating Value (Btu)	Remarks
J-63220	Core Sample	NE¼ 29	23	11	------	A	12.7	31.9	34.3	21.2	0.3	8,680	
						B	-----	36.5	39.3	24.2	0.4	9,940	
						C	-----	48.2	51.8	-----	0.5	13,120	
J-61645	Core Sample	NE¼ 29	23	11	------	A	14.6	30.8	38.6	16.0	0.34	9,440	
						B	-----	36.1	45.2	18.7	0.40	11,050	
						C	-----	44.4	55.6	-----	0.49	13,600	
*21-A	Drill Cuttings	SW¼ 9	23	12	------	A	5.28	----	-----	18.09	0.59	10,206	
						B	-----	----	-----	19.10	0.62	10,775	
						C	-----	----	-----	-----	----	13,319	
*23	Core Sample	NE¼ 10	23	12	------	A	9.39	30.11	43.10	17.41	0.72	9,915	
						B	-----	33.23	47.56	19.21	0.79	10,942	
						C	-----	-----	-----	-----	----	13,544	
*19	Drill Cuttings	SW¼ 17	23	12	------	A	5.39	-----	-----	24.23	0.46	9,497	
						B	-----	-----	-----	25.61	0.49	10,038	
						C	-----	-----	-----	-----	----	13,494	
*7	Drill Cuttings	SE¼ 25	23	12	------	A	4.98	-----	-----	20.21	0.57	10,222	
						B	-----	-----	-----	21.27	0.60	10,758	
						C	-----	-----	-----	-----	----	13,664	
J-62865	Core Sample	SE¼ 27	23	12	------	A	19.4	29.4	31.9	19.3	0.5	7,420	
						B	-----	36.5	39.5	24.0	0.6	9,210	
						C	-----	48.0	52.0	-----	0.8	12,110	
J-62275	Core Sample	SW ¼ 27	23	12	-----	A	16.6	29.3	36.5	17.6	0.46	8,880	
						B	-----	35.2	43.7	21.1	0.53	10,640	
						C	-----	44.6	55.4	-----	0.68	13,480	

*New Mexico State Bureau of Mines and Mineral Resources

To convert Btu's/lb to kj/kg, multiply Btu's/lb by 2.326

which is the noncoal portion of the Menefee coal zone. The interburden thickness varies from less than 1,700 ft (518 m) in the northern and eastern portions of the quadrangle to greater than 2,100 ft (640 m) in the western portion of the quadrangle. The large interburden values are the result of the stratigraphic spread of the coal beds and essentially reflect the thickness of the Menefee Formation plus the La Ventana. The isopach map (CRO Plate 4) illustrates the total combined thickness of the individual coal beds of the Menefee zone. The greatest thickness occurs in the northeastern portion of the quadrangle where the coals total to greater than 30 ft (9.1 m). The coal thickness decreases to less than 5 ft (1.5 m) in the central-western portion of the quadrangle.

Chemical Analyses of the Menefee Zone Coal Beds - No published analyses of Menefee coal within this quadrangle are available. However, analyses of several Menefee Formation coals in the surrounding area were published in reports by Bauer and Reeside (1921), Lease (1971), and Shomaker (1971b). The results of these analyses are given in Table 1.

Fruitland 1 Coal Bed

As illustrated by the structure contour map (CRO Plate 8), the coal bed dips approximately 1° to the northeast. Consequently, overburden (CRO Plate 9) increases from zero at the outcrop to greater than 500 ft (152 m) in the northeast. The isopach map (CRO Plate 7) indicates coal thickness varying from greater than 15 ft (4.6 m) in the central-northwest to less than 5 ft (1.5 m) in the vicinity of the outcrop.

Chemical Analyses of the Fruitland 1 Coal Bed - Analyses of several Fruitland Formation coals from this quadrangle and the surrounding area are given in Table 2 (Shomaker, 1971a).

Fruitland Coal Zone

The Fruitland coal zone extends from the top of the Fruitland Formation to the base of the lowermost coal designated on CRO Plate 3 as a Fruitland zone coal bed. Much of the Fruitland Formation has been eroded from this quadrangle. Therefore, the structure contour map of the Fruitland coal zone (CRO Plate 16) is drawn on top of the lowermost exposed Fruitland zone coal bed since the lower portions of the Fruitland Formation crop out in this quadrangle.

As illustrated by the structure contour map (CRO Plate 12), the coal zone dips approximately 1° to the north. As a result of topography and dip, overburden (CRO Plate 13) varies from zero at the outcrop of the lowermost Fruitland zone coal to greater than 400 ft (122 m) in the northeast portion of the map. The isopach map (CRO Plate 11) illustrates the total thickness of the coals of the Fruitland zone. The thickest accumulation of greater than 5 ft (1.5 m) occurs in two areas in the central portion of the map. From these areas, thickness decreases.

