UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

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FEDERAL COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE PIEDRA DE LA AGUILA 7 1/2-MINUTE QUADRANGLE, McKINLEY COUNTY, NEW MEXICO

[Report includes 19 plates]

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PIEDRA DE LA AGUILA QUADRANGLE
CONTENTS

ILLUSTRATIONS

ILLUSTRATIONS (Continued)

TABLES

INTRODUCTION

Purpose

This text complements the Coal Resource Occurrence (CRO) and Coal Development Potential (CDP) maps of the Piedra de la Aguila 7½ minute quadrangle, McKinley County, New Mexico. These maps and report are part of an evaluation of fifty-six 7½ minute quadrangles in northwestern New Mexico which were completed under U. S. Geological Survey Contract No. 14-08-0001-17459 (see figs. 1 and 2).

The purpose of this Coal Resource Occurrence-Coal Development Potential program, which was conceived by Congress as part of its Federal Coal Leasing Amendments Act of 1976, is to obtain coal resource information and to determine the geographical extent of Federal coal deposits. In addition, the program is intended to provide information on the amount of coal recoverable by various mining methods and to serve as a guide for land-use planning.

The U. S. Geological Survey initiated the program by identifying areas underlain by coal resources. These areas were designated Known Recoverable Coal Resource Areas based on the presence of minable coal thicknesses, adequate areal extent of these coal deposits, and the potential for developing commercial quantities of coal at minable depths.

This report is limited to coal resources which are 3,000 ft (914 m) or less below ground surface. Published and unpublished public information was used as the data base for this study. No new drilling or field mapping was performed as part of this study, nor were any confidential data used.

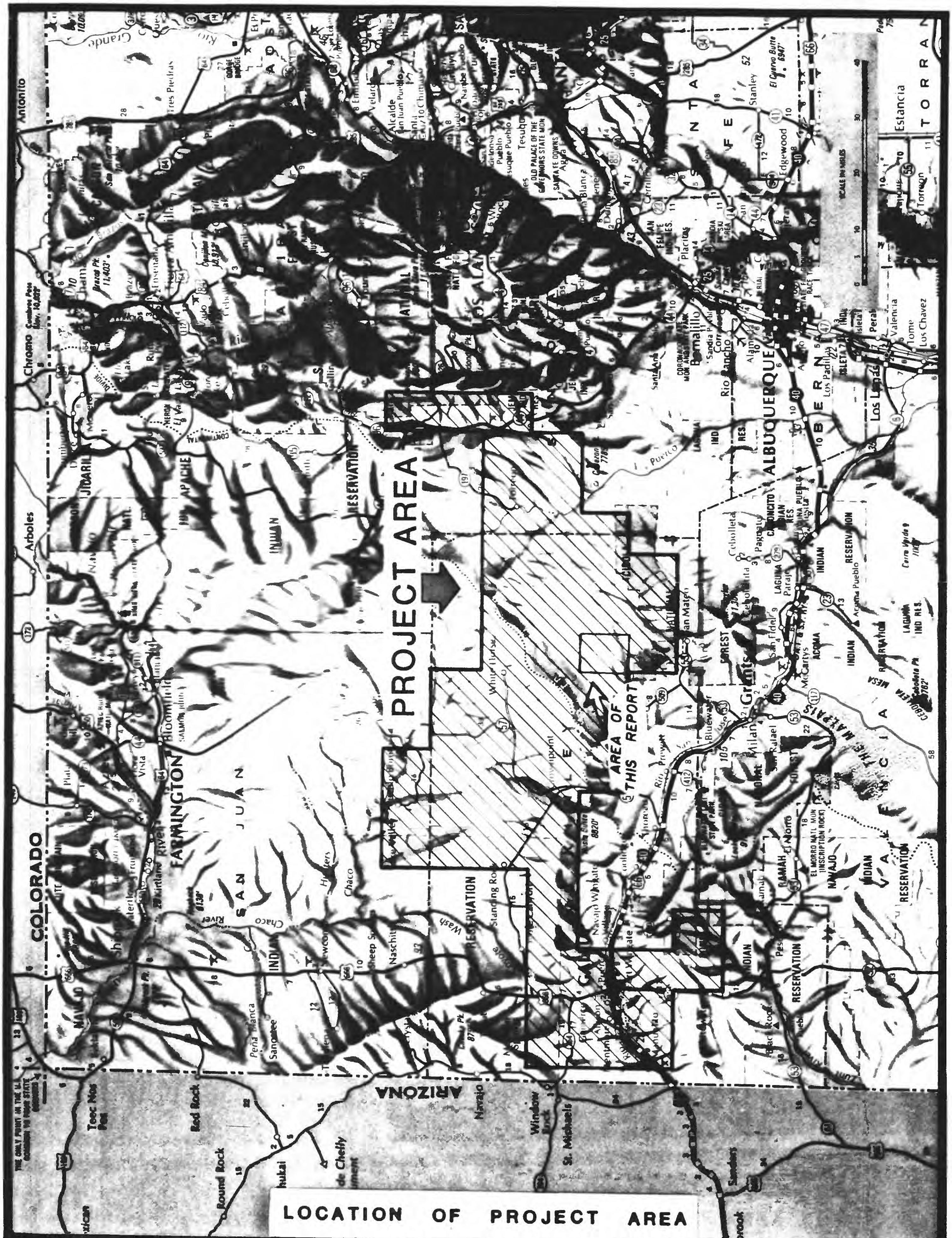
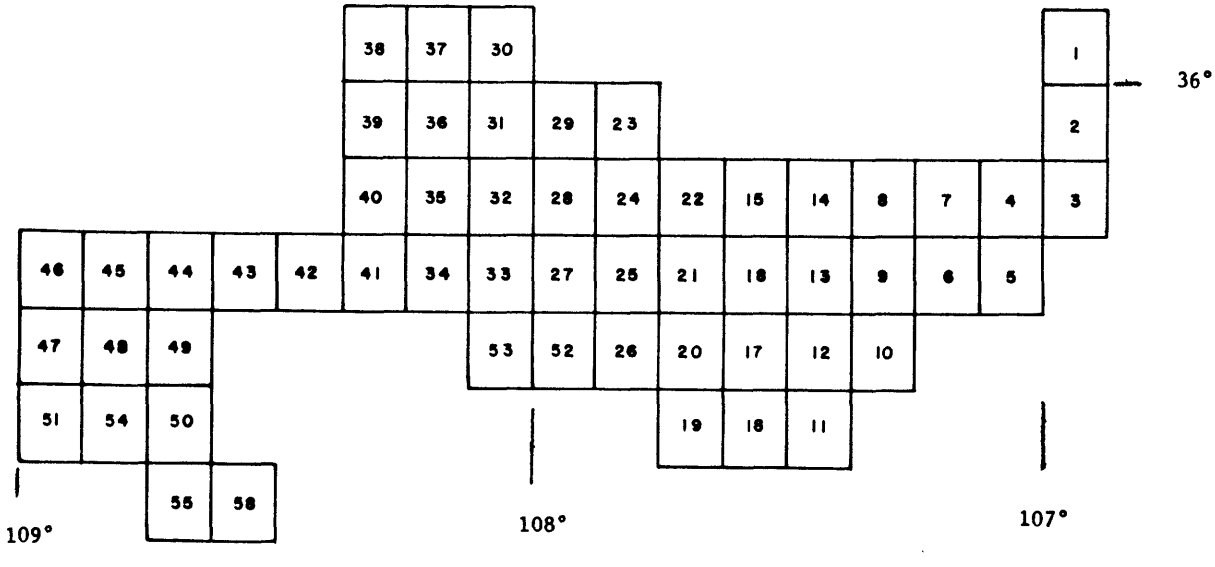

