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

[Report includes 24 plates]

by

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TANNER LAKE 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 Tanner Lake 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 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 Tanner Lake 7 1/2-minute quadrangle is in southeastern San Juan County, New Mexico. The area is approximately 35 miles (56 km) south of Farmington and 54 miles (87 km) northeast of Gallup, New Mexico.

Accessibility

The area is accessible by a light-duty road which extends southward from Farmington, New Mexico. Numerous unimproved dirt roads provide further 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 5,760 ft (1,756 m) in the Chaco River Valley to 6,240 ft (1,902 m) in the southeast. The topography is typified by gently sloping plains, which are interrupted by the Chaco River Valley in the southwest corner of the quadrangle. The Chaco River and its major tributaries, Rock Wash and Tsaya Canyon, occupy steep-walled canyons which provide local relief of more than 200 ft (61 m) in some places. De-na-zin Wash, a broad, flat stream valley, drains the northern portion of the 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 above 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

Approximately 37 percent of the quadrangle is in the southwestern boundary 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 within the quadrangle as shown on Plate 2 of the Coal Resource Occurrence Maps. Preference Right Lease applications (NM 3752, NM 3754, and NM 3835) cover 22 percent of the KRCRA. Coal Leases (NM 0186612, NM 0186613, and NM 0186615) cover 16 percent of the quadrangle.

GENERAL GEOLOGY

Previous Work

Bauer and Reeside (1921) have mapped the Fruitland Formation within the quadrangle with emphasis on outcrops of Fruitland coal beds and clinker. Reeside (1924) has mapped the Upper Cretaceous and Tertiary formations of the San Juan Basin. Shomaker (1971a) described in detail the surface occurrences of Fruitland Formation coal and estimated the strippable reserves by township and range. A publication by Fassett and Hinds (1971) includes subsurface interpretations of the Fruitland Formation coal deposits throughout the San Juan Basin. A combined study by the Bureau of Land Management, Bureau of Reclamation, and Geological Survey (1976) contains evaluations of the resources and the potential reclamation of the Bisti coal field, part of which is 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 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 in the upper part of the Menefee Formation. Subsequently, beach sands of the La Ventana Tongue (Cliff House Sandstone) were deposited over the Menefee in the northeast part of the quadrangle.

Onlap continued as the sea moved southwestward across the basin area. The transgressing northwest-southeast-trending strandline is represented in the lithologic record by several hundred feet of the Chacra Tongue (informal name of local usage) of the Cliff House Sandstone above the La Ventana Tongue in the northeast and Menefee in the southwest. 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. 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 freshwater sediments 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. Terrestrial deposition resumed in the Paleocene as represented by the Ojo Alamo Sandstone and the overlying Nacimiento Formation. The nonmarine Eocene 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 much 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 (undifferentiated), and Cliff House Sandstone; the Lewis Shale, Pictured Cliffs Sandstone, Fruitland Formation, and Kirtland 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 light gray, slightly calcareous, argillaceous, kaolinitic sandstone. It is fairly massive, averages about 170 ft (52 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 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 into the Cleary Coal Member, the barren Allison Member, and an unnamed upper coal-bearing member (Beaumont and others, 1956). These three members are referred to as the undifferentiated Menefee Formation for the purposes of this report only. The Menefee in this area is about 2,040 ft (622 m) of gray, carbonaceous to noncarbonaceous 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 basal member of the Cliff House Sandstone, the La Ventana Tongue.

In the northeastern portion of the quadrangle the La Ventana overlies the Menefee Formation, but toward the southwest (shoreward) it intertongues with and wedges out into the Menefee. The La Ventana in the area is about 80 ft (24 m) of cream to light gray, friable, calcareous sandstone.

The upper member of the Cliff House Sandstone is the Chacra Tongue (informal name of local usage) which is about 350 ft (107 m) thick in this area. It overlies the La Ventana Tongue in the northeastern part of the quadrangle; however, it overlies the Menefee in the southwestern part of the area where the La Ventana wedges out. The Chacra consists of thickly-bedded, light gray, slightly glauconitic sandstone, and interbedded gray shale with plant fossils. It is exposed in the canyons of Chaco Wash which trend northwest-southeast across 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 plant fossils. The Lewis averages 190 ft (58 m) in thickness in the northeastern part of the quadrangle. The upper contact of the Lewis Shale is gradational with the overlying Pictured Cliffs Sandstone and, therefore, is difficult to determine.

