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COAL RESOURCE OCCURRENCE MAPS AND COAL DEVELOPMENT POTENTIAL MAPS OF THE ALAMO MESA WEST QUADRANGLE, SAN JUAN COUNTY, NEW MEXICO

[Report includes 19 plates]

by

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This report has not been edited for conformity with U.S. Geological Survey editorial standards or stratigraphic nomenclature.

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ALAMO MESA WEST 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 Alamo Mesa West quadrangle, San Juan County, New Mexico. These reports were compiled to provide a systematic coal resource inventory of Federal coal lands in Known Recoverable Coal Resource Areas (KRCRA's) of 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 Alamo Mesa West 7 1/2-minute quadrangle is in south-central San Juan County, New Mexico. The area is approximately 26 miles (42 km) south of Farmington and 62 miles (100 km) northeast of Gallup.

Accessibility

The area is accessible by a light-duty road which crosses the southwest corner of the quadrangle, and by numerous unimproved dirt roads which extend into the quadrangle area. The Atchison, Topeka, and Santa Fe Railway operates an eastwest route which passes through Gallup 62 miles (100 km) to the southwest and services Grants and Albuquerque.

Physiography

This quadrangle is in the southwestern portion of the Central Basin area (Kelley, 1950) of the larger structural depression, the San Juan Basin. Elevations range from 5,780 ft (1,762 m) in the west to 6,420 ft (1,957 m) in the northeast. The topography of the northwestern half of the area is characterized by gently sloping plains. In the south and east the plains have been carved by numerous intermittent streams into a badlands topography. Alamo Wash and Hunter Wash are the major drainage systems in this area.

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 in the basin range from below 0°F (-18°C) to over 100°F (38°C). Snowfall may occur from November to April with an average of 18 inches (46 cm) in the southwestern part of the basin.

Land Status

The quadrangle is in the southwest part of the San Juan Basin Known Recoverable Coal Resource Area. The Federal Government owns the coal rights for approximately 89 percent of the KRCRA land within the quadrangle as shown on Plate 2 of the Coal Resource Occurrence Maps. Preference Right Lease Applications (NM 3834, NM 3835, NM 3838, NM 6801, NM 6802, and NM 11916) in the southern half cover 28 percent of the quadrangle. Federal coal leases (NM 0186612, NM 0186613, and NM 0186615) in the southwest cover 5 percent of the KRCRA.

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. 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 (1971) has studied in detail the surface occurrences of the Fruitland Formation coal reserves. A combined study by the Bureau of Land Management, the Bureau of Reclamation, and the Geological Survey (1976) includes evaluations of the resources and the potential reclamation of the Bisti coal field, part of which is present within the quadrangle area.

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 coal beds in the upper part of the Menefee Formation. Subsequently, several hundred feet of beach sands of the La Ventana Tongue (Cliff House Sandstone) were deposited over the Menefee to the northeast of the quadrangle; a thick tongue of the La Ventana overlies the undifferentiated Menefee in this quadrangle. Shoreward (southwest) and contemporaneous with the La Ventana beach deposits, swamps developed above the older Menefee deposits. Subsequently, coals developed in these younger deposits which are the Hogback Mountain Tongue of the Menefee (Beaumont, 1971). Fluctuations of the sea resulted in interfingering of the La Ventana (Cliff House) and Hogback Mountain (Menefee) Tongues in this area.

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 Tongue.

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 is 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. 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 beyond the limits of the quadrangle area, and modern basin structure began to develop. An erosional unconformity developed in a relatively short time by removal of part of the Cretaceous Kirtland Shale.

Terrestrial deposition resumed in the Paleocene as represented by the Ojo Alamo Sandstone and the overlying Nacimiento Formation. Alluvial plain and floodplain deposits of the Ojo Alamo were gradually 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 majority 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 Point Lookout Sandstone, Menefee Formation, and Cliff House Sandstone (the three formations of the Mesaverde Group); 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, consists of cream to light gray, calcareous, argillaceous sandstone, interbedded gray shale, and local coal beds. It is massive in character, averages about 160 ft (49 m) thick, and displays a distinctive 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 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 to as a single undifferentiated member for the purposes of this report only. The undifferentiated member is about 1,200 ft (366 m) thick in this area and is predominantly a gray, carbonaceous to noncarbonaceous shale with local plant fossils, and interbedded light gray to tan, calcareous sandstone with interstitial siderite.