LOCATION OF PROJECT AREA
PROJECT AREA
AREA OF THIS REPORT
COLORADO
ARIZONA
FARMINGTON
ALBUQUERQUE
Grants

FIGURE 1

FIGURE 2.--Index to USGS 7 1/2-minute quadrangles and coal resource occurrence/ coal development potential maps for the southern San Juan Basin area, New Mexico

Map No.	Quadrangle	Open-file report
1	Cuba	79- 623
2	San Pablo	79- 624
3	La Ventana	79-1038
4	Headcut Reservoir	79-1043
5	San Luis	79-1044
6	Arroyo Empedrado	79-1045
7	Wolf Stand	79-1046
8	Tinian	79- 625
9	Canada Calladita	79- 626
10	Cerro Parido	79- 627
11	El Dado Mesa	79- 628
12	Mesa Cortada	79- 629
13	Mesita del Gavilan	79- 630
14	Rincon Marquez	79- 631
15	Whitehorse Rincon	79- 632
16	Mesita Americana	79- 633
17	El Dado	79- 634
18	Cerro Alesna	79- 635
19	San Lucas Dam	79- 636
20	Piedra de la Aguila	79-1039
21	Hospah	79- 637
22	Whitehorse	79-1040
23	Seven Lakes NE	79- 638
24	Kin Nahzin Ruins	79- 639
25	Orphan Annie Rock	79-1041
26	Mesa de los Toros	79-1122
27	Laguna Castillo	79- 640
28	Seven Lakes	79-1042
29	Seven Lakes NW	79-1123
30	Kin Klizhin Ruins	79-1047
31	Nose Rock	79- 641
32	Becenti Lake	79-1124
33	Heart Rock	79- 642
34	Crownpoint	79-1125
35	Antelope Lookout Mesa	79-1376
36	Milk Lake	79-1377
37	La Vida Mission	79-1378
38	The Pillar 3 SE	79-1379
39	Red Lake Well	79-1380
40	Standing Rock	79-1381
41	Dalton Pass	80- 026
42	Oak Spring	80- 027
43	Hard Ground Flats	80- 028
44	Big Rock Hill	80- 029
45	Twin Lakes	80- 030
46	Tse Bonita School	80- 031
47	Samson Lake	80- 032
48	Gallup West	80- 033
49	Gallup East	80- 034
50	Bread Springs	80- 035
51	Manuelito	80- 036
52	Borrego Pass	80- 037
53	Casamero Lake	80- 038
54	Twin Buttes	80- 039
55	Pinehaven	80- 040
56	Upper Nutria	80- 041



Location

The Piedra de la Aguila 7½ minute quadrangle includes acreage in Tps. 15 and 16 N., Rs. 7, 8, and 9 W. of the New Mexico Principal Meridian, McKinley County, northwestern New Mexico (see figs. 1 and 2).

