Coal Resources of the Fruitland Formation in Part of the Ute Mountain Ute Indian Reservation, San Juan County, New Mexico

U.S. GEOLOGICAL SURVEY BULLETIN 1938

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

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By LAURA N. ROBINSON ROBERTS

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[Plate is in pocket]

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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 unit	Multiply by	To obtain metric unit
foot (ft)	0.305	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
acre	0.405	hectometer
short ton	0.907	metric ton
British thermal unit per pound (Btu/lb)	0.556	kilocalorie per kilogram

Coal Resources of the Fruitland Formation in Part of the Ute Mountain Ute Indian Reservation, San Juan County, New Mexico

By Laura N. Robinson Roberts

Abstract

The coal-bearing Upper Cretaceous Fruitland Formation occupies an area of about 14 square miles in the extreme southeast corner of the Ute Mountain Ute Indian Reservation in San Juan County, New Mexico. In this area, the Fruitland Formation contains an estimated 252 million short tons of coal in beds that range from 1.2 to 14 feet thick. About 100 million short tons of coal occur under less than 500 feet of overburden in the Ute Canyon, Upper Main, and Main coal beds. These three coal beds reach a cumulative coal thickness of about 18 feet in a stratigraphic interval that averages about 120 feet thick in the prospecting permit area, which is located in the extreme southwestern part of the study area. The southwestern part of the study area is probably best suited for surface mining, although steep dips may reduce minability locally. A major haul road that was recently constructed across the eastern half of the study area greatly improves the potential for surface mining.

Core sample analyses indicate that the apparent rank of the Ute Canyon, Upper Main, and Main coal beds is high-volatile C bituminous. Average heat-of-combustion on an as-received basis is 10,250 British thermal units per pound, average ash content is 15.5 percent, and average sulfur content is 1.0 percent.

INTRODUCTION

The Division of Energy and Mineral Resources of the U.S. Bureau of Indian Affairs and the U.S. Geological Survey initiated a program to assess the energy resources of the Ute Mountain Ute Indian Reservation at the request of the Ute Mountain Ute Tribe. As part of that program, the U.S. Geological Survey studied the distribution of coal-bearing rocks within the Reservation in order to determine the extent, quality, and quantity of the coal deposits. This report presents the results of that study.

Coal within the Reservation occurs in the Dakota Sandstone and in the Menefee and Fruitland Formations, all of which are Late Cretaceous in age. Coal beds in the Dakota Sandstone are discontinuous and contain numerous partings; these beds are deeper than 1,000 ft in the eastern half of the Reservation. The Menefee Formation underlies the eastern half of the Reservation at depths from 0 ft (outcrop) to 3,000 ft and contains coal beds in two zones: one zone near the top of the formation and another zone near the base. The coal beds in the Menefee Formation are thin and discontinuous. Shomaker and Holt (1973) described the coals, reported coal resources of the Dakota Sandstone and the Menefee Formation, and suggested locations that are best suited for auger mining in the Menefee Formation.

Only the coal beds of the Fruitland Formation were studied in detail for this report. Although the Fruitland Formation occupies only a small area in the southeastern part of the Reservation, it contains coal beds that have potential for surface mining. Since the publication of Shomaker and Holt's (1973) report, and prior to July 1987, 20 oil and gas wells were drilled through the Fruitland Formation. The coal resource estimates of the Fruitland Formation on the Reservation were refined using data from these drill holes.

Location and Access

The coal-bearing Fruitland Formation underlies about 14.5 mi^2 in the southeastern corner of the Ute Mountain Ute Indian Reservation in San Juan County, northwestern New Mexico (fig. 1). The Reservation boundary defines the southern and eastern limits of the study area. An irregular line from southwest to northeast

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that represents the outcrop of the coal-bearing Fruitland Formation defines the northwestern limit of the study area.

The study area is most easily accessed from the south by a dirt road, which comes north about 9 mi from U.S. Highway 550 at the town of Kirtland, N. Mex. Recently, a heavy-duty haul road was constructed across the eastern half of the study area for use by large trucks to transport coal from the La Plata mine, which is about 8 mi northeast of the study area, to the San Juan generating station, which is about 5 mi southwest of the study area (fig. 1).

Previous Investigations

Most of the coal beds in the study area were first described and mapped by Bauer and Reeside (1921). Hayes and Zapp (1955) used much of the data from that report in their investigations of coal in the Barker dome–Fruitland area. In a more recent study of coal resources in the Ute Mountain Ute Indian Reservation Shomaker and Holt (1973) used coal data from drill holes to supplement the outcrop data and thereby improved the overall reliability of the coal resource estimates. The