The Pictured Cliffs Sandstone consists of about 130 ft (40 m) of light gray to tan, friable, kaolinitic sandstone commonly interbedded with thin shale near the base of the formation where it grades into the Lewis and the Pictured Cliffs. The upper contact is more sharply defined than the basal contact, even though intertonguing with the overlying Fruitland results in minor variations in the formational top. Since the Pictured Cliffs is present throughout most of the basin and displays a distinctive nature 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 has an average thickness of approximately 270 ft (82 m) and consists of gray to brown, carbonaceous, calcareous shale with plant fossils, interbedded light gray 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 coal beds are characteristic of the upper portion of the formation.

The freshwater deposits of the Kirtland Shale are the youngest Cretaceous strata in the area. They consist of gray shale with plant fossils and interbedded gray siltstone.

Surface exposures in the quadrangle are influenced by the regional dip of 1° to 3° to the northeast, which exposes the progressively younger Cretaceous strata in a northeasterly direction. The oldest unit exposed in the quadrangle is the Chacra Tongue which crops out in the canyon walls of Chaco Wash. The younger Lewis Shale has been stripped from the resistant sandstone beds around Chaco Wash and crops out in a belt across the northeastern portion of the quadrangle. The entire sections of the Pictured Cliffs Sandstone and the Fruitland Formation are exposed in the northeastern corner of the quadrangle. The youngest formation exposed in the quadrangle is the Kirtland Shale, with the lowermost beds cropping out across the extreme northeastern corner of the quadrangle.

Structure

The axis of the San Juan Basin is about 40 miles (64 km) northeast of the Tanner Lake quadrangle area and trends in an arcuate pattern across the northern portion of the Central Basin area (Baltz, 1967). Measured regional dip within the quadrangle (in T. 23 N., R. 13 W.) is 3° 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 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 each drill hole, and the coals have been plotted in the column and correlated based upon their position relative to the datum. Correlations of the Fruitland coals in coal test holes and measured sections are based upon geologic maps (Bauer and Reeside, 1921; Lease, 1971) and previous correlations (U.S. Department of the Interior, 1976).

Three coal beds (Menefee 1, Fruitland 1, Fruitland zone B) and a coal zone (Fruitland) are mapped on the surface, and a coal zone (Menefee) and a coal bed (Fruitland zone A) are identified in the subsurface of this quadrangle (CRO Plate 1). The Menefee Formation coal beds are designated as the Menefee coal zone (Me zone). These coals are generally noncorrelative and less than reserve base thickness (5 ft [1.5 m]) as set by the U.S. Geological Survey. The wide vertical distribution of Menefee zone coal beds is not apparent in this quadrangle due to lack of deeply drilled well information. Derivative maps of the Menefee coal zone were not required by the U.S. Geological Survey.

Within the Menefee coal zone, near the top of the formation, is a locally correlative coal bed. This bed has been designated the Menefee 1 bed (Me 1) by the authors. The coal bed crops out in the southern and western portions of the quadrangle (CRO Plate 1) and extends into the Pillar 3 NE quarter 7 1/2-minute quadrangle.

Coal beds of the Menefee Formation 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 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 generally less than one percent, and heating values on the order 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).

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.

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 crops out across the northern portion of the quadrangle. The trace of this 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) which extends from the top of the Fruitland Formation to the lowermost coal designated on CRO Plate 3 as a Fruitland zone coal bed. The zone consists of several coal beds which are generally of less than reserve base thickness (5 ft [1.5 m]); an exception is a 5.6-ft (1.7-m) coal in measured section 18 (CRO Plate 1). Several coal beds of the Fruitland zone crop out in the northern portion of the quadrangle. The traces of the outcrop have been modified from the original data source to conform with modern topographic maps (CRO Plate 1).

Within the Fruitland coal zone are two locally thick accumulations of coal, and these have been named the Fruitland zone A (Fr zone A) and Fruitland zone B (Fr zone B) by the authors. The Fruitland zone A is present in five drill holes in the northeastern portion of the quadrangle and varies from a single bed in drill hole 12 to three beds in drill holes 7, 8, 10, and 11 (CRO Plate 3). The Fruitland zone B varies from two coal beds in drill hole 10 to three coal beds in drill hole 11 (CRO Plate 3). It has been inferred for purposes of reserve and reserve base calculations that the Fruitland zone B crops out in a small portion of the northeastern part of the map.