The informally-named Hogback Mountain Tongue of the Menefee (Beaumont, 1971) represents thick paludal sediments shoreward of and intertonguing with the massive marine sand of the La Ventana Tongue of the Cliff House Sandstone. In this quadrangle the Hogback Mountain Tongue is distinguishable from the lower Menefee deposits because it overlies a basal La Ventana tongue, intertongues with the middle part of the La Ventana, and is overlain by an upper La Ventana tongue. This member of the Menefee Formation is recognized as a major coal-bearing unit. The thickness of the Hogback Tongue is approximately 275 ft (84 m) in the souhwestern portion of the area; however, it thins in a northeasterly direction where it grades laterally into the La Ventana. Similar in lithology to the underlying undifferentiated member of the Menefee Formation, the Hogback

Mountain Tongue consists of gray, carbonaceous shale with plant fossils, interbedded light gray to tan, calcareous sandstone, and random coal beds.

Conformably overlying and intertonguing with the Menefee Formation is the La Ventana Tongue, the basal member of the Cliff House Sandstone. The basal part of the La Ventana Tongue averages 145 ft (44 m) in thickness and overlies the undifferentiated member of the Menefee Formation. Above this basal wedge the La Ventana intertongues with the Hogback Mountain Tongue of the Menefee. An upper wedge of La Ventana sand, about 108 ft (33 m) thick, overlies the Hogback Mountain Tongue throughout the quadrangle. These massive sandstone tongues of the La Ventana are composed of cream to light gray, friable, calcareous sandstone.

The upper member of the Cliff House Sandstone, the Chacra Tongue (informal name of local usage), is a transgressive sand deposit. The massive nearshore facies is present in the southern portion of the quarangle and is exposed at Chacra Mesa, the type section southeast of the quadrangle. From southwest to northeast, the Chacra lithology shows a seaward transition from massive nearshore sandstone to marine deposits of the Lewis Shale. Consequently, in that direction the sandstone is siltier, and interbedded sandy shale and siltstone are more abundant.

The marine Lewis Shale conformably overlies the Mesaverde Group. In contrast to the underlying Cliff House Sandstone, it is predominantly a gray, calcareous, fissile shale with local plant fossils. The Lewis averages 195 ft (59 m) in thickness throughout the quadrangle. The upper contact of the Lewis Shale grades into the overlying Pictured Cliffs Sandstone and, therefore, is difficult to determine.

The Pictured Cliffs Sandstone averages 90 ft (27 m) in thickness throughout the quadrangle. It consists of light gray to tan, friable, glauconitic sandstone with interstitial kaolinite, interbedded with shale 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 Sandstone 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 coals.

The Fruitland Formation is the major coal-bearing unit in the quadrangle. It averages 300 ft (91 m) in thickness in the area, and consists of tan to gray to gray-green, carbonaceous, calcareous shale with plant fossils, interbedded gray siltstone, and coal beds of varying thicknesses. The thickest and most continuous coal beds occur near the base of the formation, while discontinuous and lenticular coal beds 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 in establishing the upper contact but, in gereral, for the purposes of this report the uppermost coal was chosen (after Fasset and Hinds, 1971).

The freshwater deposits of the Kirtland Shale are the youngest Cretaceous strata in the area. They average 500 ft (152 m) in thickness and consist of gray shale with local plant fossils, and interbedded gray siltstone. The formation has previously been divided into several members by various authors; however, for the purposes of this report the individual members were not differentiated.

Unconformably overlying the Upper Cretaceous strata is the Paleocene Ojo Alamo Sandstone. It is composed primarily of about 120 ft (37 m) of white to tan, coarse-grained to conglomeratic sandstone, and interbedded gray-green to brown shale.