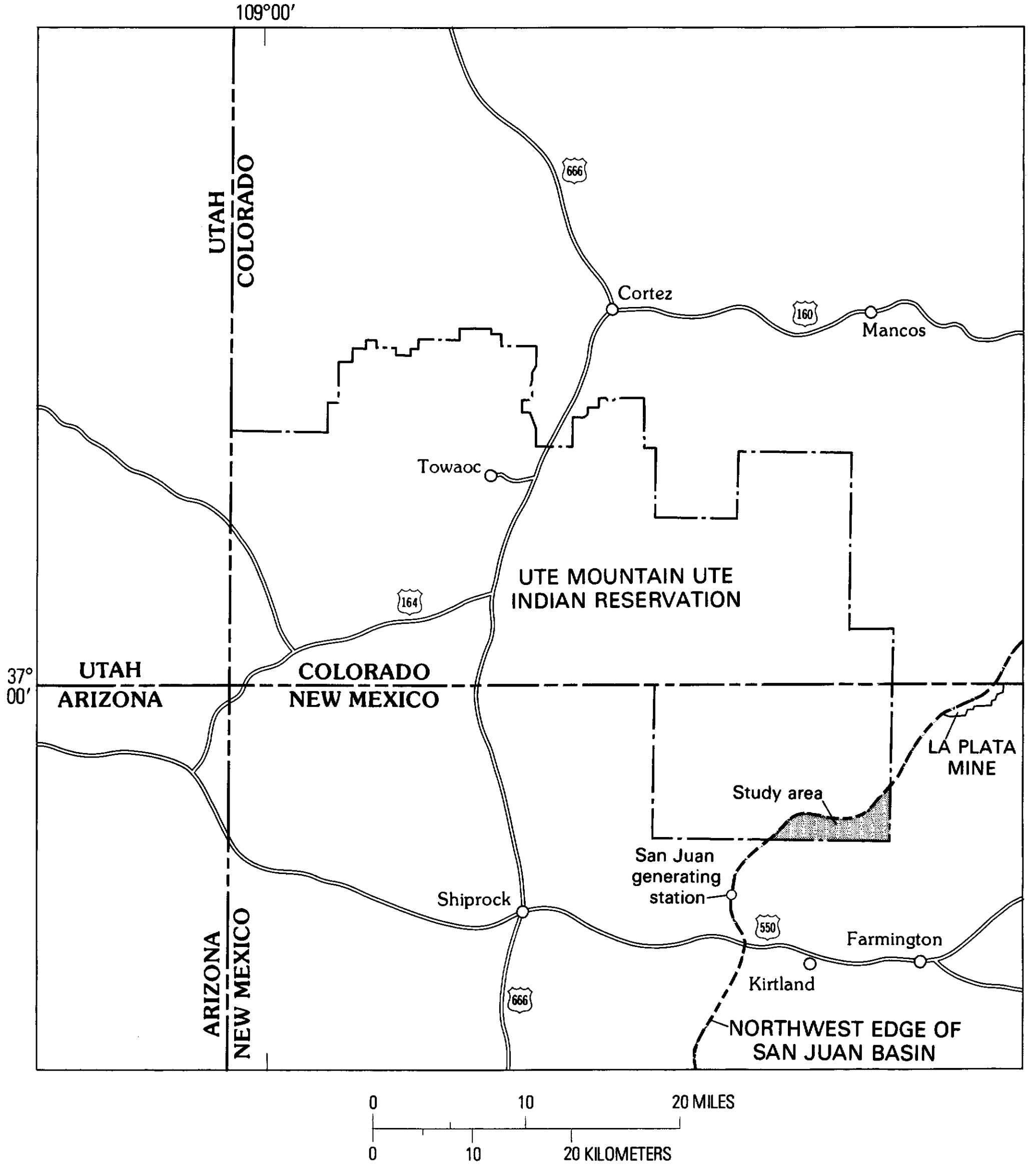

Figure 1. Map showing Ute Mountain Ute Indian Reservation and location of study area (shaded).

geologic map of the Waterflow 7.5-minute quadrangle (Strobell and others, 1980) includes information on coal correlations within the study area.

Western Coal Company drilled 17 coal exploratory holes during 1970 in an area termed the "prospecting permit area" by Shoemaker and Holt (1973). The area is located in the extreme southwestern corner of the study area in T. 31 N., R. 15 W. (map *A* on pl. 1). Unpublished products from the drilling project include nine maps, which show coal isopachs, overburden isopachs, and structure contours of the three major coal beds; geophysical and lithologic logs of the drill holes; and some coal-quality data.

Method of Investigation

Field work was done during the summers of 1986 and 1987. The work consisted of field checking coal-outcrop locations described in previous reports, mapping the extent of the coal beds onto U.S. Geological Survey base maps at a scale of 1:24,000, examining and describing newly discovered coal outcrops, and measuring sections of the Fruitland Formation.

In addition to information gathered in the field, data on the coal beds were obtained from 50 drill holes in and near the study area. The measurements of coal-bed thickness that were derived from interpretation of geophysical logs from coal test holes are considered to be accurate to within about 1 ft, and measurements from gamma-ray logs of oil and gas test wells are probably of similar accuracy. Thicknesses obtained only from the resistivity logs of oil and gas test wells may be less reliable. Table 1 is a list of drill holes that were used in the coal resource estimate, and figure 2 shows representative geophysical logs used to determine the thickness of coal beds in drill holes.

All data from outcrops and drill holes were entered into the National Coal Resource Data System (NCRDS) format. The data were then contoured using Dynamic Graphics, Inc., Interactive Surface Modeling (ISM) program to produce isopach maps of coal and overburden and to produce structure contour maps. The ISM program was also used to calculate coal resources. Cross-section and coal-section diagrams were generated using the U.S. Geological Survey's Stratigraphic Analysis Techniques System (STRATS) program (Boger, 1986).

Acknowledgments

The Division of Energy and Mineral Resources of the U.S. Bureau of Indian Affairs provided funding for the project. Steve Graham, Realty Specialist, U.S. Bureau of Indian Affairs, Towaoc, Colo., helped locate well-log information on file in their office. Darwin Whiteman, Ute Mountain Ute Indian Tribe, Energy Administration, assisted in providing access to the study area. Edward Beaumont, consulting geologist, Albuquerque, N. Mex., was the geologist on the Western Coal Company drilling project within the prospecting permit area. He provided several copies of the original maps, geophysical logs, and lithologic logs for delivery to the Tribe and for use in this report. Drafting assistance from Nina Strange, U.S. Geological Survey volunteer, was especially appreciated.

STRUCTURE

The Hogback monocline trends generally northeasterly through the center of the map area (map *A* on pl. 1). Here the monocline is reflected in the small hogbacks that are formed by steeply dipping beds of the Pictured Cliffs Sandstone, sandstones of the Fruitland Formation, and the Farmington Sandstone Member of the Kirtland Shale (Hayes and Zapp, 1955). Strata along the Hogback monocline in this area dip 20–37° southeastward. Northwestward from where the Fruitland Formation crops out in the study area, the strata flatten gradually; southeastward they flatten abruptly to 1–2°. The structure contours drawn on the top of the Main coal bed in the study area (map *B* on pl. 1) show the variation in direction and dip of the strata basinward.

STRATIGRAPHY OF FRUITLAND FORMATION

Figure 3 shows the stratigraphy of Cretaceous and Tertiary rocks in the San Juan Basin in New Mexico and Colorado. The rocks discussed in this report belong to the coal-bearing Fruitland Formation of late Campanian age. The geologic map (map *A* on pl. 1) shows the distribution of the Menefee Formation, Cliff House Sandstone, Lewis Shale, Pictured Cliffs Sandstone, Fruitland Formation, members of the Kirtland Shale, and undifferentiated Upper Cretaceous and Tertiary rocks in and near the study area. For descriptions of lithology, bedding characteristics, depositional environments, nature of formational contacts, and thickness of the rock units shown on map *A* on plate 1, see Hayes and Zapp (1955). Not shown on the geological map are surficial deposits, such as alluvium and slope wash.

The Fruitland Formation, which reaches a maximum thickness of about 380 ft in the study area, consists of interbedded siltstone, shale, sandstone, coal, and a few thin beds of limestone. The sediments that formed the Fruitland Formation accumulated about 70

Table 1. Drill holes in and near the Ute Mountain Ute Indian Reservation that were used in coal resource evaluation

[Holes with prefix U or 01 are coal exploratory holes; other holes are oil and gas test wells. Asterisks indicate holes used in resource calculations by Shomaker and Holt (1973). Sections in T. 31 N., Rs. 14 and 15 W., are projected]

