UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Text to accompany:

OPEN-FILE REPORT 80-035

1985

FEDERAL COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE BREAD SPRINGS 7 1/2-MINUTE QUADRANGLE, McKINLEY COUNTY, NEW MEXICO

[Report includes 16 plates (18 sheets)]

Prepared by Berge Exploration, Inc.

BREAD SPRINGS QUADRANGLE
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INTRODUCTION

Purpose

This text complements the Coal Resource Occurrence (CRO) and Coal Development Potential (CDP) maps of the Bread Springs 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 Published and unpublished public information was used as the data base for this study.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.

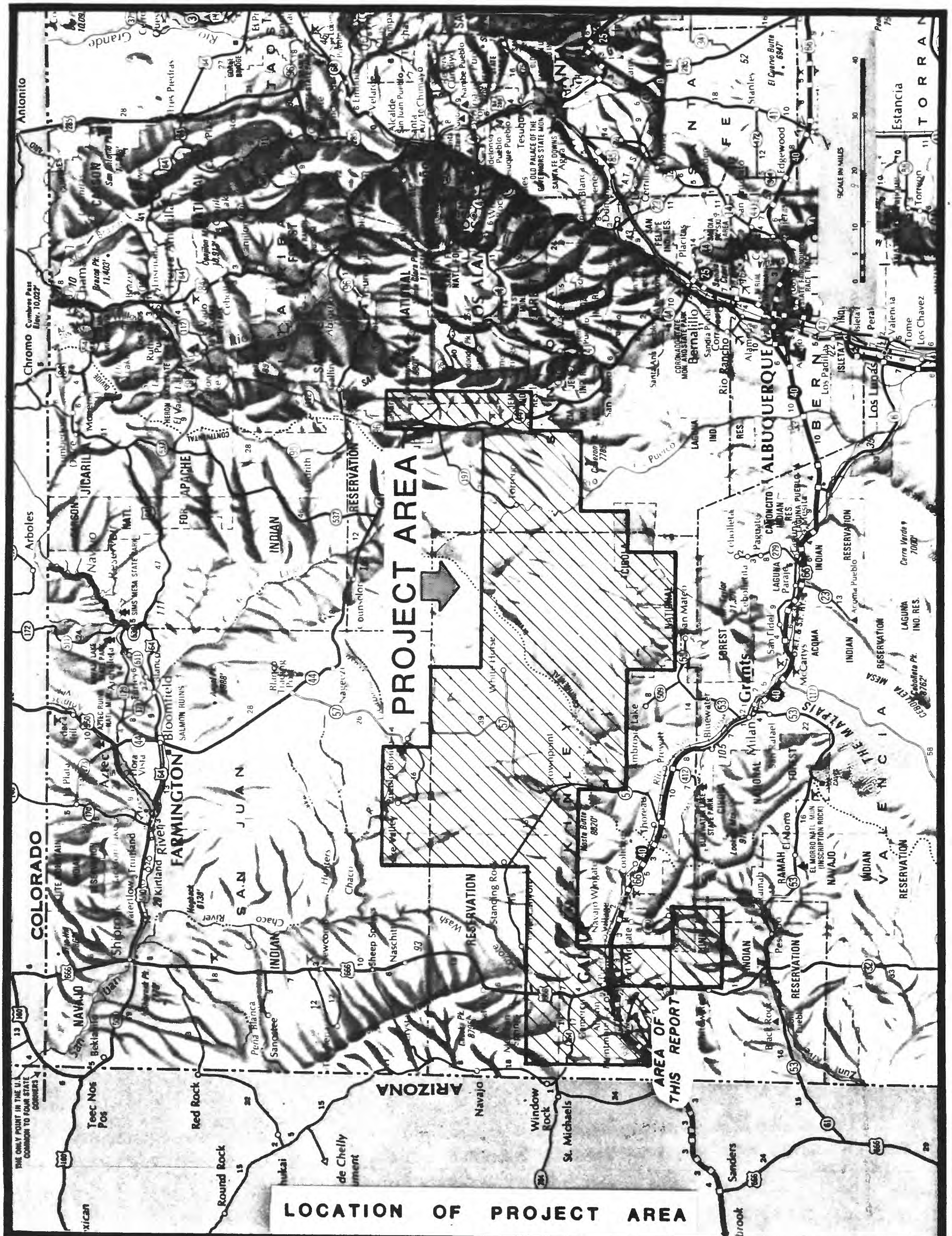
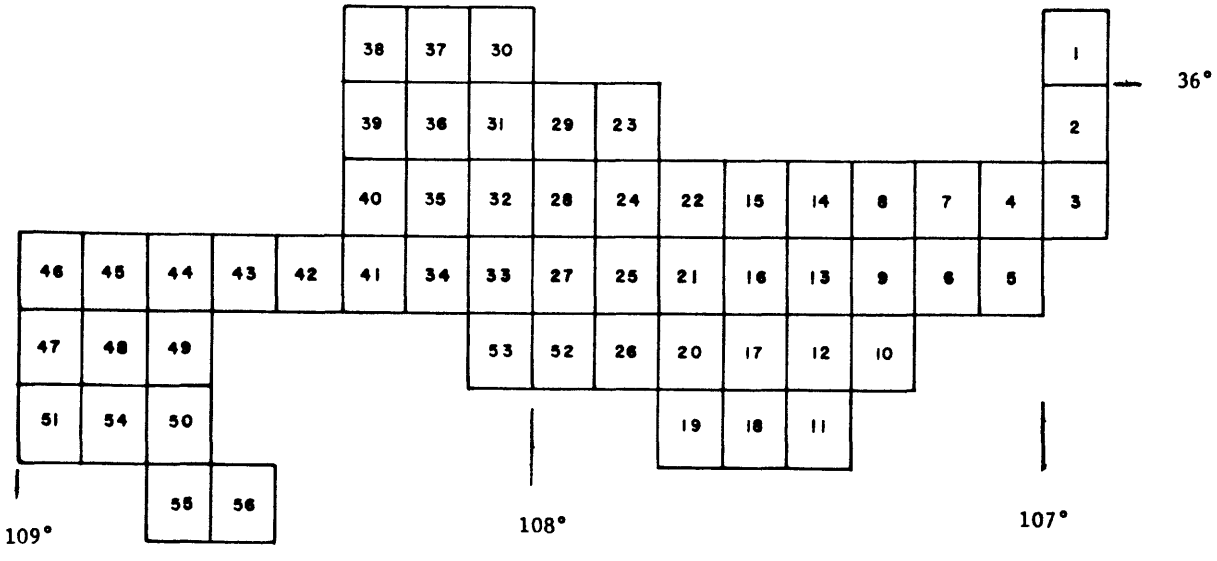