Chemical Analyses of the Fruitland Coal Zone - Analyses of several Fruitland Formation coals from this quadrangle and the surrounding area are given in Table 2 (Shomaker, 1971a).

Fruitland Zone A Coal Bed

At the base of the Fruitland coal zone is a locally thick accumulation of coal which has been named informally by the authors as the Fruitland zone A. As illustrated by the structure contour map (CRO Plate 15), the Fruitland zone A dips less than 1° to the northeast. Due to topography and dip, overburden (CRO Plate 16) varies from less than 200 ft (61 m) in the southwest to greater than 400 ft (122 m) in the northeast. Also shown on CRO Plate 16 is the amount of interburden between the beds of the Fruitland zone A. The interburden values vary from zero to greater than 40 ft (0-12.2 m). As indicated by the isopach map (CRO Plate 14), the Fruitland zone A is present only in the northeast portion of this quadrangle and extends into a small area of the Pueblo Bonito NW 7 1/2-minute quadrangle. The coal thickness is greater than 30 ft (9.1 m) in the central portion of the map. From this area the coal thickness decreases.

Chemical Analyses of the Fruitland Zone A Coal Bed - Analyses of several Fruitland Formation coals from this quadrangle and the surrounding area are given in Table 2 (Shomaker, 1971a).

Fruitland Zone B Coal Bed

Within the Fruitland coal zone there is a locally thick accumulation of coal which has been informally named by the authors as the Fruitland zone B. As illustrated by the structure contour map (CRO Plate 19), the Fruitland zone B dips approximately 1° to the northeast. Consequently, overburden (CRO Plate 20) varies from zero at the outcrop to greater than 25 ft (7.6 m) in the central portion of the mapped area. As shown by the isopach map (CRO Plate 18), the Fruitland zone B is present only in a small portion of the northwest part of the quadrangle. In the central part of the mapped area the coal is greater than 10 ft (3.0 m) thick. From this area the thickness decreases.

Chemical Analyses of the Fruitland Zone B Coal Bed - Analyses of several Fruitland Formation coals from this quadrangle and the surrounding area are given in Table 2 (Shomaker, 1971a).

COAL RESOURCES

Coal resource data from oil and gas wells (El Paso Natural Gas Co., 1978, unpublished data in well log library, Farmington, New Mexico), coal test holes (Shomaker, 1971), and geologic maps (Bauer and Reeside, 1921) were used in the construction of outcrop, isopach, and structure contour maps of the coals in this quadrangle. Outcrop traces of the Fruitland 1 coal beds and the Fruitland zone coals in the western half of the quadrangle (CRO Plate 1) are modified from Bauer and Reeside (1921). Parts of the Fruitland 1 outcrop have been inferred for purposes of Reserve Base and Reserve calculations.

The U.S. Geological Survey designated the Fruitland 1 and Fruitland zone A coal beds for the determination of coal resources in this quadrangle. The Fruitland zone B coal was not evaluated because it is entirely within PRLA land. Coals of the Fruitland and Menefee zones were not evaluated because they are discontinuous, noncorrelative, and generally less than the reserve base thickness (5 ft [1.5 m]).

For Reserve Base and Reserve calculations, each coal bed was areally divided into measured, indicated, and inferred resource categories (CRO Plates 10 and 17) according to criteria established in U.S. Geological Survey Bulletin 1450-B. Data for calculation of Reserve Base and Reserves for each category were obtained from the respective coal isopach (CRO Plates 7 and 14) and areal distribution (CRO Plates 10 and 17) maps for each coal bed. The surface area of each isopached bed was measured by planimeter, in acres, for each category, then multiplied by both the average isopached thickness of the coal bed and 1,800 short tons of coal per acre-foot (13,239 tons/hectare), the conversion factor for bituminous coal. This yields the Reserve Base coal, in short tons, for each coal bed.

In order to calculate Reserves, recovery factors of 85 percent and 50 percent were applied to the Reserve Base tonnages for strippable and underground coals, respectively. However, in areas of underground coal exceeding 12 ft (3.7 m) in thickness, the Reserves (mineable coal) were calculated on the basis of a maximum coal bed thickness of 12 ft (3.7 m), which represents the maximum economically mineable thickness for a single coal bed in this area by current underground mining technology.

Reserve Base and Reserve values for measured, indicated, and inferred categories of coal for the Fruitland 1 and Fruitland zone A beds are shown on CRO Plates 10 and 17, respectively, and are rounded to the nearest hundredth of a million short tons. The total coal Reserve Base, by section, is shown on CRO Plate 2 and totals approximately 88.2 million short tons (80.0 million metric tons).

