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COAL RESOURCE OCCURRENCE MAPS AND COAL DEVELOPMENT POTENTIAL MAPS OF THE PUEBLO BONITO NW QUADRANGLE, SAN JUAN COUNTY, NEW MEXICO

[Report includes 19 plates]

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PUEBLO BONITO NW 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 Pueblo Bonito NW 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 has been 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 Pueblo Bonito NW 7 1/2-minute quadrangle is located in southeastern San Juan County, New Mexico, approximately 38 miles (61 km) southeast of Farmington and 62 miles (100 km) northeast of Gallup, New Mexico.

Accessibility

The area is accessible by State Route 56, and also by State Route 44 which is approximately 8 miles (13 km) to the northeast of the quadrangle. Numerous light duty and unimproved dirt roads provide further access into the quadrangle. The Atchison, Topeka, and Santa Fe Railway operates a route which passes through Gallup, New Mexico, approximately 60 miles (93 km) to the southwest and connects Gallup with Grants and Albuquerque to the east.

Physiography

The Pueblo Bonito NW quadrangle is located in the south-central portion of the Central Basin area (Kelley, 1950) of the larger structural depression known as the San Juan Basin. Elevations range from 6,100 ft (1,830 m) in Ah-shi-sle-pah Wash in the southwest to 6,745 ft (2,056 m) in the northeast. The topography is characterized by gentle slopes which have been dissected by numerous intermittent streams. Kimbeto Wash, in the southeastern corner of the quadrangle, drains to the southwest, as do most of the streams in this area. In portions of the southern half of the quadrangle, the drainage pattern has resulted in a badlands topography.

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 and winter; most precipitation occurs in July and August as intense afternoon thundershowers. Annual temperatures in the basin range from below 0°F (-18C) 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 97 percent of the quadrangle is in the southwestern portion of the San Juan Basin Known Recoverable Coal Resource Area. The Federal Government owns the coal rights for approximately 90 percent of the KRCRA land within the quadrangle as shown on Plate 2 of the Coal Resource Occurrence Maps. Preference Right Lease Applications (NM 3755, NM 3836, NM 3837, NM 3918, NM 3919, NM 6803, NM 6804, NM 8592, NM 8745, and NM 9764) cover 55 percent of the KRCRA. No Federal coal leases occur within the quadrangle. The Federal Government owns the coal rights for 83 percent of the land in the quadrangle which is outside the San Juan Basin Known Recoverable Coal Resource Area boundary.

GENERAL GEOLOGY

Previous Work

Bauer and Reeside (1921) have mapped the Fruitland Formation within the quadrangle with detailed emphasis on the outcrops of Fruitland coal and clinker. Reeside (1924) has mapped the geology as part of a study of the Upper Cretaceous and Tertiary formations of the San Juan Basin. Shomaker

(1971a) described in detail the surface coal occurrences of the Fruitland Formation and estimated the strippable reserves by township and range. Fassett and Hinds (1971) have made subsurface interpretations of the Fruitland Formation coal deposits throughout the San Juan Basin. The most recent work in the area is a publication by Schneider (1978) which includes the geology, including outcrops of Fruitland clinker and various Fruitland Formation coal zones mapped at a scale of 1:24,000.

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. 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 the coal beds in the upper part of the Menefee Formation. Subsequently, beach sands of the La Ventana Tongue (Cliff House Sandstone) were deposited over the Menefee with several hundred feet in the northeast portion of the quadrangle. Shoreward (southwest) and contemporaneous with the La Ventana beach deposits, swamps developed above the older Menefee deposits. Subsequently, coals formed in these younger deposits of the Hogback Mountain Tongue of the Menefee (Beaumont, 1971). Minor fluctuations of the sea resulted in interfingering of the La Ventana (Cliff House) and Hogback Mountain (Menefee) Tongues. La Ventana sands were then deposited over the Hogback Mountain Tongue.

