Text to accompany:

Open-File Report 79-618

1979

COAL RESOURCE OCCURRENCE MAPS AND COAL DEVELOPMENT POTENTIAL MAPS OF THE NORTHWEST QUARTER OF THE NAGEEZI 15-MINUTE QUADRANGLE, SAN JUAN COUNTY, NEW MEXICO

[Report includes 20 plates]

by

Dames & Moore

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

CONTENTS

CONTENTS

CONTENTS

PLATES

CONTENTS

PLATES

TABLES

NORTHWEST QUARTER OF THE NAGEEZI 15-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 northwest quarter of the Nageezi 15-minute 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) 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 northwest quarter of the Nageezi 15-minute quadrangle is located in east-central San Juan County, New Mexico. The area is approximately 34 miles (55 km) southeast of Farmington and 82 miles (132 km) northeast of Gallup, New Mexico.

Accessibility

Access to the quadrangle is provided by a light-duty road which connects with State Route 44 5.5 miles (9 km) to the southwest. A light-duty road parallels Blanco Wash north of the quadrangle, but separates into several unimproved dirt roads where it extends into the quadrangle. Most of the northern and central parts of the area are accessible by unimproved dirt roads, but the southernmost areas are less accessible. The Atchison, Topeka, and Santa Fe Railway operates a route approximately 82 miles (132 km) to the southwest at Gallup, New Mexico, which extends to the southeast and southwest.

Physiography

The quadrangle is in the Central Basin area (Kelley, 1950) of the San Juan Basin, a structural depression in the Colorado Plateau physiographic province. Total relief is approximately 1,080 ft (329 m) with elevations ranging from 6,160 ft (1,878 m) in the bottom of Blanco Wash to 7,240 ft (2,206 m) on top of Thompson Mesa. The topography in the northwest quarter of the Nageezi 15-minute quadrangle is characteristic of the Central Basin, consisting of broad, gently-sloping plains dissected by intermittent streams. The western half of the area is dominated by the broad, gently-sloping flood-plain along Blanco Wash. The eastern half is predominantly vegetated mesas cut by steep-walled canyons.

Climate

The climate of the San Juan Basin is arid to semi-arid. Annual precipitation is usually less than about 10 inches (25 cm) with slight variations across the basin due to elevational differences. Rainfall is rare in the early summer and winter; most precipitation is received in July and August as intense afternoon thundershowers. Annual temperatures range from 0°F (-18°C) to over 100° (38°C) in the basin. Snowfall occurs from November to April with an average of 18 inches (46 cm) in the southern part of the basin.

Land Status

The quadrangle is in the east-central portion of the San Juan Basin Known Recoverable Coal Resource Area. The Federal Government owns the coal rights for approximately 90 percent of the KRCRA land within the quadrangle as shown on Plate 2 of the Coal Resource Occurrence Maps. No Federal coal leases occur within the quadrangle.

GENERAL GEOLOGY

Previous Work

Reeside (1924) mapped the surficial geology of the area on a scale of 1:250,000 as part of a study of the Upper Cretaceous and Tertiary formations of the San Juan Basin. More recently, Fassett and Hinds (1971) made subsurface interpretations of Fruitland Formation coal occurrences as part of a larger San Juan Basin coal study.

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 depositional evidence of the final retreat of the Late Cretaceous sea is the nearshore regressive Pictured Cliffs Sandstone. Southwest (shoreward) of the beach deposits, swamps, which were dissected by streams, accumulated organic matter which later became coals of the Fruitland Formation. Deposition of organic material was influenced by the strandline as shown by both the continuity of the coal beds parallel to the north-south strandline and their discontinuity perpendicular to it to the east. The less continuous Fruitland coals appear to be noncorrelative, but are stratigraphically equivalent in terms of their relative position within the Fruitland Formation.

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

Terrestrial deposition resumed in the Paleocene as represented by the Ojo Alamo Sandstone and the overlying Nacimiento Formation. Alluvial plain and floodplain deposits of the Ojo Alamo were followed by the thick, lithologically varied deposits of the Nacimiento during continuous nonmarine deposition. 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.

Stratigraphy

The formations studied in this quadrangle range from Late Cretaceous to Eocene in age. They are, in order from oldest to youngest: Pictured Cliffs Sandstone, Fruitland Formation, Kirtland Shale, Ojo Alamo Sandstone, Nacimiento Formation, and San Jose 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 Pictured Cliffs Sandstone averages 110 ft (34 m) in thickness in this area. Because the unit is persistent throughout most of the San Juan Basin and easily recognized on geophysical logs, the top of this unit was used as the datum (CRO Plate 3) for Fruitland coal correlations. The formation consists of a cream to light gray, calcareous, kaolinitic, slightly micaceous, friable sandstone, interbedded with gray shale near the base of the unit. Intertonguing with the overlying Fruitland Formation occurs throughout the entire basin and, consequently, minor Fruitland coal beds commonly are present in the upper portion of the Pictured Cliffs.

