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COAL RESOURCE OCCURRENCE MAPS AND COAL DEVELOPMENT POTENTIAL MAPS OF THE STAR LAKE QUADRANGLE, MCKINLEY AND SANDOVAL COUNTIES, NEW MEXICO

[Report includes 16 plates]

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CONTENTS

CONTENTS

PLATES

CONTENTS

Page

TABLES

STAR 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 Star Lake quadrangle, McKinley and Sandoval Counties, 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) 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 Acts 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 Star Lake 7 1/2-minute quadrangle is in northeastern McKinley County and northwestern Sandoval County, New Mexico. The area is approximately 68 miles (109 km) southeast of Farmington and 74 miles (119 km) northeast of Gallup.

Accessibility

The Star Lake quadrangle is accessible from the east by New Mexico State Route 197 and State Route 44. Numerous light-duty and unimproved dirt roads provide access into the area. The Atchison, Topeka, and Santa Fe Railway operates a route which passes through Gallup 74 miles (119 km) to the southwest.

Physiography

The quadrangle is in the southern portion of the Central Basin area, and the northern portion of the Chaco Slope area (Kelley, 1950) of the larger structural depression known as the San Juan Basin. The quadrangle is also part of the Penistaja Cuestas physiographic sector (Baltz, 1967). Elevations range from 6,580 ft (2,006 m) in Papers Wash in the southeast to 6,989 ft (2,130 m) in the north. The Continental Divide passes through the quadrangle in a northeast-southwest direction. To the southeast of the divide, the major drainage system is Papers Wash and its tributaries; the North Fork of Chaco Wash drains the area to the northwest. The topography is characterized by sparsely vegetated, moderately dissected plains of low relief; Pot Mesa and Ceja Raton are areas of higher relief.

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, and 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 southern part of the basin.

Land Status

Approximately 92 percent of the quadrangle is in the southeastern part of the San Juan Basin Known Recoverable Coal Resource Area. The Federal Government owns the coal rights for 59 percent of the KRCRA within the quadrangle, as shown on Plate 2 of the Coal Resource Occurrence Maps. Federal coal leases (NM 585 and NM 2457) in the southern part of the KRCRA cover approximately 18 percent of the area. The Federal Government owns 22 percent of the coal rights outside the San Juan Basin Known Recoverable Coal Resource Area.

GENERAL GEOLOGY

Previous Work

Dane (1936) has mapped the Late Cretaceous and Tertiary strata as part of a study of the geology and fuel resources of the southern San Juan Basin. A more recent publication by Fassett and Hinds (1971) includes subsurface interpretations of the Fruitland Formation coal deposts throughout the San Juan Basin.

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

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. 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 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 freshwater sediments then covered the area as indicated by the lacustrine, channel, and floodplain sediments 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 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 and floodplain deposits of the Ojo Alamo were followed by the thick, lithologically varied 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 some 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 relations of all but the three uppermost 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 to medium gray, slightly calcareous sandstone with interbedded gray shale, and local coal beds. The thin, discontinuous coal beds are part of a thin Menefee tongue. The Point Lookout Sandstone is fairly massive, averages 80 ft (24 m) thick, and displays a distinctive character on geophysical logs. This last characteristic was used by the authors in establishing the top of the Point Lookout as a lithologic datum for correlation of the 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 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. This member is about 940 ft (286 m) thick in the area and is predominantly a gray, locally carbonaceous shale, with interbedded sandstone and siltstone and random coal beds.

The informally named Hogback Mountain Tongue represents thick, paludal deposits shoreward of the massive marine sand of the La Ventana Tongue. This member of the Menefee Formation is distinguished as a major coal-bearing unit. The stratigraphic equivalence and complex intertonguing of the Hogback Mountain with the La Ventana make it distinguishable in the area of intertonguing. The thickness of the Hogback Mountain Tongue is approximately 650 ft (198 m) in the southwestern portion of the area; however, it thins to the northeast as the La Ventana thickens. Similar in lithology to the underlying undifferentiated member, the Hogback Mountain Tongue is composed of gray, carbonaceous shale with iron-stained nodules and plant fossils, interbedded thin 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 La Ventana in the northeastern part of the quadrangle is composed of two massive sand wedges. Toward the southwest, they interfinger and pinch out into the Hogback Mountain Tongue. The La Ventana in this area is a 650-ft (198-m) thick sequence composed primarily of white to cream friable sandstone.