Accessibility

No paved roads pass through the Piedra de la Aguila quadrangle. A light-duty maintained road provides access to the town of San Mateo, 13 mi (21 km) south of the quadrangle. Unimproved dirt roads traverse most parts of the area. The Atchison, Topeka, and Santa Fe Railroad line parallels Interstate Highway 40 about 18.5 mi (29.8 km) southwest of the quadrangle.

Physiography

The Piedra de la Aguila quadrangle is in the Navajo section of the southernmost part of the Colorado Plateau physiographic province (U. S. Geological Survey, 1965). The topography of the area is characterized by flat lands dissected by numerous arroyos.

No perennial streams are present in the quadrangle. Local drainage is provided by several intermittent arroyos, including Arroyo Leon, Voght Draw Arroyo Tinaje, Arroyo Techillas, and others. Elevations within the quadrangle range from 6,580 ft (2,006 m) along Voght Draw in the northeast to over 7,440 ft (2,268 m) in the extreme southwest corner.

Climate

The climate of this area is semiarid to arid. The following temperature and precipitation data were reported by the National Oceanic and Atmospheric Administration for the San Mateo Station. The Piedra de la Aguila quadrangle is about 10.5 mi (16.9 km) north of the San Mateo Station. Average total annual precipitation for ten of the last fifteen years is 8.37 in. (21.26 cm). Intense thunderstorms in July, August, and September account for the majority of precipitation. The area is susceptible to flash flooding associated with these thunderstorms. Mean annual temperature for four of the last fifteen years is 48.8° F (9.3° C). The average daily temperatures in January and July are 28.3° F (-2.1° C) and 69.0° F (20.6° C), respectively.

Land status

The Federal Government holds the coal mineral rights to approximately 50 percent of the Piedra de la Aguila quadrangle. For specific coal ownership boundaries, see plate 2. It is not within the scope of this report to provide detailed land-surface ownership. About 15 percent along the western edge of the quadrangle is within the Crownpoint Known Recoverable Coal Resource Area. The remaining land in the quadrangle is in the Hospash Known Recoverable Coal Resource Area. As of October 26, 1978, there were no Federal coal leases, coal preference right lease applications, or coal exploration licenses within the Piedra de la Aguila quadrangle.

GENERAL GEOLOGY

Previous work

Early reports on the area include that of Gardner (1910) who mapped all areas of R. 7 W. in the Piedra de la Aguila quadrangle. Areas in the quadrangle are not specifically mentioned in the text of the report, but are mapped as "Mesaverde Formation containing workable coal beds." Hunt (1936) reports on the area and maps Menefee Cleary coal outcrops in the quadrangle. He stated, "In general, all these coals are of low grade, dirty, and highly lenticular..." Hunt doubted the coal in the quadrangle could be commercially mined, but noted uncertainty exists due to lack of good exposure, and that mineable coal beds may be present.

Shomaker, Beaumont, and Kottlowski (1971) report T. 16 N., R. 8 W. is underlain by the Menefee Cleary Member, with thin coals exposed on the surface. They note the low rolling topography would be favorable for stipping if sufficient coal were found, and that further exploration in the township is warranted. The southern two-thirds of T. 16 N., R. 8 W. is within the Piedra de la Aguila quadrangle. They also estimate about 70,000 short tons (40,000 t) of strippable coal with less than 60 ft (18 m) of overburden in the area of a poorly exposed impure coal outcrop in T. 15 N., R. 8 W., and that a significant amount of coal might be strippable in this township. Approximately three-fourths of T. 15 N., R. 8 W. is in the Piedra de la Aguila quadrangle.

Stratigraphy

Within the San Juan Basin, the shoreline positions of the Cretaceous seaways changed innumerable times. The overall regional alignment of the shorelines trended N. 60° W. - S. 60° E. (Sears, Hunt, and Hendricks, 1941). The transgressive and regressive shoreline migrations are evidenced by the intertonguing relationships of continental and marine facies. Rates of trough (geosynclinal) subsidence and the availability of sediment supplies are the major factors that controlled the transgressive-regressive shoreline sequences.

Exposed rock units in the Piedra de la Aguila quadrangle include some of the sedimentary units of Upper Cretaceous age. There is Quaternary alluvium along drainages in the area.

The Dalton Sandstone Member of the Crevasse Canyon Formation was deposited in a nearshore environment during a major regression of the Cretaceous seaways in the San Juan Basin. The unit is composed of yellowish-gray, very fine grained quartzose sandstone and is 160 to 200 ft (49 to 61 m) thick locally . The continental sediments deposited inland from the beach area during deposition of the Dalton Sandstone compose the overlying Gibson Coal Member of the Crevasse Canyon Formation. Stratigraphically, the Gibson Coal Member contains the lowest identified coal beds in the Piedra de la Aguila quadrangle. Medium gray carbonaceous siltstone with interbedded gray to tan sandstones and coal beds comprise the lithologies of the Gibson Coal Member which is 140 to 200 ft (43 to 61 m) thick locally.

The Hosta Tongue of the Point Lookout Sandstone was deposited over the Gibson Coal Member during the succeeding southwestward advance of the Cretaceous seaways. The unit is composed of light gray to reddish-brown, fine to medium grained sandstone with interbedded shales and is from 60 to 85 ft (18 to 26 m) thick locally. As the transgression proceeded and the Cretaceous seaways deepened, the Satan Tongue of the Mancos Shale was deposited over the Hosta Tongue, and is composed of dark gray to black silty shale with interbedded tan to buff sandstone, and averages 160 ft (49 m) thick locally.