The major coal-bearing unit in the quadrangle, the Fruitland Formation, conformably overlies the Pictured Cliffs Sandstone. Wide variations in reported thickness of the Fruitland are common because of an indistinct upper contact with the Kirtland Shale, but the average thickness is about 275 ft (84 m) in this area. Many authors have used various criteria for establishing the upper contact, but, in general, for this study the uppermost coal of the Fruitland Formation was chosen (after Fassett and Hinds, 1971). The formation is primarily gray to brown, carbonaceous shale with plant fossils; interbedded kaolinitic siltstone; and lenticular coal beds.

The Upper Cretaceous Kirtland Shale conformably overlies the Fruitland Formation and averages 380 ft (116 m) in thickness in this area. It consists predominantly of freshwater, gray-green to brown to mottled siltstone with plant fossils and interbedded white quartzitic, kaolinitic, friable sandstone. The Kirtland Shale 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.

The Paleocene Ojo Alamo Sandstone unconformably overlies the Kirtland Shale. It is a white to cream, coarse-grained to conglomeratic sandstone with traces of pyrite and interbedded gray-green to brown shale and averages 190 ft (58 m) in thickness in this area.

Approximately 1,170 ft (357 m) of the Paleocene Nacimiento Formation overlie the Ojo Alamo Sandstone. These deposits are exposed in the western half of the quadrangle where they consist of light to dark gray siltstone, gray shale, and buff to yellow sandstone.

The San Jose Formation of Eocene age unconformably overlies the Nacimiento Formation and crops out over the eastern half of the quadrangle area. It is predominantly buff to yellow, fine- to very coarse-grained, locally conglomeratic, arkosic sandstone and gray to green, silty shale and contains many lithologies gradational between the two.

Structure

The northeast quarter of the Nageezi 15-minute quadrangle is located in the Central Basin area (Kelley, 1950) of the major structural depression, the San Juan Basin. The axis of the basin is about 23 miles (37 km) northeast of the quadrangle area and trends in an arcuate pattern across the northern portion of the Central Basin area (Baltz, 1967). Regional dip within the quadrangle is to the northeast at approximately 1° to 2°.

COAL GEOLOGY

Four coal beds (Fruitland 1, Fruitland 2, Fruitland 3, Fruitland 4) and a coal zone (Fruitland) were identified in the subsurface of this quadrangle (CRO Plate 1). The Fruitland 1 (Fr 1) coal bed is defined as the lowermost coal of the Fruitland Formation which generally occurs directly above the Pictured Cliffs Sandstone. The Fruitland 2 (Fr 2) coal bed occurs above the Fruitland 1 (when present), separated by a rock interval of 3 to 23 ft (0.9-7.0 m). Above the Fruitland 2 is the Fruitland 3 (Fr 3) coal bed; the two are separated by a rock interval of approximately 40 ft (12.2 m). The Fruitland 4 (Fr 4) coal bed is separated from the Fruitland 3 by a rock interval of about 40 ft (12.2 m). Between these coal beds are several local coals which are discontinuous and less than reserve base thickness (5 ft [1.5 m]). Although the Fruitland 1, Fruitland 2, Fruitland 3, and Fruitland 4 have been correlated and mapped as consistent horizons, they may actually be several different coal beds that are lithostratigraphically equivalent but not laterally continuous. The remaining coals in the upper portion of the Fruitland Formation have been grouped together and designated as the Fruitland coal zone (Fr zone). These coals are generally noncorrelative and less than reserve base thickness (5 ft [1.5 m]); exceptions are a 5-ft (1.5-m) coal bed in drill holes 18 and 19 (CRO Plate 3).

Fruitland Formation coals in the central portion of the San Juan Basin are considered high volatile B to high volatile A bituminous in rank. The rank of the coal has been determined on a moist, mineral-matter-free basis with calorific values averaging 14,696 Btu's per pound (34,183 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 ranging from 1.4 to 4.2 percent, ash content varying from 13.4 to 31.0 percent, sulfur content less than one percent, and heating values on the order of 10,857 Btu's per pound (25,253 kj/kg). Analyses of several Fruitland Formation coals are given in Table 1 (Fassett and Hinds, 1971).