Onlap continued as the sea moved southwestward across the basin area. The transgressing northwest-southeast-trending strandline is represented in the lithologic record by the Chacra Tongue (informal name of local usage) of the Cliff House Sandstone which overlies the La Ventana. 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 later became coals of the Fruitland Formation. Again, 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 to the northeast beyond the limits of the quadrangle area, and modern basin structure began to develop. An erosional unconformity developed in a relatively short time as part of the Cretaceous Kirtland Shale was removed.

Terrestrial deposition resumed in the Paleocene as represented by the Ojo Alamo Sandstone and the overlying Nacimiento Formation. Alluvial plain deposits of the Ojo Alamo were followed by the thick, lithologically varied floodplain deposits of the Nacimiento during continuous nonmarine deposition (Powell, 1973). The Nacimiento was later exposed to erosion. The Eocene San Jose Formation was subsequently deposited over the Nacimiento erosional surface, reflecting various nonmarine environments which developed across the basin. 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 and the upper part of the Nacimiento Formation from the area.

Stratigraphy

The formations studied in this quadrangle range from Late Cretaceous to Paleocene 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, Kirtland Shale, Ojo Alamo Sandstone, and Nacimiento Formation. 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 composed of cream to light gray, calcareous, argillaceous sandstone. It is fairly massive, averages about 150 ft (46 m) in thickness in this area, and possesses 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 the 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 coal-bearing Hogback Mountain Tongue (Beaumont, 1971). The first three members were grouped together as an undifferentiated member for the purposes of this report only. The undifferentiated member is about 1,050 ft (320 m) in thickness and is composed predominantly of medium gray to brown, carbonaceous to noncarbonaceous, slightly calcareous shale with plant fossils, interbedded white to tan, calcareous sandstone with interstitial kaolinite, and random coal beds.

The informally-named Hogback Mountain Tongue is distinguishable from the lower Menefee because it is shoreward of and stratigraphically equivalent to the massive marine sand of the La Ventana Tongue (basal Cliff House Formation). This member of the Menefee Formation is recognized as a major coal-bearing unit. In this area it is a 260-ft (79-m) wedge between two tongues of La Ventana sandstone which thins to the northeast. Similar in lithology to the undifferentiated member of the Menefee, it is a dark gray to brown, carbonaceous shale.

Conformably underlying, overlying, and intertonguing with the upper portion of the Menefee Formation is the basal member of the transgressive Cliff House Sandstone, the La Ventana Tongue. Its basal sandstone tongue overlies the undifferentiated Menefee member; an upper sand overlies the Hogback Mountain Tongue. The La Ventana is composed of light gray, calcareous sandstone with interstitial kaolinite.

The upper member of the Cliff House Sandstone, the Chacra Tongue (informal name of local usage), is about 350 ft (107 m) thick and overlies the La Ventana Tongue. The Chacra lithology in this quadrangle is transitional between the massive sandstone of the Chacra type section to the south and the marine deposits of the Lewis Shale. It is composed of gray to brown, calcareous siltstone beds with interbedded light gray sandstone with interstitial kaolinite.

The marine Lewis Shale conformably overlies the Mesaverde Group. In contrast to the underlying Cliff House Sandstone, it is predominantly a dark gray-brown shale with local plant fossils and limy nodules. The Lewis averages 210 ft (64 m) in thickness throughout the quadrangle. The upper contact is gradational with the Pictured Cliffs Sandstone and, therefore, it is difficult to determine.

The Pictured Cliffs Sandstone consists of about 100 ft (30 m) of white to gray, calcareous sandstone with clay stringers, commonly interbedded with thin, light gray to brown siltstone near the base of the formation where it grades into the Lewis. The upper contact is more sharply defined than the basal contact, even though intertonguing with the 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 as a lithologic datum for correlation of overlying Fruitland coals.

