Coal Resources of Upper Cretaceous Fruitland Formation in the Southern Ute Indian Reservation, Southwestern Colorado

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COVER CAPTION

COVER PHOTOGRAPH—Chief Buckskin Charley (circa 1840–1936) was the last hereditary chief of the Utes. He was named Chief of the Utes at the request of Chief Ouray, under whom he had served as sub-chief for many years. He is wearing an 1890 Benjamin Harrison peace medal, which was the last medal designed specifically for presentation to Indians. The photograph is from the Lisle Updyke Photo-Collection of Dr. Robert W. Delany and is reprinted by permission of Dr. Robert W. Delany and Jan Pettit.

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Coal Resources of Upper Cretaceous Fruitland Formation in the Southern Ute Indian Reservation, Southwestern Colorado

By DOROTHY T. SANDBERG

GEOLOGY AND MINERAL RESOURCES OF THE
SOUTHERN UTE INDIAN RESERVATION

Edited by ROBERT S. ZECH

U.S. GEOLOGICAL SURVEY PROFESSIONAL PAPER 1505–D

*Prepared in cooperation with the
Southern Ute Tribe and the
U.S. Bureau of Indian Affairs*

*The Fruitland Formation contains
large resources of bituminous coal on the
Southern Ute Indian Reservation,
which is in the northern part of the
San Juan Basin*

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PREFACE

At the request of the Southern Ute Tribe and the Energy and Mineral Division of the U.S. Bureau of Indian Affairs, the U.S. Geological Survey began a program in 1984 to study the geology and mineral resources of the Southern Ute Indian Reservation. The objective is to develop a series of investigations that characterize the geology and structure of the Reservation and that address a variety of resource-related problems. The boundary of the area covered by each investigation is determined by the nature of the specific investigation and accordingly may include only topical areas within the Reservation or entire Reservation and adjacent areas.

The U.S. Geological Survey received valuable information and contributions from the Southern Ute Energy Department, without which these investigations would not have been possible. The final interpretive results of each investigation are presented as chapters of U.S. Geological Survey Professional Paper 1505. The chapters will be published as the interpretive products of the investigations become available.

Robert S. Zech
Editor

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[Plates are in pocket]

TABLES

CONVERSION FACTORS

For readers who wish to convert measurements from U.S. customary units to the metric system of units, the conversion factors are listed below.

U.S. customary units	Multiply by	To obtain metric units
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
short ton	0.9072	megagram
British thermal unit per pound (BTU/lb)	2326	joule per kilogram

Edited by Robert S. Zech

COAL RESOURCES OF UPPER CRETACEOUS FRUITLAND FORMATION IN THE SOUTHERN UTE INDIAN RESERVATION, SOUTHWESTERN COLORADO

By Dorothy T. Sandberg

ABSTRACT

Coal resources of the Upper Cretaceous Fruitland Formation in the Southern Ute Indian Reservation are estimated to total 16 billion short tons of bituminous coal in beds 2 feet thick or more. The coal-bearing Fruitland Formation underlies about 700 square miles of the Southern Ute Indian Reservation and crops out in a roughly semicircular band around the northern edge of the structural San Juan Basin. The coal beds locally dip more than 10° to the southeast along the northwestern rim of the basin.

This estimate of coal resources is based on a study of about 500 geophysical logs, mostly of oil and gas wells. Total coal resources include 15 billion short tons of identified resources, based on data points 3 miles or less apart, and about 1 billion short tons of undiscovered or hypothetical resources, based on data points more than 3 miles apart.

In this report, the coal-bearing interval is divided into three overlapping zones: lower, middle, and upper. Coal resources were estimated by aggregate thickness for each zone. The lower zone, which is southwest of a large stratigraphic rise of the Pictured Cliffs Sandstone, contains the thickest coal beds, generally in two thick beds that locally have an aggregate thickness as much as 50 feet. The lower zone contains about 28 percent of the estimated resources; in the lower zone, 6 percent of the resources are less than 500 feet beneath the surface, 10 percent of the resources are 500–2,000 feet beneath the surface, and 84 percent are more than 2,000 feet beneath the surface. The middle zone contains 22 percent of the estimated resources; in the middle zone, only 2 percent of the resources are less than 500 feet beneath the surface, 4 percent of the resources are 500–2,000 feet beneath the surface, and 94 percent are more than 2,000 feet beneath the surface. The upper zone contains about half the estimated resources, in part because it occupies about three-fourths of the area underlain by the Fruitland Formation; in the upper zone, about 2 percent of the resources are less then 500 feet beneath the surface, 11 percent are 500–2,000 feet beneath the surface, and 87 percent are more than 2,000 feet beneath the surface. In general the coal beds are thinner in the middle and upper zones than in the lower zone.

Although the coal on the Reservation is of comparatively high rank, coal in the Fruitland is generally characterized by high ash content. Mining on the Reservation has been restricted generally to small underground and strip mines within 200 feet of the surface along the edges of the San Juan Basin.

Manuscript approved for publication, April 24, 1989.

INTRODUCTION

At the request of the Southern Ute Tribe and the Division of Energy and Mineral Resources of the U.S. Bureau of Indian Affairs, the U.S. Geological Survey began a resource assessment program of tribal lands. This study, which is a part of that program, is focused on determination of the location, thickness, extent, and quantity of coal deposits of the Fruitland Formation in the Southern Ute Indian Reservation.

LOCATION OF STUDY AREA

The Southern Ute Indian Reservation is in southwestern Colorado and is bordered by New Mexico on the south (fig. 1). The study area includes Tps. 32–34 N. and Rs. 1½–13 W.; it is between long 107° 00′ and 108° 7½′ W. and lat 37° 00′and 37° 15′ N. The Reservation is south of the towns of Durango and Pagosa Springs, Colo. Tribal headquarters are in the town of Ignacio, Colo., in T. 33 N., R. 7 W. Townships and ranges are shown on plates 1–3, which are in the pocket of this report.

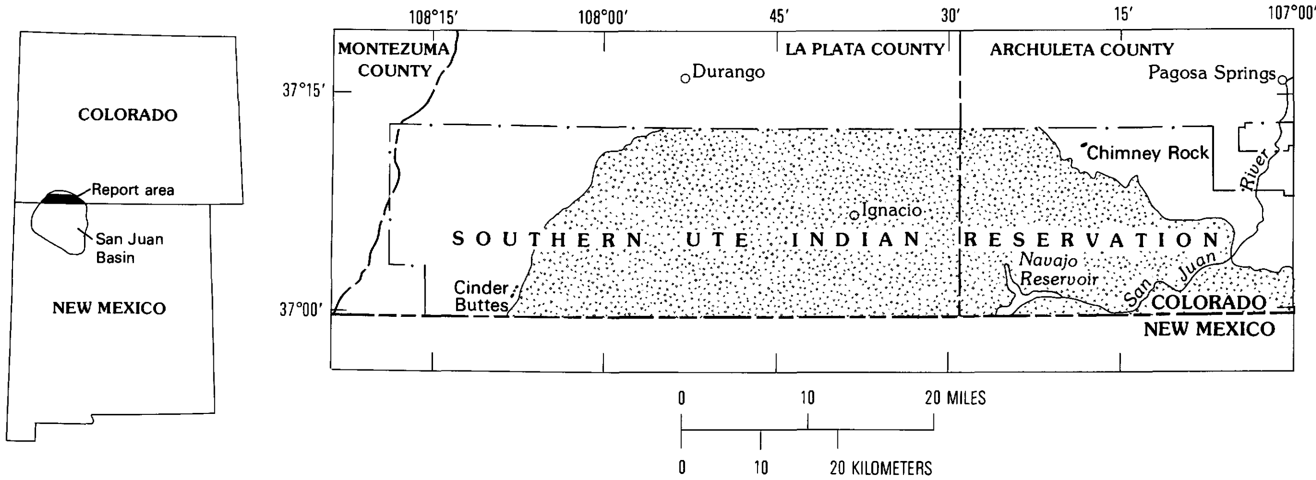

FIGURE 1.—Index map showing location of Southern Ute Indian Reservation and area of Reservation underlain by Fruitland Formation (stippled).

Elevations on the Reservation range from less than 6,000 ft along the larger rivers at the southern boundary to more than 8,900 ft in T. 34 N., R. 6 W., in the north-central part of the Reservation. The most con-conspicuous topographic feature is Chimney Rock (7,903- ft elevation), in the northeastern part of the Reservation; this landmark butte, which stands more than 500 ft above the surrounding terrain, is capped by the Upper Cretaceous Pictured Cliffs Sandstone. Other landmark features are Cinder Buttes (the highest of which is about 6,660 ft in elevation) just west of the study area, which are outliers of the Fruitland Formation that contain burned coal beds.

The Reservation is within the San Juan River drainage system. The San Juan River drains the eastern one-third of the Reservation to the southwest. The river flows southward into the Navajo Reservoir in Colorado; the reservoir was formed by a dam on the San Juan River in New Mexico. Drainage is mostly to the south in the western two-thirds of the Reservation, toward the San Juan River, which flows westward across northwestern New Mexico.

The area is readily accessible by several paved roads as well as by dirt roads (pls. 1–3). Paved roads that cross the Reservation include Colorado State Highways 140, 172, and 151; U.S. Highway 550 nearly bisects the Reservation from the north near Durango southward along the Animas River into New Mexico; U.S. Highway 160 roughly parallels the northern boundary of the Reservation.

PREVIOUS WORK

Numerous investigations have been made of the coal-bearing rocks in the northern part of the San Juan Basin. Selected references include Barnes (1953), Barnes and others (1954), Fassett (1977), Fassett and Hinds (1971), Kelso and others (1980), Molenaar (1977), Reeside (1924), Shomaker and others (1971), Shomaker and Feldman (1978), Shomaker and Holt (1973), Shomaker and Whyte (1977), Wood and others (1948), and Zapp (1949). These writers have reported on the geology of the coal-bearing Fruitland Formation and related rock units. The reports issued in the 1940's and 1950's include geologic maps of most areas within the Reservation; some of these reports also contain estimates of coal resources for their mapped areas.

Estimates of coal resources in the Fruitland Formation for some areas in the Reservation were included in a report on the coal resources of Colorado by Landis (1959). Landis and Cone (1971) tabulated by bed some of the coal resources in the Reservation. Several later reports included estimates of the coal resources in varying degrees of detail. Shomaker and Holt (1973) have prepared the most comprehensive report on the coal resources of the entire Reservation. Speltz (1976) summarized resources of strippable coal in the Colorado part of the San Juan Basin.

Shomaker and Feldman (1978), in an unpublished report for the Southern Ute Tribe, reevaluated the strippable coal resources of the Picnic Flats area, which is in the western part of the Reservation, near the outcrop of the Fruitland Formation. Their study of Fruitland coal less than 200 ft beneath the surface included data from cores and geophysical logs of about 30 coal test holes drilled by SUNEDCO (Sunoco Energy Development Company). In 1982, two test wells in the north-central part of the Reservation were drilled and partly cored in a cooperative effort by the Southern Ute Tribe and the Department of Energy to study methane in coal beds (Kelso and Rushworth, 1982).

PRESENT WORK

This report is the result of a subsurface study and interpretation of about 500 geophysical logs, most of which were from oil and gas test holes. Most other subsurface information is from 24 coal test holes along the western part of the study area (Shomaker and Feldman, 1978). Spacing of data points is about 1 mi or less where possible, in order to correlate coal beds as accurately as possible. Drill-hole locations that were used to construct subsurface maps are shown on those maps. Drill holes that were used in lines of sections are listed in table 1.

Sandberg (1988a) summarized the present study in a report, which included page-size maps, on the coal geology and resources of the Fruitland Formation in the Southern Ute Indian Reservation. A related publication (Sandberg, 1988b) included the same maps of the coal geology, but at the preparation scale of 1:100,000.

ACKNOWLEDGMENTS

This study was done in cooperation with the Division of Energy and Mineral Resources of the Bureau of Indian Affairs under the direction of Steve Manydeeds. Marvin Cook, Brad Boyce, and Clarence Harr of the Southern Ute Tribal Energy Office provided pertinent subsurface information that otherwise would not have been used for this study.

GEOLOGIC SETTING

The Southern Ute Indian Reservation is in the northern part of the San Juan Basin, which is a structural basin that underlies northwestern New Mexico and southwestern Colorado. Sedimentary rocks associated with the coal-bearing Fruitland Formation (Upper Cretaceous) crop out in a semicircular band around the northern edge of the basin. The Fruitland underlies about 700 mi^2 of the Reservation. Stratigraphically younger Upper Cretaceous and Tertiary formations are exposed toward the more central part of the basin.

The formations discussed in this report include, in ascending stratigraphic order, the Lewis Shale, Pictured Cliffs Sandstone, Fruitland Formation, and Kirtland Shale, all of Late Cretaceous age (fig. 2). These formations were deposited during the final regression of a sea that covered most of this region during Late Cretaceous time. The Lewis Shale is an offshore marine unit that was deposited mostly as muds. The Pictured Cliffs Sandstone is a shoreline deposit that was laid down as the sea regressed to the northeast. The nonmarine Fruitland Formation originated in an environment of coastal swamps and river systems (Fassett and Hinds,

AGE	ROCK UNIT
Late Cretaceous	Kirtland Shale Upper shale member Farmington Sandstone Member Lower shale member
	Fruitland Formation
	Pictured Cliffs Sandstone
	Lewis Shale ——Huerfanito Bentonite Bed——

FIGURE 2.—Stratigraphic section of units related to coal resources of the Fruitland Formation in the Southern Ute Indian Reservation.