LOCATION OF PROJECT AREA
PROJECT AREA
AREA OF THIS REPORT
COLORADO
ARIZONA
FARMINGTON
ALBUQUERQUE
Grants
Bloomfield
Aztec
Shiprock
Window Rock
St. Michaels
Sanders
Bernalillo
Estancia
Los Lunas
Chromo
Arboles
Antonito
SAN JUAN
RESERVATION
INDIAN
NAVAJO
SCALE IN MILES

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 Bread Springs 7½ minute quadrangle includes acreage in Tps. 13, 14, and 15 N., Rs. 17 and 18 W. of the New Mexico Principal Meridian, McKinley County, northwestern New Mexico (see figs. 1 and 2).

Accessibility

State Route 32 passes through the western part of the Bread Springs quadrangle and provides access to the city of Gallup, 2 mi (3 km) north, and intersects State Highway 53, 22 mi (35 km) south of the quadrangle. Light-duty and unimproved dirt roads traverse most parts of the quadrangle. The main line of the Atchison, Topeka, and Santa Fe Railroad passes through the city of Gallup, about 2.5 mi (4.0 km) north of the quadrangle (see fig. 1). The Gallup-McKinley County Airport which provides small plane access to the area is about 1.5 mi (2.4 km) northwest of the Bread Springs quadrangle.

Physiography

The Bread Springs quadrangle is in the Navajo section of the southernmost part of the Colorado Plateau physiographic province. The topography of the quadrangle is characterized by alluvial valley floors, eroded mesas, and rugged badlands. The Hogback is a prominent topographic feature in the northeastern part of the quadrangle. Mining activities in the past 100 years have contributed various mine dumps and tailings ponds to the quadrangle surface.

No perennial streams are present in the area. Local drainage is provided by several intermittent arroyos. Elevations within the quadrangle range from less than 6,640 ft (2,024 m) along the western quadrangle boundary to 7,802 ft (2,378 m) in the central eastern part of the area.