Hole No.	Location Sec.,	T. N.,	R. W.	Approximate surface elevation (feet)	Total depth (feet)	Company	Well name
10031*	3	30	14	5,647	5,046	Albert C. Bruce	Bryan No. 1.
10039	5	30	14	5,582	5,811	do.	Fed Pipkin 1.
10040*	4	30	14	5,586	5,084	do.	Richardson 1 No. 5.
10184	36	31	15	5,598	4,291	Humble Oil & Refining	Ute Tribe "B" No. 4.
10222*	29	31	14	5,495	4,554	Standard Oil of Texas	Ute Mountain Tribal 2-29 No. 15.
10283*	30	31	14	5,511	4,472	Three States Natural Gas	Tribal No. 5.
10284*	29	31	14	5,517	4,450	Standard Oil of Texas	Ute Mountain Tribal 2-29 No. 6.
10287	30	31	14	5,534	4,480	Three States Natural Gas	Ute Mountain Tribal No. 6.
13153*	30	31	14	5,558	4,500	do.	Ute Mountain Tribal No. 7.
13154	30	31	14	5,511	4,400	do.	Tribal No. 9.
13155*	30	31	14	5,473	4,516	do.	Tribal No. 15.
13156	31	31	14	5,509	4,580	do.	Tribal No. 10.
13157*	31	31	14	5,540	4,600	do.	Tribal No. 11.
13158*	31	31	14	5,550	4,600	do.	Tribal No. 12.
20666	5	30	14	5,429	846	Jerome P. McHugh	Norton No. 1.
20680*	35	31	14	5,626	1,293	do.	No. 1 Foxtail.
21604	36	31	14	5,685	6,455	El Paso Natural Gas	Piñon Mesa No. 1.
21608	25	31	14	5,616	6,300	do.	Piñon Mesa No. 2.
21613	23	31	14	5,712	5,590	do.	Piñon Mesa No. 3.
21638	35	31	15	5,425	4,600	Clinton Oil	V.G. 35-1.
21968	36	31	14	5,711	6,394	El Paso Natural Gas	Piñon Mesa A No. 2.
21992	24	31	14	5,705	6,521	do.	Piñon Mesa C No. 2.
21993	25	31	14	5,688	6,440	do.	Piñon Mesa B-2.
21999	13	31	14	5,681	6,503	do.	Piñon Mesa D No. 2.
22377	1	30	14	5,877	6,550	Odessa Natural	Little Fed 2.
23286	35	31	14	5,632	6,275	El Paso Natural Gas	Piñon Mesa A No. 3.
60042	31	31	14	5,465	4,600	Three States Natural Gas	Tribal No. 8.
PMA1E	36	31	14	5,836	6,500	El Paso Natural Gas	Piñon Mesa A No. 1E.
PMA2E	36	31	14	5,655	6,300	do.	Piñon Mesa A No. 2-E.
PMA4	35	31	14	5,677	6,300	do.	Piñon Mesa A No. 4.
PMB1E	25	31	14	5,609	6,260	do.	Piñon Mesa B No. 1E.
PMB2E	25	31	14	5,641	6,310	do.	Piñon Mesa B No. 2-E.
PMC2E	24	31	14	5,723	6,522	do.	Piñon Mesa C No. 2-E.
U1*	35	31	15	5,420	200	Western Coal	Unnamed.
U2*	35	31	15	5,445	210	do.	Do.
U3*	25	31	15	5,450	200	do.	Do.
U4*	25	31	15	5,496	236	do.	Do.
U5*	34	31	15	5,424	142	do.	Do.
U6*	35	31	15	5,393	242	do.	Do.
U7*	35	31	15	5,402	179	do.	Do.
U8*	35	31	15	5,455	240	do.	Do.
U9*	35	31	15	5,435	130	do.	Do.
U10*	35	31	15	5,452	212	do.	Do.
U11*	35	31	15	5,481	162	do.	Do.
U12*	25	31	15	5,459	181	do.	Do.
U13*	25	31	15	5,463	240	do.	Do.
01L	3	30	15	5,499	95	do.	Do.
01M	3	30	15	5,460	162	do.	Do.
01P	2	30	15	5,407	198	do.	Do.
01T	2	30	15	5,397	300	do.	Do.

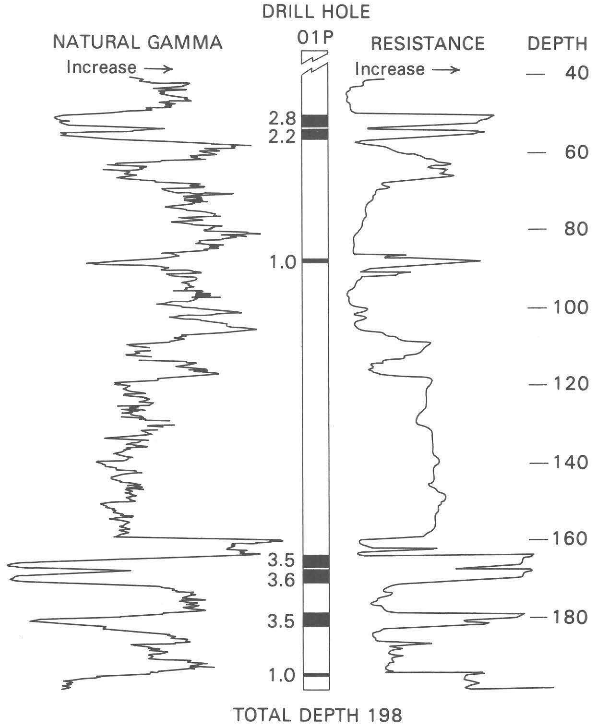

Figure 2. Representative geophysical logs used to determine coal-bed thickness in drill holes. All values in feet. Coal shown as black unit in center column; thickness of coal shown to left of center column.

million years ago (Manfrino, 1984) in swamps, lagoons, and stream channels on a broad, flat coastal plain. The Fruitland coals developed inland from and contemporaneously with the shoreline deposits of the Pictured Cliffs Sandstone.

The contact of the Fruitland Formation with the underlying Pictured Cliffs Sandstone is conformable and sharp. In drill holes the contact is placed at the top of the massive sandstone below the lowermost coal of the Fruitland Formation; on the surface the contact is usually placed at the top of the highest Ophiomorpha-bearing sandstone (Fassett and Hinds, 1971). In the study area, the first major coal bed of the Fruitland either directly overlies or occurs within about 15 ft of the sandstone of the Pictured Cliffs. Therefore, for simplicity on the geologic map (map *A* on pl. 1), the contact between the Pictured Cliffs Sandstone and the Fruitland Formation is placed at the base of the lowest coal bed. The contact of the Fruitland Formation with the overlying continental deposits of Kirtland Shale is conformable, gradational, and variable. The contact is generally placed at the top of the highest prominent sandstone or coal bed of the Fruitland Formation.

Sandstone of the Fruitland Formation is yellowish gray and light brownish gray, very fine to fine grained, and well sorted. Sandstone occurs in lenses a few inches thick and in lenticular beds as much as 30 ft thick. Common sedimentary structures in the sandstones include small- to medium-scale trough crossbedding, low-angle crossbedding, and ripple lamination, the last of which usually occurs toward the top of a sandstone unit. The sandstone is generally friable and weathers readily, but where it is more resistant, it forms the hogbacks that typify the scenery. Shale in the Fruitland Formation is commonly interbedded with thin lenses of medium-gray siltstone, brown and dark-gray carbonaceous shale, silty limestone, and sandstone. Very thin lenses of pink and grayish-orange claystone (altered volcanic ash) commonly occur as partings in the coal beds. Several coal beds are present and range in thickness from a few inches to 14 ft. Almost all the coal beds contain at least one parting.

COAL DEPOSITS

The distribution of the coal beds in the Fruitland Formation is shown in the generalized stratigraphic sections that accompany the geologic map (map *A* on pl. 1). The areal distribution of the coal beds is shown on the geologic map and in the three cross sections (sections *A–C* on pl. 1). Figure 4 shows the location of these cross sections.