The uppermost member of the Cliff House Sanstone, the Chacra Tongue (informal name of local usage), overlies the La Ventana Tongue in the northeast and the Hogback Mountain Tongue in the southwest. It is about 330 ft (101 m) thick within the quadrangle and is composed of cream, locally kaolinitic, slightly calcareous, thin sandstone beds with interbedded shale and siltstone lenses. It represents a seaward transition from the thick sandstone beds of the type section (Chacra Mesa) to the south to the marine deposits of the Lewis Shale.

The Lewis Shale conformably overlies the Mesaverde Group. In contrast to the underlying Cliff House Sandstone, it is predominantly a gray to gray-brown calcareous shale with local plant fossils and limy nodules, and interbedded gray, calcareous sandstone. The Lewis averages 285 ft (87 m) thick throughout the quadrangle. The upper contact of the Lewis Shale is gradational with the overlying Pictured Cliffs Sandstone; and, therefore, it is difficult to establish.

The Pictured Cliffs Sandstone consists of cream to light brown, calcareous, poorly indurated sandstone commonly interbedded with thin, gray 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 results in minor variations in the formational top. Since the Pictured Cliffs is present throughout most of the basin and displays a distinctive character on geophysical logs, the authors have used the top of the unit as a lithologic datum for correlation of the overlying Fruitland coals.

The Fruitland Formation is the major coal-bearing unit in the quadrangle. It has an average thickness of 270 ft (82 m) and consists of dark gray, carbonaceous shale with local 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). Authors have used various criteria in determining 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. These deposits consist of brown to gray shale with local plant fossils and sandy stringers. The formation has previously been divided into several members by various authors; however, for the purposes of this report it was not necessary to distinguish between the individual members.

Unconformably overlying the Upper Cretaceous deposits is the Paleocene Ojo Alamo Sandstone which consists of approximately 200 ft (61 m) of white to light gray, coarse-grained to conglomeratic, friable sandstone with quartz and feldspar grains, interbedded with thin, gray to brown shale in the lower half.

The Nacimiento Formation grades into the underlying Ojo Alamo. Approximately 1,000 ft (305 m) of the Nacimiento are present and consist of gray to brown sandy shale, thin conglomeratic lenses, and siltstone.

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

Structure

The axis of the San Juan Basin is about 36 miles (58 km) northeast of the Star Lake quadrangle and trends in an arcuate pattern across the northern portion of the Central Basin (Baltz, 1967). Measured regional dip within the quadrangle ranges from 1° to 2° to the northeast (Dane, 1936). Dane also indicates that a fault extends across the southeast corner of this quadrangle. The amount of displacement was not determined.

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 and 2 coal beds have been correlated and mapped as if each 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 each drill hole, and the coals have been plotted in the column and correlated based upon their position relative to the datum. Correlations in the coal test holes (Chaco Energy, unpublished data; Beaumont and Speer, 1977) and measured sections (Beaumont and Speer, 1977) are based upon previous correlations and geologic maps (Beaumont and Speer, 1977).

Two coal beds (Fruitland 1 and 2) were mapped on the surface, and a coal zone (Menefee) was identified and mapped in the subsurface of this quadrangle. The Menefee coals were designated and mapped as the Menefee coal zone (Me zone). Many of the coals in the Menefee coal zone are correlative for short distances, and nearly all are less than the reserve base thickness of 5 ft (1.5 m) as set by the U.S. Geological Survey; exceptions are a 5-ft (1.5-m) coal bed in drill holes 1 and 4, and a 5-ft (1.5-m) and a 6-ft (1.8-m) coal bed in drill hole 17 (CRO Plate 1).