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 Gallup 5E Station. The Bread Springs quadrangle is about 3 mi (5 km) south of the Gallup 5E Station. Average total annual precipitation for eleven of the previous fifteen years is 9.53 in. (24.21 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 seven of the previous fifteen years is 48.8°F (9.3°C). The average daily temperatures in January and July are 29.0°F (-1.7°C) and 71.3°F (21.8°C), respectively.

Land status

The Federal Government holds the coal mineral rights to approximately 70 percent of the Bread Springs quadrangle. For the specific coal ownership boundaries, see plate 2. It is not within the scope of this report to provide detailed land-surface ownership. All of the quadrangle except about 8,950 acres (3,622 ha) in the southwest, northeast and along the eastern boundary of the quadrangle is within the Gallup Known

Recoverable Coal Resource Area. As of October 26, 1978, there were no Federal coal leases or coal preference right lease applications within the Bread Springs quadrangle. A coal exploration license covers sec. 8, T. 14 N., R. 17 W. in the quadrangle. The Fort Wingate Military Reservation includes about 975 acres (395 ha) along the eastern quadrangle boundary.

GENERAL GEOLOGY

Previous work

Early reports on the area include that of Lupton (1914) who mapped coal outcrops and reported coal thicknesses of the Gallup Sandstone, and Dilco and Gibson Coal Members of the Crevasse Canyon Formation. Sears (1925) reported numerous coal thicknesses from outcrop measurements and coal test holes for coal beds within the Dilco Coal Member, Bartlett Barren Member, and Gibson Coal Member. Shomaker, Beaumont, and Kottlowski (1971) reviewed the area and noted that the Dilco and Gibson Coal Members crop out and underlie large portions of the area. They outlined areas of potential strippable coals, and suggest that detailed field work and coal test drilling would be worthwhile in the area. Jentgen and Fassett (1977) report lithologic and geophysical well logs for five coal test holes in sec. 8, T. 14 N., R. 17 W. Memorandums from the Farmington District of the Conservation Division, U. S. Geological Survey (February, 1978) include additional outcrop and coal test hole data from Casey Jones and William Speer. Lambert (1978) reported coal outcrop measurements within the area.

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 Bread Springs quadrangle include units of Triassic, Jurassic, Upper Cretaceous, and Quaternary age. Triassic and Jurassic rock units crop out along and east of The Hogback. All of the coal beds occur in Upper Cretaceous strata which are exposed along and west of The Hogback. Quaternary deposits include alluvium and terrace gravels along drainages in the area.

The Dakota Sandstone represents coastal sands, fluvial deposits, and marine shales, and is the basal unit of the Upper Cretaceous section. The Dakota Sandstone is composed of yellowish-brown to buff, fine-to medium-grained sandstone, interbedded dark gray to black carbonaceous shales, and coals. Thickness of the unit ranges from 200 to 250 ft (61 to 76 m) locally. The "main body" of the Mancos Shale overlies the Dakota Sandstone, and represents transgressive marine deposits. Light to dark gray, silty shales with interbedded brown, calcareous sandstones comprise the lithologies of the Mancos Shale, which ranges from 500 to 700 ft (152 to 213 m) thick locally.

A major northeastward regression of the Cretaceous seaways resulted in the deposition of the Gallup Sandstone in a nearshore or littoral environment. Pink to gray, fine-to very coarse-grained, massive sandstone, interbedded gray shales, and coal beds comprise the lithologies of the unit, which ranges from 180 to 250 ft (55 to 76 m) thick locally. The Dilco Coal Member of the Crevasse Canyon Formation overlies the Gallup Sandstone and represents the continental deposits which formed inland from the beach area during the deposition of the Gallup Sandstone. Medium to dark gray siltstone with interbedded medium-grained, tan sandstones, and coal beds comprise the lithologies of the Dilco Coal Member, which ranges from 205 to 255 ft (62 to 78 m) thick in the area.

The Dalton Sandstone Member which divided the Dilco Coal Member into upper and lower units in the northern adjacent Gallup East quadrangle was not deposited in this quadrangle. The Bartlett Barren Member of the Crevasse Canyon Formation overlies the Dilco Coal Member and consists of yellowish-brown to olive-gray siltstone, light gray shales, white to brown locally calcareous sandstones, and thin local coal beds. Thickness of the unit ranges from 225 to 285 ft (69 to 87 m) locally.