1971, p. 19). In some of the swamps, conditions were favorable for the accumulation of great thicknesses of plant remains that gradually were compressed and altered into the thick and extensive coal deposits. The Kirtland Shale, also nonmarine, was deposited farther landward than the Fruitland Formation, probably in relatively higher areas of better drainage (Fassett and Hinds, 1971, p. 25).

Most rocks exposed in the study area are sedimentary, but a number of northeast-trending Tertiary dikes cut the sedimentary rocks near Cat Creek in R. 3 W. and in areas to the east. Lithologic descriptions in the following paragraphs are mostly from Barnes (1953), Barnes and others (1954), Wood and others (1948), and Zapp (1949).

STRATIGRAPHY

LEWIS SHALE

The Lewis Shale is typically dark-gray to light-gray shale; locally it contains thin beds of concretionary limestone (Barnes and others, 1954). In the upper part, the unit grades upward from silty and sandy shale to argillaceous sandstone, in an interval of transition into the overlying Pictured Cliffs Sandstone. Although the contact between the Lewis and the Pictured Cliffs is arbitrary, it generally is placed at the highest level where shale predominates over sandstone. Measured

TABLE 1.—*Location data for drill holes shown in lines of sections* A–A′, B–B′, C–C′, D–D′, *and* E–E′, *Southern Ute Indian Reservation and vicinity*

Age	Location in section	Township and range	Company, well name, and number	Year drilled
			Colorado	
1	SE¼SW¼ 13	32 N., 12 W.	SUNEDCO 1–13–32	1977
2	SE¼SW¼ 13	32 N., 12 W.	Western Hydrocarbons Consolidated Ute 1–13	1965
3	NW¼NW¼ 17	32 N., 11 W.	Arco Oil and Gas Co. Southern Ute 17–3	1982
4	NE¼ NE¼ 15	32 N., 11 W.	Southern Union Gas Co. Farmer 1	1955
5	SE¼ NE¼ 11	32 N., 11 W	Southern Union Gas Co. Ivie 2	1955
6	NE¼ NE¼ 12	32 N., 11 W.	Southern Union Gas Co. Ute 6–A	1957
7	NE¼ NE¼ 4	32 N., 10 W.	Arco Oil and Gas Co. Southern Ute 4–1	1980
8	NE¼ SW¼ 2	32 N., 10 W.	Compass Exploration, Inc. N. Cox Canyon 1–2	1963
9	SE¼ NE¼ 6	32 N., 9 W.	St. Louis Car Co.–Menlo Corp. 5–6 Block 6	1960
10	NW¼ SW¼ 4	32 N., 9 W.	Skelly Oil Co. Sam Burch 2	1958
11	SE¼ SE¼ 3	32 N., 9 W.	Getty Oil Co. Sam Burch 13	1982
12	NE¼ SW¼ 1	32 N., 9 W	Atlantic Richfield Co. Southern Ute 1–1 32–9	1974
13	NW¼ NW¼ 18	32 N., 8 W.	Murchison Bros. Block 3, 7–18	1983
14	SW¼ NE¼ 21	32 N., 8 W.	Arco Oil and Gas Co. Southern Ute 21–3	1982
15	SE¼ NW¼ 11	32 N., 8 W.	Arco Oil and Gas Co. Southern Ute 11–2	1979
16	NE¼ SE¼ 7	32 N., 7 W.	Amoco Production Co. Snooks Gas Unit "A" 1–A	1979
17	SW¼ SE¼ 14	32 N., 7 W.	Sohio Southern Ute 9	1980
18	NE¼ NE¼ 1	32 N., 7 W.	Kimbark Operating Co. Squires 1	1976
19	NE¼ SE¼ 8	32 N., 6 W.	Tenneco Oil Co. Payne 1–8	1982
20	NE¼ SW¼ 10	32 N., 6 W..	Feldt and Maytag Walton 1	1961
21	SW¼ NE¼? 12 or NE¼ SW¼?	32 N., 6 W.	Feldt and Maytag Luchini 1	1963
22	NE¼ SW¼ 17	32 N., 4 W.	Sun Oil Co. Zabrinski 1	1973
23	NE¼ SE¼ 19	33 N., 11 W.	SUNEDCO 1–19–33	1977
24	NE¼ NE¼ 20	33 N., 11 W.	Aspen Drilling Co. Ute Tribal 1	1959
25	NE¼ SE¼ 22	33 N., 11 W.	Arco Oil and Gas Co. Southern Ute 22–1	1980
26	NW¼ NW¼ 19	33 N., 10 W.	Arco Oil and Gas Co. Southern Ute 19–3	1982
27	NE¼ NW¼ 16	33 N., 10 W.	Lynco Oil Co. Flume Canyon Ute 3	1976
28	NW¼ NW¼ 15	33 N., 10 W.	Arco Oil and Gas Co. Southern Ute 15–1	1977
29	NE¼ NE¼ 19	33 N., 9 W.	Amoco Production Co. Koon Gas Unit 2E	1983
30	NE¼ SE¼ 21	33 N., 9 W.	Pacific Northwest Pipeline Corp. Bondad 30–21	1958
31	SW¼ NW¼ 25	33 N., 9 W.	Compass Exploration Southern Ute 1–25A	1961
32	SW¼ SW¼ 20	33 N., 8 W.	Arco Oil and Gas Co. Southern Ute Herrera 2	1980
33	NE¼ NE¼ 23	33 N., 8 W.	Amoco Production Co. Pan Am Fee Gas Unit "B" 1A	1984
34	NE¼ SE¼ 8	33 N., 7 W.	Amoco Production Co. Southern Ute 1–89 1A	1983
35	NW¼ SW¼ 10	33 N., 7 W.	Martin Exploration Management Corp. Shelhammer 10–1	1981
36	C SW¼ 31	33 N., 6 W.	Fred W. Pool–Durango Syndicate Jones 1	1962
37	SE¼ SE¼ 21	33 N., 6 W.	Amoco Production Co. Southern Ute C 4	1984
38	NW¼ SW¼ 24	34 N., 11 W.	SUNEDCO 1–24–34	1977
39	SW¼ NW¼ 19	34 N., 10 W.	SUNEDCO 1–19–34	1977
40	NW¼ SE¼ 31	34 N., 10 W.	American Petroleum Energy Co. Argenta-Ute 2	1977
41	SE¼ SE¼ 28	34 N., 10 W.	Grantham, Jackson, and Marcus McCulloch 5	1956
42	NW¼ SE¼ 22	34 N., 10 W.	Cabeen Exploration Corp. Thompson 1	1961
43	SE¼ NW¼ 24	34 N., 10 W.	Lynco Oil Co. Dorothy Gould 8	1977
44	NE¼ SW¼ 19	34 N., 9 W.	Rincon Operating Co. Rincon Clarey 1	1977
45	NE¼ NW¼ 16	34 N., 9 W.	Fuelco Craig 1	1978
46	C SW¼ 13	34 N., 9 W.	Samson Resources Co. Fassett 1–13	1982
47	SW¼ SE¼ 18	34 N., 8 W.	Fuelco Sun–Tyner Lunt 1	1977
48	NW¼ SE¼ 20	34 N., 8 W.	Fuelco McCaw 1	1978
49	SE¼ SE¼ 32	34 N., 8 W.	Rincon Operating Co. Rea 1	1977
50	NE¼ SW¼ 36	34 N., 8 W.	Amoco Production Co. Southern Ute A 1 M	1983
51	SE¼ SE¼ 32	34 N., 7 W.	William Perlman Southern Ute 32–1	1981
52	NW¼ SE¼ 26	34 N., 7 W.	Fuelco Southern Ute 1	1977

TABLE 1.—*Location data for drill holes shown in lines of sections* A–A′, B–B′, C–C′, D–D′, and E–E′, *Southern Ute Indian Reservation and vicinity*—Continued

No.	Location in section	Township and range	Company, well name, and number	Year drilled
			Colorado—Continued	
53	NW¼ SE¼ 13	34 N., 7 W.	Natomas North America, Inc. Harper 1–13	1981
54	NW¼ SW¼ 17	34 N., 6 W.	Natomas North America, Inc. Glaser 1–17	1981
55	SE¼ SE¼ 14	34 N., 5 W.	Big Horn–Powder River Corp. Schamburg 1	1961
			New Mexico	
56	NW¼ NE¼ 31	32 N., 10 W.	El Paso Natural Gas Co. Scott 16	1976
57	NE¼ NW¼ 26	32 N., 11 W.	El Paso Natural Gas Co. Barnes 4A	1978
58	SE¼ SE¼ 20	32 N., 10 W.	Supron Energy Corp. Payne 1A	1978
59	SW¼ SW¼ 8	32 N., 10 W.	Pacific Northwest Pipeline Corp. Aztec 2–8	1956
			Colorado	
60	SE¼ SW¼ 14	32 N., 10 W.	Arco Oil and Gas Co. Southern Ute 14–2	1980
61	SW¼ SW¼ 1	32 N., 10 W.	Amoco Production Co. Bonds Gas Unit 2E	1983
62	SE¼ NW¼ 31	33 N., 9 W.	Dixie M. McLane Trust Spatter 4	1973
63	NW¼ NE¼ 30	33 N., 9 W.	Centennial Oil Co. Florida Gas Unit 1	1970
64	NE¼ SW¼ 9	33 N., 9 W.	Mesa Petroleum Co. Ute Indian 6A	1978
65	SE¼ NW¼ 9	33 N., 9 W.	PUBCO Petroleum Corp. Ute 6	1956
66	NW¼ SW¼ 4	33 N., 9 W.	Mesa Petroleum Co. Ute Indian 4A	1978
67	NE¼ NW¼ 32	34 N., 9 W.	Southern Union Production Co. Beaston 2.	1961
68	NW¼ NE¼ 30	34 N., 9 W.	Ladd Petroleum Corp. Fee 2–30	1982
			New Mexico	
69	NE¼ SE¼ 30	31 N., 12 W.	John Hill and others Taliferro 5M	1981
70	SW¼ SW¼ 12	31 N., 12 W.	Southland Royalty Co. Davis 10E	1980
71	SE¼ NE¼ 1	31 N., 12 W.	Southland Royalty Co. Dusenberry 3E	1979
72	SW¼ NW¼ 34	32 N., 11 W.	El Paso Natural Gas Co. Fields 7A	1977
73	SE¼ NW¼ 16	32 N., 11 W.	Northwest Pipeline Corp. Cox Canyon 1A	1976
			Colorado	
[1]74	NW¼ SW¼ 23	32 N., 11 W.	Suprion Energy Corp. Virbeth Land Co. 1A	1977
[1]74a	SW¼ SE¼ 23	32 N., 11 W.	Southern Union Gas Co. Ute 5A	1955
75	SE¼ NW¼ 10	32 N., 11 W.	Ladd Petroleum Corp. Southern Ute 2–10	1981
76	NW¼ SE¼ 34	33 N., 11 W.	Val R. Reese & Assoc. Inc. Ute 2–34	1959
77	SW¼ SE¼ 26	33 N., 11 W.	Sanchez-O'Brien Oil & Gas Corp. Southern Ute 26–1	1981
78	SW¼ SE¼ 13	33 N., 11 W.	American Petroleum Energy Co., Inc. Argenta-Ute 9	1979
79	SW¼ SE¼ 12	33 N., 11 W.	Transocean Oil Co., Inc. Ute 3–12	1980
80	NE¼ SE¼ 1	33 N., 11 W.	Transocean Oil Co., Inc. Ute 1–1	1979
81	SE¼ NW¼ 6	33 N., 10 W.	American Petroleum Energy Co., Inc. Argenta-Ute 4	1978
82	NE¼ SE¼ 5	33 N., 10 W.	Lynco Oil Co. La Posta Canyon 1	1976
83	NE¼ NW¼ 3	33 N., 10 W.	Lynco Oil Co. Indian Springs 1	1976
84	SW¼ NW¼ 33	34 N., 10 W.	Robert L. Haynie Ute 34–10 1	1975
85	NW¼ SE¼ 9	34 N., 10 W.	SUNEDCO 2–9U–34	1977

[1]Nos. 74 and 74a are used in combination on line of section *E–E′*; No. 74 was used to identify coal beds, but the log does not include the Huerfanito Bentonite Bed, which was used as datum; No. 74a could not be used for coal beds, but it was satisfactory to locate the Huerfanito Bentonite Bed.

surface thicknesses of the Lewis range from about 1,400 ft in the southwestern part of the Reservation (Barnes and others, 1954) to 2,400 ft in the eastern part (Wood and others, 1948).

Marker beds in the Lewis Shale have been used to show the alignment of Upper Cretaceous shoreline sandstone deposits. One marker bed in the Lewis Shale of the San Juan Basin, identified in the subsurface and named the "Green Marker Horizon" by Hollenshead and Pritchard (1961, p. 101), was used as a datum to show the geometry of the shoreline sandstone deposits of the regressive Point Lookout Sandstone and the transgressive Cliff House Sandstone of the Mesaverde Group. With this datum, which is in the lower part of the Lewis

Shale, Hollenshead and Pritchard were able to locate vertical and lateral positions of the Point Lookout and Cliff House shorelines.

Fassett and Hinds (1971, p. 6) identified and named the Huerfanito Bentonite Bed of the Lewis Shale as a marker bed in a subsurface study of the Fruitland Formation and Kirtland Shale of the San Juan Basin. This unit, which is characterized by a distinctive geophysical log response, was identified in the subsurface by Fassett and Hinds throughout the San Juan Basin. The Huerfanito is believed to have been deposited everywhere at the same time on a sea floor that "* * * was relatively smooth and even * * *" (Fassett and Hinds, 1971, p. 12), and is, therefore, useful as a datum to show depositional patterns of the regressive Pictured Cliffs Sandstone.