No published analyses of the quality of Menefee Formation coals are available for this quadrangle. However, information on the quality of coals from surrounding areas is assumed to be similar to that of the coals from this quadrangle. There is no apparent consistent difference between the various Menefee Formation coals. In the southern part of the San Juan Basin 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 9,983 to 11,966 Btu's per pound (23,220-27,833 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 about 12.1 to 20.0 percent, sulfur content between 0.6 and 2.8 percent, ash content ranging between 4.9 and 9.9 percent, and heating values on the order of 10,326 Btu's per pound (24,018 kj/kg). Analyses of several Menefee coals are given in Table 1 (Bauer and Reeside, 1921; Dane, 1936; Lease, 1971; Shomaker, 1971).

The Point Lookout Sandstone contains local, random Menefee coal beds in the upper portion where the formations interfinger. These coals have been designated as local beds because they are random, discontinuous, and less than the reserve base thickness of 5 ft (1.5 m).

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 southern part of the quadrangle. Above the Fruitland 1 (Fr 1) coal bed, separated by an average rock interval of 60 ft (18 m), is the Fruitland 2 (Fr 2) coal bed. The Fruitland 2 coal bed crops out and is present exclusively in the western portion of this quadrangle, extending westward through the Pueblo Alto Trading Post, Pueblo Pintado, Lybrook SE, and Fire Rock Well 7 1/2-minute quadrangles.

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 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
A47085	Mine Sample San Juan Mine	SW¼ 31	19	1	----	A	15.8	34.5	43.8	5.9	0.6	10,900	Cleary Member
						B	----	41.0	52.0	7.0	0.7	12,950	
A46366	Mine Sample San Juan Mine	SW¼ 31	19	1	----	A	15.7	32.0	45.1	7.2	0.6	10,790	Cleary Member
						B	----	38.0	53.5	8.5	0.7	12,800	
						C	----	41.5	58.5	----	0.8	13,990	
A47084	Prospect Pit Wilkins No. 2 Prospect	SW¼ 26	19	1	----	A	18.2	34.4	40.8	6.6	0.9	10,280	Cleary Member
						B	----	42.0	49.9	8.1	1.0	12,570	
A60026	Mine Sample Rio Puerco Mine	SE¼ 19	19	1	----	A	12.1	35.8	44.5	7.6	2.8	10,940	Allison Member
						B	----	40.7	50.6	8.7	3.2	12,460	
						C	----	44.6	55.4	----	3.5	13,640	
A64268	Mine Semple Anderson Mine	SE¼ 35	19	2	----	A	20.0	32.5	42.6	4.9	0.7	10,240	Allison Member
						B	----	40.7	53.2	6.1	0.8	12,790	
						C	----	43.3	56.7	----	0.9	13,630	
A46367	Prospect Drift	35	19	2	----	A	14.8	33.9	41.4	9.9	1.2	8,910	Allison Member; sample may have been somewhat weathered
						B	----	39.8	48.6	11.6	1.4	10,460	
						C	----	45.1	54.9	----	1.6	11,840	
3823	Mine Sample	14	20	11	----	A	17.5	32.9	41.2	8.4	2.2	----	
23004	Outcrop Sample	14	20	11	----	A	14.4	34.8	42.3	7.5	1.5	10,220	
						B	----	40.7	50.5	8.8	1.8	11,940	

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

The remaining Fruitland coals above the Fruitland 1 coal bed were designated as the Fruitland coal zone (Fr zone) (exclusive of the Fruitland 2 when present). None of the Fruitland zone coal beds are extensive, and the coals are generally less than the reserve base thickness of 5 ft (1.5 m); an exception is a 5.4-ft (1.6-m) coal in drill hole 8 (CRO Plate 1). Due to these characteristics, derivative maps were not constructed.