The Point Lookout Sandstone overlies the Satan Tongue, and represents nearshore or littoral deposits which formed during the succeeding regression. This regression was the most extensive northeastward retreat prior to the final withdrawal of the Cretaceous seaways in the San Juan Basin (Sears, Hunt, and Hendricks, 1941). Lithology of the Point Lookout Sandstone is identical to the Hosta Tongue. The Point Lookout Sandstone averages 100 ft (30 m) thick in the area. The continental sediments deposited inland from the beach area during the deposition of the Point Lookout Sandstone compose the Menefee Formation.

The Menefee Formation consists of dark gray to brown,carbonaceous to noncarbonaceous shales, light gray sandstones, and coal beds, and is divisible into the basal Cleary Coal Member and upper Allison Member. A massive channel sandstone sequence, which crops out in the northern portion of the quadrangle, defines the boundary between the two members. The upper strata of Cleary Coal Member have been eroded in this area. This unit, which contains the thickest coal beds in this quadrangle, has a maximum thickness of about 130 ft (40 m) locally. The Allison Member is absent in the Piedra de la Aguila quadrangle.

Depositional environments

The Cretaceous System sedimentary units in the quadrangle represent transgressive and regressive depositional conditions. There were innumerable minor cycles of widely varying duration and extent within the major sedimentary sequences. The paucity of data in this quadrangle and the intended scope of this report permit only general interpretations of the depositional environments.

The Cretaceous coal deposits of the San Juan Basin are products of former coastal swamps and marshes. These swamps and marshes were supported by heavy precipitation and a climate conducive to rapid vegetal growth in moderately fresh water. Due to the relatively low sulfur contents of the San Juan Basin coals, Shomaker and Whyte (1977) suggest the coals formed in fresh water environments.

Most of the coal-bearing units were deposited in coastal plain environments. The majority of the peat deposits formed in a transition zone between lower and upper deltaic sediments during periods of relative shoreline stability. Coals also formed in lake margin swamps inland from the coastal area. Shoreline oscillations and the subsequent influx of continental or marine debris upon the peat accumulations produced the vertical buildup or "stacking" of peat deposits. This sediment debris is represented by variable ash contents, rock partings, and splits within the coal seams.

The peat accumulated in lenses or pods which were generally parallel to the ancient shorelines. The coals in the lower portions of the coal-bearing units represent regressive depositional conditions (Sears, Hunt, and Hendricks, 1941). The coals in the upper portions of these units are relatively sporadic in occurrence.

Structure

The Piedra de la Aguila quadrangle is in the Chaco Slope structural division in the southern portion of the structural depression known as the San Juan Basin (Kelley, 1950). The quadrangle is situated between the Walker Dome to the west, the San Mateo Dome to the south, and the San Miguel Creek Dome to the east. Several faults, apparently related to the Walker and San Mateo Domes, are mapped in the quadrangle (Hunt, 1936). Dips range from 1^{o} to 5^{o} E and are locally affected by folding and faulting.

COAL GEOLOGY

In this quadrangle, the authors identified four coal beds and two coal zones in oil and gas well logs and Hunt's (1936) surface mapping. The beds and zones are here informally called the Crevasse Canyon Gibson No. 1 coal bed, Menefee Cleary No. 1, No. 2, and No. 3 coal beds, Crevasse Canyon Gibson coal zone, and Menefee Cleary coal zone.

The Crevasse Canyon Gibson No. 1 coal bed is, stratigraphically, the lowest identified coal. It was identified and correlated through five drill holes, occurring from 10 to 15 ft (3 to 5 m) above the Dalton Sandstone Member. The bed is thin and does not exceed 2.5 ft (0.8 m) in thickness. Ranging from 25 to 180 ft (8 to 55 m) above the Crevasse Canyon Gibson No. 1 coal bed occur numerous beds of the Crevasse Canyon Gibson coal zone. Crevasse Canyon Gibson coal zone beds are all identified in the subsurface and individually range in thickness from 2.0 to 4.5 ft (0.6 to 1.4 m).

The Menefee Cleary No. 1 coal bed is the first persistent coal bed above the Point Lookout Sandstone. It occurs 7 ft (2 m) above the Point Lookout Sandstone in this quadrangle. The bed is inferred to be continuous, although it may be several individual beds that are stratigraphically equivalent. About 28 to 39 ft (9 to 12 m) above the Point Lookout Sandstone, the Menefee Cleary No. 2 coal bed occurs. The bed contains to as much as 14.0 ft (4.3 m) of total coal, including a rock parting of 2.0 ft (0.6 m).

The Menefee Cleary No. 3 coal bed was identified in the subsurface from 64 to 67 ft (19 to 20 m) above the Point Lookout Sandstone. The youngest coals in this quadrangle occur from 6 to 401 ft (2 to 122 m) above the Point Lookout Sandstone and comprise the Menefee Cleary coal zone. Up to six individual beds with thicknesses of 0.5 to 4.5 ft (0.2 to 1.4 m) represent the Menefee Cleary coal zone in the Piedra de la Aguila quadrangle.

Inadequate subsurface control makes the continuity, thickness, and occurrence of all identified coal beds and zones uncertain or unknown in many parts of the quadrangle. Individual coal beds in the San Juan Basin often are lenticular, discontinuous, and have a limited areal extent, although certain stratigraphic horizons are commonly coaliferous. Due to the limited areal extent of the Menefee Cleary No. 1 and No. 3 coal beds, the isopach, structure contour, and overburden isopachs were combined on the same map (plates 7, 8, and 9).