Overlying the Bartlett Barren Member, the Menefee Cleary-Crevasse Canyon Gibson undifferentiated unit was combined based on similar lithologies and stratigraphic continuity respresenting essentially continuous continental deposition. Light to medium gray, carbonaceous siltstones, interbedded gray to tan sandstones, gray shales, and coal beds comprise the lithologies of the unit, which ranges from 310 to 480 ft (94 to 146 m) thick in the area. The Allison Member of the Menefee Formation overlies the Menefee Cleary-Crevasse Canyon Gibson undifferentiated unit, and represents continued continental deposition. Dark gray to brown, car-

bonaceous to noncarbonaceous shales, light gray sandstones, and thin coal beds comprise the lithologies of the Allison Member. The lower contact of the Allison Member is gradational with the underlying Menefee Cleary-Crevasse Canyon Gibson unit. Thickness of the Allison Member is at least 100 ft (30 m) in the Bread Springs 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 Bread Springs quadrangle is in the Gallup Sag, Nutria Monocline (Baltz, 1967), and Zuni Uplift structural divisions in the southwestern part of the structural depression known as the San Juan Basin (Kelley, 1950). Hackman and Olson (1977) mapped the northwest plunging Allison Syncline, Gallup Anticline, and Gallup Syncline in the area. Additional monoclinal flexures and folds are present in the area. The rock units dip steeply westward from The Hogback. Dips in the area range from 3° to 34° W to SW in the northern part of the area and 2° to 8° SE to SW in the southern part of the Bread Springs quadrangle. A few low displacement faults are present in the area.

COAL GEOLOGY

In this quadrangle, the authors identified fourteen coal beds, four coal zones, and several local coal beds in coal test holes, Lupton's (1914) and Sears' (1925) surface mapping, and Lambert"s (1978) compilation. These coal beds and

coal zones are here informally called the Gallup coal zone, Gallup No. 1 coal bed, Crevasse Canyon Dilco coal zone, Crevasse Canyon Dilco No. 2, No. 2A, No. 3, No. 4, No. 5, No. 6, No. 7, and No. 8 coal beds, Local coal beds, Crevasse Canyon Gibson coal zone, Crevasse Canyon Gibson No. 4, No. 5, No. 6, No. 7, and No. 8 coal beds, and the Menefee Cleary-Crevasse Canyon Gibson coal zone (see plate 3A).

Stratigraphically, the Gallup coal zone contains the lowest identified coal beds in the Bread Springs quadrangle. Up to four individual coal beds that range in thickness from 0.3 to 1.2 ft (0.1 to 0.4 m) and occur from 95 to 155 ft (29 to 47 m) below the top of the Gallup Sandstone comprise the Gallup coal zone. The Gallup No. 1 coal bed ranges from 1.5 to 4.2 ft (0.5 to 1.3 m) thick and occurs from 62 to 68 ft (19 to 21 m) below the top of the Gallup Sandstone.

Up to ten individual coal beds that occur from 40 to 240 ft (12 to 73 m) above the top of the Gallup Sandstone comprise the Crevasse Canyon Dilco coal zone. These zone coals,as with all identified zone coals in this quadrangle, may be correlated for limited distances in portions of the area, but they lack sufficient continuity with poorly defined stratigraphic position and cannot be designated as persistent coal beds. The Crevasse Canyon Dilco No. 2, No. 2A, No. 3, No. 4, No. 5, No. 6, No. 7, and No. 8 coal beds occur from 45 to 62 ft (14 to 19 m), 75 to 85 ft (23 to 26 m), 90 to 105 ft (27 to 32 m), 125 to 145 ft (38 to 44 m), 160 to 200 ft (49 to 61 m), 195 to 220 ft (59 to 67 m), 225 to 240 ft (69 to 73 m), and 245 to 250 ft (75 to 76 m), respectively, above the top of the Gallup Sandstone.

Several local coal beds that range in thickness from 0.4 to 5.9 ft (0.1 to 1.8 m) and occur from 15 to 205 ft (5 to 62 m) above the top of

the Dilco Coal Member comprise the beds of the Bartlett Barren Member. In most areas nearby, these local coal beds are generally less than 2.0 ft (0.6 m) thick. The Crevasse Canyon Gibson coal zone contains up to five individual coal beds that occur from 20 to 162 ft (6 to 49 m) above the top of the Bartlett Barren Member.