The coals of the Fruitland Formation in the southeastern part of the San Juan Basin are considered high volatile C bituminous in rank, although they range from subbituminous A to high volatile B bituminous. The rank has been determined on a moist, mineral-matter-free basis with calorific values ranging from 11,358 to 13,442 Btu's per pound (25,419-31,266 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 5.8 to 13.48 percent, ash content ranging from 5.8 to 32.68 percent, sulfur content less than one percent, and heating values on the order of 9,358 Btu's per pound (21,767 kj/kg). Analyses of several Fruitland coals are given in Table 2 (Dane, 1936; Fassett and Hinds, 1971; Shomaker and Lease, 1971).

The Pictured Cliffs Sandstone occassionally contains random Fruitland coal beds in the upper portion where the formations intertongue. They have been designated as local beds because they are random, discontinuous, and less than reserve base thickness.

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
I-53220	Pit Sample	SE¼ 9	19	5	----	A	5.8	35.8	31.0	27.4	0.6	9,450	
						B	-----	38.1	32.8	29.1	0.6	10,040	
						C	-----	53.7	46.3	----	0.9	14,160	
*TH-57167	Core Sample	----	19	5	----	A	13.13	32.63	32.46	21.75	0.49	9,003	
						B	-----	37.56	37.37	25.07	0.56	10,364	
*TH-57168	Core Sample	----	19	5	----	A	12.05	30.39	27.96	29.60	0.59	7,870	
						B	-----	34.55	31.79	33.66	0.67	8,948	
*TH-57166	Cuttings Sample	----	19	5	----	A	13.48	29.55	28.05	28.92	0.50	7,829	
						B	-----	34.15	32.42	33.43	0.58	9,049	
*TH-54419	Cuttings Sample	----	19	6	----	A	12.38	28.21	26.73	32.68	0.46	7,393	
						B	-----	32.20	30.51	37.29	0.52	8,438	
*TH-54321	Cuttings Sample	----	19	6	----	A	11.88	35.58	33.37	19.17	0.40	9,455	
						B	-----	40.37	37.87	21.76	0.45	10,730	
*TH-53401	Core Sample	----	19	6	----	A	11.98	35.63	36.43	15.96	0.48	9,915	
						B	-----	40.48	41.39	18.13	0.55	11,265	
+C-14106	Core Sample	----	19	6	----	A	9.2	34.5	39.5	16.8	0.57	10,141	
						B	-----	38.0	43.5	18.5	0.63	11,168	
						C	-----	46.7	53.3	----	0.77	13,701	
*TH-53399	Core Sample	----	19	6	----	A	11.23	35.86	36.05	16.86	0.49	10,030	
						B	-----	40.40	40.61	18.99	0.55	11,299	
+C-14107	Core Sample	----	19	6	----	A	10.00	34.3	38.8	16.9	0.57	10,042	
						B	-----	38.1	43.1	18.8	0.63	11,163	
						C	-----	46.9	53.1	----	0.77	13,738	
A-23141	Outcrop Sample	NW¼ 11	19	6	----	A	11.2	40.0	43.0	5.8	0.5	11,360	
						B	----	45.1	48.4	6.5	0.5	12,800	
						C	----	48.2	51.8	----	0.6	13,690	
*TH-53400	Core Sample	----	20	6	----	A	12.44	34.95	34.05	18.56	0.56	9,499	
						B	----	39.91	38.89	21.20	0.64	10,848	
+C-14108	Core Sample	----	20	6	----	A	10.7	33.4	37.5	18.4	0.65	9,667	
						B	----	37.4	42.0	20.6	0.72	10,826	
						C	----	47.1	52.9	----	0.91	13,637	

*analysis by Commercial Testing and Eng. Co.
+analysis by Illinois Geological Survey

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

Menefee Coal Zone

The Menefee coal zone extends from the top of the La Ventana (Cliff House) or Hogback Mountain (Menefee) Tongue, whichever is uppermost, to the base of the Menefee Formation. Because of its contemporaneous relationship with the coal-bearing Hogback Mountain Tongue of the Menefee Formation, the top of the La Ventana was chosen to represent a mappable surface of the coal zone. It portrays the upper boundary of the coal-bearing zone more consistently than the randomly occurring uppermost Menefee coal.