There are no published coal quality analyses for the Gibson or Cleary Coal Member beds from the Piedra de la Aguila quadrangle. An analysis of a Gibson Coal Member bed sampled at the abandoned Boone Mine about 20 mi (32 km) south of the quadrangle has been reported by the U. S. Bureau of Mines (1936) and is shown in table 1. Rank of the Gibson Coal Member beds is probably

high volatile C bituminous in this area. An analysis of one Cleary Coal Member core sample taken about 6 mi (10 km) northwest of the quadrangle has been reported by Shomaker, Beaumont, and Kottlowski (1971) and is shown in table 2. The Cleary Coal Member bed analyzed is probably similar in quality to the Cleary Coal Member beds in this quadrangle. Rank of the Cleary Coal Member seams is probably subbituminous A in this area.

Menefee Cleary coal zone

The Menefee Cleary coal zone was identified in nine measured sections by Hunt (1936), and four drill hole logs. Although Hunt measured several Menefee Cleary zone coals, he only mapped three coal outcrop traces which represent stratigraphic horizons containing Menefee Cleary zone coals. Total coal thickness at each isopached data point ranges from 1.0 to 11.5 ft (0.3 to 3.5 m). Menefee Cleary zone coals are generally thin, lenticular, and correlative over very limited distances in this quadrangle.

Plate 6 indicates the zero overburden line to be the oldest identified Menefee Cleary coal zone outcrop. Because the oldest identified Menefee Cleary coal zone outcrop cannot be recognized in the subsurface, east or down dip of the zero overburden line, the overburden of the zone is calculated to the base of the Cleary Coal Member of the Menefee Formation. The interburden value is the total rock thickness between the lowest and the uppermost zone coal. Data point #15 (see plate 3) has partial interburden because surface casing does not permit identification of Menefee Cleary zone coals in the well log.

Table 1. - Analysis of a coal sample from the Gibson Coal Member of the Crevasse Canyon Formation

(Boone Mine Sample from SE¼ sec. 6, T. 11 N., R 8 W.)

[Form of analysis: A, as received; B, moisture free; C, moisture and ash free].

from U. S. Bureau of Mines, 1936

Form of analysis	Proximate analysis (percent)				Sulfur (percent)	Heating Value (Btu/lb)
	Moisture	Volatile Matter	Fixed Carbon	Ash		
A	13.5	37.9	42.9	5.7	0.6	11,400
B	----	43.8	49.6	6.6	0.7	13,170
C	----	46.9	53.1	---	0.8	14,100

Remarks:

A moist, mineral-matter-free (MMMF) calculation, using the Parr formula (American Society for Testing and Materials, 1973), yields a heating value of 12,159 Btu/lb (28,282 kJ/kg). No agglomerating characteristics were included with the analysis.

Table 2. - Analysis of a coal sample from the Cleary Coal Member of the Menefee Formation

(Core sample from NE¼ sec. 36, T. 17 N., R. 10 W.)

[Form of analysis: A, as received; B, moisture free; C, moisture and ash free].

from Shomaker, Beaumont, and Kottlowski, 1971

Form of analysis	Proximate analysis (percent)				Sulfur (percent)	Heating Value (Btu/lb)
	Moisture	Volatile Matter	Fixed Carbon	Ash		
A	16.5	33.4	40.4	9.7	0.6	10,070
B	----	40.0	48.3	11.7	0.7	12,060
C	----	45.3	54.7	----	0.8	13,650

Remarks:

A moist, mineral-matter-free (MMMF) calculation using the Parr formula (American Society for Testing and Materials, 1973), yields a heating value of 11,256 Btu/lb (26,181 kJ/kg). The free-swelling index of the analysis shows the sample to be nonagglomerating.

Isopachs are inferred and generalized over much of the quadrangle due to limited data. In areas where Hunt (1936) did not map the trace of the oldest or lowest Menefee Cleary zone coal and there is structural potential for outcrop, isopleths were shown to infer the coal zone to pinch out. Data points #14, #15, and #16 are considered to be partial isopach values since there is not a complete well log record of the Cleary Coal Member beds.

Menefee Cleary No. 1 and No. 3 coal beds

The Menefee Cleary No. 1 coal bed was identified in two sections measured by Hunt (1936) and three drill hole logs. The bed thickens to 4.0 ft (1.2 m) with a 4.5 ft (1.4 m) rock parting. The bed was mapped for a short distance on the surface by Hunt. In places where the Menefee Cleary No. 1 coal bed was not mapped (Hunt) and there is structural potential for outcrop, the bed was shown to pinch out. Sparse data causes the known areal extent of the bed to be minimal.

The Menefee Cleary No. 3 coal bed was identified in two drill hole logs and thickens to 6.5 ft (2.0 m) with a 2.5 ft (0.8 m) rock parting. The coal bed was mapped in the SE¼ of the quadrangle. Since other drill hole data in the area does not indicate the beds presence, it was inferred to pinch out a reasonable distance from data points.

Existence and character of the Menefee Cleary No. 1 and No. 3 coal beds over most of the quadrangle are unknown due to insufficient data. Because of both beds limited areal extent, the isopach, structure contour, and overburden maps for each bed were incorporated on the same plates (plates 7, 8, and 9). A coal separation line differentiates between the occurrence of the two beds and eliminates potential misinterpretations.