The Fruitland Formation is the major coal-bearing unit in the quadrangle. It is composed of an average of 445 ft (136 m) of gray, carbonaceous shale with plant fossils, interbedded siltstone and sandstone, and coal beds of varying thicknesses. The thickest and most continuous coal beds occur near the base of the formation, while discontinuous and lenticular coals are characteristic of the upper portion. 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 to establish 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 about 520 ft (158 m) of light gray to green, platy, locally silty shale with plant fossils, and interbedded gray siltstone. The formation has previously been divided into several members by various authors; however, for the purpose of this report it was not necessary to distinguish between the individual members.

Unconformably overlying the Upper Cretaceous deposits is the Paleocene Ojo Alamo Sandstone. It is primarily composed of about 90 ft (27 m) of light gray, locally conglomeratic, calcareous sandstone.

The Nacimiento Formation gradationally overlies the Ojo Alamo. A thickness of approximately 400 ft (122 m) of Nacimiento is exposed in the area. The rocks consist of gray to brown shale, buff to brown, thin sandstone beds, and interbedded siltstone and claystone.

A total of six formations crop out within the quadrangle. The outcrop pattern trends in a northwest-southeast direction with the formations becoming successively younger to the northeast. The oldest formation exposed is the Lewis Shale, which crops out in the extreme southwestern corner. The complete sections of the Pictured Cliffs Sandstone, Fruitland Formation, Kirtland Shale, and Ojo Alamo Sandstone are exposed consecutively northeastward across the quadrangle. The lower beds of the Nacimiento Formation, the youngest formation in the area, crop out in the northeastern corner.

Structure

The axis of the San Juan Basin is about 36 miles (58 km) northeast of the Pueblo Bonito NW quadrangle and trends in an arcuate pattern across the northern portion of the Central Basin area (Baltz, 1967). Regional dips measured within the quadrangle range from 1° to 1° 30' to the northeast (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 were 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 oil and gas test holes; the coals have been plotted in the column and correlated based upon their position relative to the datum. Correlations of coals in measured sections (Bauer and Reeside, 1921) and coal test holes (New Mexico State Bureau of Mines and Mineral Resources in Shomaker, 1971a) are based upon previous correlations and geologic maps (Bauer and Reeside, 1921; Shomaker, 1971a).

Two coal zones (Menefee, Fruitland) and two coal beds (Fruitland 1, Fruitland zone A) were identified in 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 noncorrelative and generally less than reserve base thickness (5 ft [1.5 m]) as set by the U.S. Geological Survey; exceptions are a 5-ft (1.5-m) coal in drill hole 25 and a 7-ft (2.1-m) bed in drill hole 28 (CRO Plate 1).

Menefee Formation coal beds in the southern part of the San Juan Basin are considered subbituminous A in rank. The rank of the coal has been determined on a moist, mineral-matter-free basis with calorific values averaging 11,166 Btu's per pound (25,972 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 averaging 15.7 percent, ash content ranging from 7.5 to 10.2 percent, sulfur content varying from 0.6 to 2.2 percent, and heating values on the order of 10,053 Btu's per pound (23,383 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) coal bed is defined by the authors as the lowermost coal of the Fruitland Formation; it is generally directly above the Pictured Cliffs Sandstone. The Fruitland 1 coal bed crops out across the southwest portion of this quadrangle. The trace of this outcrop has been modified from the original data source to conform with modern topographic maps.

Above the Fruitland 1 is a locally thick accumulation of coal which has been designated by the authors as the Fruitland zone A (Fr zone A). The remaining coals in the upper portion of the Fruitland Formation have been designated as the Fruitland coal zone (Fr zone). These coals are usually discontinuous and less than reserve base thickness (5 ft [1.5 m]). Several of these coals crop out in the southwest part of the quadrangle (CRO Plate 1). Traces of outcrop have been modified from the original data source to conform with modern topographic maps.