Consequently the structure contour map (CRO Plate 5) was constructed using the top of the La Ventana Tongue or Hogback Mountain Tongue. This map illustrates the dip of the coal zone varies from less than 1° to approximately 2° to the northeast. Due to topography and dip, overburden (CRO Plate 6) ranges from less than 200 ft (61 m) in the southwest to over 1,400 ft (427 m) in the northeast. Also shown on CRO Plate 6 is the total amount of interburden, which is the noncoal portion of the coal zone. The interburden thickness ranges from less than 1,500 ft (457 m) to over 1,650 ft (503 m). The thick interburden values are the result of the stratigraphic spread of the coal beds and reflect the thickness of the Menefee Formation plus the intertonguing La Ventana. The isopach map (CRO Plate 4) illustrates the total combined thickness of the coal beds of the Menefee zone. The greatest combined thickness occurs in the northwest, south, and northeast where the coals total more than 20 ft (6.1 m). From these areas the thickness decreases.

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 included in reports by Lease (1971) and Shomaker (1971). The results of these analyses are given in Table 1.

Fruitland 1 Coal Bed

As illustrated by the structure contour map (CRO Plate 8) the coal bed dips approximately 1° to the northeast. Due to dip and topography, overburden (CRO Plate 9) ranges from zero at the outcrop to more than 600 ft (183 m) in the northeast (CRO Plate 9). The isopach map (CRO Plate 7) shows that the coal bed is greater than 25 ft (7.6 m) thick in a portion of the southwest. From this area, the coal thins.

Chemical Analyses of the Fruitland 1 Coal Bed - Several analyses of Fruitland Formation coals from the Star Lake 7 1/2-minute quadrangle and surrounding area were published by Fassett and Hinds (1971) and Shomaker and Lease (1971). The results of these analyses are given in Table 2.

Fruitland 2 Coal Bed

As illustrated by the structure contour map (CRO Plate 12) the coal bed dips approximately 1° to the northeast. Due to dip and topography, overburden (CRO Plate 13) ranges from zero at the outcrop to over 400 ft (122 m) in the north (CRO Plate 13). The isopach map (CRO Plate 11) shows the coal bed is present only in a portion of the west. The coal is greater than 10 ft (3.0 m) thick in the central part of the mapped area. The coal thins from this area.

<u>Chemical Analyses of the Fruitland 2 Coal Bed</u> - Several analyses of Fruitland Formation coals from the Star Lake 7 1/2-minute quadrangle and surrounding area were published by Fassett and Hinds (1971) and Shomaker and Lease (1971). 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., unpublished data in well log library in Farmington, New Mexico), coal test holes (Chaco Energy, unpublished data; Beaumont and Speer, 1977), and geologic maps (Beaumont and Speer, 1977) were utilized in the construction of outcrop, isopach, and structure contour maps of coals in this quadrangle.

The U.S. Geological Survey designated the Fruitland 1 and Fruitland 2 coal beds for the determination of coal resources in this quadrangle. For Reserve Base and Reserve calculations, each coal bed was areally divided into measured, indicated, and inferred resource categories (CRO Plate 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 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 and Reserve values for measured, indicated, and inferred categories of coal for the Fruitland 1 and Fruitland 2 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 150 million short tons (136 million metric tons).

The coal development potential for each bed is 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 Star Lake quadrangle has development potential for both surface and subsurface mining methods (CDP Plates 15 and 16).