Three economically important coal beds occur in the Fruitland Formation in this area. Table 2 compares the coal-bed nomenclature used in this report with that of previous reports. The Ute Canyon bed was named in this report for a small arroyo located along the Fruitland outcrop in the western part of the study area. The Main, Upper Main, and Ute Canyon coal beds correlate with coal beds designated as the lower split of the Main bed, upper split of the Main bed, and Upper bed, respectively, by Western Coal Company, based on the drilling done on the prospecting permit area. Strobell and others (1980) mapped what they termed the E and F coal beds in the extreme northeastern corner of the Waterflow 7.5-minute quadrangle. Information from the coal exploratory drilling in the prospecting permit area indicates that the E and F beds are actually one continuous bed that correlates with the Ute Canyon bed. The C and B beds of Strobell and others (1980) are the Upper Main and Main beds, respectively, of this report. According to Hayes and Zapp (1955), the 79-ft-thick Carbonera bed south of Durango, Colo., had been mistakenly correlated by Bauer and Reeside (1921) with the Upper Main bed. The Upper Main bed is actually stratigraphically lower than the Carbonera bed. Because the intertonguing relationship of the Fruitland Formation with the underlying Pictured Cliffs Sandstone was unknown at the time, Bauer and Reeside

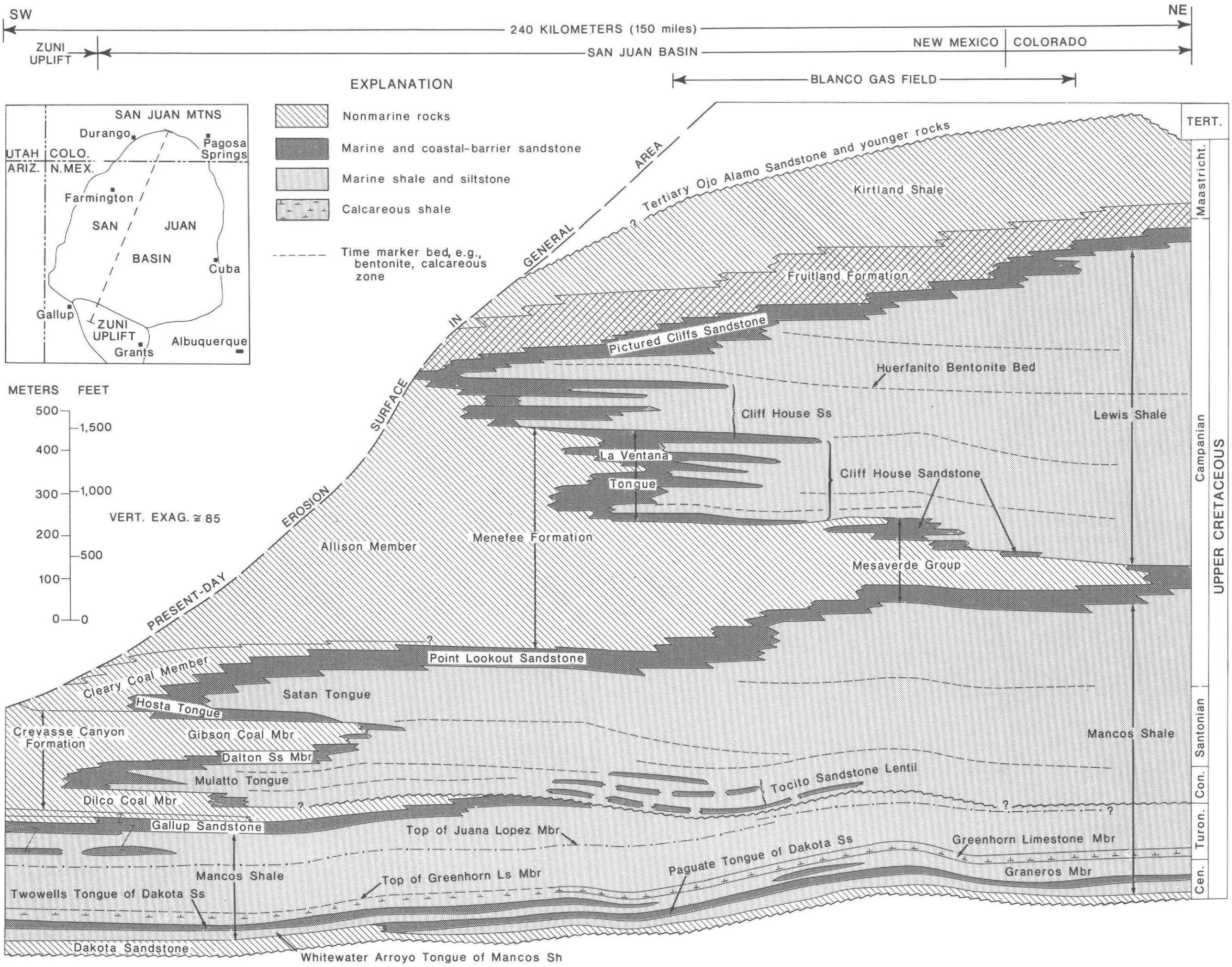

Figure 3. Stratigraphic cross section showing Upper Cretaceous and Tertiary rocks from southwest to northeast across the San Juan Basin in New Mexico and Colorado. Cen., Cenomanian; Turon., Turonian; Con., Coniacian; Maastricht., Maastrichtian; Ss, Sandstone; Ls, Limestone; Sh, Shale; Mbr, Member. From Molenaar (1988). The nonmarine coal-bearing Fruitland Formation is crosshatched.

erroneously based this correlation on the similar position of the two coal beds above the Pictured Cliffs Sandstone (Hayes and Zapp, 1955). The Local 1, Local 2, and Lower Ute Canyon beds were named specifically in this report, because they could not be correlated with beds in nearby areas.

Coal-bed thicknesses have been determined in the study area by measurements on outcrops and in drill holes. Measurements on outcrops are shown on the measured coal sections on plate 1. Coal sections from Hayes and Zapp (1955) have the same section numbers in this report as in their report. Thick soil, slope wash, and talus cover at least part of the coal beds at many outcrop locations and allow only partial thickness measurements at those sites. Although thickness measurements of entire coal beds at outcrops may be less reliable than measurements from drilling (except in holes where the coal was cored), measurements of the number and thickness of partings within the coal are more reliable at outcrops.

Thirty-four of the 50 drill holes that penetrate the Fruitland Formation in and near the southeast corner of the Ute Mountain Ute Indian Reservation were selected to illustrate coal-bed distribution and correlations (fig. 4). Table 3 lists the coals that were found in the drill holes used in this report and the thickness and depth from the surface of each coal bed. All the hole locations are plotted on the geologic map, and holes that were used to determine coal and overburden isopachs for the three major coal beds are shown on the maps of the individual beds. The point-location identifiers for all the oil and gas test wells, except those with the prefix PM, are the

Table 2. Names used for coal beds in the study area

[Leaders (---) indicate that the equivalent bed is not named]

This report	Strobell and others (1980)	Western Coal Company, 1970	Bauer and Reeside (1921)
Ute Canyon	E and F	Upper bed	---
Upper Main	C	Upper split, Main bed	Carbonera.
Main	B	Lower split, Main bed	---