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 borderline subbituminous A - high volatile C bituminous to high volatile A bituminous. The rank of the coal has been determined on a moist, mineral-matter-free basis with calorific values ranging from 11,246 to

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-63534	Core Sample	NE¼ 36	17	10	----	A	16.5	33.4	40.4	9.7	0.6	10,070	
						B	----	40.0	48.3	11.7	0.7	12,060	
						C	----	45.3	54.7	----	0.8	13,650	
3823	Mine Sample	14	20	11	----	A	17.5	32.9	41.2	8.4	2.2	----	
23004	Pueblo Bonito Mine	14	21	11	----	A	14.4	34.8	43.3	7.5	1.54	10,220	Allison Member
						B	----	40.7	50.5	8.8	1.80	11,940	
						C	----	44.6	55.4	----	1.97	13,090	
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	

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

14,102 Btu's per pound (26,158-32,801 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 3.9 to 14.6 percent, ash content ranging from 13.65 to 35.14 percent, sulfur content generally less than one percent, and heating values on the order of 9,519 Btu's per pound (22,141 kj/kg). Analyses of several Fruitland Formation coal beds are given in Table 2 (Dane, 1936; Fassett and Hinds, 1971; Shomaker, 1971a).

Menefee Coal Zone

The Menefee coal zone extends from the top of the La Ventana Tongue (Cliff House) to the base of the Menefee Formation. The La Ventana Tongue is contemporaneous with the coal-bearing Hogback Mountain Tongue of the Menefee Formation (Beaumont, 1971) and exhibits 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.

The structure contour map of the Menefee coal zone (CRO Plate 5) was consequently drawn on the top of the La Ventana Tongue. The map shows that the Menefee coal zone dips less than 1° to the northeast. Due to topography and dip, overburden (CRO Plate 6) ranges from less than 600 ft (183 m) in the southwest to greater than 1,600 ft (488 m) in the northeast. Also shown on CRO Plate 6 is the total amount of interburden, which is the noncoal portion of the Menefee coal zone. The interburden thickness varies from less

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 Mois-ture	Volatile matter	Fixed Carbon	Ash	Sulfur	Heating Value (Btu)	Remarks
*29	Drill Cuttings	NW¼ 5	22	10	----	A	4.52	-----	-----	13.65	0.59	11,035	
						B	-----	-----	-----	14.30	0.62	11,577	
						C	-----	-----	-----	-----	----	13,485	
*34	Drill Cuttings	SE¼ 9	22	10	----	A	9.28	29.26	38.42	23.04	0.54	9,240	
						B	-----	32.25	42.35	25.40	0.60	10,185	
						C	-----	-----	-----	-----	----	13,653	
J-63526	Core Sample	NE¼ 15	22	10	269.0-290.2	A	12.4	33.9	37.6	16.1	0.49	9,630	
						B	-----	38.7	42.9	18.4	0.56	10,990	
						C	-----	47.5	52.5	-----	0.68	13,470	
*27	Drill Cuttings	NW¼ 12	22	11	104-110	A	5.01	-----	-----	35.14	0.44	7,740	May be
						B	-----	-----	-----	36.99	0.46	8,148	weathered
						C	-----	-----	-----	-----	----	12,931	sample
*	Drill Cuttings	NW¼ 12	22	11	155-159	A	5.42	-----	-----	19.41	0.66	10,427	
						B	-----	-----	-----	20.52	0.70	10,835	
						C	-----	-----	-----	-----	----	13,634	
J-63220	Core Sample	NE¼ 29	23	11	252.5-283.0	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	321.5-330.0	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	
H-5022	Dorfman Production Nancy Fed. No. 1	SE¼ 12	24	8	2,525-2,535	A	3.9	35.4	33.7	27.0	1.1	9,960	
						B	-----	36.8	35.1	28.1	1.1	10,370	
						C	-----	51.2	48.8	-----	1.5	14,410	

*New Mexico State Bureau of Mines and Mineral Resources

To convert Btu's/lb to kj/kg, multiply Btu's/lb by 2.326.
To convert feet to meters, multiply feet by 0.3048.

than 1,620 ft (494 m) to greater than 1,680 ft (512 m). These large values are the result of the stratigraphic spread of the coal beds and, consequently, reflect the thickness of the Menefee Formation plus the La Ventana. The isopach map (CRO Plate 4) illustrates the total thickness of the individual coal beds of the Menefee zone. The greatest combined thickness occurs in the northwestern portion of the quadrangle where the coals total over 30 ft (9.1 m). In general, the thickness decreases to the south, east, and north to less than 10 ft (3.0 m) in the eastern portion of the quadrangle.