The Huerfanito Bentonite Bed was utilized by Sandberg (1986) as a datum for cross sections in the west-central part of the San Juan Basin to correlate coal beds of the Fruitland Formation in the subsurface.

In this report on the Southern Ute Indian Reservation the same general model that has been applied successfully in the past is used again, but with more detailed subsurface control than was available to Fassett and Hinds (1971, p. 56, "* * * 2 to more than 6 miles * * *"), to correlate locally some coal beds in the Fruitland Formation.

Map *A* on plate 1 is a structure contour map of the top of the Huerfanito Bentonite Bed. Correlation of the Huerfanito Bentonite Bed on logs was extended by the author from the type well, the Turner and Webb Huerfanito Unit 60 in the SW¼, sec. 4, T. 26 N., R. 9 W., in northwestern New Mexico northward into the Reservation. Within the Reservation, the Huerfanito Bentonite Bed is less evident on geophysical logs than in areas closer to the type well. In the study area, the bed ranges from about 400 to 800 ft below the contact between the Lewis Shale and the Pictured Cliffs Sandstone. Because the Pictured Cliffs is time-transgressive and the Huerfanito is isochronous, the Pictured Cliffs rises stratigraphically northeastward, relative to the Huerfanito.

Map *B* on plate 1 is an isopach map of the interval between the Huerfanito Bentonite Bed and the top of the Pictured Cliffs Sandstone. This interval ranges in thickness from about 680 ft in the southwestern part of the Reservation to more than 1,140 ft in the northeastern part and is described in more detail in the following discussion of the Pictured Cliffs Sandstone.

PICTURED CLIFFS SANDSTONE

The Pictured Cliffs Sandstone is a regressive marine sandstone that overlies the Lewis Shale. It is generally light gray to buff, very fine to fine grained, and locally medium grained, and includes some interbedded shale (Wood and others, 1948). The upper part of the Pictured Cliffs is massive, whereas the lower part is a thin-bedded interval of transition that grades into the Lewis Shale. Measured surface sections show that the Pictured Cliffs ranges in thickness from 285 ft in the southwestern part of the Reservation (Barnes and others, 1954) to 90 ft east of the Reservation (Wood and others, 1948), where apparently only the upper massive sandstone was mapped as Pictured Cliffs. Map *C* on plate 1 is a structure contour map on the top of the Pictured Cliffs Sandstone based on subsurface data.

In the subsurface the thickness of the Pictured Cliffs interval ranges from 200 ft to more than 440 ft (pl. 2). In this report the basal Pictured Cliffs contact is placed at the base of the lowest sandstone that was identifiable on geophysical logs. The greatest thickness of Pictured Cliffs Sandstone is partly the result of intertonguing with the overlying Fruitland Formation and occurs where the shoreline paused during regression, transgressed (at least locally), and built up vertically (line of section *C–C′* on pl. 2, drill holes 45 and 46). Evidence of relatively minor transgressive and regressive pulses of shoreline movement is fairly common in the San Juan Basin in both the upper and lower parts of the Pictured Cliffs.

Fassett and Hinds (1971), in their study of the Fruitland Formation and the Kirtland Shale in the San Juan Basin, showed stratigraphic variations at the top of the Pictured Cliffs by constructing an isopach map of the interval between the top of the Pictured Cliffs Sandstone and the Huerfanito Bentonite Bed of the Lewis Shale, which was used as a datum. Map *B* on plate 1 of this report is an isopach map of the same interval and shows a similar picture for the Southern Ute Indian Reservation. An area (stippled on map *B* on pl. 1) of large-scale intertonguing in the upper part of the Pictured Cliffs is interpreted from logs. A stratigraphic rise of as much as 150 ft is recognized over a distance of about 2–4 mi. The lower part of this stratigraphic rise extends west of the stippled area on map *B* on plate 1 across the northern part of T. 33 N., Rs. 9 and 10 W., beginning approximately with the 800-ft isopach. The suggested trend of the Pictured Cliffs paleoshoreline is about N. 20°–30° W. South and west of the 800-ft isopach, northeast- and east-trending sandstone thickness patterns are suggested by the isopachs. A pause in the general northeastward retreat of the shoreline and vertical stacking of the Pictured Cliffs, suggested in the stratigraphic rise, is one of the conditions necessary for the accumulation of thick deposits of peat in swamps in the southwestern part of the Reservation. The stacking of Pictured Cliffs sands and accumulation shoreward of thick deposits of vegetal matter while the shoreline apparently remained in essentially one position were identified and modeled in the San Juan Basin by Fassett and Hinds (1971, p. 11).

FRUITLAND FORMATION

The Fruitland Formation is a nonmarine formation that includes interbedded sandstone, shale, and coal. The sandstone in the lower part of the formation at the surface is gray, brown, and olive colored, fine to medium grained, crossbedded, and lenticular. The shale is dark gray to black and pale olive to grayish green (Barnes and others, 1954). Most of the coal beds are in the lower part of the formation. In many places a coal bed in the Fruitland directly overlies the Pictured Cliffs Sandstone. The main coal-bearing interval ranges in thickness from as thin as about 20 ft (line of section *A–A′* on pl. 2, drill hole 21) to more than 400 ft (line of section *B–B′* on pl. 2, drill hole 28). The coal beds in the Fruitland Formation of the Reservation make up some of the largest coal resources in the San Juan Basin.

The upper part of the Fruitland generally contains less sandstone and coal and is more shaly than the lower part. Zapp (1949) noted changes in the upper part of the Fruitland to gray-green shale and sandstone that include chlorite and small grains of feldspar.

Thickness of the Fruitland is generally between 300 and 500 ft at the surface; in lines of section on plate 2, the thickness varies from about 200 ft to more than 500 ft in the subsurface. The formation thins to about 200 ft in places to the east of the large stratigraphic rise of the Pictured Cliffs.

The Fruitland contact with the overlying Kirtland Shale is gradational and was identified by Barnes and others (1954) at the top of "* * * all coal beds more than 1.2 feet thick and the associated shale and resistant sandstone beds * * *." Fassett and Hinds (1971, p. 19), and other workers, have picked the Fruitland-Kirtland contact in the subsurface at the top of the highest coal bed or carbonaceous shale bed that can be detected on geophysical logs. This practice was followed in the present study where possible. On some logs the contact can be identified at an overall change in lithology from shale and poorly resistant sandstone of the Fruitland to predominantly shale of the Kirtland.

KIRTLAND SHALE

The Kirtland Shale is a sequence of nonmarine shale and sandstone that is divided into the lower shale member, Farmington Sandstone Member, and upper shale member. The lower shale member includes olive-gray to olive-green, fine-grained sandy and silty shale, thin beds of fine-grained sandstone, and in places, carbonaceous shale and thin lenticular coal beds (Barnes and others, 1954; Barnes, 1953). The Farmington Sandstone Member is thin-bedded to massive, fine- to medium-grained, light-buff to light-gray sandstone interbedded with shale and silty and sandy shale. The upper shale member in the western part of the Reservation contains shale and weakly cemented sandstone in a ratio of about 2:1 (Barnes and others, 1954). The Kirtland Shale is about 500 ft thick in the southwestern part of the Reservation (Barnes and others, 1954) and more than 700 ft thick north of the Reservation, east of the Los Pinos River (Barnes, 1953). In the southwestern part of the Reservation the lower member is 325 ft thick.

STRUCTURE

On the Southern Ute Indian Reservation, the rocks generally dip basinward toward the south-central part of the Reservation. In the western part of the area along the Hogback monocline, the coal-bearing Fruitland Formation dips as much as 26° to the southeast in sec. 9, T. 33 N., R. 11 W. (Barnes and others, 1954). The dip at this location flattens out about one and a half miles from the outcrop. This structure is shown on map *A* on plate 1, which is a structure contour map of the top of the Huerfanito Bentonite Bed, and map *C* on plate 1, which is a structure contour map of the top of the Pictured Cliffs Sandstone.

A major structure within the area of subsurface control is a feature called the Ignacio anticline (Steven and others, 1974), the axis of which extends from T. 32 N., R. 5 W., northwest through T. 33 N., R. 7 W. The anticline continues west as far as T. 33 N., R. 9 W., where the contours indicate that the axis turns to the southwest. Barnes (1953) suggested a "roughly oval dome southwest of the town of Ignacio" and noted that the dome trends northwest. Subsurface information that has subsequently become available has confirmed that this structure is part of an anticline that extends across several townships within the Reservation.

COAL DEPOSITS

MEASUREMENT OF COAL BEDS ON GEOPHYSICAL LOGS

Accuracy of coal-bed thickness measurements on logs varies according to whether the suite of logs was run for an oil and gas test hole or for a coal test hole. Logs of oil and gas holes are recorded at more rapid speeds than logs of coal holes. According to Wood and others (1983, p. 57), "Density, neutron, gamma ray, and acoustic velocity logs of oil and gas wells *** recorded at speeds of 30 to 60 feet per minute *** should permit the measurement of the thickness of coal beds within an error of ±1 foot and allow identification of beds as thin as about 2 feet." Most of the older (1950's) oil and gas well logs were run at higher speeds, and therefore thickness measurements are less accurate. Generally logs for coal exploratory holes, such as gamma-ray, resistivity, and density curves, are run about 15 ft per minute and permit thickness measurement within ±0.5 ft (Wood and others, 1983, p. 57). Another factor that affects the delineation of coal beds is the spacing of the electrodes on the logging tool. Electrodes on "oil-and-gas" tools are usually spaced more widely than on "coal" tools and therefore cannot discriminate thin beds (thin coal) as well as "coal" tools.

DISTRIBUTION AND THICKNESS OF COAL BEDS

Distribution of coal beds within the Fruitland Formation is controlled by the relative position of the underlying Pictured Cliffs Sandstone. The stratigraphically lowest coal beds are southwest of the paleoshorelines that form the large stratigraphic rise of the Pictured Cliffs Sandstone (map *B* on pl. 1). The highest and youngest coal beds are in the northeast in the upper part of, or above, the large stratigraphic rise. This relationship can be seen in the five lines of section on plate 2. The interval logged between the top of the Fruitland Formation and the Huerfanito Bentonite Bed of the Lewis Shale is shown for each drill hole, where possible, on the lines of section.

The Fruitland Formation contains three zones in which coal beds are at least 2 ft thick. In this report these three zones within the Reservation are termed lower, middle, and upper. The lower zone is located in the southwestern part of the Fruitland area and contains the two thickest and stratigraphically lowest coal beds on the Reservation; aggregate thickness of coal beds in the lower zone is more than 50 ft in places (map *A* on pl. 3). The middle zone, which overlies and overlaps the lower zone in places, is generally thickest north of the area of the lower zone and is made up of thinner coal beds that reach a maximum aggregate thickness of more than 30 ft (map *B* on pl. 3). The upper zone, which overlies and overlaps the middle zone in places, also is generally made up of thinner coal beds than the lower zone; the upper zone is the most extensive of the three zones in the Reservation. The greatest aggregate thickness of coal beds in the upper zone is in the central part of the study area (map *C* on pl. 3) where the aggregate thickness is generally more than 20 ft; apparently the maximum thickness is near the northern boundary in the central part of the Reservation.

Aggregate thickness of coal beds in the western part of the Reservation reported here is less than that reported by others, such as Shomaker and Holt (1973) and Kelso and others (1980). The lesser thickness shown in this report are in part the result of not including impure coal beds with 33 percent ash or more, on the dry basis, near the western edge of the Fruitland outcrop. This greater accuracy was achieved by using information from an unpublished report prepared for the Southern Ute Tribe by Shomaker and Feldman (1978). In their report, proximate analyses of coal samples were made generally for each 2 ft of thickness, from cores of about 31 coal exploratory holes drilled by SUNEDCO. These analyses show that intervals of highly impure coal are common. Those parts of beds in which the ash content on the dry basis is 33 percent or more are excluded as a coal resource. The suite of logs run in the coal exploratory holes includes gamma ray, resistivity, and density, which confirm the changes in quality shown in the results of the analyses. Eastward and deeper into the subsurface, geophysical logs of many oil and gas test wells also suggest to some extent that quality of coal differs considerably within the coal beds and that noncoal partings are common. Where the quality of logs was judged to be good, parts of some coal beds in these holes that could be identified as high in ash content were omitted from aggregate coal thicknesses.

Zapp (1949) described the thickest known coal bed at the surface in the Fruitland Formation of the San Juan Basin south of Durango (north of the Reservation) as including 80 ft of interbedded coal and partings. Zapp suggested that this bed contains more than 40 ft of "good coal." The high ash content of the bed overall is characteristic of coal in the Fruitland.

COAL ZONES

Isopach maps of the lower, middle, and upper coal zones (maps *A*, *B*, and *C*, respectively, on pl. 3) are combined with overburden thickness maps that show where the respective zones are 500, 1,000, 2,000, and 3,000 ft or more deep. Dashed lines, which indicate the northwestern limit of the zones on these maps, were determined from points where structure contours and topographic contours intersect on 7.5-minute topographic quadrangle maps that were used as base maps for the data.

Overburden thickness was determined for each zone separately on 7.5-minute topographic quadrangle maps after plotting at each control point the elevation at the top of, and the depth to, each coal zone. Structure contours were constructed on the top of the respective coal zones. Overburden lines were then drawn for each coal zone by connecting points where the difference between the elevation of structure contours at the top of the coal zone and the topographic contours at the surface was 500, 1,000, 2,000, or 3,000 ft. Where the coal beds are nearly flat lying, the overburden lines tend to follow the topography; where the dip of the coal beds is steeper, as along the western border of the Fruitland area of the Reservation, the overburden lines are nearly straight. The quadrangle maps were then reduced and composited into overlays on isopach maps of the respective coal zones.