COAL DEVELOPMENT POTENTIAL

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

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

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

Based on economic and technological criteria, the U.S. Geological Survey has established standards for the determination of high, moderate, and low coal development potentials for surface and subsurface coal beds of reserve base thickness (5 ft [1.5 m]) or greater. Mining ratio values for strippable coal (overburden less than 200 ft [61 m] thick) are 0 to 10, high; 10 to 15, moderate; and greater than 15, low. Underground coal beds (overburden 200 to 3,000 ft [61-914 m] thick) are assigned high, moderate, or low development potentials according to the overburden thickness, 200 to 1,000 ft (61-305 m), high; 1,000 to 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 2 coal beds.

TABLE 3

STRIPPABLE COAL RESOURCES FOR FEDERAL COAL LANDS
(in short tons) IN THE STAR LAKE
QUADRANGLE, MCKINLEY AND SANDOVAL COUNTIES, 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 2	—	—	170,000	170,000
Fruitland 1	20,820,000	3,210,000	2,140,000	26,170,000
TOTAL	20,820,000	3,210,000	2,310,000	26,340,000

TABLE 4

COAL RESOURCE DATA FOR UNDERGROUND MINING
METHODS FOR FEDERAL COAL LANDS
(in short tons) IN THE STAR LAKE QUADRANGLE
MCKINLEY AND SANDOVAL COUNTIES, 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 2	4,310,000	—	—	4,310,000
Fruitland 1	119,520,000	—	—	119,520,000
TOTAL	123,830,000	—	—	123,830,000

Development Potential For Surface Mining Methods

Strippable coal of the Fruitland 1 bed has a high development potential in the southeastern part of the quadrangle (CDP Plate 15). The thickness of the Fruitland 1 in the high potential area at the outcrop (southern quadrangle boundary) is less than 10 ft (3.0 m) (CRO Plate 7). The coal is 15 to 20 ft (4.6-6.1 m) thick north of the outcrop in a large area with high development potential where the overburden ranges from approximately 80 to 150 ft (24.3-45.7 m) thick (CRO Plate 9). North of the area of high potential, the Fruitland 1 coal bed forms a small area with moderate development potential where the coal is 12 to 14 ft (3.7-4.3 m) thick, and the overburden approaches 200 ft (61 m) in thickness.

The Fruitland 2 coal bed has no high or moderate development potential in the quadrangle; however, it does form a small, isolated section of low development potential in the northwest quadrant where the coal is 5 ft (1.5 m) thick (CRO Plate 11), and the overburden thickness is approximately 200 ft (61 m) (CRO Plate 13). The remaining section of low development potential near the center of the quadrangle is the result of the Fruitland 1 coal bed which is 10 to 11 ft (3.0-3.4 m) thick in this area and overlain by almost 200 ft (61 m) of overburden.

The remainder of the quadrangle has no development potential for surface mining methods in areas outside the Fruitland 1 and Fruitland 2 outcrops in the south, areas beyond the limit of the Fruitland 2 bed (CRO Plate 13), and areas outside the 200-foot (61-m) stripping limit of the Fruitland 1 and Fruitland 2 beds.

Development Potential for Subsurface Mining Methods

Underground coal of the Fruitland 1 coal bed has high development potential in the northwest corner and along a northwest-trending band through the center of the quadrangle (CDP Plate 16). In these areas the coal bed thickness ranges from 5 to 10 ft (1.5-3.0 m) (CRO Plate 7), and the overburden thickness increases from approximately 200 ft (61 m) in the center of the area to more than 450 ft (137 m) in the northwest and east (CRO Plate 9). The Fruitland 2 has high development potential near the northwest corner of the quadrangle where the coal bed is 5 to 10 ft (1.5-3.0 m) thick (CRO Plate 11), and the overburden thickness ranges from 200 to 400 ft (61-122 m) (CRO Plate 13).

The northern part of the quadrangle has unknown development potential. The Fruitland 1 is less than 5 ft (1.5 m) thick in this area and the Fruitland 2 does not extend into this part of the quadrangle (CRO Plate 13). The remainder of the quadrangle has no development potential for subsurface mining methods in areas inside the 200-foot (61-m) stripping limits and outside the outcrops of the Fruitland 1 and Fruitland 2.

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