The Crevasse Canyon Gibson No. 4, No. 5, No. 6, No. 7, and No. 8 coal beds occur from 20 to 40 ft (6 to 12 m), 50 to 75 ft (15 to 23 m), 110 to 135 ft (34 to 41 m), 140 to 148 ft (43 to 45 m), and 155 to 160 ft (47 to 49 m), respectively, above the Bartlett Barren Member. These coal beds, as with all numerically designated coal beds identified in this quadrangle, are inferred to be continuous although they are probably several individual coal beds that are stratigraphically equivalent. Up to two individual coal beds that occur from 57 to 110 ft (17 to 34 m) above the top of the Crevasse Canyon Gibson No. 8 coal bed comprise the Menefee Cleary-Crevasse Canyon Gibson coal zone.

There are no known published coal quality analyses for Gibson Coal Member beds from the Bread Springs quadrangle. Analyses of mine samples taken from 4.6 to 5.4 mi (7.4 to 8.7 km) north of the Bread Springs quadrangle have been reported by the U. S. Bureau of Mines (1936) and are shown in table 1. The Gibson Coal Member beds analyzed are probably similar in quality to the Gibson Coal Member beds in this quadrangle. Rank of the Gibson Coal Member beds is probably high volatile C bituminous in this area.

Several coal quality analyses are available for Dilco Coal Member beds from the Bread Springs quadrangle. An analysis of delivered coal from Amcoal's Sundance strip mine (sample 1, table 2) has been reported by Shomaker, Beaumont, and Kottlowski (1971). Coal quality analyses from

Table 1. - Analyses of coal samples from the Gibson Coal Member of the Crevasse Canyon Formation.

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

from U. S. Bureau of Mines, 1936

Sample	Type of sample	Location Sec.	T. N.	R. W.	Form of analysis	Proximate analysis (percent) Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Heating value (Btu/lb)
1	mine sample (Navajo mine)	SE¼ 33	16	18	A	12.5	38.9	39.4	9.17	0.43	10,800
					B	----	44.4	45.1	10.49	0.49	12,350
					C	----	49.7	50.3	----	0.55	13,800
2	mine sample (Heaton mine)	NW¼ 35	16	18	A	14.6	38.8	40.9	5.7	0.60	11,030
					B	----	45.4	47.9	6.7	0.70	12,920
					C	----	48.7	51.3	----	0.75	13,840
3	mine sample (Weaver mine)	SE¼ 34	16	18	A	15.8	38.0	43.1	3.14	0.45	11,300
					B	----	45.1	51.2	3.73	0.53	13,430
					C	----	46.9	53.1	----	0.55	13,950
4	mine sample (Navajo No. 1 mine)	SE¼ 33	16	18	A	13.7	38.5	41.3	6.54	0.56	11,120
					B	----	44.6	47.8	7.58	0.65	12,880
					C	----	48.2	51.8	----	0.70	13,930

Remarks:

A moist, mineral-matter-free (MMMF) calculation using the Parr formula (American Society for Testing and Materials, 1973) yields heating values of 11,995 Btu/lb (27,900 kJ/kg; sample 1), 11,763 Btu/lb (27,361 kJ/kg; sample 2), 11,703 Btu/lb (27,221 kJ/kg; sample 3), and 11,975 Btu/lb (27,854 kJ/Kg; sample 4). No agglomerating characteristics were included with the analyses.

Table 2. - Analyses of coal samples from the Dilco Coal Member of the Crevasse Canyon Formation.