Fruitland Formation coal beds 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 of the coal has been determined on a moist, mineral-matter-free basis with calorific values ranging from 9,675 to 12,876 Btu's per pound (22,504-29,950 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 5.39 to 25.0 percent, ash content ranging from 10.5 to 42.8 percent, sulfur content less than one percent, and heating values varying from 5,200 to 11,320 Btu's per pound (12,095-26,330 kj/kg). Analyses of several Fruitland Formation coal beds are given in Table 2 (Bauer and Reeside, 1921; Dane, 1936; Fassett and Hinds, 1971; Shomaker, 1971a; U.S. Dept. of the Interior, 1976).

The coal beds of the Fruitland zone A are considered borderline 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 pound (23,067-26,181 kj/kg) (Amer. Soc. for Testing and Materials, 1977). The "as received" analyses of the Fruitland zone A coal beds 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 averaging 8,329 Btu's per pound (19,373 kj/kg). Analyses of several Fruitland zone A coal beds are given in Table 3 (U.S. Dept. of the Interior, 1976).

The coal beds of the Fruitland zone B are considered subbituminous B in rank. The rank has been determined on a moist, mineral-matter-free basis with a calorific value of 10,098 Btu's per pound (23,488 kj/kg) (Amer. Soc. for Testing and Materials, 1977). The "as received" analyses indicate

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
D177042	Core Sample	NW¼ 7	23	12	113.7-116.9	A	25.0	28.5	33.3	13.2	0.4	8,390	
						B	—	38.0	44.4	17.6	0.6	11,180	
						C	—	46.2	53.8	—	0.7	13,580	
D177045	Core Sample	SW¼ 7	23	12	69.2- 71.4	A	11.1	25.5	24.6	38.8	0.4	6,640	
						B	—	28.7	27.6	43.7	0.4	7,470	
						C	—	51.0	49.0	—	0.8	13,270	
D177046	Core Sample	NW¼ 8	23	12	30.6- 32.0	A	16.1	22.7	18.4	42.8	0.8	5,200	
						B	—	27.0	21.9	51.1	0.9	6,200	
						C	—	55.2	44.8	—	1.9	12,670	
*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	
D178929	Core Sample	NW¼ 17	23	12	74.8- 81.0	A	16.7	33.4	37.0	12.9	0.4	9,700	
						B	—	40.1	44.5	15.4	0.5	11,640	
						C	—	47.4	52.6	—	0.6	13,770	
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	
*63	Core Sample	SW¼ 8	23	13	72 - 81	A	13.2	26.0	47.8	12.3	0.63	9,851	
						B	—	30.2	55.5	14.3	0.73	11,349	
*3	Core Sample	NW¼ 11	23	13	80 - 95	A	10.3	23.3	35.6	30.8	0.7	7,436	
						B	—	26.0	39.7	34.3	0.7	8,290	
*4	Core Sample	NW¼ 11	23	13	105 -108	A	14.5	20.9	43.8	20.8	0.8	8,721	
						B	—	24.5	51.2	24.3	0.8	10,200	
*5	Core Sample	NW¼ 11	23	13	147 -163	A	14.9	24.4	44.5	16.1	0.6	9,470	
						B	—	28.7	52.4	18.9	0.7	11,140	

*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

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 Section	Location T.N.	Location R.W.	Approx. Depth Interval of Sample (ft.)	Form of Analysis	Proximate, percent: Moisture	Volatile matter	Fixed Carbon	Ash	Sulfur	Heating Value (Btu)	Remarks
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.

a moisture content of 21.7 percent, an ash content of 16.1 percent, a sulfur content of 0.4 percent, and a heating value of 8,340 Btu's per pound (19,399 kj/kg). An analysis of a Fruitland zone B coal bed is given in Table 4 (U.S. Dept. of the Interior, 1976).

Menefee 1 Coal Bed

As indicated by the structure contour map (CRO Plate 5), the coal bed dips approximately 1° in a northerly direction. Due to topography and dip, overburden (CRO Plate 6) ranges from zero at the outcrop to greater than 300 ft (91 m) on a mesa to the east. The isopach map (CRO Plate 4) illustrates that the coal bed is thickest in the south-central portion of the quadrangle. In this area, the coal bed is greater than 6 ft (1.8 m) thick. The thickness decreases in all directions, and the coal bed is absent in the northern portion of the quadrangle.

Chemical Analyses of the Menefee 1 Coal Bed - Analyses of several Menefee Formation coals from this quadrangle and the surrounding area are given in Table 1 (Bauer and Reeside, 1921; Lease, 1971; Shomaker, 1971b).