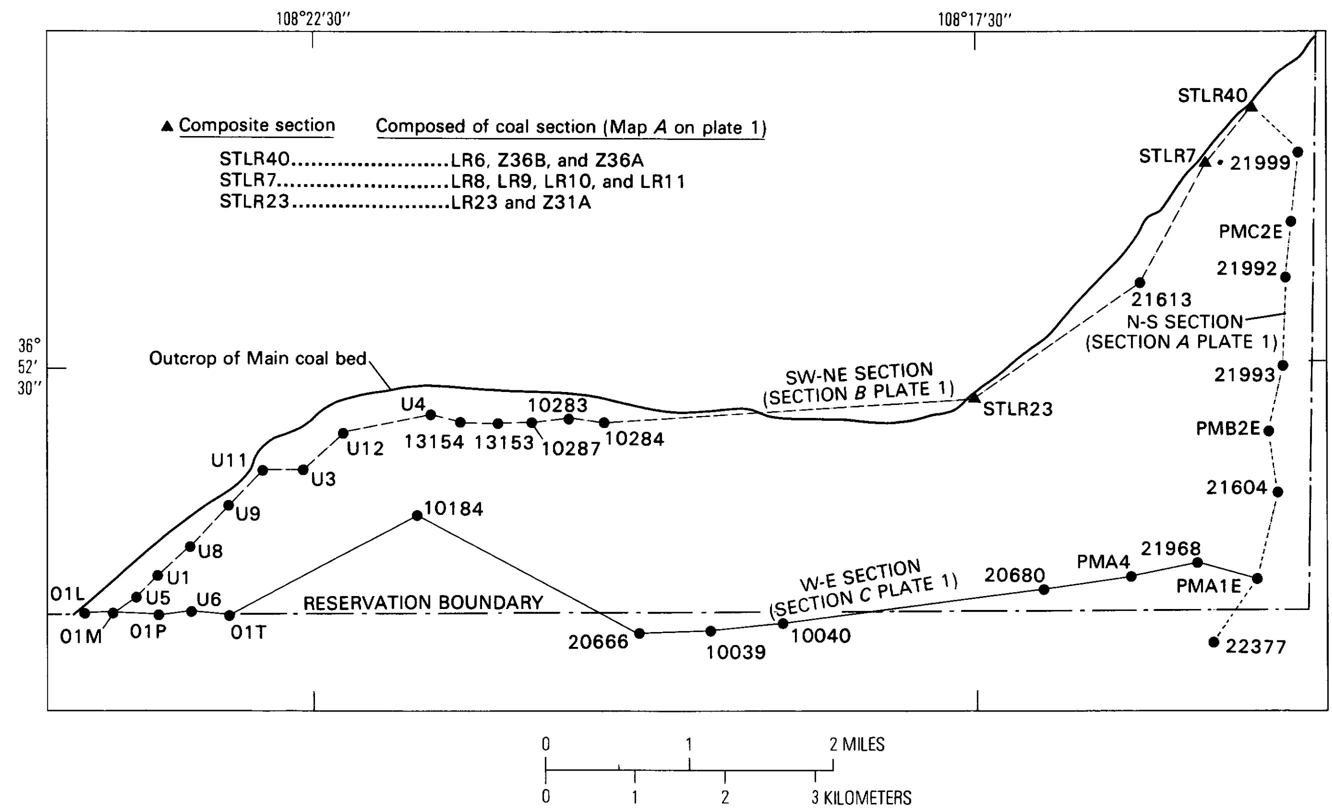

Figure 4. Map showing location of cross sections.

American Petroleum Institute (API) numbers for wells listed in the Well History Control System (WHCS) of Petroleum Information, Inc. The PM holes are wells drilled in the southeast corner of the study area that were not listed in the WHCS.

Description of Coal Beds

The three most important coal beds occur in the lowermost part of the Fruitland Formation; the description of the individual beds begins with the lowest coal bed and continues stratigraphically upward. Two generalized stratigraphic sections that accompany the geologic map show the distribution of the coal beds in the southwestern part and in the northeastern part of the area (map *A* on pl. 1). The cross sections on sections *A–C* on plate 1 show that the coal beds and the rock intervals between the coal beds tend to vary in thickness and that some coal beds pinch out and split. Thickness variations in coal, interburden, and overburden related to the beds for which resources have been calculated are shown on maps *C–G* on plate 1.

Table 3. Thickness of coal and depth to correlated coal beds greater than 1.2 feet thick

[All values are in feet. Leaders (---) indicate coal bed is not present. Where two numbers occur in thickness column, the first denotes net thickness of coal and the second denotes net thickness of partings]