The Nacimiento Formation gradationally overlies the Ojo Alamo Sandstone and lacks a distinct basal contact. The lower one hundred feet (30 m) of the Nacimiento crop out within the quadrangle area and predominantly consist of gray to brown shale, interbedded gray-green claystone, and interbedded tan sandstone.

A total of four formations crop out within the quadrangle area. The outcrop pattern trends in a general northwest-southeast direction, with successively younger formations exposed to the northeast. The oldest outcrop is the upper portion of the Fruitland Formation in the southwestern corner of the quadrangle. The entire sections of the Kirtland Shale and the Ojo Alamo Sandstone crop out consecutively to the northeast. The lowermost beds of the Nacimiento Formation, the youngest formation in the area, are exposed in the extreme northeastern corner of the quadrangle.

Structure

The axis of the San Juan Basin is about 30 miles (48 km) north of the Alamo Mesa west quadrangle area, and trends in an arcuate pattern across the northern portion of the Central Basin (Baltz, 1967). Regional dip within the quadrangle is approximately 2° to the north, as measured 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 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 and the coals have been plotted and correlated based upon their position in the column relative to the datum. Correlations in coal test holes (U.S. Department of the Interior, 1976) and measured sections (Bauer and Reeside, 1921) are based upon previous correlations and geologic maps (Bauer and Reeside, 1921; U.S. Department of the Interior, 1976).

One coal zone (Menefee) and five coal beds (Menefee 1, Menefee 2, Menefee 3, Fruitland 1, Fruitland zone A) were identified in the subsurface and one coal zone (Fruitland) was mapped on the surface of this quadrangle (CRO Plate 1).

Many of the coal beds of the Menefee Formation have been combined 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 coals are generally noncorrelative, discontinuous, and less than reserve base thickness (5 ft [1.5 m]) as established by the U.S. Geological Survey. Coal beds in the Hogback Mountain Tongue (Beaumont, 1971) of the Menefee Formation which are greater than reserve base thickness have been designated as the Menefee 1, Menefee 2, and Menefee 3. These coals each occur in a single drill hole: Menefee 1 in drill hole 12, Menefee 2 in drill hole 10, and the Menefee 3 in drill hole 9 (CRO Plate 3). Consequently, derivative maps were not constructed.

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 ranging from 10,830 to 11,103 Btu's per pound (25,191-25,826 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 (Bauer and Reeside, 1921; Dane, 1936). The "as received" analyses indicate moisture content varying from 14.4 to 19.0 percent, ash content ranging from 5.4 to 10.2 percent, sulfur content less than one percent, and heating values on the average of 10,030 Btu's per pound (23,330 kj/kg). Analyses of several Menefee Formation coals are given in Table 1 (Bauer and Reeside, 1921; Lease, 1971).

The Fruitland 1 coal bed (Fr 1) is defined by the authors as the lowermost coal of the Fruitland Formation; generally, it occurs directly above the Pictured Cliffs Sandstone. The upper Fruitland Formation coal beds

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	

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

are designated as the Fruitland coal zone (Fr zone). These coal beds are usually discontinuous, noncorrelative, and less than reserve base thickness (5 ft [1.5 m]); exceptions are a 6-ft (1.8 m) bed in drill hole 9, an 8-ft (2.4 m) bed in drill hole 12, a 9-ft (2.7 m) bed in drill hole 13, and a 14-ft (4.3 m) and a 6-ft (1.8 m) bed in drill hole 18 (CRO Plate 1). Several of the upper Fruitland coal beds crop out in the southern portion of the quadrangle. The traces of the outcrop have been modified from the original data source to conform with the modern topographic map (CRO Plate 1).

The coal beds of the Fruitland Formation in the southern part of the San Juan Basin are considered high volatile C bituminous in rank, although they vary from subbituminous B to high volatile C bituminous. The rank has been determined on a moist, mineral-matter-free basis with calorific values ranging from 10,483 to 12,782 Btu's per pound (24,383-29,731 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 (Bauer and Reeside, 1921; Dane, 1936). The "as received" analyses indicate moisture content varying from 6.7 to 17.6 percent, ash content ranging from 10.1 to 27.7 percent, sulfur content less than one percent, and heating values varying from 7,410 to 11,320 Btu's per pound (17,236-26,330 kj/kg). Analyses of several Fruitland Formation coal beds are given in Table 2 (Fassett and Hinds, 1971; Shomaker, 1971).