Fruitland 1 Coal Bed

As illustrated by the structure contour map (CRO Plate 9), the coal bed dips approximately 1° to the north. Overburden (CRO Plate 10) varies from zero at the outcrop to greater than 200 ft (61 m) in the north. The isopach map (CRO Plate 8) illustrates that, in the north, a portion of the

Analyses of coal samples from the Fruitland Zone B 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		
D177047-D177048	Composite Core Sample	NW¼ 8	23	12	78.4-87.0 87.4-94.7	A	21.7	29.6	32.6	16.1	.4	8,340	
						B	——	37.8	41.7	20.5	.5	10,660	
						C	——	47.5	52.5	——	.7	13,420	

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

northeast, and in a small area of the center, the Fruitland 1 coal bed is greater than 5 ft (1.5 m) thick. However, the coal bed is less than 5 ft (1.5 m) thick throughout most of the quadrangle.

Chemical Analyses of the Fruitland 1 Coal Bed - Analyses of several Fruitland Formation coal beds from this quadrangle are given in Table 2 (Fassett and Hinds, 1971; Shomaker, 1971a; U.S. Dept. of the Interior, 1976).

Fruitland Zone A Coal Beds

As illustrated by the structure contour map (CRO Plate 13), the Fruitland zone A dips less than 1° to the northeast. Due to topography and dip, overburden (CRO Plate 14) varies from less than 50 ft (15.2 m) to greater than 150 ft (45.7 m) to the northeast. Also shown on CRO Plate 14 is the interburden between the coal beds of the Fruitland zone A. The interburden varies from zero to greater than 30 ft (9.1 m). The isopach map (CRO Plate 12) shows that the Fruitland zone A is present only in the northeast part of this quadrangle. The largest accumulation of coal is greater than 20 ft (6.1 m) in the central part of the mapped area. The coal beds decrease in thickness to the east, south, and west.

Chemical Analyses of the Fruitland Zone A Coal Beds - Analyses of several Fruitland zone A coal beds are given in Table 3 (U.S. Dept. of the Interior, 1976).

Fruitland Zone B Coal Beds

As illustrated by the structure contour map (CRO Plate 17), the coal bed dips less than 1° to the northeast. Due to topography and dip, overburden (CRO Plate 18) ranges from zero at the inferred outcrop to greater than 50 ft (15.2 m) in the northeast. The isopach map (CRO Plate 16) shows that the Fruitland zone B is present only in the northeast portion of this quadrangle. Its greatest thickness of more than 15 ft (4.6 m) is in the northern part of the mapped area. The thickness decreases from this area.

Chemical Analyses of the Fruitland Zone B Coal Beds - An analysis of a Fruitland zone B coal bed is given in Table 4 (U.S. Dept. of the Interior, 1976).

Fruitland Coal Zone

The structure contour map of the Fruitland coal zone (CRO Plate 21) was drawn on top of the lowermost Fruitland zone coal bed. The top of the Fruitland coal zone is coincident with the top of the Fruitland Formation; however, since the lower part of the Fruitland Formation crops out in the northern portion of the quadrangle, the top of the lowermost coal was used as a mappable surface for the coal zone. As illustrated by the structure contour map (CRO Plate 21), the coal zone dips less than 1° to the northeast. Overburden (CRO Plate 22) increases from zero at the outcrop to greater than 100 ft (30.5 m) to the north. As indicated by the isopach map (CRO Plate 20), the greatest thickness of over 5 ft (1.5 m) occurs in the north-central and central portions of the map. Throughout the remainder of the quadrangle, the total thickness is less than 5 ft (1.5 m).

Chemical Analyses of the Fruitland Zone Coal Beds - Analyses of several Fruitland Formation coals from this quadrangle and the surrounding area are given in Table 2 (Fassett and Hinds, 1971; Shomaker, 1971a; U.S. Dept. of the Interior, 1976).

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 (U.S. Dept. of Interior, 1976; Lease, 1971), and geologic maps (Bauer and Reeside, 1921; Lease, 1971) were utilized in the construction of outcrop, isopach, and structure contour maps of the coals in this quadrangle. Outcrops of the Menefee 1 in the southern part of the quadrangle are modifed from Lease (1971). The Fruitland 1 and Fruitland zone outcrops in the central parts of the area are taken from Bauer and Reeside (1921), and outcrops of the Fruitland 1, Fruitland zone B, and Fruitland zone in the north are modified from Bauer and Reeside (1921) and the U.S. Department of the Interior (1976).

The U.S. Geological Survey designated the Menefee 1, Fruitland 1, Fruitland zone A, and Fruitland zone B 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 of 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 7, 11, 15, and 19) 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 4, 8, 12, and 16) and areal distribution (CRO Plates 7, 11, 15, and 19) 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-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.