LOWER COAL ZONE

The lower coal zone directly overlies, or is generally less than 50 ft above, the top of the Pictured Cliffs Sandstone. The area in which aggregate coal of the lower zone is 20 ft or more thick is stippled on map *A* of plate 3; locally the aggregate thickness is more than 50 ft. Within the stippled area the thickest coal is in two beds that can be correlated with reasonable certainty. The lower of the two thickest beds is much thinner in a northeast-trending area in the northern part of T. 32 N., R. 9 W., and in the eastern part of T. 32 N., R. 10 W. The configuration of the top of the Pictured Cliffs (map *B* on pl. 1) and of some of the coal beds suggests a northeast trend or alignment. The upper of the two thickest beds has a similar area of thinning that trends east-northeast, beginning in T. 33 N., R. 10 W. Toward the east and north the coal beds split, become thinner, and terminate in the Pictured Cliffs Sandstone.

The stratigraphic interval between the two thickest beds ranges from about 100 to 0 ft, where they merge in T. 32 N., R. 11 W., and T. 33 N., R. 9 W. (lines of section *A–A′* and *D–D ′* on pl. 2). Most of the area of thickest aggregate coal is more than 2,000 ft beneath the surface. Near the Fruitland outcrop along the western part of the study area, the coal is not as deep, but the dip there ranges from about 8° to 26° to the southeast.

East of the area of thickest aggregate coal, near the stratigraphic rise of the Pictured Cliffs Sandstone in T. 32 N., R. 8 W., sandstone replaces coal in the lower part of the Fruitland Formation (map *B* on pl. 1, line of section *A–A′* on pl. 2, map *A* on pl. 3). There, the lower coal zone essentially ends and is apparently replaced by as much as 100 ft of sandstone. The curves on the geophysical logs are not characteristic of the Pictured Cliffs in this area and suggest that possibly a Fruitland estuary system drained into the Pictured Cliffs sea here. On the north-south lines of section, the gradual stratigraphic rise of the Pictured Cliffs leaves only a thin upper split of the upper coal bed (of the lower coal zone) in sec. 4, T. 33 N., R. 9 W. (line of section *D–D ′* on pl. 2, drill hole 66), and sec. 3, T. 33 N., R. 10 W. (line of section *E–E′* on pl. 2, drill hole 83).

Coal beds near the outcrop along the northwestern limit of the lower zone are also present in the Hogback monocline, where the dip of the coal varies but locally is more than 20° to the southeast. The steepest dips are in the northern part of T. 33 N., R. 11 W., and the southern part of T. 34 N., R. 11 W. In the area of steepest dip, the coal is at a depth of 3,000 ft about 1.3 mi from the outcrop. In T. 32 N., R. 12 W., where the dip is more gentle, generally less than 10° to the southeast, the coal is at a depth of 2,000 ft about 2 mi from the outcrop. In places the coal has burned along the outcrop, especially in T. 32 N., R. 12 W. (Barnes and others, 1954). The Cinder Buttes just west of the Reservation are burned remnants of the coal-bearing interval of the Fruitland Formation.

MIDDLE COAL ZONE

The middle coal zone overlies the lower coal zone throughout most of the study area but extends farther eastward than the lower zone. The lowest coal of the middle zone ranges from directly overlying to as much as 100 ft above the top of the lower zone (see lines of section on pl. 2). The middle zone includes two fairly persistent beds and several others that are more local.

The maxiumum aggregate thickness of coal in the middle zone is more than 20 ft in an area mostly in Tps. 33 and 34 N, Rs. 9–11 W. (stippled area on map *B* on pl. 3). In sec. 25, T. 34 N., R. 10 W., the aggregate thickness is 40 ft. Areas of thickest aggregate coal of the middle zone coincide with areas of thin aggregate coal in the lower zone. In general thick coal in the middle zone is more than 2,000 ft beneath the surface. Other areas of thick coal of the middle zone, where the thickness is more than 14 ft, extend roughly in a band from T. 34 N., R. 10 W., southeast to T. 32 N., R. 8 W., and the eastern part of T. 32 N., R. 9 W. This band of thick coal is intersected by a northeast-trending area, mostly in T. 32 N., Rs. 9–11 W., in which the coal is less than 2 ft thick or is missing (map *B* on pl. 3). This area of thin or missing coal in the middle zone coincides with the area of thickest coal in the underlying lower zone. The northeast trend also coincides with the direction of trends of sandstone in the Pictured Cliffs and trends of coal in the lower zone. The distribution pattern suggests that possibly a drainage system crossed the backshore swamps here, and to the south, in a similar area within the New Mexico part of the map.

The middle coal zone extends into the lower part of the large stratigraphic rise of the Pictured Cliffs Sandstone, gradually thins, and terminates in the Pictured Cliffs (lines of section *A–A′*, *B–B′*, and *C–C ′* on pl. 2).

UPPER COAL ZONE

The upper coal zone occurs in most of the area of the Reservation that is underlain by the Fruitland Formation. The area of the upper zone in the western part of the Reservation coincides in part with the area of the underlying middle zone, but only local thin beds of the upper zone are present. The lowest coal bed of the upper zone ranges from directly overlying to more than 100 ft above the top of the middle zone (pl. 2). Aggregate thickness of coal in the upper zone is more than 20 ft in a roughly northwest trending band across the central part of the Reservation; (stippled area on map *C* on pl. 3). Coal in the upper zone attains a maximum aggregate thickness of more than 40 ft near the northern boundary of the Reservation in T. 34 N., R. 7 W., but this area of thickest coal lies more than 2,000 ft beneath the surface. East of this area of thickest coal, data are generally sparse but suggest 10–20 ft of aggregate thickness of coal beds.

Where the upper zone is thickest, it generally includes several beds within a stratigraphic interval typically between 100 and 200 ft thick. Most of the thick coal beds appear at or near the top of the large stratigraphic rise of the Pictured Cliffs Sandstone. In places some individual coal beds probably can be correlated for short distances, such as from drill holes 40 to 51 on line of section *C–C′* on plate 2.

COAL QUALITY

The rank of coal in the Fruitland Formation in the northern part of the San Juan Basin is generally considered to be high-volatile A bituminous to medium-volatile bituminous. This designation is in accordance with the definitions of the American Society for Testing and Materials (ASTM) (1984). To estimate the coal resources, the coal was assumed to be of bituminous rank. Table 2 lists selected chemical analyses of coal samples from the Fruitland Formation in, and north of, the Reservation.

Vitrinite reflectance of coal samples is another method used to determine coal rank (McCartney and Teichmuller, 1972). Results from this method, which is particularly useful for various ranks of bituminous coal, show that Fruitland coal in the Reservation is high- to medium-volatile bituminous (Kelso and Rushworth, 1982).

Coal in the Fruitland Formation of this region is reported to be coking coal. In discussing coal in the Fruitland of the San Juan region, Goolsby and others (1979, p. 40) stated that, "In Colorado, the coal resources in this formation are predominantly marginal to latent grade high-volatile A bituminous coking coal." They further stated that the high ash content generally prevents coal in the Fruitland from being premium-grade coking coal. To determine which coal constitutes coking coal, Goolsby and others (1979) combined a number of criteria but used especially ash and sulfur percentages and ASTM determination of rank.

COAL RESOURCES

The estimated original coal resources in the Fruitland Formation of the Southern Ute Indian Reservation total 16 billion short tons (table 3). Original coal resources are estimated resources in the ground before production. This total includes 15 billion short tons of identified resources and about 1 billion short tons of undiscovered resources. Identified resources are based on data that are spaced 3 mi or less apart; undiscovered resources are based on more widely spaced data and knowledge of the coal-bearing interval in the region. Undiscovered resources are limited to the eastern half of the Reservation where there is little subsurface information. The method used here to estimate the coal resources is in accordance with guidelines established by the U.S. Geological Survey (Wood and others, 1983) for estimation of coal resources to obtain comparable results when when prepared by different geologists. Tabulations are by county, township, aggregate thickness of coal, and reliability of information in four overburden categories for three coal zones. The aggregate thickness of coal beds in each zone is based mostly on interpretation of geophysical logs of drill holes shown on the isopach maps of the respective zones on plate 3.

To estimate the resources, thickness, depth, and elevation of coal were plotted on 7.5-minute topographic quadrangle maps. Structure contours and overburden isopachs were drawn on the topographic maps. Coal isopachs and lines that delineate resources according to reliability of information were constructed on separate overlays of the respective quadrangle maps. Coal isopachs used in this report for thickness categories of bituminous coal are 2.3, 3.6, 7, and 14 ft, which are part of the guidelines given by the U.S. Geological Survey for estimating coal resources (Wood and others, 1983). Identified resources are classified according to reliability of information and include measured, indicated, and inferred categories. Measured coal resources are within ¼-mi radius of a thickness measurement; indicated coal resources are between ¼- and ¾-mi radius of a thickness measurement; inferred coal resources are between ¾- and 3-mi radius of a thickness measurement. Undiscovered resources are beyond a radius of 3 mi of a thickness measurement and are in the hypothetical class of undiscovered resources in this report. Each category was planimetered to obtain the areas underlain by coal. Coal tonnages were calculated using an average coal weight of 1,800 short tons per acre-foot. Resources were obtained by multiplying area underlain by coal by average thickness of coal by 1,800 short tons per acre-foot.

TABLE 2.—*Chemical analyses of coal samples from the Fruitland Formation in the Colorado portion of the San Juan Basin*

[A, as-received; B, moisture free; C, moisture and ash free; leaders (- - -), not applicable]

Locality and sample source	Sample No.	Proximate analyses (percent)					Ultimate analysis (percent) sulfur	Heat value (Btu/lb)
		Condition	Moisture	Volatile matter	Fixed carbon	Ash		
[1]Sec. 30,	K88634	A	4.9	27.7	54.2	13.2	0.8	11,740
T. 34 N., R. 4 W.;	D205233	B	---	29.1	57.0	13.9	0.8	12,340
channel.		C	---	33.8	66.2	---	1.0	14,330
	K88635	A	1.5	31.0	56.7	10.8	0.9	13,530
	D205234	B	---	31.5	57.6	11.0	0.9	13,740
		C	---	35.3	64.7	---	1.0	15,430
	K88640	A	2.3	25.5	45.1	27.1	0.9	10,710
	D205239	B	---	26.1	46.2	27.7	0.9	10,960
		C	---	36.1	63.9	---	1.3	15,170
[2]Sec.5,	H555350	A	0.8	21.5	56.4	21.3	0.7	12,140
T. 32 N., R. 7 W.;		B	---	21.6	56.9	21.5	0.7	12,240
well cuttings.		C	---	27.6	72.4	---	0.8	15,600
[2]Sec. 15,	H46452	A	2.3	23.6	54.6	19.5	0.7	12,070
T. 32 N., R. 10 W.;		B	---	24.2	55.9	19.9	0.7	12,360
well cuttings.		C	---	30.2	69.8	---	0.9	15,440
[2]Sec. 36,	H38041	A	0.9	20.8	51.7	26.6	0.8	11,230
T. 34 N., R. 10 W.;		B	---	21.0	52.2	26.8	0.8	11,330
well cuttings.		C	---	28.7	71.3	---	1.1	15,480
[3]Sec. 27,	3551	A	3.1	32.7	47.4	16.8	1.3	11,900
T. 35 N., R. 9 W.;		B	---	33.7	49.0	17.3	1.3	12,270
mine.		C	---	40.8	59.2	---	1.6	14,840
[4]Sec. 25,	204	A	1.1	16.4	56.1	26.4	0.4	11,280
T. 34 N., R. 8 W.		B	---	16.6	56.7	26.7	0.5	11,410
well core.		C	---	22.6	77.4	---	0.6	15,560
	209	A	0.9	15.1	59.1	24.9	0.6	11,580
		B	---	15.3	59.6	25.1	0.6	11,680
		C	---	20.4	79.6	---	0.6	15,590

[1]Khalsa, 1981. Tests of samples show coal to be agglomerating.
[2]Fassett and Hinds, 1971.
[3]U.S. Bureau of Mines, 1937.
[4]Kelso and Rushworth, 1982.

Where the dip of coal beds is less than 10°, the coal beds are treated as flat lying. Where the dip is more than 10°, as in places in the western part of the Reservation, resources were divided by the cosine of the dip to obtain final estimated resources.