The Fruitland zone A coal beds occur within the Fruitland coal zone and represents a thick accumulation of coal which is not extensive. Coal of the Fruitland zone A is considered subbituminous A to subbituminous B in rank. The rank has been determined on a moist, mineral-matter-free basis with calorific values ranging from 9,917 to 11,256 Btu's per

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			Approx. Depth Interval of Sample (ft.)	Form of Analysis	Proximate, percent					Heating Value (Btu)	Remarks
		Section	T.N.	R.W.			Moisture	Volatile matter	Fixed Carbon	Ash	Sulfur		
*14	Core Sample	SE¼ 1	23	13	80-87	A	15.4	24.8	40.7	19.1	0.64	8,652	
						B	----	29.3	48.1	22.6	0.76	10,227	
*15	Core Sample	SE¼ 1	23	13	97-116	A	15.8	22.2	35.4	26.6	0.48	7,630	
						B	----	26.4	42.0	31.6	0.57	9,062	
*1	Core Sample	SE¼ 1	23	13	192-209	A	13.0	23.5	36.4	27.1	0.6	7,410	
						B	----	27.0	41.8	31.2	0.7	8,520	
H-22722	N.M.P.S.C.C. DH-3-2	SW¼ 3	23	13	42-44	A	6.7	35.9	46.9	10.5	0.6	11,320	Coal core not floated in CCl_4
						B	----	38.5	50.3	11.2	0.6	12,140	
						C	----	43.4	56.6	----	0.7	13,680	
*53	Core Sample	SW¼ 4	23	13	33-40	A	17.6	20.7	34.0	27.7	0.71	8,098	
						B	----	25.1	41.3	33.6	0.86	9,828	
*54	Core Sample	SW¼ 4	23	13	132-140	A	16.4	27.8	45.7	10.1	0.70	10,075	
						B	----	33.2	54.7	12.1	0.84	12,051	
H-19885	N.M.P.S.C.C. DH-32-1	NW¼ 32	24	13	100-112	A	12.0	32.5	39.3	16.2	0.5	9,670	Coal core crushed and floated in CCl_4
						B	----	36.9	44.7	18.4	0.6	10,990	
						C	----	45.2	54.8	----	0.7	13,460	
*28	Core Sample	SE¼ 32	24	13	17-21	A	14.4	31.8	40.7	13.1	0.58	9,067	
						B	----	37.1	47.6	15.3	0.68	10,592	

*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

pound (23,067-26,181 kj/kg) (Amer. Soc. for Testing and Materials, 1977). The "as received" analyses indicate moisture content varying from 13.4 to 22.3 percent, ash content ranging from 11.2 to 40.2 percent, sulfur content less than one percent, and heating values on the average of 8,329 Btu's per pound (19,373 kj/kg). Analyses of several coals from the Fruitland zone A are given in Table 3 (U.S. Dept. of the Interior, 1976).

Menefee Coal Zone

The structure contour map of the Menefee coal zone (CRO Plate 5) was constructed using the top of the La Ventana Tongue of the Cliff House Sandstone. 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 occuring uppermost Menefee coal.

As illustrated by the structure contour map (CRO Plate 5), the Menefee zone dips approximately 1° to the north. Due to topography and dip, overburden (CRO Plate 6) varies from less than 800 ft (244 m) in the southwest to greater than 1,800 ft (549 m) in the north. Also shown on CRO Plate 6 is the total amount of interburden, the noncoal portion of the zone. The interburden thickness varies from less than 1,600 ft (488 m) to greater than 1,700 ft (518 m). The large interburden values are the result of the stratigraphic spread of the coal beds and reflect the thickness of the undifferentiated Menefee Formation plus the interfingering La Ventana and Hogback Mountain Tongues. The isopach map (CRO Plate 4) illustrates the total combined thickness of the individual coal beds of the Menefee zone.