The coal development potential for each bed was calculated in a manner similar to the Reserve Base, from planimetered measurements, in acres, for areas of high, moderate, and low potential for surface and/or subsurface mining methods. The Pretty Rock quadrangle has development potential for both surface and subsurface mining methods (CDP Plates 21 and 22).

COAL DEVELOPMENT POTENTIAL

Coal beds of 5 ft (1.5 m) or more in thickness which are overlain by 200 ft (61 m) or less of overburden are considered to have potential for strip mining and are designated as having high, moderate, or low development potential according to the mining ratios (cubic yards of overburden per ton of recoverable coal). The formula utilized in the calculation of mining ratios for bituminous coal is:

$$MR = \frac{t_o \ (0.896)}{t_c \ (rf)}$$

where MR = mining ratio
t_o = thickness of overburden
t_c = thickness of coal
rf = recovery factor

Based on economic and technological criteria, the U.S. Geological Survey has established standards for the determination of high, moderate, and low coal development potentials for surface and subsurface coal beds of reserve base thickness (5 ft [1.5 m]) or greater. Mining ratio values for strippable coal (overburden less than 200 ft [61 m] thick) are 0 to 10, high; 10 to 15, moderate; and greater than 15, low. Underground coal beds (overburden 200 to 3,000 ft [61-914 m] thick) are assigned high, moderate, or low development potentials according to the overburden thickness, 200 to 1,000 ft

(61-305 m), high; 1,000 to 2000 ft (305-610 m), moderate; and 2,000 to 3,000 ft (610-914 m), low. Tables 3 and 4 summarize the coal development potential, in short tons, for surface and underground coal, respectively, of the Fruitland 1 and Fruitland 2 coal beds.

Development Potential For Surface Mining Methods

Strippable coal of the Fruitland 1 bed has a high development potential in the west-central part of the quadrangle (CDP Plate 21), where the coal thickness increases from 5 ft (1.5 m) at the outcrop to more than 15 ft (4.6 m) to the north (CRO Plate 7), and the overburden thickness is zero at the outcrop and increases 100 to 200 ft (30.5-61.0 m) down-dip, north of the outcrop (CRO Plate 9). The small area of high potential in the extreme northwest corner is the result of strippable coal of the Fruitland zone B bed in the adjacent quadrangle, Tanner Lake.

The Fruitland 1 is the only coal bed with moderate and low development potential in the area (CDP Plate 21). Moderate and low potential areas occur in the west-central and east-central parts of the quadrangle where the coal bed thickness ranges from 5 to 17 ft (1.5-5.2 m) and 5 to 7 ft (1.5-2.1 m), respectively, and the overburden varies from zero to 200 ft (61.0 m) thick.

The areas of unknown potential occur adjacent to the outcrop of the Fruitland 1 where the coal is less than 5 ft (1.5 m) thick. The remainder of the quadrangle area has no development potential for surface mining methods and includes areas beyond the stripping limit and areas outside the outcrop of the Fruitland 1.

TABLE 3

STRIPPABLE COAL RESOURCES FOR FEDERAL COAL LANDS (IN SHORT TONS) IN THE PRETTY ROCK QUADRANGLE, SAN JUAN COUNTY, NEW MEXICO

[Development potentials are based on mining ratios (cubic yards of overburden/ton of underlying coal). To convert short tons to metric tons, multiply by 0.9072; to convert mining ratios in yd^3/ton coal to m^3/ton, multiply by 0.842]

Coal Bed	High Development Potential (0-10 mining ratio)	Moderate Development Potential (10-15 mining ratio)	Low Development Potential (15 mining ratio)	Total
Fruitland 1	12,340,000	18,780,000	16,150,000	47,270,000
TOTAL	12,340,000	18,780,000	16,150,000	47,270,000

TABLE 4

COAL RESOURCE DATA FOR UNDERGROUND MINING METHODS FOR FEDERAL COAL LANDS
(in short tons) IN THE PRETTY ROCK QUADRANGLE,
SAN JUAN COUNTY, NEW MEXICO

(To convert short tons to metric tons, multiply by 0.9072)

Coal Bed	High Development Potential	Moderate Development Potential	Low Development Potential	Total
Fruitland zone A	2,650,000	--	--	2,650,000
Fruitland 1	38,300,000	--	--	38,300,000
TOTAL	40,950,000	--	--	40,950,000

Development Potential for Subsurface Mining Methods

Underground coal of the Fruitland 1 and Fruitland zone A coal beds has high development potential in the northeastern corner of the quadrangle (CDP Plate 22). The Fruitland zone A coal with high potential covers only a small part of the area with high development potential (refer to CRO Plate 17). Coal bed thicknesses in this area are approximately 8 to 11 ft (2.4-3.4 m) for the Fruitland 1 (CRO Plate 7) and 5 to 12 ft (1.5-3.7 m) for the Fruitland zone A (CRO Plate 14). The overburden is 300 to 500 ft (91-152 m) thick for Fruitland 1 (CRO Plate 9) and 300 to 400 ft (91-122 m) thick for Fruitland zone A (CRO Plate 16). Coal of the Fruitland 1 also has high development potential in a small area at the central part of the eastern quadrangle boundary where the coal is approximately 7.5 ft (2.3 m) thick and the overburden is 200 ft (61 m) thick.