The resources were estimated using thickness categories suggested (Wood and others, 1983) for bituminous coal, with the exception of the thinnest category, 1.2–2.3 ft. The 1.2–2.3-ft category could not be assessed with confidence on most of the geophysical logs of oil and gas test wells and, therefore, was not considered in this report. A summary table of coal resources by aggregate thickness of coal follows:

Estimated coal resources by aggregate coal thickness

Aggregate thickness (feet)	Estimated resource (millions of short tons)	Percent of total
Identified		
2.3–3.6	135	1
3.6–7.0	520	3
7.0–14.0	2,890	19
More than 14.0	11,770	77
Undiscovered		
7.0–14.0	70	6
More than 14.0	1,080	94

TABLE 3.—*Estimated original coal resources of the Fruitland Formation in the Southern Ute Indian Reservation, as of September 1, 1987*

[In millions of short tons, rounded to two significant figures; 1,800 tons per acre-foot used in the calculations; leaders (- - -), not applicable]

County, township and range, overburden (feet)	Aggregate thickness of coal beds																
	2.3–3.6 feet				3.6–7 feet				7–14 feet				>14 feet				Total all thicknesses
	Measured	Indicated	Inferred	Total	Measured	Indicated	Inferred	Total	Measured	Indicated	Inferred	Total	Measured	Indicated	Inferred	Total	
IDENTIFIED RESOURCES																	
Upper Zone																	
Archuleta County																	
T. 32 N., R. 2 W.																	
<500	---	---	---	---	---	---	---	---	---	---	7.0	7.0	---	---	---	---	7.0
500–1,000	---	---	---	---	---	---	---	---	---	---	5.2	5.2	---	---	---	---	5.2
T. 32 N., R. 3 W.																	
<500	---	---	---	---	---	---	---	---	---	---	36	36	---	---	---	---	36
500–1,000	---	---	---	---	---	---	---	---	---	4.8	82	87	---	---	---	---	87
1,000–2,000	---	---	---	---	---	---	---	---	3.3	25	77	110	---	---	---	---	110
2,000–3,000										0.70	55	56	---	---	---	---	56
T. 32 N., R. 4 W.																	
1,000–2,000	---	---	---	---	---	---	---	---	---	---	0.22	0.22	---	---	0.07	0.07	0.29
2,000–3,000	---	---	---	---	---	---	---	---	2.4	8.7	100	120	---	---	8.0	8.0	120
>3,000	---	---	---	---	---	---	---	---	0.3	11	109	120	---	---	39	39	160
T. 32 N., R. 5 W.																	
2,000–3,000	---	---	---	---	0.57	0.09	---	0.66	0.96	23	130	160	---	2.3	3.0	5.4	160
>3,000	---	---	---	---	---	---	---	---	---	---	72	72	---	2.5	2.2	4.6	77
T. 32 N., R. 6 W.																	
2,000–3,000	---	---	---	---	---	---	---	---	2.2	14	0.54	17	16	76	7.9	100	120
>3,000	---	---	---	---	---	---	---	---	---	6.3	5.2	11	2.6	4.1	---	6.7	18
T. 33 N., R. 3 W.																	
<500	---	---	---	---	---	---	---	---	---	---	9.8	9.8	---	---	19	19	29
500–1,000	---	---	---	---	---	---	---	---	---	2.1	37	39	---	0.35	50	50	89
1,000–2,000	---	---	---	---	---	---	---	---	2.3	4.5	4.7	12	---	7.1	34	42	53
T. 33 N., R. 4 W.																	
500–1,000	---	---	---	---	---	---	---	---	---	---	---	---	0.14	---	2.5	2.7	2.7
1,000–2,000	---	---	---	---	---	---	---	---	---	---	---	---	0.39	9.9	140	150	150
2,000–3,000	---	---	---	---	---	---	---	---	---	---	---	---	---	---	62	62	62
>3,000	---	---	---	---	---	---	---	---	---	---	---	---	---	---	24	24	24
T. 33 N., R. 5 W.																	
500–1,000	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1.0	1.0	1.0
1,000–2,000	---	---	---	---	---	---	---	---	---	---	---	---	---	---	35	35	35
2,000–3,000	---	---	---	---	---	---	---	---	---	---	9.3	9.3	---	---	8.4	8.4	18
>3,000	---	---	---	---	---	---	---	---	---	---	43	43	---	---	2.6	2.6	45
T. 33 N., R. 6 W.																	
2,000–3,000	---	---	---	---	---	---	---	---	0.24	0.26	---	0.50	0.28	0.09	---	0.37	0.87
>3,000	---	---	---	---	---	---	---	---	0.67	6.6	37	44	---	---	130	130	180
T. 34 N., R. 4 W.																	
<500	---	---	---	---	---	---	---	---	---	---	---	---	---	1.1	43	44	44
500–1,000	---	---	---	---	---	---	---	---	---	---	---	---	1.9	9.9	21	33	33
1,000–2,000	---	---	---	---	---	---	---	---	---	---	---	---	0.81	4.2	5.2	10	10
T. 34 N., R. 5 W.																	
<500	---	---	---	---	---	---	---	---	---	---	---	---	0.68	7.2	31	39	39
500–1,000	---	---	---	---	---	---	---	---	---	---	---	---	3.3	17	49	70	70
1,000–2,000	---	---	---	---	---	---	---	---	---	---	---	---	---	4.6	130	130	130
2,000–3,000	---	---	---	---	---	---	---	---	---	---	---	---	---	---	62	62	62
T. 34 N., R. 6 W.																	
>3,000	---	---	---	---	---	---	---	---	---	---	---	---	---	---	67	67	67
Archuleta County Subtotal upper zone	---	---	---	---	0.57	0.09	---	0.66	12	110	830	950	26	150	970	1,100	2,100
La Plata County																	
T. 32 N., R. 6 W.																	
2,000–3,000	---	---	---	---	---	---	---	---	2.5	8.9	0.92	12	46	210	37	290	300
>3,000	---	---	---	---	---	---	---	---	---	---	---	---	4.3	8.3	0.45	13	13
T. 32 N., R. 7 W.																	
2,000–3,000	---	---	---	---	---	---	---	---	16	21	---	37	56	150	73	270	310
>3,000	---	---	---	---	0.49	1.1	---	1.6	10	32	1.1	43	18	26	0.28	45	90

TABLE 3.—*Estimated original coal resources of the Fruitland Formation in the Southern Ute Indian Reservation, as of September 1, 1987*—Continued

[In millions of short tons, rounded to two significant figures; 1,800 tons per acre-foot used in the calculations; leaders (- - -), not applicable]

County, township and range, overburden (feet)	Aggregate thickness of coal beds																
	2.3–3.6 feet				3.6–7 feet				7–14 feet				>14 feet				Total all thicknesses
	Measured	Indicated	Inferred	Total	Measured	Indicated	Inferred	Total	Measured	Indicated	Inferred	Total	Measured	Indicated	Inferred	Total	
IDENTIFIED RESOURCES—Continued																	
Upper zone—Continued																	
La Plata County— Continued																	
T. 32 N., R. 8 W.																	
2,000–3,000	---	---	---	---	---	---	---	---	---	0.62	0.09	0.71	---	0.37	---	0.37	1.1
>3,000	1.7	5.7	1.6	8.9	11.2	30	1.0	42	25	51	0.26	77	5.0	11	0.45	17	140
T. 32 N., R. 9 W.																	
>3,000	1.7	5.5	0.21	7.4	2.4	5.3	0.01	7.8	---	---	---	---	---	---	---	---	15
T. 33 N. R. 6 W.																	
2,000–3,000	---	---	---	---	---	---	---	---	1.5	0.56	---	2.1	13	54	31	98	100
>3,000	---	---	---	---	---	---	---	---	1.7	12	1.6	16	20	120	200	340	350
T. 33 N., R. 7 W.																	
2,000–3,000	---	---	---	---	---	0.10	0.05	0.15	2.6	9.8	0.41	13	97	480	255	830	840
>3,000	---	---	---	---	---	---	---	---	---	---	0.73	1.8	---	1.4	3.6	5.0	6.8
T. 33 N., R. 8 W.																	
2,000–3,000	0.09	1.1	1.0	2.2	2.0	8.1	4.9	15	13	49	9.0	71	36	210	95	340	430
>3,000	0.23	1.3	0.85	2.4	1.3	5.8	3.8	11	5.0	22	---	27	11	31	7.3	49	89
T. 33 N., R. 9 W.																	
2,000–3,000	0.65	1.8	0.21	2.6	5.4	9.9	1.2	17	4.4	17	3.3	25	---	2.5	0.70	3.2	47
T. 33 N., R. 10 W.																	
2,000–3,000	0.85	2.6	0.24	3.7	4.7	9.0	0.05	14	13	18	---	31	---	---	---	---	48
>3,000	0.19	0.84	0.17	1.2	1.3	5.7	0.30	7.3	3.1	14	1.8	19	---	---	---	---	28
T. 33 N., R. 11 W.																	
2,000–3,000	0.35	0.47	0.02	0.84	0.51	3.0	---	3.5	0.07	---	---	0.07	---	---	---	---	4.4
>3,000	0.23	1.6	0.20	2.0	3.1	8.6	0.09	12	1.4	0.22	---	1.6	---	-	---	---	15
T. 34 N., R. 6 W.																	
2,000–3,000	---	---	---	---	---	---	---	---	---	---	---	---	16	80	77	170	170
>3,000	---	---	---	---	---	---	---	---	---	---	---	---	6.0	62	180	250	250
T. 34 N., R. 7 W.																	
2,000–3,000	---	---	---	---	0.23	0.10	---	0.33	2.4	12	5.7	20	57	320	430	810	830
T. 34 N., R. 8 W.																	
1,000–2,000	---	---	---	---	---	---	---	---	---	---	---	---	---	5.4	0.99	6.4	6.4
2,000–3,000	---	---	---	---	1.2	0.41	---	1.6	3.8	28	39	71	52	230	260	540	610
T. 34 N., R. 9 W.																	
<500	---	---	---	---	---	---	---	---	---	---	0.19	0.19	---	---	---	---	0.19
500–1,000	---	---	---	---	---	---	---	---	---	---	0.28	0.28	---	---	---	---	0.28
1,000–2,000	---	---	---	---	---	---	---	---	---	0.57	24	24	---	---	0.89	0.89	24
2,000–3,000	0.30	1.7	1.4	3.3	1.5	10	5.6	18	14	62	44	120	3.5	50	90	140	280
>3,000	---	---	0.06	0.06	---	---	0.05	0.05	---	---	---	---	---	---	---	---	0.11
T. 34 N., R. 10 W.																	
<500	0.23	0.02	0.07	0.32	---	---	0.22	0.22	---	---	1.6	1.6	---	---	---	---	2.1
500–1,000	0.50	0.15	0.07	0.72	0.10	---	0.26	0.36	---	---	1.1	1.1	---	---	---	---	2.2
1,000–2,000	0.20	0.86	0.69	1.8	0.19	0.11	1.6	1.9	---	---	7.2	7.2	---	---	---	---	11
2,000–3,000	0.13	3.3	0.55	4.0	1.5	12	1.3	15	2.1	9.5	2.5	14	---	---	---	---	33
>3,000	0.23	0.50	---	0.73	1.1	0.50	---	1.6	0.09	---	---	0.09	---	---	---	---	2.4
La Plata County Subtotal upper zone	7.5	27	7.3	42	38	110	21	170	120	370	140	640	440	2,000	1,700	4,200	5,100
Archuleta and La Plata Counties Total upper zone	7.5	27	7.3	42	39	110	21	170	130	480	970	1,600	470	2,200	2,700	5,400	7,200
Middle zone																	
La Plata County																	
T. 32 N., R. 7 W.																	
2,000–3,000	1.2	2.9	0.01	4.1	4.6	3.5	---	8.1	0.16	0.95	---	1.1	---	---	---	---	1.3
3,000	0.41	1.7	0.10	2.2	5.3	4.1	---	9.3	4.0	7.1	---	11	---	0.09	---	0.09	23
T. 32 N., R. 8 W.																	
>3,000	---	0.43	0.03	0.46	5.5	12	0.28	18	24	64	0.31	88	58	140	22	220	330

TABLE 3.—*Estimated original coal resources of the Fruitland Formation in the Southern Ute Indian Reservation, as of September 1, 1987*—Continued

[In millions of short tons, rounded to two significant figures; 1,800 tons per acre-foot used in the calculations; leaders (- - -), not applicable]