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

Sample 1 from Shomaker, Beaumont, and Kottlowski, 1971

Samples 2 and 3 from U. S. Geological Survey, Memorandum, February 10, 1978

Sample 4 from U. S. Bureau of Mines, 1936

Sample	Type of sample	Location			Form of analysis	Proximate analysis (percent)				Sulfur	Heating value (Btu/lb)
		Sec.	T. N.	R. W.		Moisture	Volatile matter	Fixed carbon	Ash		
	Delivered coal				A	12.5	38.3	42.5	6.8	0.6	11,390
1	1½ in. x 0	9	14	17	B	----	43.7	48.5	7.8	0.7	13,020
	core test hole	SE¼ NE¼			A	----	----	----	11.9	1.0	11,196
2	BS 8-5c	8	14	17	B	----	----	----	12.8	1.1	12,041
	(71.3' - 76.2')				C	----	----	----	----	1.2	13,812
	core test hole	SE¼ NE¼			A	----	----	----	12.6	0.7	11,184
3	BS 8-5c	8	14	17	B	----	----	----	13.6	0.7	11,992
	(77.2' - 79.5')				C	----	----	----	----	0.8	13,874
	composite sample				A	11.1	37.3	44.8	6.8	0.7	11,600
4	(Gallup South-	28	15	18	B	----	42.0	50.3	7.7	0.8	13,050
	western Atherton mine)				C	----	45.4	54.6	----	0.8	14,130

Remarks:

A moist, mineral-matter-free (MMMF) calculation using the Parr formula (American Society for Testing and Materials, 1973) yields heating values of 12, 304 Btu/lb (28,619 kJ/kg; sample 1), 12,871 Btu/lb (29,938 kJ/kg; sample 2), 12,963 Btu/lb (30,152 kJ/kg; sample 3), and 12,534 Btu/lb (29,154 kJ/kg; sample 4). No agglomerating characteristics were included with the analyses.

Jentgen's and Fassett's (1977) core test hole BS 8-5c (samples 2 and 3, table 2) were reported by the U. S. Geological Survey (1978). Samples 1, 2, and 3 are from the "Sundance" seam which the author's called the Crevasse Canyon Dilco No. 8 coal bed (see p.16). The analysis from the Gallup Southwestern-Atherton mine (sample 4, table 2), about 0.4 mi (0.6 km) north of the quadrangle, is the author's Crevasse Canyon Dilco No. 5 coal bed (Black Diamond bed of Sears, 1925). Rank of the Dilco Coal Member beds is high volatile C bituminous in this area.

Crevasse Canyon Gibson No. 7 coal bed

The Crevasse Canyon Gibson No. 7 coal bed was identified in several outcrop measured sections in the Bread Springs quadrangle. Thickness of the bed ranges from 0.1 to 4.9 ft (0.1 to 1.5 m). The bed contains rock partings in several of the outcrop measured sections. The mine sample from the Heaton mine (sample 2, table 1) is from the same coal bed as the author's Crevasse Canyon Gibson No. 7 coal bed. Existence and character of the Crevasse Canyon Gibson No. 7 coal bed are unknown in the southern and southwestern parts of the quadrangle because of insufficient data. The coal bed is inferred to pinch out toward the north (see plate 4).

Crevasse Canyon Gibson No. 4 coal bed

The Crevasse Canyon Gibson No. 4 coal bed was identified in three outcrop measured sections by Sears (1925). Thickness of the bed ranges from 3.5 to 4.2 ft (1.1 to 1.3 m). The author's Crevasse Canyon Gibson No. 4 coal bed is the same coal bed as Sears' (1925) Old Enterprise bed. Because

of limited data, the isopach, structure contour, and overburden isopach maps of the Crevasse Canyon Gibson No. 4 coal bed are included in this text as page-sized maps (figs. 3, 4, and 5). The bed is inferred to pinch out in the southern part of the mapped area (see fig. 3).

Crevasse Canyon Dilco No. 8 coal bed

The Crevasse Canyon Dilco No. 8 coal bed was identified in two coal test holes and several outcrop measured sections. Thickness of the bed ranges from 0.5 to 11.9 ft (0.2 to 3.6 m). Jentgen and Fassett (1977) report that the Sundance seam is within the lower part of the Bartlett Barren Member. However, by definition the Bartlett Barren Member contains only very thin, irregular coal beds (Sears, 1925). The authors believe that the Sundance seam is the Crevasse Canyon Dilco No. 8 coal bed. Samples 1, 2, and 3 (table 2) are from the same coal bed as the author's Crevasse Canyon Dilco No. 8 coal bed. Existence and character of the Crevasse Canyon Dilco No. 8 coal bed are unknown in most parts of the quadrangle because of insufficient data.