Menefee Cleary No. 2 coal bed

The Menefee Cleary No. 2 coal bed was identified in three drill hole logs in this quadrangle. The bed thickens to 14.0 ft (4.3 m) with rock partings totaling up to 13.0 ft (4.0 m). As specified by the U. S. Geological Survey, only 8.0 ft (2.4 m) of coal were isopached (plate 12) on the Menefee Cleary No. 2 isopach map due to underground mining limitations of thick coal and rock intervals. The bed has been identified only in the SE¼ of the quadrangle and is inferred to pinch out a reasonable distance from data points where it was identified. Existence and character of the bed in the remaining parts of the quadrangle are unknown.

Crevasse Canyon Gibson coal zone

The Crevasse Canyon Gibson coal zone was identified in 7 drill hole logs with total thicknesses ranging from 2 to 16.5 ft (0.6 to 5.0 m) locally. Individual coal beds are generally thin, lenticular, and correlative over very limited distances. The zone occurs throughout most of the quadrangle, but pinches out in areas along the western edge and in the southeastern corner of the quadrangle. Since there are no laterally continuous coal beds that occur at a constant horizon in the Crevasse Canyon Gibson coal zone, the structural datum used was the top of the Gibson Coal Member of the Crevasse Canyon Formation. Interburden was calculated from the top of the Gibson Coal Member to the lowest identified zone coal, less intervening zone coal thicknesses. Isopach, structure, overburden, and interburden contours for coal zones are highly generalized because of limited data.

COAL RESOURCES

The U. S. Geological Survey requested resource evaluations of the Menefee Cleary No. 1, No. 2, and No. 3 coal beds where the beds are 3.0 ft (0.9 m) or more thick. The evaluation is restricted to Federal coal lands.

The following procedures were prescribed by the U. S. Geological Survey for the calculation of reserve base. Criteria established in U. S. Geological Survey Bulletin 1450-B were used to areally divide the bed into measured, indicated, and inferred reserve base categories. Reserve base was calculated for each category, by section, using data from the isopach and overburden maps (plates 7, 9, 10, and 12). The acreage in each category (measured by planimeter) multiplied by the average coal bed thickness and a bituminous coal conversion factor (1,800 tons of coal per acre-ft) yields the reserve base for that category. There is much variability in quality over short distances of the San Juan Basin coals and most of the Menefee Formation coals range from subbituminous A to high volatile C bituminous in rank. The bituminous coal conversion factor was used in calculations because the authors believe, based on published coal quality analyses, that a bituminous conversion factor is appropriate for the majority of coals in the area.

Coal beds with 3.0 ft (0.9 m) minimum thickness are included in reserve base and reserve data rather than the 28 in. (71 cm) minimum thickness prescribed in U. S. Geological Survey Bulletin 1450-B. Reserve figures are derived from reserve base totals by applying recovery factors of 85 percent and 50 percent for coal beds 0 to 200 ft (0 to 61 m) and 200 to 3,000 ft (61 to 914 m) deep, respectively. All reserve base and reserve values are rounded to the nearest 10,000 short tons (9,072 t).

Total reserve base data for the Menefee Cleary No. 1, No. 2, and No. 3 coal beds, which include all reserve base categories, are shown by section on plate 2. Because the Menefee Cleary No. 1 and No. 3 coal beds have limited areal extent, they were combined on the same areal distribution and identified resources map (plate 16). Reserve base and reserve data in the various categories are shown on plates 16 and 17.

The U. S. Geological Survey also requested resource evaluations of the Crevasse Canyon Gibson coal zone and the Menefee Cleary coal zone. Total identified resources were calculated only where the total coal thickness is 5.0 ft (1.5 m) or greater. The Crevasse Canyon Gibson and Menefee Cleary coal zone have total identified resources of 164.67 and 103.24 million short tons (149.39 and 93.66 million t), respectively.

COAL DEVELOPMENT POTENTIAL

The factors used to determine the development potential are the presence of a potentially coal-bearing formation, and the thickness and overburden of correlative coal beds. The U. S. Geological Survey supplied the criteria to evaluate the coal development potential for Federal lands in this quadrangle. These criteria are based on current industry practice, U. S. Geological Survey Bulletin 1450-B, and anticipated technological advances. All available data were utilized for the surface and subsurface coal development potential evaluations.

Any area underlain by a potentially coal-bearing formation with 200 ft (61 m) or less of overburden has potential for surface mining. The U. S.

Geological Survey designated the 200 ft (61 m) maximum depth as the stripping limit. Areas where a potentially coal-bearing formation is overlain by more than 200 ft (61 m) of overburden have no potential for surface mining. Areas with no correlative coal bed or a correlative coal bed less than 3.0 ft (0.9 m) in thickness and overlain by 200 ft (61 m) or less of overburden have unknown surface mining potential. Areas which have a correlative coal bed 3.0 ft (0.9 m) or more thick with surface mining potential are assigned a high, moderate or low development potential based on the mining ratio (cubic yards of overburden per short ton of recoverable coal). The formula used to calculate mining ratios is:

$$MR = \frac{t_o\ (C)}{t_c (Rf)}$$

Where MR = Mining ratio

t_o = Thickness of overburden in feet

t_c = Thickness of coal in feet

Rf = Recovery factor

C = Volume-weight conversion factor

(.896 yd^3/short ton for bituminous coal)

(.911 yd^3/short ton for subbituminous coal)

High, moderate, and low development potential areas have respective surface mining ratio values of 0 to 10, 10 to 15, and greater than 15.