County, township and range, overburden (feet)	Aggregate thickness of coal beds: 2.3–3.6 feet				3.6–7 feet				7–14 feet				>14 feet				Total all thicknesses
	Measured	Indicated	Inferred	Total	Measured	Indicated	Inferred	Total	Measured	Indicated	Inferred	Total	Measured	Indicated	Inferred	Total	
IDENTIFIED RESOURCES—Continued																	
Middle zone—Continued																	
La Plata County— Continued																	
T. 32 N., R. 9 W.																	
2,000–3,000	0.39	2.5	0.42	3.4	4.8	11	2.0	18	1.6	4.9	3.3	9.8	0.14	1.2	---	1.3	32
>3,000	0.04	0.91	0.23	1.2	4.5	8.3	0.68	13	9.1	44	9.7	62	42	104	1.7	148	230
T. 32 N., R. 10 W.																	
2,000–3,000	1.4	4.4	0.41	6.2	3.8	13	2.2	19	7.6	20	3.6	32	1.3	---	---	1.3	58
>3,000	0.69	3.4	0.45	4.6	4.4	13	0.84	18	2.1	12	---	14	---	---	---	---	36
T. 32 N. R. 11 W.																	
2,000–3,000	---	0.44	0.38	0.82	---	0.18	---	0.18	---	---	---	---	---	---	---	---	1.0
>3,000	---	0.12	---	0.12	---	0.28	---	0.28	---	---	---	---	---	---	---	---	0.40
T. 33 N., R. 7 W.																	
2,000–3,000	0.64	2.5	0.58	3.7	0.15	3.0	1.3	4.4	3.1	---	0.75	3.9	---	---	---	---	12
>3,000	---	---	---	---	---	0.14	---	0.14	---	---	---	---	---	---	---	---	0.14
T. 33 N., R. 8 W.																	
2,000–3,000	0.55	2.2	1.4	4.2	3.0	8.8	3.3	15	11	46	10	67	10	18	9.4	38	124
>3,000	0.20	3.1	1.0	4.4	2.9	13	2.7	18	7.0	54	10	71	29	61	8.5	98	190
T. 33 N., R. 9 W.																	
2,000–3,000	1.4	3.8	0.06	5.3	7.2	27	0.37	35	30	70	4.9	100	52	180	11	240	380
>3,000	0.30	1.0	0.53	1.9	0.70	4.1	1.2	6.0	2.5	22	8.4	33	7.1	17	3.2	27	68
T. 33 N., R. 10 W.																	
2,000–3,000	0.19	1.6	0.12	2.0	1.4	6.8	1.5	9.7	10	30	4.4	45	120	300	9.0	430	490
>3,000	---	0.18	0.22	0.40	---	0.93	1.8	2.7	7.2	29	9.6	46	39	150	19	210	260
T. 33 N., R. 11 W.																	
<500	0.08	0.39	---	0.47	0.49	1.8	---	2.3	3.4	11	0.54	15	5.0	0.54	---	5.5	23
500–1,000	---	0.09	0.02	0.11	0.01	0.34	0.03	0.38	1.2	6.8	---	7.9	1.4	11	0.74	13	21
1,000–2,000	---	0.12	0.05	0.17	0.01	0.58	0.16	0.75	0.64	7.5	3.9	12	5.9	26	12	44	57
2,000–3,000	---	0.88	0.69	1.6	0.59	4.2	1.6	6.5	9.1	42	14	64	6.5	51	19	76	150
>3,000	---	---	---	---	---	---	---	---	0.94	4.1	0.36	5.4	28	78	2.8	110	110
T. 34 N., R. 9 W.																	
2,000–3,000	0.32	0.69	2.2	3.2	1.0	2.9	7.6	12	5.1	27	32	64	49	180	66	290	370
T. 34 N., R. 10 W.																	
<500	0.28	0.46	0.04	0.78	0.47	1.3	0.30	2.0	1.7	5.0	1.8	8.4	8.9	14	3.1	26	37
500–1,000	---	---	0.36	0.36	---	---	0.52	0.52	0.44	2.6	1.7	4.7	2.6	4.0	7.1	14	19
1,000–2,000	---	---	0.28	0.28	---	---	2.1	2.1	---	2.2	7.3	9.5	3.5	13	11	27	39
2,000–3,000	---	---	0.18	0.18	---	---	0.79	0.79	---	2.1	14	17	47	220	76	350	360
>3,000	---	---	---	---	---	---	---	---	5.6	18	4.5	28	7.8	19	3.9	31	60
T. 34 N., R. 11 W.																	
<500	---	0.12	0.07	0.19	0.62	0.90	0.79	2.3	2.1	4.0	0.61	6.8	---	0.07	---	0.07	9.3
500–1,000	---	---	0.14	0.14	---	0.44	1.1	1.5	0.25	2.2	0.41	2.9	---	1.2	---	1.2	5.8
1,000–2,000	---	---	---	---	---	0.01	2.3	2.3	---	1.7	3.4	5.1	---	2.8	---	2.8	10
2,000–3,000	---	---	---	---	---	---	---	---	---	---	5.7	5.7	---	0.74	3.8	4.6	10
>3,000	---	---	---	---	---	---	---	---	---	0.10	1.9	2.0	---	2.0	4.1	6.1	8.1
La Plata County Total middle zone	8.1	34	10	52	51	140	35	230	150	540	160	850	520	1,600	290	2,400	3,500
Lower zone																	
La Plata County																	
T. 32 N.,R. 7 W.																	
2,000–3,000	0.10	0.46	---	.56	0.34	0.03	---	0.37	---	---	---	---	---	---	---	---	0.93
>3,000	1.3	3.3	0.2	4.8	5.0	5.0	---	10	---	---	---	---	---	---	---	---	14
T. 32 N., R. 8 W.																	
>3,000	1.6	2.3	0.01	3.9	3.0	12	0.23	15	7.7	20	2.0	29	2.3	4.3	---	6 6	55
T. 32 N., R. 9 W.																	
2,000–3,000	---	---	---	---	---	---	---	---	---	---	---	---	33	71	0.16	100	100
>3,000	4.0	4.2	1.4	9.7	2.4	7.2	2.8	12	2.6	8.6	2.4	14	60	140	9.3	210	240

TABLE 3.—*Estimated original coal resources of the Fruitland Formation in the Southern Ute Indian Reservation, as of September 1, 1987*—Continued

[In millions of short tons, rounded to two significant figures; 1,800 tons per acre-foot used in the calculations; leaders (- - -), not applicable]

County, township and range, overburden (feet)	Aggregate thickness of coal beds																Total all thicknesses
	2.3–3.6 feet				3.6–7 feet				7–14 feet				>14 feet				
	Measured	Indicated	Inferred	Total	Measured	Indicated	Inferred	Total	Measured	Indicated	Inferred	Total	Measured	Indicated	Inferred	Total	
IDENTIFIED RESOURCES—Continued																	
Lower zone—Continued																	
La Plata County—Continued																	
T. 32 N., R. 10 W.																	
2,000–3,000	---	---	---	---	---	---	---	---	---	---	---	---	61	170	22	250	250
>3,000	---	---	---	---	---	---	---	---	---	---	---	---	140	390	10	540	540
T. 32 N., R. 11 W.																	
<500	---	---	---	---	---	---	---	---	---	---	---	---	15	9	---	24	24
500–1,000	---	---	---	---	---	---	---	---	---	---	---	---	5	40	0.84	46	46
1,000–2,000	---	---	---	---	---	---	---	---	---	---	---	---	23	59	28	110	110
2,000–3,000	---	---	---	---	---	---	---	---	---	---	---	---	180	500	50	730	730
>3,000	---	---	---	---	---	---	---	---	---	---	---	---	10	26	–	36	36
T. 32 N. R. 12 W.																	
<500	---	---	---	---	---	---	---	---	---	---	---	---	34	57	0.19	91	91
500–1,000	---	---	---	---	---	---	---	---	---	---	---	---	10	24	1.2	35	35
1,000–2,000	---	---	---	---	---	---	---	---	---	---	---	---	2.3	13	---	15	15
T. 33 N., R. 7 W.																	
2,000–3,000	0.26	1.8	---	2.0	---	0.02	---	0.02	---	---	---	---	---	---	---	---	2.0
>3,000	0.15	0.12	---	0.27	---	---	---	---	---	---	---	---	---	---	---	---	0.27
T. 33 N., R. 8 W.																	
>3,000	0.31	1.3	2.4	4.0	0.76	5.6	5.2	12	5.6	9.5	0.31	15	---	---	---	---	31
T. 33 N., R. 9 W.																	
2,000–3,000	0.43	3.1	0.24	3.7	6.4	15	0.39	22	13	42	2.6	57	47	160	3.2	210	290
>3,000	1.2	4.6	0.64	6.5	1.1	6.0	1.7	8.8	5.2	16	0.21	22	36	72	---	110	140
T. 33 N., R. 10 W.																	
2,000–3,000	0.89	0.44	---	1.3	4.3	12	---	17	24	41	2.1	67	69	210	19	300	380
>3,000	0.13	---	---	0.13	1.5	9.0	0.18	11	12	48	2.3	62	40	210	58	300	380
T. 33 N., R. 11 W.																	
<500	---	---	---	---	---	---	---	---	0.93	4.8	---	2.3	38	47	---	85	87
500–1,000	---	---	---	---	---	---	---	---	0.96	0.98	---	1.9	3.3	51	15	69	71
1,000–2,000	---	---	---	---	---	---	---	---	0.38	0.11	---	0.49	9.1	68	43	120	120
2,000–3,000	---	---	---	---	---	---	---	---	---	---	---	---	48	240	70	360	360
>3,000	---	---	---	---	0.11	---	---	0.11	4.0	9.0	0.19	13	25	110	20	150	170
T. 33 N., R. 12 W.																	
<500	---	---	---	---	---	---	---	---	---	---	---	---	0.32	0.82	---	1.1	1.1
T. 34 N., R. 9 W.																	
2,000–3,000	0.17	0.73	0.02	0.92	0.65	0.77	---	1.4	---	---	---	---	---	---	---	---	2.3
T. 34 N., R. 10 W.																	
<500	0.03	0.06	0.02	0.11	0.51	0.76	0.05	1.3	3.2	7.7	1.5	12	12	17	0.98	30	44
500–1.000	---	---	0.06	0.06	---	---	0.28	0.28	0.46	1.3	2.9	4.7	3.1	5.3	0.87	9.3	14
1,000–2,000	---	0.01	0.04	0.05	---	0.04	0.31	0.35	---	4.2	9.3	13	4.5	10	1.3	16	30
2,000–3,000	---	1.4	0.67	2.1	0.53	5.0	1.0	6.5	2.7	20	18	40	---	3.5	1.4	4.9	54
>3,000	---	---	---	---	1.0	1.7	---	2.8	10	29	11	50	---	---	---	---	53
T. 34 N., R. 11 W.																	
<500	---	---	---	---	---	---	---	---	3.2	5.0	1.6	9.9	5.5	11	---	17	27
500–1,000	---	---	---	---	---	---	---	---	0.22	5.9	1.7	7.8	0.10	1.2	---	1.3	9.1
1,000–2,000	---	---	---	---	---	---	---	---	---	5.2	9.7	15	---	1.9	---	1.9	17
2,000–3,000	---	---	---	---	---	---	---	---	---	0.27	7.5	7.8	---	0.19	0.58	0.77	8.5
>3,000	---	---	---	---	---	---	---	---	---	1.4	5.5	6.9	---	---	0.06	0.06	6.9
La Plata County Total lower zone	11	24	5.8	40	28	80	12	120	97	280	80	450	920	2,700	360	4,000	4,600
Identified resources																	
Total upper, middle, and lower zones	26	85	23	140	120	330	68	520	380	1,300	1,200	2,900	1,900	6,500	3,400	12,000	15,000

TABLE 3.—*Estimated original coal resources of the Fruitland Formation in the Southern Ute Indian Reservation, as of September 1, 1987*—Continued

[In millions of short tons, rounded to two significant figures; 1,800 tons per acre-foot used in the calculations; leaders (- - -), not applicable]

County, township and range, overburden (feet)	Aggregate thickness of coal beds								
	2.3–3.6 feet		3.6–7 feet		7–14 feet		>14 feet		Total all thicknesses
	Hypothetical	Total	Hypothetical	Total	Hypothetical	Total	Hypothetical	Total	
UNDISCOVERED RESOURCES									
Upper Zone									
Archuleta County									
T. 32 N., R. 3 W.									
2,000–3,000	---	---	---	---	5.2	5.2	---	---	5.2
T. 32 N., R. 4 W.									
2,000–3,000	---	---	---	---	13	13	4.4	4.4	17
>3,000	---	---	---	---	0.38	0.38	5.9	5.9	6.3
T. 32 N., R. 5 W.									
>3,000	---	---	---	---	14	14	0.12	0.12	14
T. 33 N., R. 4 W.									
1,000–2,000	---	---	---	---	---	---	48	48	48
2,000–3,000	---	---	---	---	---	---	88	88	88
>3,000	---	---	---	---	---	---	110	110	110
T. 33 N., R. 5 W.									
1,000–2,000	---	---	---	---	---	---	46	46	46
2,000–3,000	---	---	---	---	6.3	6.3	150	150	160
>3,000	---	---	---	---	29	29	210	210	240
T. 33 N., R. 6 W.									
>3,000	---	---	---	---	---	---	44	44	44
T. 34 N., R. 5 W.									
1,000–2,000	---	---	---	---	---	---	20	20	20
2,000–3,000	---	---	---	---	---	---	66	66	66
>3,000	---	---	---	---	---	---	130	130	130
T. 34 N., R. 6 W.									
>3,000	---	---	---	---	---	---	140	140	140
Archuleta County Subtotal upper zone	---	---	---	---	68	68	1,100	1,100	1,100
La Plata County									
T. 34 N., R. 6 W.									
>3,000	---	---	---	---	---	---	0.16	0.16	0.16
La Plata County Subtotal upper zone	---	---	---	---	---	---	0.16	0.16	0.16
Undiscovered resources Total	---	---	---	---	68	68	1,100	1,100	1,100
Identified and undiscovered resources Grand total	---	130	---	520	---	3,000	---	13,000	16,000

Classification of estimated coal resources by overburden category shows that by far most of the coal is more than 2,000 ft beneath the surface.

Estimated coal resources by overburden category

Overburden category (feet)	Estimated resources (millions of short tons)	Percent of total
Identified		
Less than 500	500	3
500–1,000	510	3
1,000–2,000	920	6
2,000–3,000	8,820	58
More than 3,000	4,550	30
Undiscovered		
1,000–2,000	110	10
2,000–3,000	330	29
More than 3,000	700	61

A summary table of coal resources classified according to reliability of data is shown below. These categories are described earlier in this section on coal resources.

Estimated coal resources by reliability of data

Reliability	Estimated resources (millions of short tons)	Percent of total
Identified		
Measured	2,430	15
Indicated	8,210	50
Inferred	4,610	28
Undiscovered		
Hypothetical	1,140	7

Distribution of lower, middle, and upper coal zones is shown on maps *A*, *B*, and *C*, respectively, on plate 3. The upper zone contains nearly half the identified resources but extends over a much larger area than the other zones. The lower zone includes much thicker beds within a smaller area. The estimated coal resources of each zone are summarized in the table in the adjacent column.

The estimated coal resources are in all or part of 28 townships in the Southern Ute Indian Reservation. The largest estimated tonnage is in T. 33 N., R. 10 W., which contains 10 percent of the total identified resources; a close second is T. 33 N., R. 11 W., which has 8 percent of the total identified resources. In these two townships the estimate includes resources in all three zones. Estimated coal resources by township are summarized in the table in the adjacent column.