Hole No.	Location Sec.,	T. N.,	R. E.	Local 2 Thickness	Local 2 Depth to top	Local 1 Thickness	Local 1 Depth to top	Ute Canyon Thickness	Ute Canyon Depth to top	Lower Ute Canyon Thickness	Lower Ute Canyon Depth to top	Upper Main Thickness	Upper Main Depth to top	Main Thickness	Main Depth to top
10031	3	30	14	---	---	---	---	---	---	---	---	---	---	5.0/3.0	1,154
10039	5	30	14	---	---	---	---	8.0	831	---	---	---	---	---	---
10040	4	30	14	---	---	---	---	6.0	842	---	---	---	---	7.0	977
10184	36	31	15	---	---	---	---	8.0/1.0	421	---	---	4.0	503	4.0	520
10222	29	31	14	---	---	---	---	9.0	442	---	---	6.0	527	6.0	553
10283	30	31	14	---	---	---	---	9.0	270	---	---	5.0	355	6.0	379
10284	29	31	14	---	---	---	---	8.0	281	---	---	7.0	351	6.0	377
10287	30	31	14	---	---	---	---	9.0	283	---	---	5.0	365	6.0	387
13153	30	31	14	---	---	---	---	8.0	283	---	---	4.0	354	6.0	379
13154	30	31	14	---	---	---	---	8.0/1.0	221	---	---	8.0	286	5.0	308
13155	30	31	14	---	---	---	---	6.0	372	---	---	5.0	455	5.0	478
13156	31	31	14	---	---	---	---	3.0	464	---	---	4.0	543	5.0	562
13157	31	31	14	---	---	---	---	8.0/2.0	432	---	---	5.0	523	---	---
13158	31	31	14	---	---	---	---	10.0/1.0	402	---	---	5.0	482	4.0	501
20666	5	30	14	---	---	---	---	4.0	592	---	---	---	---	6.0	719
20680	35	31	14	---	---	---	---	3.0	1,054	---	---	---	---	5.0	1,161
21604	36	31	14	---	---	---	---	7.0	1,386	---	---	---	---	5.0	1,486
21608	25	31	14	---	---	4.0	1,134	6.0	1,243	---	---	---	---	6.0	1,346
21613	23	31	14	---	---	3.0	249	11.0/1.0	392	---	---	---	---	5.0	498
21638	35	31	15	---	---	---	---	---	---	---	---	6.0/5.0	201	5.0	229
21968	36	31	14	---	---	---	---	6.0	1,344	---	---	---	---	8.0	1,447
21992	24	31	14	---	---	5.0	1,317	9.0/3.0	1,467	---	---	---	---	4.0	1,548
21993	25	31	14	---	---	5.0	1,230	9.0/1.0	1,416	---	---	---	---	5.0	1,513
21999	13	31	14	2.0	1,137	6.0/4.0	1,220	13.0/3.0	1,361	---	---	---	---	9.0	1,440
22377	1	30	14	---	---	---	---	4.0	1,524	---	---	---	---	3.0	1,630
23286	35	31	14	---	---	---	---	5.0	1,162	---	---	---	---	3.0	1,266
60042	31	31	14	---	---	---	---	6.0/3.0	459	---	---	4.0	526	6.0	545
PMA1E	36	31	14	---	---	2.0	1,453	4.0	1,531	---	---	---	---	5.0	1,626
PMA2E	36	31	14	---	---	2.0	1,169	4.0	1,293	---	---	---	---	6.0	1,387
PMA4	35	31	14	---	---	5.0/3.0	1,148	6.0	1,253	---	---	---	---	6.0	1,359
PMB1E	25	31	14	---	---	3.0	1,096	6.0/2.0	1,220	---	---	---	---	2.0	1,318
PMB2E	25	31	14	---	---	2.0	1,227	6.0	1,334	3.0	1,354	---	---	5.0	1,441
PMC2E	24	31	14	3.0	1,267	8.0/2.0	1,369	14.0/2.0	1,484	---	---	---	---	10.0/2.0	1,550
U1	35	31	15	---	---	---	---	---	---	---	---	7.6/6.6	82	4.0/0.5	112
U2	35	31	15	---	---	---	---	---	---	---	---	7.0/0.8	161	6.3/0.5	184
U3	25	31	15	---	---	---	---	8.0/2.4	66	---	---	6.0/1.0	136	3.8/0.3	157
U4	25	31	15	---	---	---	---	11.5/0.8	118	---	---	4.4/1.3	180	3.6/1.2	200
U5	34	31	15	---	---	---	---	---	---	---	---	6.9/0.7	90	6.0/1.3	111
U6	35	31	15	---	---	---	---	6.4	94	2.5	139	8.2/2.0	195	6.7/1.6	214
U7	35	31	15	---	---	---	---	---	---	---	---	6.2/1.0	139	5.8/1.1	159
U8	35	31	15	---	---	---	---	---	---	---	---	7.8/1.0	100	6.2/0.8	124
U9	35	31	15	---	---	---	---	---	---	---	---	7.6/0.7	73	6.3/0.7	96
U10	35	31	15	---	---	---	---	5.3/0.4	72	3.1	86	7.2/0.6	166	5.7/0.8	189
U11	35	31	15	---	---	---	---	---	---	1.9/1.2	42	7.2/0.5	104	5.3/0.4	126
U12	25	31	15	---	---	---	---	9.3/2.5	59	---	---	7.1/0.5	126	2.8/0.5	146
U13	25	31	15	---	---	---	---	11.7/0.8	136	---	---	7.6/0.2	198	---	---
01L	3	30	15	---	---	---	---	---	---	---	---	8.0/0.2	63	8.6	80
01M	3	30	15	---	---	---	---	2.7	23	---	---	8.0/0.2	132	7.9	148
01P	2	30	15	---	---	---	---	5.0/0.8	50	---	---	7.1/0.4	163	3.5	178
01T	2	30	15	---	---	---	---	6.4	152	---	---	7.5/0.8	255	6.2/1.1	275

Main Bed

The Main coal bed underlies the entire study area except locally in the north-central part of sec. 31, T. 31 N., R. 14 W. The Main coal bed occurs directly on or within about 15 ft of the top of the Pictured Cliffs Sandstone. About 40 percent of the coal in the Main bed is under less than 500 ft of overburden (map *C* on pl. 1). The thickness of the Main bed ranges from 1.1 ft at the outcrop in secs. 26 and 27, T. 31 N., R. 14 W., to 10.0 ft at drill hole PMC2E in sec. 24, T. 31. N, R. 14 W. The thickness averages about 5.0 ft over most of the area but is greatest in the extreme northeastern and extreme southwestern corners of the study area. Because of limited information, the thickness of the Main bed is inferred in an area of several square miles in the central part of the study area.

One or more partings occur in the Main coal bed at many outcrop locations and in the core samples from coal exploratory drill holes. It is likely that partings also occur in the Main bed where it is represented on the oil and gas well logs, but because of the poor resolution of these logs, the partings are not detectable.

Upper Main Bed

The interval between the Main and Upper Main coal beds ranges in thickness from 3.5 ft at the outcrop in measured sections Z30 and Z32, secs. 26 and 27, T. 31 N., R. 14 W., to more than 20 ft near the center of sec. 30, T. 31 N., R. 14 W. Map *D* on plate 1 shows that the thickness of this interval generally decreases from southwest to northeast.

The Upper Main bed is confined to the western half of the study area. Everywhere in this area the overburden is less than 1,000 ft thick (map *E* on pl. 1). In the subsurface, the Upper Main coal bed pinches out along a line that trends roughly northeast from the southwest quarter of sec. 33, T. 31 N., R. 14 W., to the northwest quarter of sec. 26 in the same township (map *E* on pl. 1). The Upper Main coal bed reaches a maximum thickness of 8.2 ft in the southwestern corner of sec. 35, T. 31 N., R. 15 W. In general the Upper Main bed increases in thickness from southeast to northwest and, near the outcrop, maintains an average thickness of about 7 ft.

At least one parting exists in the Upper Main bed at all but one measured-section location (coal section Z30, measured coal sections on pl. 1) and at all the coal exploratory drill-hole locations. This suggests that even though partings do not show up on logs from the oil and gas wells, partings are probably present. At drill hole U1 in sec. 35, T. 31 N., R. 15 W., a parting increases to a thickness greater than the thickness of the coal above and below it. For resource calculations the thickness of the upper and lower split were combined.

Ute Canyon and Lower Ute Canyon Beds

The Ute Canyon coal bed is present throughout the study area and occurs from 45 ft to about 130 ft above the Upper Main bed or above the Main where the Upper Main has pinched out (map *F* on pl. 1). The Ute Canyon bed ranges in thickness from 2.7 ft at drill hole 01M in the southwestern corner of the study area to 14.0 ft at drill hole PMC2E in the northeastern corner of the study area (map *G* on pl. 1).

This coal bed also contains partings; the number of partings appears to increase northeastward as the total thickness of the coal bed increases (measured coal sections on pl. 1). In the area between drill holes 21993 and PMB2E in the eastern part of the study area (section *A* on pl. 1), the Ute Canyon bed splits into two beds. The lower split, here called the Lower Ute Canyon bed, pinches out southward within about one-half mile. The Ute Canyon bed also splits into two beds between drill holes U3 and U11 (section *B* on pl. 1) and along the outcrop in the north-central part of sec. 35, T. 31 N., R. 15 W. (map *A* on pl. 1). Here the upper split (Ute Canyon bed) thins to its minimum thickness on the Reservation. The interval between the Ute Canyon bed and the lower split (Lower Ute Canyon bed) increases rapidly from where the bed splits and then maintains a consistent thickness of about 35 ft.

At drill hole U8 (map *A* and section *B* on pl. 1) in sec. 35, T. 31 N., R. 15 W., thick sandstone units at the stratigraphic position of the Lower Ute Canyon coal bed indicate the existence of a paleochannel in this vicinity. The presence of a high-energy fluvial channel and the associated influx of overbank sand and silt inhibited the formation of peat in the Ute Canyon swamp.