The small area with unknown development potential in the extreme northwestern corner of the quadrangle is the result of Fruitland 1 coal which is less than reserve base thickness (5 ft [1.5 m]). The remainder of the quadrangle area has no coal development potential for subsurface mining methods and includes areas inside the stripping limits and areas outside the outcrops of the Fruitland 1 and Fruitland zone A coal beds.

REFERENCES

American Soc. for Testing and Materials, 1977, Gaseous fuels; coal and coke; atmospheric analysis, in Annual book of ASTM standards, part 26: p. 214-218.

Baltz, E.H., Jr., 1967, Stratigraphy and regional tectonic implications of part of Upper Cretaceous and Tertiary rocks, east-central San Juan Basin, New Mexico: U.S. Geol. Survey Prof. Paper 552, p. 12.

Bauer, C.M., and Reeside, J.B., Jr., 1921, Coal in the middle and eastern parts of San Juan County, New Mexico: U.S. Geol. Survey Bull. 716-G, p. 177-178.

Beaumont, E.C., 1971, Stratigraphic distribution of coal in San Juan Basin in Shomaker, J.W., and others, eds., Strippable low-sulfur coal resources of the San Juan Basin in New Mexico and Colorado: New Mexico Bur. of Mines and Mineral Resources Memoir 25, p. 15-30.

Beaumont, E.C., Dane, C.H., and Sears, J.D., 1956, Revised nomenclature of Mesaverde Group in San Juan Basin, New Mexico: Amer. Assoc. of Petroleum Geologists Bull., v. 40, no. 9, p. 2,160.

Coal Resource Map Co., 1977, Land grid and coal ownership map: a portion of San Juan County, New Mexico: Farmington, N.M., Coal Resource Map E-4, 1:24,000.

Dane, C.H., 1936, The La Ventana - Chacra Mesa coal field, pt. 3 of Geology and fuel resources of the southern part of the San Juan Basin, New Mexico: U.S. Geol. Survey Bull. 860-C, p. 137-138, [1937].

El Paso Natural Gas Co., 1978, unpublished data in well log library, Farmington, New Mexico.

Fassett, J.E., and Hinds, J.S., 1971, Geology and fuel resources of the Fruitland Formation and Kirtland Shale of the San Juan Basin, New Mexico and Colorado: U.S. Geol. Survey Prof. Paper 676, 76 p.

Kelley, V.C., 1950, Regional structure of the San Juan Basin in New Mexico Geol. Soc. Guidebook of the San Juan Basin, New Mexico and Colorado, 1st Field Conf., p. 102.

Lease, R.C., 1971, Chaco Canyon Upper Menefee area in Shomaker, J.W., and others, eds., Strippable low-sulfur coal resources of the San Juan Basin in New Mexico and Colorado: New Mexico Bur. of Mines and Mineral Resources Memoir 25, p. 59.

Molenaar, C.M., 1977, Stratigraphy and depositional history of Upper Cretaceous rocks of the San Juan Basin area, New Mexico and Colorado, with a note on economic resources in New Mexico Geol. Soc. Guidebook of the San Juan Basin III, Northwestern New Mexico, 28th Field Conf., p. 165.

Reeside, J.B., Jr., 1924, Upper Cretaceous and Tertiary formations of the western part of the San Juan Basin of Colorado and New Mexico: U.S. Geol. Survey Prof. Paper 134, p. 1-70.

Shomaker, J.W., 1971a, Bisti Fruitland area in Shomaker, J.W., and others, eds., Strippable low-sulfur coal resources of the San Juan Basin in New Mexico and Colorado: New Mexico Bur. of Mines and Mineral Resources Memoir 25, p. 110-119.

________, 1971b, Newcomb Upper Menefee area in Shomaker, J.W., and others, eds., Strippable low-sulfur coal resources of the San Juan Basin in New Mexico and Colorado: New Mexico Bur. of Mines and Mineral Resources Memoir 25, p. 54.

U.S. Bureau of Mines and U.S. Geological Survey, 1976, Coal resource classification system of the U.S. Bureau of Mines and U.S. Geological Survey: U.S. Geol. Survey Bull. 1450-B, 7 p.

U.S. Department of the Interior, 1957, Map of portion of San Juan County, New Mexico: U.S. Geol. Survey Oil and Gas Operations Map Roswell 77, revised 1974, 1:31,680.