Estimated coal resources by coal zone

Coal zone	Estimated resources (millions of short tons)	Percent of total
Identified		
Upper	7,170	47
Middle	3,540	23
Lower	4,600	30
Undiscovered		
Upper	1,140	100

Estimated coal resources by township

[leaders (- - -), value too insignificant to include as percentage of total]

Township and range	Estimated resources (millions of short tons)	Percent of total
Identified resources		
T. 32 N., R. 2 W.	12	- - -
T. 32 N., R. 3 W.	280	2
T. 32 N., R. 4 W.	280	2
T. 32 N., R. 5 W.	240	2
T. 32 N., R. 6 W.	450	3
T. 32 N., R. 7 W.	460	3
T. 32 N., R. 8 W.	540	3
T. 32 N., R. 9 W.	630	4
T. 32 N., R. 10 W.	880	6
T. 32 N., R. 11 W.	940	6
T. 32 N., R. 12 W.	140	1
T. 33 N., R. 3 W.	170	1
T. 33 N., R, 4 W.	240	2
T. 33 N., R. 5 W.	99	1
T. 33 N., R. 6 W.	630	4
T. 33 N., R. 7 W.	860	6
T. 33 N., R. 8 W.	870	6
T. 33 N., R. 9 W.	930	6
T. 33 N., R. 10 W.	1,600	10
T. 33 N., R. 11 W.	1,200	8
T. 34 N., R. 4 W.	90	- - -
T. 34 N., R. 5 W.	300	2
T. 34 N., R. 6 W.	490	3
T. 34 N., R. 7 W.	830	5
T. 34 N., R. 8 W.	620	4
T. 34 N., R. 9 W.	680	4
T. 34 N., R. 10 W.	760	5
T. 34 N., R. 11 W.	110	1
Total identified resources.	15,300	100
Undiscovered resources		
T. 32 N., R. 3 W.	5	- - -
T. 32 N., R. 4 W.	20	2
T. 32 N., R. 5 W.	10	1
T. 33 N., R. 4 W.	250	22
T. 33 N., R. 5 W.	450	40
T. 33 N., R. 6 W.	40	4
T. 34 N., R. 5 W.	220	19
T. 34 N., R. 6 W.	140	12
Total undiscovered resources.	1,100	100

POTENTIAL FOR MINING

Coal beds in the Fruitland Formation that are less than 200 ft beneath the surface are limited to narrow areas along the eastern and western sides of the Reservation. Although the coal beds are unusually thick in the Hogback monocline along the western side of the San Juan Basin, the dip is locally more than 20° in the northern part of T. 33 N., R. 11 W., and in the extreme southern part of T. 34 N., R. 11 W. (Barnes and others, 1954). In T. 32 N., R. 12 W., and in the southern part of T. 33 N., R. 12 W., however, the dip is generally less than 15°. Along the outcrop in T. 34 N., R. 10 W., and in the extreme eastern part of T. 34 N., R. 11 W., the dip is less than 15° (Barnes and others, 1954).

Several reports contain estimates of strippable coal resources along the western edge of the area underlain by the Fruitland Formation; the criteria on which the estimates are based vary. Speltz (1976) based his estimate in general on a minimum coal-bed thickness of 2 ft and an overburden limited to no more than 150 ft. His map of strippable coal areas shows a continuous northeast-trending band on the western side of the Reservation along the Fruitland outcrop in the Hogback monocline. Shomaker and Feldman (1978), in a reevaluation of previous, original coal estimates, used for criteria a coal thickness of at least 3 ft and an overburden thickness limited to no more than 200 ft. Their area of strippable resources also is a continuous band along the monocline.

The U.S. Geological Survey (Dames and Moore, 1979) calculated coal resources in the Fruitland Formation on Federal lands within the Known Recoverable Coal Resource Area (KRCRA) of the La Plata 7.5-minute quadrangle, which is mostly in New Mexico, directly southwest of the Reservation. In the La Plata quadrangle, as well as in the Reservation, coal in the Fruitland Formation crops out along the Hogback monocline. Criteria used for this estimate of coal resources are minimum coal-bed thickness of 5 ft, maximum overburden thickness of 200 ft, and dip less than 15°. Development potential for strip mining was then determined according to mining ratios of cubic yards of overburden per ton of recoverable coal. The strippable coal resources are shown on maps as narrow discontinuous areas.

Interest in the deeper coal beds of the Fruitland and related rock units is currently related to methane production. In the future some of the deeper coal beds may be mined by underground or in-situ gasification methods. Deeper coal beds that are 5 ft or more thick have high, moderate, or low development potential for underground mining methods where dip is less than 15°, according to standards established by the U.S. Geological Survey in the La Plata quadrangle (Dames and Moore, 1979). According to these standards, coal with an overburden thickness of 200–1,000 ft has high potential; 1,000–2,000 ft, moderate potential; and 2,000–3,000 ft, low potential. For example, the dip of coal beds in the lower zone of the Fruitland is apparently less than 10° about 2 mi from the outcrop along the Hogback monocline, but the overburden thickness is at least 2,000 ft; therefore the coal has low development potential. Most coal resources estimated for the Southern Ute Indian Reservation—about 88 percent—are deeper than 2,000 ft beneath the surface.

REFERENCES CITED

American Society for Testing and Materials, 1984, Standard classification of coals by rank (ASTM Designation D 388–84), *in* Gaseous fuels, coal, and coke; atmospheric analysis: 1984 Annual book of ASTM standards, pt. 26, p. 190–195.

Barnes, Harley, 1953, Geology of the Ignacio area, Ignacio and Pagosa Springs quadrangles, La Plata and Archuleta Counties, Colorado: U.S. Geological Survey Oil and Gas Investigations Map OM–138, scale 1:63,360.

Barnes, Harley, Baltz, E.H., Jr., and Hayes, P.T., 1954, Geology and fuel resources of the Red Mesa area, La Plata and Montezuma Counties, Colorado: U.S. Geological Survey Oil and Gas Investigations Map OM–149, scale 1:62,500.

Dames and Moore, 1979, Coal resource occurrence maps and coal development potential maps of the La Plata quadrangle, San Juan County, New Mexico, and La Plata County, Colorado: U.S. Geological Survey Open-File Report 79–1110, scale 1:24,000, 26 p.

Fassett, J.E., 1977, Geology of the Point Lookout, Cliff House, and Pictured Cliffs Sandstones of the San Juan Basin, New Mexico and Colorado: New Mexico Geological Society Guidebook, 28th Field Conference, San Juan Basin III, northwestern New Mexico, p. 193–197.

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. Geological Survey Professional Paper 676, 76 p.

Goolsby, S.M., Reade, N.S., and Murray, D.K., 1979, Evaluation of coking coals in Colorado: Colorado Geological Survey Resource Series 7, 72 p.

Hayes, P.T., and Zapp, A.D., 1955, Geology and fuel resources of the Upper Cretaceous rocks of the Barker Dome–Fruitland area, San Juan County, New Mexico: U.S. Geological Survey Oil and Gas Investigations Map OM–144, scale 1:62,500.

Hollenshead, C.T., and Pritchard, R.L., 1961, Geometry of producing Mesaverde sandstones, San Juan Basin, *in* Geometry of sandstone bodies: American Association of Petroleum Geologists Research Committee Symposium, p. 98–118.

Kelso, B.S., Goolsby, S.M., and Tremain, C.M., 1980, Deep coal bed methane potential of the San Juan River coal region, southwestern Colorado: Colorado Geological Survey Open-File Report 80–2, 56 p.

Kelso, B.S., and Rushworth, Peter, 1982, Southern Ute/ Department of Energy coalbed methane test wells: Colorado Geological Survey Open-File Report 82–4, 21 p.

Khalsa, N.S., 1981, Chemical analyses of coal samples from San Juan River Region, *in* Colorado coal analyses 1976–1979: Colorado Geological Survey Information Series 10, p. 214–239.

Landis, E.R., 1959, Coal resources of Colorado: U.S. Geological Survey Bulletin 1072–C, p. 131–232.

Landis, E.R., and Cone, G.C., 1971, Coal resources of Colorado; tabulated by bed: U.S. Geological Survey Open-file Report, 515 p.

McCartney, J.T., and Teichmuller, M., 1972, Classification of coals according to degree of coalification by reflectance of the vitrinite component: Fuel, v. 51–1, p. 64–68.

Molenaar, C.M., 1977, Stratigraphy and depositional history of Upper Cretaceous rocks of the San Juan Basin area, New Mexico and Colorado, with a note on economic resources: New Mexico Geological Society Guidebook, 28th Field Conference, San Juan Basin III, northwestern New Mexico, p. 159–166.

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

Sandberg, D.T., 1986, Correlation of coal beds in the Fruitland Formation as interpreted from geophysical logs, east-central San Juan County, New Mexico: U.S. Geological Survey Miscellaneous Field Studies Map MF–1848.

______ 1988a, Coal resources and coal-bed geometry, Fruitland Formation, Southern Ute Indian Reservation, Archuleta and La Plata Counties, Colorado, *in* Fassett, J.E., ed., Geology and coal-bed methane resources of the northern San Juan Basin, Colorado and New Mexico: Denver, Rocky Mountain Association of Geologists Guidebook, p. 39–50.

______ 1988b, Distribution of coal beds in the Fruitland Formation, Southern Ute Indian Reservation, Archuleta and La Plata Counties, southwestern Colorado: U.S. Geological Survey Open-File Report 88–230, 5 maps, scale 1:100,000.

Shomaker, J.W., Beaumont, E.C., and Kottlowski, F.E., 1971, Strippable low-sulfur coal resources of the San Juan Basin in New Mexico and Colorado: New Mexico Bureau of Mines and Mineral Resources Memoir 25, 189 p.

Shomaker, J.W., and Feldman, S.C., 1978, 1978 re-evaluation of original strippable coal reserves, Picnic Flats area, Southern Ute project: unpublished report prepared for the Southern Ute Tribe, 21 p.

Shomaker, J.W., and Holt, R.D., 1973, Coal resources of Southern Ute and Ute Mountain Ute Indian Reservations, Colorado and New Mexico: New Mexico State Bureau of Mines and Mineral Resources Circular 134, 22 p.

Shomaker, J.W., and Whyte, M.R., 1977, Geologic appraisal of deep coals, San Juan Basin, New Mexico: New Mexico Bureau of Mines and Mineral Resources Circular 155, 39 p.

Speltz, C.N., 1976, Strippable coal resources of Colorado—Location, tonnage, and characteristics of coal and overburden: U.S. Bureau of Mines Information Circular 8713, 70 p.

Steven, T.A., Lipman, P.W., Hail, W.J., Jr., Barker, Fred, and Luedke, R.G., 1974, Geologic map of the Durango quadrangle, southwestern Colorado: U.S. Geological Survey Miscellaneous Investigations Series Map I–764, scale 1:250,000.

U.S. Bureau of Mines, 1937, Analyses of Colorado coals: U.S. Bureau of Mines Technical Paper 574, 327 p.

Wood, G.H., Jr., Kehn, T.M., Carter, M.D., and Culbertson, W.C., 1983, Coal resource classification of the U.S. Geological Survey: U.S. Geological Survey Circular 891, 65 p.

Wood, G.H., Jr., Kelley, V.C., and MacAlpin, A.J., 1948, Geology of southern part of Archuleta County, Colorado: U.S. Geological Survey Oil and Gas Investigations Preliminary Map 81, scale 1:63,360.

Zapp, A.D., 1949, Geology and coal resources of the Durango area, La Plata and Montezuma Counties, Colorado: U.S. Geological Survey Oil and Gas Investigations Preliminary Map OM–109, scale 1:31,680.

SELECTED GEOPHYSICAL LOGS OF COAL BEDS IN LINES OF SECTION

SELECTED GEOPHYSICAL LOGS OF COAL BEDS IN LINES OF SECTION

The geophysical logs shown in figures 3–7 are typical examples of the logs that were used to construct the lines of section (pl. 2). The position of the coal beds is shown by the black units in the center of each log.

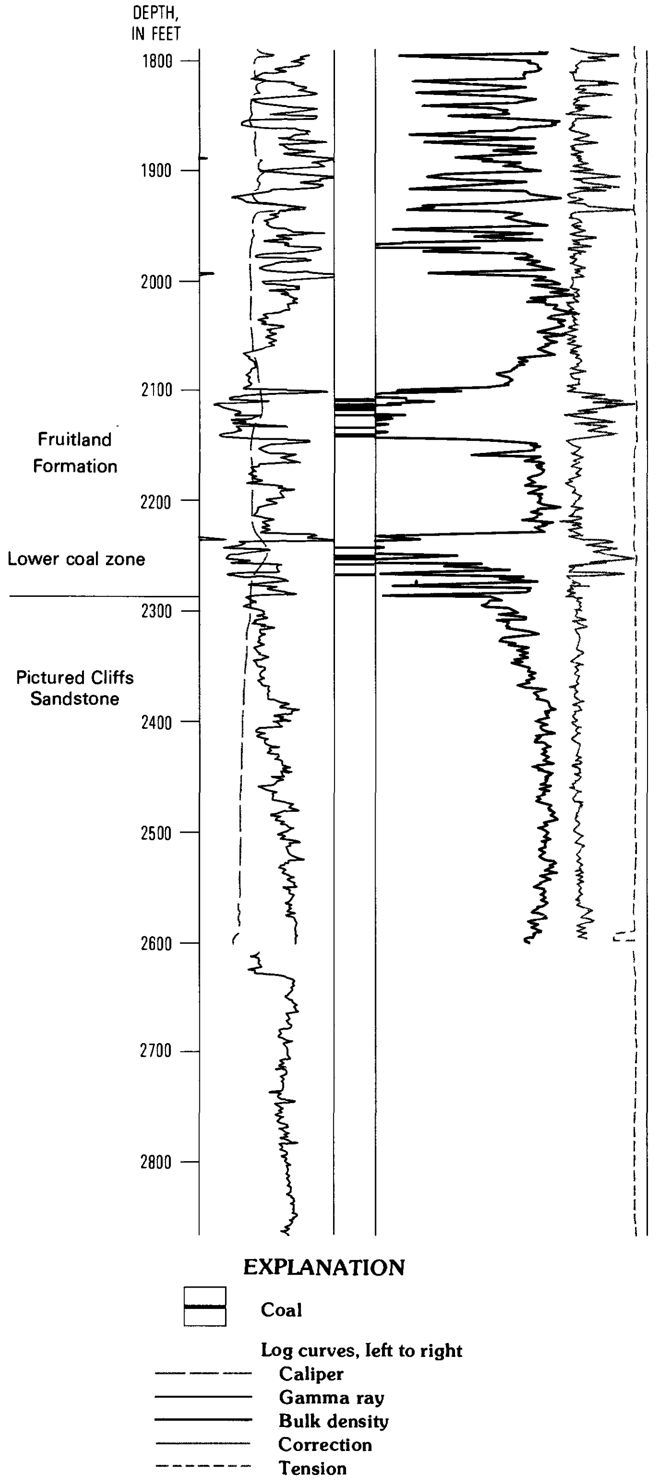

FIGURE 3.—Geophysical log of drill hole 3, line of section *A–A′* on plate 2. Arco Oil and Gas Co. Southern Ute 17–3; NW¼NW¼ sec. 17, T. 32 N., R. 11 W.