Local 1 Bed

A zone of thin coal beds, here termed the Local 1 bed, was mapped along the outcrop from the northeastern part of the study area to within 1 mi of the southwestern corner. This bed, which occurs about 100 ft above the Ute Canyon bed, is characterized on the outcrop by thin coal beds (average thickness about 1.5 ft), separated by intervals of rock that are about the same thickness as the coals (measured coal sections on pl. 1). The Local 1 bed is assumed to be continuous in the area between measured section LR35 in sec. 30, T. 31 N., R. 14 W., and measured section LR36 in sec. 25, T. 31 N., R. 15 W. (map *A* on pl. 1), even though there is no indication of its existence in the oil and gas wells (map *A* and section *B* on pl. 1). Here the coals of the Local 1 bed are probably too thin to be detected by the logging equipment.

Local 2 Bed

A coal bed here named the Local 2 bed crops out for about three-quarters of a mile in the extreme northeastern corner of the study area (map *A* on pl. 1). The Local 2 bed pinches out in the subsurface less than a mile to the southeast of the outcrop, south of drill hole PMC2E (section *A* on pl. 1). This coal bed lies about 85 ft above the Local 1 bed and ranges in thickness from 2.0 to 3.0 ft.

Coal Quality

The apparent rank of the coal in the Ute Canyon, Upper Main, and Main beds is high-volatile C bituminous. Seven samples from four core holes drilled by Western Coal Company show sulfur values that range from 0.81 to 1.25 percent, ash values that range from 8.08 to 19.84 percent, and heat-of-combustion values that range from 9,443 to 11,689 Btu/lb on an as-received basis (table 4). Average values for coal quality of the Main, Upper Main, and Ute Canyon coal beds are shown in table 5. These values are within the range of values for Cretaceous coals of the Western United States (R.H. Affolter, oral commun., 1989).

Table 4. Analyses of coal in the Fruitland Formation from Western Coal Company core holes

[All analyses, except heat-of-combustion and Hardgrove Grindability Index, are in percent. For each sample number, the analyses are reported first, as-received, and second, moisture-free. Analyses by Commercial Testing and Engineering Co. Table modified from Shomaker and Holt (1973). Leaders (---) indicate no data]

Hole No.	Location Sec.,	T. N.,	R. W.	Sample No.	Depth interval sampled (feet)	Proximate analysis Moisture	Ash	Ultimate analysis Sulfur	Heat-of-combustion (BTU/lb)	Hardgrove Grindability Index
					Ute Canyon bed					
U4	25	31	15	72-4338	117.6-129.9	12.47	17.64	0.88	9,670	44.2
						---	20.15	1.00	11,048	
U13	25	31	15	72-4337	136.1-150.2	10.44	19.84	.99	9,669	45.6
						---	22.15	1.11	10,796	
					Upper Main bed					
U7	35	31	15	72-4259	139.5-146.7	9.16	8.08	1.14	11,689	39.1
						---	8.90	1.25	12,868	
U9	35	31	15	72-4336	73.0-81.3	12.57	14.29	1.09	10,193	41.8
						---	16.34	1.25	11,659	
U13	25	31	15	72-4335	197.9-205.7	11.02	11.83	.81	10,871	40.8
						---	13.29	.91	12,217	
					Main bed					
U7	35	31	15	72-4260	158.9-165.8	13.21	18.66	1.25	9,443	40.4
						---	21.50	1.44	10,880	
U9	35	31	15	72-4334	95.7-102.7	8.55	18.04	.90	10,221	39.6
						---	19.73	.98	11,177	

Table 5. Average heat-of-combustion and moisture, ash, and sulfur content on an as-received basis, Hardgrove Grindability Index, and apparent rank, by coal bed, of seven coal samples from the southeastern part of the Ute Mountain Ute Indian Reservation

[The Parr formula (American Society for Testing and Materials, 1977) was used to calculate moist mineral-matter-free heating value and to determine coal rank]

Coal bed	Number of samples	Moisture (percent)	Ash (percent)	Sulfur (percent)	Heating value (Btu/lb)	Moist mineral-matter-free heat-of-combustion (Btu/lb)	Hardgrove Grindability Index	Apparent coal rank
Ute Canyon	2	11.46	18.74	0.94	9,670	12,143	44.9	High-volatile C bituminous.
Upper Main	3	10.92	11.40	1.01	10,917	12,471	40.6	Do.
Main	2	10.88	18.35	1.08	9,832	12,285	40.0	Do.

Coal Resources

Resource estimates were calculated for the Ute Canyon, Upper Main, and Main beds. The three major beds contain an estimated 215 million short tons of coal distributed in various categories as shown in table 6. An additional 37 million short tons are contained in the Local 1, Local 2, and Lower Ute Canyon beds, and in other beds 1.2 ft thick or greater that could not be correlated within the study area. Table 7 shows estimated total coal resources of the Fruitland Formation, and map *H* on plate 1 shows the distribution of total coal thickness within the formation. Coal resources were not calculated for the Lower Ute Canyon, Local 1, and Local 2 as

Table 6. Summary of estimated coal resources, by bed

[In thousands of short tons. Leaders (---) indicate no coal for specific category. Tonnages may not total precisely because of rounding to three significant figures]

Coal bed	Overburden 0-200 feet				Overburden 200-500 feet				Overburden 500-1,000 feet				Overburden >1,000 feet				Grand total
	Measured	Indicated	Inferred	Total	Measured	Indicated	Inferred	Total	Measured	Indicated	Inferred	Total	Measured	Indicated	Inferred	Total	
In beds greater than 14 feet thick																	
Ute Canyon	127	323	---	450	104	429	---	533	7.48	493	---	500	585	56.0	---	641	2,120
In beds 7-14 feet thick																	
Ute Canyon	8,000	2,990	554	11,500	13,000	10,600	2,700	26,300	1,990	13,000	1,820	16,800	8,140	3,220	---	11,400	66,000
Upper Main	4,000	---	---	4,000	766	---	---	766	---	---	---	---	---	---	---	---	4,770
Main	668	109	---	777	737	116	---	853	579	1,360	---	1,940	3,720	586	---	4,310	7,880
Subtotal	12,700	3,100	554	16,300	14,500	10,700	2,700	27,900	2,570	14,400	1,820	18,700	11,900	3,810	---	15,700	78,600
In beds 3.5-7 feet thick																	
Ute Canyon	3,060	1,900	---	4,960	2,320	5,840	400	8,560	695	10,900	1,480	13,100	9,640	5,940	251	15,800	42,400
Upper Main	5,170	495	---	5,660	6,000	4,520	24.1	10,500	2,440	895	---	3,340	---	---	---	---	19,500
Main	5,940	661	---	6,600	7,180	5,920	92.3	13,200	3,690	14,200	1,890	19,800	10,600	7,410	---	18,000	57,600
Subtotal	14,200	3,060	---	17,300	15,500	16,300	516	32,300	6,820	26,000	3,370	36,200	20,200	13,400	251	33,800	120,000
In beds 2.3-3.5 feet thick																	
Ute Canyon	9.72	---	---	9.72	31.2	---	---	31.2	0.927	130	---	131	387	392	0.449	779	951
Upper Main	311	369	---	680	156	210	---	366	186	1,840	---	2,030	---	---	---	---	3,080
Main	708	230	---	938	341	713	---	1,050	266	2,760	---	3,030	808	1,460	---	2,270	7,290
Subtotal	1,030	599	---	1,630	528	923	---	1,450	453	4,730	---	5,190	1,200	1,850	0.449	3,050	11,300
In beds 1.2-2.3 feet thick																	
Upper Main	11.4	---	---	11.4	118	474	30.0	622	---	921	70.6	992	---	---	---	---	1,620
Main	90.5	20.3	---	111	133	237	---	370	90.2	1,030	---	1,120	145	13.4	---	158	1,760
Subtotal	102	20.3	---	122	251	711	30.0	992	90.2	1,950	70.6	2,110	145	13.4	---	158	3,380
Total	28,200	7,100	554	35,800	30,900	29,100	3,250	63,200	9,940	47,600	5,260	62,800	34,000	19,100	251	53,400	215,000