Any area underlain by a potentially coal-bearing formation with 200 to 3,000 ft (61 to 914 m) of overburden has potential for subsurface mining. Areas where a potentially coal-bearing formation is overlain by more than 3,000 ft (914 m) of overburden have no subsurface mining potential. Development potential for subsurface mining is unknown where a potentially

coal-bearing formation within 200 to 3,000 ft (61 to 914 m) of the surface contains no identified correlative coal bed or a correlative coal bed less than 3.0 ft (0.9 m) thick. High, moderate, and low development potential areas have respective overburden values of 200 to 1,000 ft (61 to 305 m), 1,000 to 2,000 ft (305 to 610 m), and 2,000 to 3,000 ft (610 to 914 m). The no and unknown development potential boundaries for surface mining methods (plate 18) are defined at the formation contact of the coal-bearing Menefee Formation with the underlying noncoal-bearing Point Lookout Sandstone. These contacts are approximated due to the inaccuracies of adjusting old geologic maps to modern topographic bases.

Boundaries of coal development potential areas coincide with the boundaries of the smallest legal land subdivision (40 acres or lot). When a land subdivision contains areas with different development potentials, the potential shown on the map is that of the areally largest of the component areas. When an area is underlain by more than one bed, the potential shown on the map is that of the bed with the highest potential.

Reserve base (in short tons) in the various development potential categories for surface and subsurface mining methods are shown in tables 3 and 4, respectively.

The coal development potential maps are subject to revision. Map boundary lines and reserve base values are based on coal resource occurrence map isopachs, overburden isopachs, and coal bed correlations that are interpretive and subject to change as additional coal information becomes available.

Development potential for surface mining methods

The coal development potential for surface mining methods in the Piedra de la Aguila quadrangle is shown on plate 18. All Federal coal lands, where the Menefee Cleary No. 1, No. 2, and No. 3 coal beds are 3.0 ft (0.9 m) or more thick have mining ratios greater than 15 and have low development potential for surface mining methods. Since the area where the Menefee Cleary No. 1 has low development potential for surface mining methods does not encompass more than 50 percent of the smallest legal land subdivision, it was not shown on the coal development map. Refer to table 5 for reserves and planimetered acreage, by section, for Federal coal lands with development potential for surface mining methods. The remainder of the Federal coal land in the Piedra de la Aguila quadrangle has either no or unknown development potential for surface mining methods.

Development potential for subsurface mining methods and in situ gasification

The coal development potential for subsurface mining methods in the Piedra de la Aguila quadrangle is shown on plate 19. All Federal coal lands, where the Menefee Cleary No. 2 and No. 3 coal beds are 3.0 ft (0.9 m) or more thick, are overlain by 200 to 1,000 ft (61 to 305 m) of overburden and have high development potential for subsurface mining methods. Refer to table 6 for reserves and planimetered acreage, by section, for Federal coal lands with subsurface mining potential. The remainder of the Federal coal land in the Piedra de la Aguila quadrangle has unknown development potential for subsurface mining methods.

In situ gasification of coal has not been done on a commercial scale in the United States and criteria for rating the development potential of this method are unknown.

Table 3. - Reserve base data (in short tons) for surface mining methods for Federal coal lands in the Piedra de la Aguila quadrangle, McKinley County, New Mexico.

[Development potentials are based on mining ratios (cubic yards of overburden/ton of underlying coal). To convert short tons to metric tonnes, multiply by 0.9072; to convert mining ratios in yds^3/ton coal to m^3/t, multiply by 0.842].

Coal Bed	High Development Potential (0-10 Mining Ratio)	Moderate Development Potential (10-15 Mining Ratio)	Low Development Potential (greater than 15 Mining Ratio)	Total
Menefee Cleary No. 1	----	----	10,000	10,000
Menefee Cleary No. 2	----	----	18,970,000	18,970,000
Menefee Cleary No. 3	----	----	6,290,000	6,290,000
Total	----	----	25,270,000	25,270,000

Table 4. - Reserve base data (in short tons) for subsurface mining methods for Federal coal lands in the Piedra de la Aguila quadrangle, McKinley County, New Mexico.

[Development potentials are based on thickness of overburden. To convert short tons to metric tonnes, multiply by 0.9072].

Coal Bed	High Development Potential (200'-1,000' overburden)	Moderate Development Potential (1,000'-2,000' overburden)	Low Development Potential (2,000'-3,000' overburden)	Total
Menefee Cleary No. 2	12,270,000	-------	-------	12,270,000
Menefee Cleary No. 3	3,090,000	-------	-------	3,090,000
Total	15,360,000	-------	-------	15,360,000

Table 5. - Reserves and planimetered acreage, by section, for Federal coal lands in the Piedra de la Aguila quadrangle with surface mining potential.

[To convert acres to hectares, divide acres by 2.471; to convert short tons to metric tonnes, multiply short tons by 0.9072].