TABLE 3

Analyses of coal samples from the Fruitland Zone A Coal Bed

(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.			Moisture	Volatile matter	Fixed Carbon	Ash	Sulfur		
D176821	Core Sample DH-2	SE¼ 6	23	12	101.0-102.0 103.7-111.0	A	20.2	31.0	34.7	14.1	.5	8,920	
						B	----	38.8	43.5	17.7	.6	11,180	
						C	----	47.2	52.8	----	.8	13,580	
D176822	Core Sample DH-2	SE¼ 6	23	12	113.0-119.6	A	16.2	32.7	34.2	16.9	.6	9,030	
						B	----	39.0	40.8	20.2	.7	10,780	
						C	----	48.9	51.1	----	.9	13,500	
D176823	Core Sample DH-2	SE¼ 6	23	12	132.3-137.0 138.0-141.0	A	22.3	29.6	31.2	16.9	.4	8,230	
						B	----	38.1	40.2	21.8	.5	10,590	
						C	----	48.7	51.3	----	.7	13,540	
D176824	Core Sample DH-2	SE¼ 6	23	12	141.0-143.1	A	13.4	30.5	31.6	24.5	.4	8,160	
						B	----	35.2	36.5	28.3	.5	9,420	
						C	----	49.1	50.9	----	.6	13,140	
D176820	Core Sample DH-2	SE¼ 6	23	12	96.5-101.0	A	17.8	33.0	31.4	17.8	.6	8,760	
						B	----	40.1	38.2	21.7	.7	10,660	
						C	----	51.2	48.8	----	.9	13,600	
D177033- D177034	Composite Core Sample DH-1	NW¼ 6	23	12	297.5-302.0 302.0-317.5	A	17.9	29.5	32.3	20.3	.4	8,260	
						B	----	35.9	39.3	24.8	.5	10,060	
						C	----	47.7	52.3	----	.7	13,380	
D177035- D177036	Composite Core Sample DH-1	NW¼ 6	23	12	320.4-330.0 330.0-338.0	A	15.5	21.8	22.5	40.2	.4	5,610	
						B	----	25.8	26.7	47.5	.4	6,640	
						C	----	49.1	50.9	----	.8	12,650	
D177039	Core Sample DH-3	NW¼ 7	23	12	53.4-57.7	A	16.2	24.9	21.8	37.1	.5	5,980	
						B	----	29.7	26.0	44.3	.6	7,140	
						C	----	53.3	46.7	----	1.1	12,810	

TABLE 3 (Continued)

Analyses of coal samples from the Fruitland Zone A Coal Bed

(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.			Moisture	Volatile Matter	Fixed Carbon	Ash	Sulfur		
D177040	Core Sample DH-3	NW 7	23	12	81.8-89.5	A	20.4	29.0	36.9	13.7	.4	8,870	
						B	——	36.4	46.4	17.1	.5	11,140	
						C	——	44.0	56.0	——	.6	13,460	
D177041	Core Sample DH-3	NW 7	23	12	100.0-105.5	A	22.3	27.9	35.0	14.8	.4	8,440	
						B	——	35.9	45.0	19.0	.5	10,860	
						C	——	44.4	55.6	——	.6	13,420	
D177043	Core Sample DH-4	SW 7	23	12	40.3-48.0	A	17.4	30.2	39.2	13.2	.5	9,340	
						B	——	36.6	47.5	16.0	.6	11,310	
						C	——	43.5	56.5	——	.7	13,460	
D177044	Core Sample DH-4	SW 7	23	12	60.3-64.9	A	14.5	30.9	36.5	18.1	.5	9,050	
						B	——	36.1	42.7	21.2	.6	10,580	
						C	——	45.8	54.2	——	.7	13,430	
D178925	Core Sample DH-6	SW 8	23	12	133.8-138.4	A	20.9	31.0	36.9	11.2	.4	9,280	
						B	——	39.2	46.6	14.2	.5	11,730	
						C	——	45.7	54.3	——	.6	13,670	
D178926	Core Sample DH-6	SW 8	23	12	141.9-142.8 146.3-147.5	A	17.4	27.7	26.6	28.3	.5	7,310	
						B	——	33.6	32.2	34.2	.6	8,850	
						C	——	51.0	49.0	——	.9	13,450	
D178928	Core Sample DH-5	NW 17	23	12	57.1-64.0	A	17.2	31.6	39.4	11.8	.4	9,700	
						B	——	38.1	47.7	14.2	.5	11,720	
						C	——	44.5	55.5	——	.6	13,660	