Chemical Analyses of the Menefee Zone Coal Beds - No analyses of Menefee coals from this quadrangle are known to be available. However, analyses of several Menefee Formation coals from the surrounding area were published by Bauer and Reeside (1921), Lease (1971), and Shomaker (1971b) and these are assumed to be similar to the coals of this quadrangle. 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 Fruitland 1 coal bed dips less than 1° to the north. Due to topography and dip, overburden (CRO Plate 9) ranges from zero at the outcrop to greater than 1,000 ft (305 m) in the northeast. The isopach map (CRO Plate 7) indicates a maximum thickness of greater than 20 ft (6.1 m) in the southeast. In general, the coal bed decreases in thickness from this area.

Chemical Analyses of the Fruitland 1 Coal Bed - Analyses of several Fruitland Formation coal beds from this quadrangle and the surrounding area were published by Fassett and Hinds (1971) and Shomaker (1971a). The results of these analyses are given in Table 2.

Fruitland Zone A Coal Bed

As illustrated by the structure contour map (CRO Plate 12), the Fruitland zone A dips less than 1° to the north-northeast. Due to topography and dip, overburden (CRO Plate 13) varies from less than 200 ft (61 m) in the south to greater than 800 ft (244 m) in the northeast. Also shown on CRO Plate 13 is the amount of interburden between the coal beds. The interburden thickness ranges from zero to greater than 30 ft (9.1 m). The isopach map (CRO Plate 11) shows the Fruitland zone A is present in all but the north-eastern and southern portions of the quadrangle. The Fruitland zone A is greater than 40 ft (12.2 m) thick in the northwest. From this area, the coal thins.

Chemical Analyses of the Fruitland Zone A Coal Bed - Analyses of several Fruitland Formation coal beds from this quadrangle and the surrounding area were published by Fassett and Hinds (1971) and Shomaker (1971a). The results of these analyses are given in Table 2.

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. The structure contour map of the Fruitland coal zone (CRO Plate 16) was drawn on top of the lowermost Fruitland zone coal since the Fruitland Formation crops out in this quadrangle. As illustrated by the structure contour map (CRO Plate 16), the coal zone dips approximately 1° to the northeast. Due to topography and dip, overburden (CRO Plate 17) varies from zero at the outcrop to greater than 1,000 ft (305 m) in the northeast. The isopach map (CRO Plate 15) illustrates the total thickness of the coals of the Fruitland zone. The maximum thickness of greater than 5 ft (1.5 m) occurs in several small areas in the southwest. The thickness decreases from these areas, and there is no coal to the east and in a portion of the northwest.

Chemical Analyses of Fruitland Zone Coal Beds - Analyses of several Fruitland Formation coal beds from this quadrangle and the surrounding area were published by Fassett and Hinds (1971) and Shomaker (1971a). The results of these analyses are given in Table 2.

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 utilized in the construction of outcrop, isopach, and structure contour maps of coals in this quadrangle. Outcrop traces of the Fruitland 1 and Fruitland zone coal beds in the southern half of the quad rangle (CRO Plate 1) were modified from Bauer and Reeside (1921), and parts of the Fruitland 1 outcrop were inferred beyond the known outcrop for purposes of establishing boundaries to compute the Reserve Base values.