Table 7. Estimated total coal resources of the Fruitland Formation as of July 1, 1987

[In thousands of short tons. All beds 1.2 feet thick or greater were considered in resource estimate. Values rounded to three significant figures]

Overburden thickness	Less than 200 feet	200-500 feet	500-1,000 feet	Greater than 1,000 feet	Total
Measured	30,000	26,400	7,400	41,500	105,000
Indicated	11,700	33,100	53,300	16,500	115,000
Inferred	11,700	17,200	3,200	---	32,100
Total	53,400	76,700	63,900	58,000	252,000

individual beds for the following reasons: (1) The Lower Ute Canyon bed is generally too thin (less than 1.2 ft) to provide an appreciable resource, (2) the Local 2 bed has a very limited distribution, and (3) the Local 1 bed contains partings that compose more than half of the total thickness of the bed. The estimates were obtained from information in this report and are current as of July 1, 1987.

Resources of the Ute Canyon, Upper Main, and Main coal beds were calculated for beds in five thickness categories according to U.S. Geological Survey standards for bituminous coal (Wood and others, 1983). The totals are summarized in table 8.

Resources of the three major coal beds were also calculated according to reliability, or degree of geologic assurance, of the estimates. "Measured" coal is coal located within a ¼-mi radius of a coal measurement in a drill hole or at an outcrop. "Indicated" coal is between ¼ mi and ¾ mi of a coal measurement; it extends ½ mi beyond the limit of measured coal. "Inferred" coal is between ¼ mi and 3 mi of a coal measurement; it extends 2 ¼ mi beyond the limit of indicated coal. All the coal in the study area is within 3 mi of a measurement. Resources calculated for each degree of geologic assurance are summarized in table 9.

Coal resource estimates were further divided into categories according to depth of the three major beds below the surface: 0–200 ft, 200–500 ft, 500–1,000 ft, and greater than 1,000 ft. The four overburden categories and estimates of coal for each category are listed in tables 10 and 11.

Isopach maps of overburden for the Main, Upper Main, and Ute Canyon coal beds are shown on maps *C*, *E*, and *G*, respectively, on plate 1.

Potential for Surface Mining

Shomaker and Holt (1973) determined that the prospecting permit area in the southwestern corner of the study area is suitable for surface mining. Based on the 17 coal exploratory holes drilled in and near this area, an estimated 14.6 million short tons of coal are contained in the Ute Canyon, Upper Main, and Main beds. These beds have a combined maximum thickness of 20.5 ft and lie at depths between 20 and 200 ft (Edward Beaumont, oral commun., 1986).

Table 8. Estimated coal resources, by bed thickness

[Ute Canyon, Upper Main, and Main coal beds only. >, greater than]

Bed thickness, in feet	Estimated coal, in thousands of short tons	Percent of total
1.2- 2.3	3,380	2
2.3- 3.5	11,300	5
3.5- 7.0	120,000	56
7.0-14.0	78,600	36
>14.0	2,120	1

Table 9. Estimated coal resources, by degree of geologic assurance

[Ute Canyon, Upper Main, and Main coal beds only]

Degree of geologic assurance	Estimated coal, in thousands of short tons	Percent of total
Measured	103,000	48
Indicated	103,000	48
Inferred	9,320	4

Table 10. Estimated coal resources, by overburden thickness and bed thickness

[Ute Canyon, Upper Main, and Main coal beds only. >, greater than; <, less than]

Bed thickness, in feet	Estimated resources, in thousands of short tons	Percent of total
	Overburden less than 200 feet	
1.2- 2.3	122	<1
2.3- 3.5	1,630	<1
3.5- 7.0	17,300	8
7.0-14.0	16,300	8
>14	450	<1
	Overburden 200-500 feet	
1.2- 2.3	992	<1
2.3- 3.5	1,450	<1
3.5- 7.0	32,300	15
7.0-14.0	27,900	13
>14	533	<1
	Overburden 500-1,000 feet	
1.2- 2.3	2,110	1
2.3- 3.5	5,190	2
3.5- 7.0	36,200	17
7.0-14.0	18,700	8
>14	500	<1
	Overburden greater than 1,000 feet	
1.2- 2.3	158	<1
2.3- 3.5	3,050	1
3.5- 7.0	33,800	16
7.0-14.0	15,700	7
>14	641	<1

Table 11. Estimated coal resources, by overburden thickness and degree of geologic assurance

[<, less than]

Degree of geologic assurance	Estimated resources, in thousands of short tons	Percent of total
Overburden less than 200 feet		
Measured	28,200	13
Indicated	7,100	3
Inferred	554	<1
Overburden 200-500 feet		
Measured	30,900	14
Indicated	29,100	13
Inferred	3,250	1
Overburden 500-1,000 feet		
Measured	9,940	7
Indicated	47,600	22
Inferred	5,260	2
Overburden greater than 1,000 feet		
Measured	34,000	16
Indicated	19,100	9
Inferred	251	<1

From the eastern edge of the prospecting permit area eastward to a north-south line through the location of measured section Z26B in sec. 29, T. 31 N., R. 14 W., an estimated 20 million short tons of coal occur less than 500 ft below the surface in the Main, Upper Main, and Ute Canyon coal beds, which here have a combined thickness of about 18 ft. Farther eastward from this location, more drilling is required to determine details on the occurrence, thickness, and correlation of the coals.

It is important to keep in mind that the resource estimates represent the total amount of coal present in the study area and not necessarily the amount that is minable. Steep dips may adversely affect the suitability of certain areas for surface mining. Economic feasibility of mining of the coal in the Fruitland Formation in the southeastern corner of the Ute Mountain Ute Indian Reservation is improved by the presence and proximity of the recently constructed haul road that crosses the eastern half of the study area.

Potential for Coal Bed Methane

It is beyond the scope of this report to assess the resource potential of methane gas from coal beds within the Reservation. It should be noted, however, that methane gas has been produced in wells from coal beds of the Fruitland Formation in other parts of the San Juan Basin that have similar geologic settings. Methane resources of the San Juan Basin have been estimated and reported by several authors; Fassett (1988) summarized reports of these estimates. There is potential for recovery of methane from Fruitland Formation coal beds in the southeastern corner of the Reservation, but further investigation is necessary to estimate resources. Information in this report will be useful when beginning an assessment of the coal-bed methane potential.

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