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

The greatest accumulation occurs in the central portion of the quadrangle where the coals total more than 20 ft (6.1 m) thick. The thickness decreases to less than 10 ft (3.0 m) to the west and south.

Chemical Analyses of the Menefee Zone Coal Beds - No published analyses of the quality of Menefee Formation coals are available for this quadrangle. However, information from surrounding areas is assumed to be similar to that for the coals from this quadrangle. Analyses of several Menefee Formation coals are given in Table 1 (Bauer and Reeside, 1921; Lease, 1971).

Fruitland 1 Coal Bed

As shown by the structure contour map (CRO Plate 8), the coal bed dips approximately 1° to the north. Due to topography and dip, overburden (CRO Plate 9) ranges from less than 100 ft (30.5 m) in the southwest to greater than 1,100 ft (335 m) in the north. The isopach map (CRO Plate 7) indicates that the greatest thickness of the Fruitland 1 coal bed occurs in the eastern-central part of the quadrangle where the coal is greater than 15 ft (4.6 m). The thickness decreases to less than 5 ft (1.5 m) to the south, west, and north.

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

Fruitland Zone A Coal Bed

As illustrated by the structure contour map (CRO Plate 12), the coal beds dip approximately 1° to the northeast. Due to topography and dip, overburden (CRO Plate 13) varies from less than 100 ft (30.5 m) in the south to greater than 600 ft (183 m) to the northeast. The interburden is also shown on CRO Plate 13 and ranges from zero to greater than 20 ft (6.1 m) in the south. The greatest accumulation of coal, as illustrated by the isopach map (CRO Plate 11), occurs in the southeastern part of the quadrangle. In this area the coal totals greater than 35 ft (10.7 m) and decreases in thickness in all directions. The Fruitland zone A coal appears to be present in only the southeastern portion of this quadrangle, extending into portions of the adjacent quadrangles, Tanner Lake and Alamo Mesa East.

Chemical Analyses of the Fruitland Zone A Coal Beds - Several analyses of Fruitland zone A coals from this quadrangle and the surrounding area are given in Table 3 (U.S. Dept. of the Interior, 1976).

Fruitland Coal Zone

The Fruitland coal zone extends from the top of the uppermost Fruitland coal to the base of the lowermost coal designated on CRO Plate 3 as a Fruitland zone coal bed. Therefore, the structure contour map (CRO Plate 16) was constructed using the top of the uppermost coal bed of the Fruitland Formation. The coal zone dips approximately 1° to the north. Due to topography and dip, overburden (CRO Plate 17) ranges from zero at the outcrop of the uppermost coal to greater than 1,000 ft (305 m) in the northern portion of the quadrangle. The isopach map (CRO Plate 15) shows that the greatest combined thickness occurs in the northwest, where the coals total more than 20 ft (6.1 m) thick. From this area, the thickness decreases in all directions.

Chemical Analyses of the Fruitland Zone Coal Beds - Analyses of several Fruitland Formation coal beds from this quadrangle and the surrounding area are given in Table 2 (Fassett and Hinds, 1971; Shomaker, 1971).

COAL RESOURCES

Coal resource data from oil and gas wells (El Paso Natural Gas Co., 1978, unpublished data in well log library in Farmington, New Mexico), coal test holes (U.S. Dept. of Interior, 1976), and geologic maps (Bauer and Reeside, 1921; Beaumont and Speer, 1976), were utilized in the construction of outcrop, isopach, and structure contour maps of coals in this quadrangle. Outcrop traces of the Fruitland zone coal beds in the southern half of the quadrangle (CRO Plate 1) are modified from Bauer and Reeside (1921).