The U.S. Geological Survey designated the Fruitland 1 and Fruitland zone A coal beds for the determination of coal resources in this quadrangle. 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 14) according to criteria established in U.S. Geological Survey Bulletin 1450-B. Coal outside the 3-mile (4.8-km) inferred radius is designated as a hypothetical resource; however, Reserves were not calculated for hypothetical coal resources. Data for calculation of Reserve Base and Reserves for each category were obtained from the respective coal isopach (CRO Plates 7 and 11) and areal distribution maps (CRO Plates 10 and 14) 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-meter), 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, Reserve, and Hypothetical values for each category of coal for the Fruitland 1 and Fruitland zone A beds are shown on CRO Plates 10 and 14, 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 260 million short tons (236 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 Pueblo Bonito NW quadrangle has development potential for both surface and subsurface mining methods (CDP Plates 18 and 19).

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, and low development potential according to the overburden thickness: 200 to 1,000 ft (61-305 m), high; 1,000 to 2,000 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 zone A coal beds.

Development Potential for Surface Mining Methods

Strippable coal of the Fruitland 1 coal bed has low development potential in a small area near the center of the western quadrangle boundary and approximately one mile (1.6 km) east in a smaller area. The coal thickness in these areas varies from 5 to 7 ft (1.5-2.1 m) (CRO Plate 7). Coal of the Fruitland zone A bed has low development potential in two small areas in the west-central part of the quadrangle where the coal thickness is 5 to 14 ft (1.5-4.3 m) (CRO Plate 11).

The three areas with unknown development potential in the southwest quarter of the quadrangle are areas where the Fruitland 1 and Fruitland zone A coal beds are less than the reserve base thickness of 5 ft (1.5 m). The remainder of the quadrangle area has no coal development potential and includes areas outside the Fruitland 1 outcrop and Fruitland zone A limit and areas beyond the stripping limits of each coal bed.

Development Potential for Subsurface Mining Methods

Underground coal of the Fruitland 1 bed has high development potential in the north and east-northeast, and in two small areas in the southwest

TABLE 3

STRIPPABLE COAL RESOURCES FOR FEDERAL COAL LANDS (IN SHORT TONS) IN THE PUEBLO BONITO NW 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 zone A	2,290,000	130,000	--	2,420,000
Fruitland 1	--	90,000	4,610,000	4,700,000
TOTAL	2,290,000	220,000	4,610,000	7,120,000

TABLE 4

COAL RESOURCE DATA FOR UNDERGROUND MINING METHODS FOR FEDERAL COAL LANDS
(in short tons) IN THE PUEBLO BONITO NW 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	105,730,000	--	--	105,730,000
Fruitland 1	146,090,000	990,000	--	147,080,000
TOTAL	251,820,000	990,000	--	252,810,000

(CDP Plate 19). The coal bed thickness in these areas varies from 5 to 12 ft (1.5-3.7 m) in the northern part of the quadrangle to 5 to 6 ft (1.5-1.8 m) in the southwest (CRO Plate 7), and the overburden thickness increases from approximately 200 to 1,000 ft (61-305 m) from the southwest to the northeast corner of the area (CRO Plate 9). Coal of the Fruitland zone A bed has high development potential in the east-central and southwestern parts of the quadrangle. The Fruitland zone A is 5 to 20 ft (1.5-6.1 m) thick (CRO Plate 11) in the southwest where the overburden is 200 to 300 ft (61-91 m) thick (CRO Plate 13) in the high potential area. Coal bed thickness in the east-central area ranges from 5 to 25 ft (1.5-7.6 m), and the overburden is approximately 400 to 800 ft (122-244 m) thick.

The only area with moderate development potential occurs in the extreme northeast corner of the quadrangle where the Fruitland 1 coal bed has more than 1,000 ft (305 m) of overburden and the coal is approximately 16 ft (4.9 m) thick. Fruitland zone A coal does not extend into this area.

Areas of unknown potential in the east-central and southeast are the result of Fruitland 1 and Fruitland zone A coal less than the reserve base thickness of 5 ft (1.5 m). The remainder of the quadrangle area has no coal development potential and includes areas inside the stripping limits of the Fruitland 1 and Fruitland zone A beds and areas outside the Fruitland 1 outcrop and the Fruitland zone A limit.

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