Fruitland 1 Coal Bed

As illustrated by the structure contour map (CRO Plate 5), the coal bed dips less than 1° to the northeast. As a result of dip and topography, overburden (CRO Plate 6) varies from less than 1,800 ft (549 m) within Blanco Canyon to greater than 2,800 ft (853 m) on Thompson Mesa. The isopach map (CRO Plate 4) shows that the coal bed is greater than 5 ft (1.5 m) thick in the central, northeastern, and northwestern parts of the quadrangle. The thickness decreases in all directions, and the coal is absent in the central-northeast, west, and southeast.

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

Fruitland 2 Coal Bed

The structure contour map (CRO Plate 9) illustrates that the dip of the coal bed is less than 1° to the northeast. Due to topography and dip,

TABLE 1

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.			Mois-ture	Volatile matter	Fixed Carbon	Ash	Sulfur		
H-16695	Century Exploration Mobil-Rudman No. 2	SW¼ 21	25	9	1,620-1,625	A	4.2	31.5	33.3	31.0	0.9	9,280	
						B	---	32.8	34.8	32.4	0.9	9,680	
						C	---	48.6	51.4	----	1.4	14,310	
H-15776	Aztec Oil & Gas Hanks No. 14-D	SW¼ 12	27	10	1,900-1,905	A	2.2	40.4	44.0	13.4	0.6	12,520	
						B	---	41.3	45.1	13.6	0.6	12,790	
						C	---	47.9	52.1	----	0.7	14,820	
H-13063	Aztec Oil & Gas Hudson No. 5-D	NW¼ 29	27	9	2,135-2,145	A	2.7	38.3	40.4	18.6	0.8	11,650	
						B	---	39.3	41.6	19.1	0.8	11,970	
						C	---	48.6	51.4	----	1.0	14,800	
H-12705	Aztec Oil & Gas Whitley No. 6-D	SW¼ 8	27	9	2,215-2,230	A	2.2	36.7	41.2	19.9	0.8	11,440	
						B	---	37.5	42.1	20.4	0.8	11,700	
						C	---	47.1	52.9	----	1.1	14,700	
H-21490	El Paso Nat. Gas Schwerdtfeger No. 20-A	NE¼ 8	27	8	2,800-2,820	A	1.9	29.5	32.9	35.7	0.6	9,170	
						B	---	30.0	33.6	36.4	0.6	9,350	
						C	---	47.2	52.8	----	1.0	14,700	
H-13061	Aztec Oil & Gas Reid No. 23-D	SW¼ 17	28	9	1,985-1,990	A	1.4	36.1	42.1	20.4	0.8	11,670	
						B	---	36.6	42.7	20.7	0.8	11,830	
						C	---	46.2	53.8	----	1.0	14,920	
H-13779	El Paso Nat. Gas Florence No. 10-C	NE¼ 30	28	8	2,185-2,195	A	1.9	33.7	35.1	29.3	0.6	10,270	
						B	---	34.3	35.8	29.9	0.7	10,460	
						C	---	48.9	51.1	----	0.9	14,920	

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.

the overburden (CRO Plate 10) varies from less than 1,800 ft (549 m) in Blanco Canyon to greater than 2,600 ft (792 m) on Thompson Mesa. The isopach map (CRO Plate 8) shows the coal bed is present only in the northern portion of the quadrangle. The Fruitland 2 is greater than 10 ft (3.0 m) thick in the northeast and thins in all directions.

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

Fruitland 3 Coal Bed

The structure contour map (CRO Plate 13) indicates the coal bed dips less than 1° to the northeast. As a result of topography and dip, overburden (CRO Plate 14) varies from less than 1,800 ft (549 m) in Blanco Canyon to greater than 2,600 ft (792) on Thompson Mesa. As illustrated by the isopach map (CRO Plate 12), the coal bed is present only in the northern portion of the quadrangle. The coal bed thickness is greater than 5 ft (1.5 m) in the northwest and decreases in all directions.

Chemical Analyses of the Fruitland 3 Coal Bed - Analyses of several Fruitland Formation coal beds from the area surrounding this quadrangle are given in Table 1 (Fassett and Hinds, 1971).

Fruitland 4 Coal Bed

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) varies from less than 1,800 ft (549 m) in Blanco Canyon to greater than 2,600 ft (792 m) on Thompson Mesa. The isopach map (CRO Plate 16) shows the coal bed is greater than 10 ft (3.0 m) in the north-central part of the quadrangle. The coal bed thickness decreases in all directions, and the coal is present only in the north.

Chemical Analyses of the Fruitland 4 Coal Bed - Analyses of several Fruitland Formation coal beds from the area surrounding this quadrangle are given in Table 1 (Fassett and Hinds, 1971).