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. 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 (CRO Plates 10 and 14) 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 a conversion factor for bituminous or subbituminous coal, which yields the Reserve Base coal, in short tons, for each coal bed. The conversion factor for bituminous coal (Fruitland 1) is 1,800 short tons of coal per acre-foot (13,239 tons/hectare-meter) and that of subbituminous coal (Fruitland zone A) is 1,770 short tons of coal per acre-foot (13,018 tons/hectare-meter).

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 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 219 million short tons (199 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 Alamo Mesa West 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 (Fruitland 1) 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

For subbituminous coal (Fruitland zone A), 0.912 is substituted for 0.896 in the above equation.

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 4 and 5 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 high development potential in small areas in the extreme southwest corner of the area (CDP Plate 18), where the coal bed thickness is approximately 7 ft (2.1 m) (CRO Plate 7), and the overburden thickness is less than 100 ft (30 m) (CRO Plate 9). The Fruitland zone A coal bed has high development potential in the southeast corner where it is 15 to 30 ft (4.6-9.1 m) thick (CRO Plate 11) and overlain by 100 to 200 ft (30-61 m) of overburden (CRO Plate 13). Small areas of moderate and low potential for the Fruitland zone A bed occur adjacent to the high potential area. The Fruitland 1 has moderate and low development potential in the southwest quarter of the quadrangle adjacent to the PRLA lands. The coal bed thickness in the area varies from 7 to 10 ft (2.1-3.0 m) and overburden ranges from 100 to 200 ft (30-61 m) thick.

The remainder of the quadrangle has no surface coal development potential. This includes areas beyond the stripping limits (200-foot [61-m] overburden) of the Fruitland 1 and Fruitland zone A beds.

Development Potential for Subsurface Mining Methods

Underground coal of the Fruitland 1 coal bed has high development potential in the central and southeastern parts of the quadrangle, as well as

TABLE 4

STRIPPABLE COAL RESOURCES FOR FEDERAL COAL LANDS (in short tons) IN THE ALAMO MESA WEST 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	22,910,000	2,350,000	1,440,000	26,700,000
Fruitland 1	1,230,000	2,260,000	26,680,000	30,170,000
TOTAL	24,140,000	4,610,000	28,120,000	56,870,000

TABLE 5

COAL RESOURCE DATA FOR UNDERGROUND MINING METHODS FOR FEDERAL COAL LANDS (in short tons) IN THE ALAMO MESA WEST 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	16,120,000	--	--	16,120,000
Fruitland 1	125,010,000	19,800,000	--	144,810,000
TOTAL	141,130,000	19,800,000	--	160,930,000

in small areas in the north and southwest (CDP Plate 19). Coal bed thickness increases from 5 ft (1.5 m) in the north and south to 18 ft (5.5 m) at the southeast-central part of the area (CRO Plate 7). Overburden ranges from 200 ft (61 m) in the south to 1,000 ft (305 m) at the northern zone of high potential (CRO Plate 9). The Fruitland zone A coal bed has underground development potential only in the southeast quarter of the quadrangle, where it has high potential coincident with the Fruitland 1 (northwest corner of southeast quadrant). The coal bed thickness in that area varies from 5 ft (1.5 m) to 30.5 ft (11.7 m) (CRO Plate 11) and overburden ranges from 200 to 500 ft (61-152 m) (CRO Plate 13).

The Fruitland 1 has moderate development potential near the center of the quadrangle's northern border where the coal is greater than 5 ft (1.5 m) thick and the overburden ranges from 1,000 to more than 1,100 ft (305-335 m) thick.

A major portion of the northern half of the quadrangle area has unknown development potential because the coal of the Fruitland 1 bed is less than the reserve base thickness (5 ft [1.5 m]). The Fruitland zone A coal bed does not extend into this area. The area of unknown development potential in the extreme southeastern corner also includes Fruitland 1 coal less than 5 ft (1.5 m) thick; however, the Fruitland zone A coal bed has surface development potential in this area.

The remainder of the quadrangle (southwest corner) has no development potential and includes areas inside the stripping limits for Fruitland 1 and Fruitland zone A coal beds.

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