Potential category	Coal bed	Sec.	T. N.	R. W.	Acres (planimetered)	Reserves (in short tons)
Low	Menefee Cleary No. 1	8	16	8	2.0	less than 10,000
	Menefee Cleary No. 2	18	15	7	69.7	520,000
		14	15	8	17.4	170,000
		22			495.0	4,540,000
		24			581.2	7,000,000
		26			329.6	3,850,000
	Menefee Cleary No. 3	14	15	8	150.5	1,120,000
		22			229.5	1,400,000
		24			343.5	2,370,000
		26			83.5	430,000

Table 6. - Reserves and planimetered acreage, by section for Federal coal lands in the Piedra de la Aguila quadrangle with subsurface mining potential.

[To convert acres to hectares, divide acres by 2.471; to convert short tons to metric tonnes, multiply short tons by 0.9072].

Potential category	Coal bed	Sec.	T. N.	R. W.	Acres (planimetered)	Reserves (in short tons)
High	Menefee Cleary No. 2	18	15	7	58.8	240,000
		12	15	8	514.2	1,900,000
		14			631.8	3,470,000
		22			5.0	20,000
		24			49.3	490,000
	Menefee Cleary No. 3	14	15	8	369.5	1,540,000

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coal bed--A stratified sequence of coal, composed of relatively homogeneous material, exhibiting some degree of lithologic unity and separated from the rocks above and below by physically rather well defined boundary planes.

coal bed separation line--A line on a map plate separating areas where different coal beds or zones are mapped.

coal bench--One of two or more divisions of a coal bed separated by rock.

coal conversion factor--A factor used to convert acre-feet of coal into short tons of coal; bituminous coal is 1800 tons/acre-ft; subbituminous coal is 1770 tons/acre-ft.

coal development potential--A subjective determination of the comparative potential of Federal coal lands for development of a commercially viable coal mining operation.

coal exploration license--An area of Federal coal lands in which the licensee is granted the right, after outlining the area and the probable methods of exploration, to investigate the coal resources. An exploration license has a term not to exceed 2 years and does not confer rights to a lease.

coal lease--An area of Federal coal lands in which the Federal Government has entered into a contractual agreement for development of the coal deposits.

coal split--A coal bed resulting from the occurrence of a noncoal parting within the parent coal bed which divides the single coal bed into two or more coal beds.

coal zone--A distinctive stratigraphic interval containing a sequence of alternating coal and noncoal layers in which the coal beds may so lack lateral persistence that correlating individual beds in the zone is not feasible.

Federal coal land--Land for which the Federal Government holds title to the coal mineral rights, without regard to surface ownership.

hypothetical resources--Undiscovered coal resources in beds that may reasonably be expected to exist in known mining districts under known geologic conditions. In general, hypothetical resources are in broad areas of coal fields where points of observation are absent and evidence is from distant outcrops, drill holes or wells. Exploration that confirms their presence and reveals quantity and quality will permit their reclassification as a Reserve or Identified Subeconomic Resource.

identified resources--Specific bodies of coal whose location, rank, quality, and quantity are known from geologic evidence supported by engineering measurements.

indicated--Coal for which estimates for the rank, quality, and quantity have been computed partly from sample analyses and measurements and partly from reasonable geologic projections.

inferred--Coal in unexplored extensions of demonstrated resources for which estimates of the quality and quantity are based on geologic evidence and projections.

isopach--A line joining points of equal bed thickness.

Known Recoverable Coal Resource Area (KRCRA)--Formerly called Known Coal Leasing Area (KCLA). Area in which the Federal coal land is classified (1) as subject to the coal leasing provisions of the Mineral Leasing Act of 1920, as amended, and (2) by virtue of the available data being sufficient to permit evaluation as to extent, location, and potential for developing commercial quantities of coal.

measured--Coal for which estimates for rank, quality, and quantity can be computed, within a margin of error of less than 20 percent, from sample analyses and measurements from closely spaced and geologically well known sample sites.

mining ratio--A numerical ratio equating the in-place volumes, in cubic yards, of rocks that must be removed in order to recover 1 short ton of coal by surface mining.

overburden--A stratigraphic interval (composed of noncoal beds and coal beds) lying between the ground surface and the top of a coal bed. For coal zones, overburden is the stratigraphic interval lying between the ground surface and the structural datum used to map the zone.

parting--A noncoal layer occurring along a bedding plane within a coal bed.

Preference Right Lease Application (PRLA)--An area of Federal coal lands for which an application for a noncompetitive coal lease has been made as a result of exploration done under a coal prospecting permit. PRLA's are no longer obtainable.

quality or grade--Refers to measurements such as heat value; fixed carbon; moisture; ash; sulfur; phosphorus; major, minor, and trace elements; coking properties; petrologic properties; and particular organic constituents.

rank--The classification of coal relative to other coals, according to degree of metamorphism, or progressive alteration, in the natural series from lignite to anthracite (Classification of coals by rank, 1973, American Society for Testing and Materials, ASTM Designation D-388-66).

recovery factor--The percentage of total tons of coal estimated to be recoverable from a given area in relation to the total tonnage estimated to be in the Reserve Base in the ground.

reserve--That part of identified coal resource that can be economically mined at the time of determination. The reserve is derived by applying a recovery factor to that component of the identified coal resource designated as the reserve base.

reserve base--That part of identified coal resource from which Reserves are calculated.

stripping limit--A vertical depth, in feet, measured from the surface, reflecting the probable maximum, practical depth to which surface mining may be technologically feasible in the forseeable future. The rock interval, expressed in feet, above the stripping limit is the "strippable interval."

structure contour--A line joining points of equal elevation on a stratum or bed.