COAL RESOURCES

Coal resource data from oil and gas wells and pertinent publications were utilized in the construction of isopach and structure contour maps of coals in this quadrangle. All of the coals studied in the northwest quarter of the Nazeezi 15-minute quadrangle are more than 1,670 ft (509 m) below the ground surface and, thus, have no outcrop or surface development potential.

The U.S. Geological Survey designated the Fruitland 1, Fruitland 2, Fruitland 3, and Fruitland 4 coal beds for the determination of coal resources in this quadrangle. Coals of the Fruitland zone 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 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 maps (CRO Plates 7, 11, 15, and 19) 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, a recovery factor of 50 percent was applied to the Reserve Base tonnages for underground coal. 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, Fruitland 2, Fruitland 3, and Fruitland 4 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 159 million short tons (144 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 subsurface mining methods. The northwest quarter of the Nageezi 15-minute quadrangle has development potential for subsurface mining methods only (CDP Plate 20).

COAL DEVELOPMENT POTENTIAL

Coal beds of 5 ft (1.5 m) or more in thickness which are overlain by 200 to 3,000 ft (61-914 m) of overburden are considered to have potential for underground mining and are designated as having high, moderate, or 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. Table 2 summarizes the coal development potential, in short tons, for underground coal of the Fruitland 1, Fruitland 2, Fruitland 3, and Fruitland 4 coal beds.

Development Potential for Surface Mining Methods

All coals studied in the northwest quarter of the Nageezi 15-minute quadrangle occur more than 1,670 ft (509 m) below the ground surface and, thus, they have no coal development potential for surface mining methods.

Development Potential for Subsurface Mining Methods

Underground coal of the Fruitland 1, Fruitland 2, Fruitland 3, and Fruitland 4 coal beds has moderate development potential in the northwest quadrant (CDP Plate 20). Coal bed thicknesses range from 5 to 6 ft (1.5-1.8 m) for the Fruitland 1 (CRO Plate 4), 5 to 9 ft (1.5-2.7 m) for the Fruitland 2 and Fruitland 3 (CRO Plates 8 and 12), and 5 to 10 ft (1.5-3.0 m) for the Fruitland 4 coal bed (CRO Plate 16). Overburden thickness for these beds is approximately 1,800 to 2,000 ft (549-610 m) (CRO Plates 6, 10, 14, and 18, respectively).

TABLE 2

COAL RESOURCE DATA FOR UNDERGROUND MINING METHODS FOR FEDERAL COAL LANDS (in short tons) IN THE NORTHWEST QUARTER OF THE NAGEEZI 15-MINUTE 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 4	--	15,940,000	4,710,000	20,650,000
Fruitland 3	--	21,570,000	2,580,000	24,150,000
Fruitland 2	--	14,830,000	61,940,000	76,770,000
Fruitland 1	--	19,700,000	17,130,000	36,830,000
TOTAL	--	72,040,000	86,360,000	158,400,000

The Fruitland 1 coal bed has low potential in the center of the quadrangle where the coal bed thickness is approximately 5 ft (1.5 m), and overburden thickness increases from 2,000 to 2,650 ft (610-808 m) from west to east. Coal of the Fruitland 2 has low potential along the northern half of the eastern quadrangle boundary. The coal bed thickness in this area ranges from 5 to 14 ft (1.5-4.3 m), and overburden thickness increases from 2,200 to more than 2,800 ft (671-853 m). Coal of the Fruitland 3 bed has low development potential in a small area adjoining the west side of the moderate potential zone. The thickness of the coal bed in this area is 5 to 6 ft (1.5-1.8 m) (CRO Plate 12), and the overburden is approximately 2,000 ft (610 m) thick (CRO Plate 14). The Fruitland 4 coal bed has low development potential at the east-central boundary of the quadrangle where the coal thickness ranges from 5 to 10 ft (1.5-3.0 m) (CRO Plate 16) and the overburden increases from 2,000 to more than 2,400 ft (610-731 m) from west to east (CRO Plate 18).

Over half of the quadrangle area has unknown potential where the evaluated coal beds are less than the reserve base thickness of 5 ft (1.5 m); however, only the Fruitland 1 coal bed extends into the southern half of the quadrangle. Small areas in the southwest and southeast have no Fruitland 1, Fruitland 2, Fruitland 3, and Fruitland 4 coals and, thus, have no development potential.

REFERENCES

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

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

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

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

El Paso Natural Gas Co., Well log library, Farmington, New Mexico.

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

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

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

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

U.S. Department of the Interior, 1949, Map of a portion of San Juan and Rio Arriba Counties, New Mexico: U.S. Geol. Survey Oil and Gas Operations Map Roswell 66, revised 1974, 1:31,680.