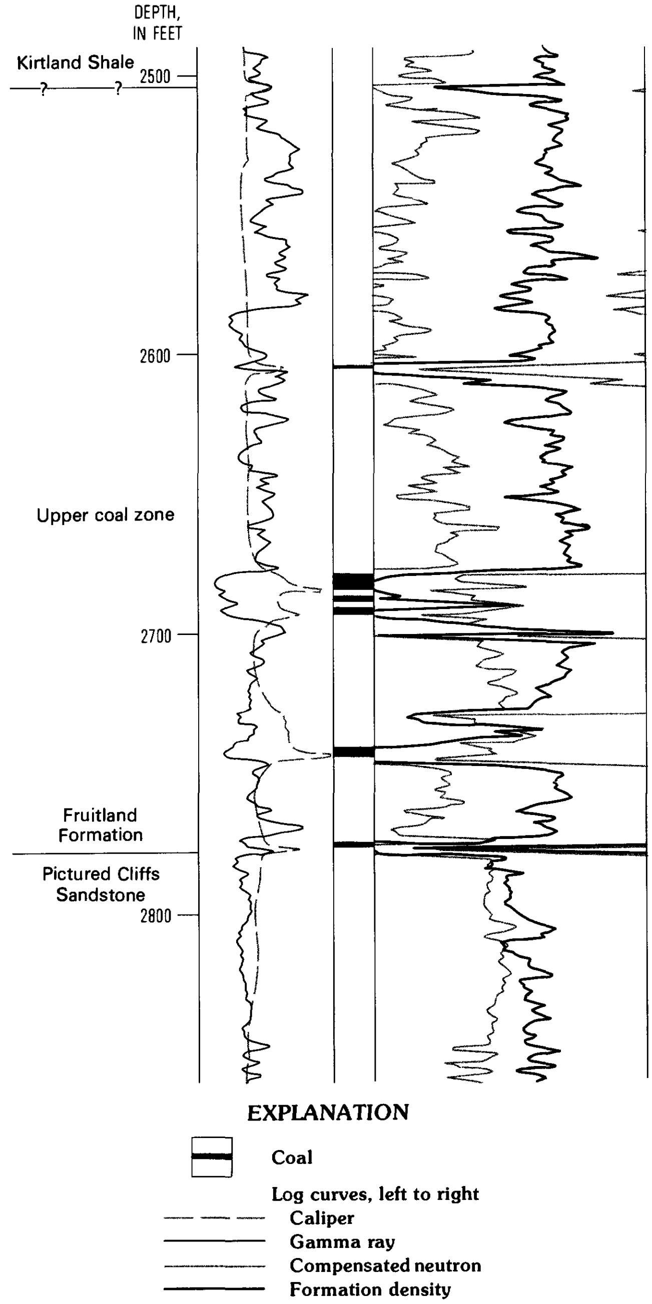

FIGURE 4.—Geophysical log of drill hole 19, line of section *A–A′* on plate 2. Tenneco Oil Co. Payne 1–8; NE¼SE¼ sec. 8, T. 32 N., R. 6 W.

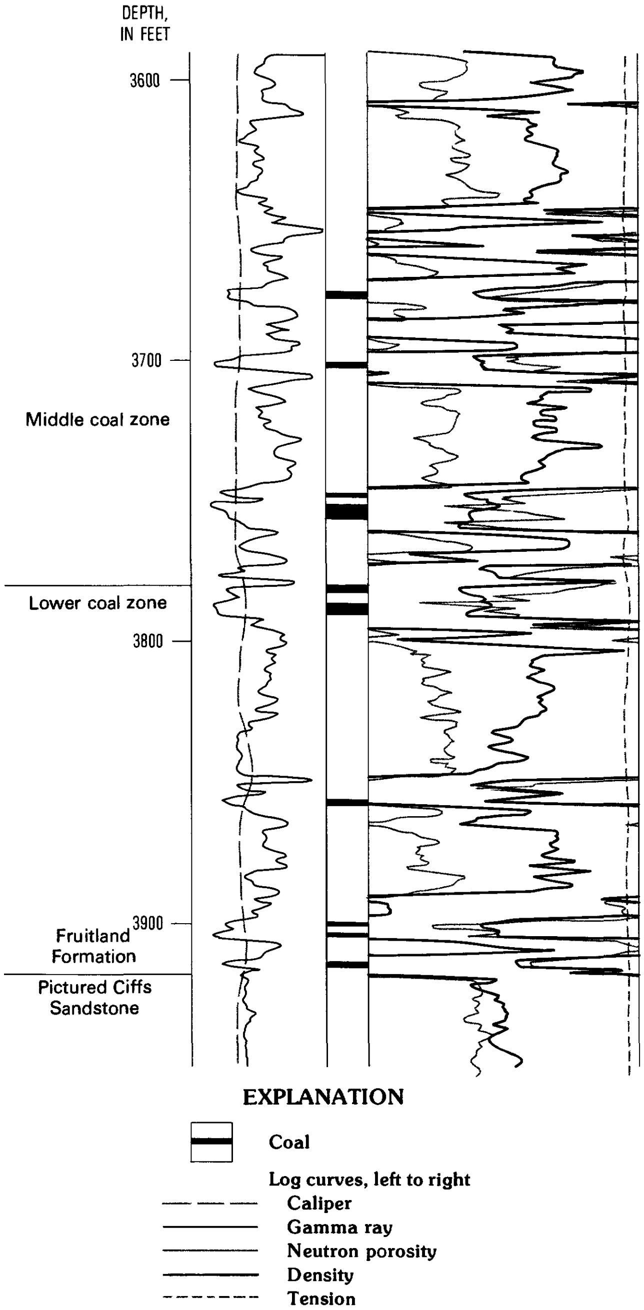

FIGURE 5.—Geophysical log of drill hole 26, lines of section *B–B′* and *E–E′* on plate 2. Arco Oil and Gas Co. Southern Ute 19–3; NW¼NW¼ sec. 19, T. 33 N., R. 10 W.

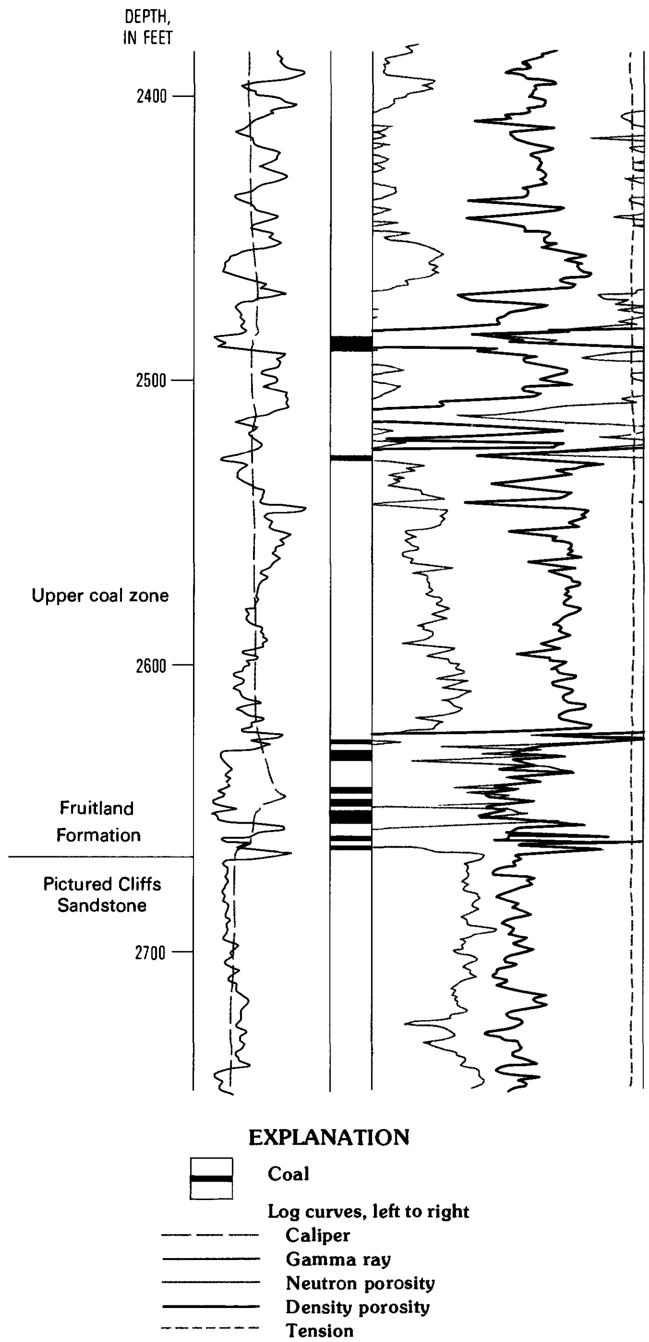

FIGURE 6.—Geophysical log of drill hole 34, line of section *B–B′* on plate 2. Amoco Production Co. Southern Ute 1–8 1A; NE¼SE¼ sec. 8, T. 33 N., R. 7 W.

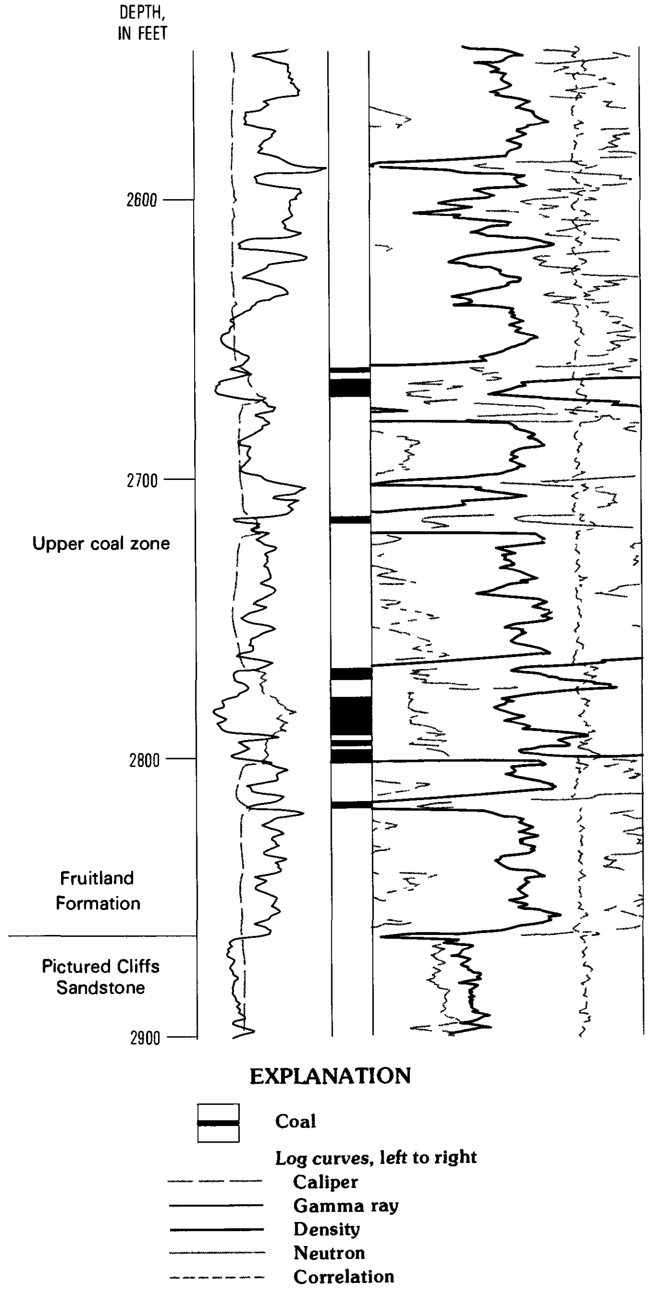

FIGURE 7.—Geophysical log of drill hole 49, line of section *C–C′* on plate 2. Rincon Operating Co. Rea 1; SE¼SE¼ sec. 32, T. 34 N., R. 8 W.