Reserve Base and Reserve values for measured, indicated, and inferred categories of coal for the Menefee 1, Fruitland 1, Fruitland zone A, and Fruitland zone B beds are shown on CRO Plates 7, 11, 15, and 19, 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 78.8 million short tons (71.5 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 Tanner Lake quadrangle has development potential for both surface and subsurface mining methods (CDP Plates 23 and 24).

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 5 and 6 summarize the coal development potential, in short tons, for surface and underground coal, respectively, of the Menefee 1, Fruitland 1, Fruitland 2, and Fruitland zone B coal beds.

Development Potential for Surface Mining Methods

Strippable coal of the Menefee 1 coal bed has high development potential in the south-central part of the quadrangle (CDP Plate 23) where the coal is 5 to 6 ft (1.5-1.8 m) thick (CRO Plate 4) and the overburden thickness ranges from zero at the outcrop to approximately 50 ft (15.2 m) (CRO Plate 6). The Fruitland 1, Fruitland zone A, and Fruitland Zone B coal beds each have high potential in the northeastern corner of the area. Coal

TABLE 5

STRIPPABLE COAL RESOURCES FOR FEDERAL COAL LANDS (IN SHORT TONS) IN THE TANNER LAKE 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 B	40,000	10,250,000	0	10,290,000
Fruitland zone A	30,470,000	2,200,000	2,820,000	35,490,000
Fruitland 1	740,000	2,200,000	7,910,000	10,850,000
Menefee 1	13,160,000	6,720,000	1,880,000	21,760,000
TOTAL	44,410,000	21,370,000	12,610,000	78,390,000

TABLE 6

COAL RESOURCE DATA FOR UNDERGROUND MINING METHODS FOR FEDERAL COAL LANDS (in short tons) IN THE TANNER LAKE 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 1	--	--	200,000	200,000
TOTAL	--	--	200,000	200,000

bed thicknesses are 5 ft (1.5 m) for the Fruitland 1 (CRO Plate 8), 5 to 20 ft (1.5-6.1 m) for the Fruitland zone A (CRO Plate 12), and approximately 5 to 16 ft (1.5-4.9 m) for the Fruitland zone B (CRO Plate 16). The overburden thickness for these coal beds is approximately 75 ft (22.9 m) for the Fruitland 1 (CRO Plate 10), 50 to 100 ft (15.2-30.5 m) for the Fruitland zone A (CRO Plate 14), and zero to 78 ft (23.8 m) for the Fruitland zone B (CRO Plate 18). The Fruitland 1 coal bed also has high potential in the extreme northwestern corner of the area where the coal is approximately 5 ft (1.5 m) thick and the overburden thickness is 75 ft (22.9 m).

Coal of the Menefee 1 bed has moderate and low development potential in the south-central area where the coal thickness is 5 to 6 ft (1.5-1.8 m) and the overburden is 50 to 100 ft (15.2-30.5 m) thick. Areas of moderate and low potential in the northeast and northwest are the result of the Fruitland 1 bed. The coal in these areas is 5 ft (1.5 m) thick, and the overburden is 75 to 100 ft (22.9-30.5 m) thick in the northeast and 75 to 200 ft (22.9-61.0 m) thick in the northwest.

Several areas with unknown coal development potential occur in the northern half of the quadrangle (CDP Plate 23) where the Menefee 1 bed is underground, and the Fruitland 1, Fruitland zone A, and Fruitland zone B coal beds are less than the reserve base thickness of 5 ft (1.5 m). Large areas in the southwest, east-central, and north have no coal development potential and include areas outside the outcrops of the Menefee 1, Fruitland 1, and Fruitland zone B beds, and the limit of the Fruitland zone A bed, and areas beyond the stripping limits of the Menefee 1 coal bed.

Development Potential for Subsurface Mining Methods

Coal of the Fruitland 1 bed has high development potential along the central part of the northern quadrangle boundary (CDP Plate 24) where the coal is approximately 5 ft (1.5 m) thick (CRO Plate 8), and the overburden is about 200 ft (61 m) thick (CRO Plate 10).

The area of unknown potential across the center of the quadrangle is the result of the Menefee 1 coal bed which is less than 5 ft (1.5 m) thick in this area. The Fruitland zone A and Fruitland zone B beds have no subsurface development potential. The remainder of the area has no subsurface development potential and includes areas of strippable coal and areas outside the outcrops or limits of the Menefee 1, Fruitland 1, Fruitland zone A, and Fruitland zone B beds.

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