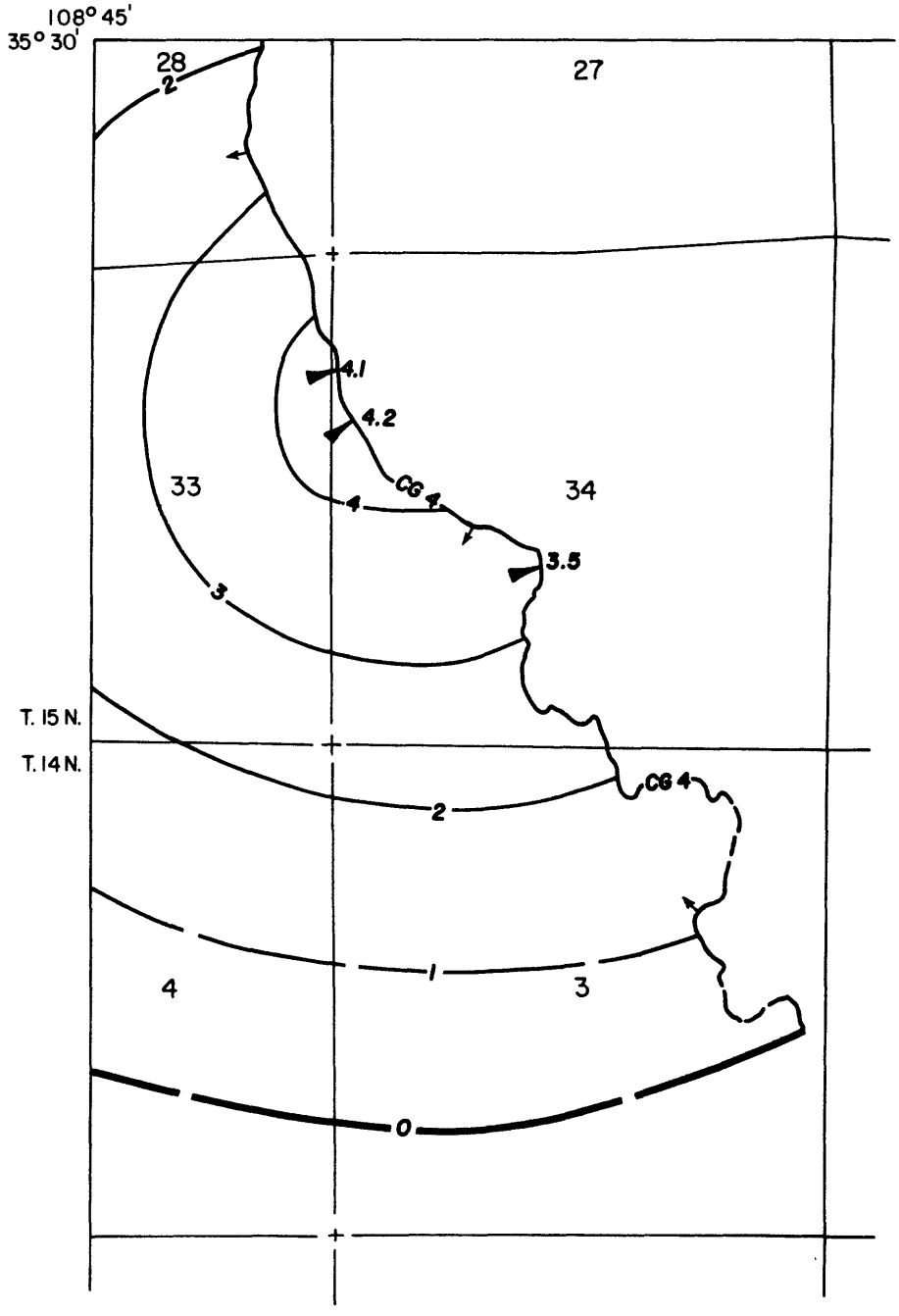
Crevasse Canyon Dilco No. 6 coal bed

The Crevasse Canyon Dilco No. 6 coal bed was identified in two coal test holes and several outcrop measured sections. Thickness of the bed ranges from 1.2 to 6.4 ft (0.4 to 1.9 m). Because of the limited areal extent of the Crevasse Canyon Dilco No. 6 coal bed, the isopach, structure contour, and overburden isopach maps are included in this text as page-sized maps (figs. 6, 7, and 8). Faults displace the coal bed outcrop in

Figure 3

ISOPACH MAP OF THE CREVASSE CANYON GIBSON NO. 4 COAL BED

(See explanation p. 20)

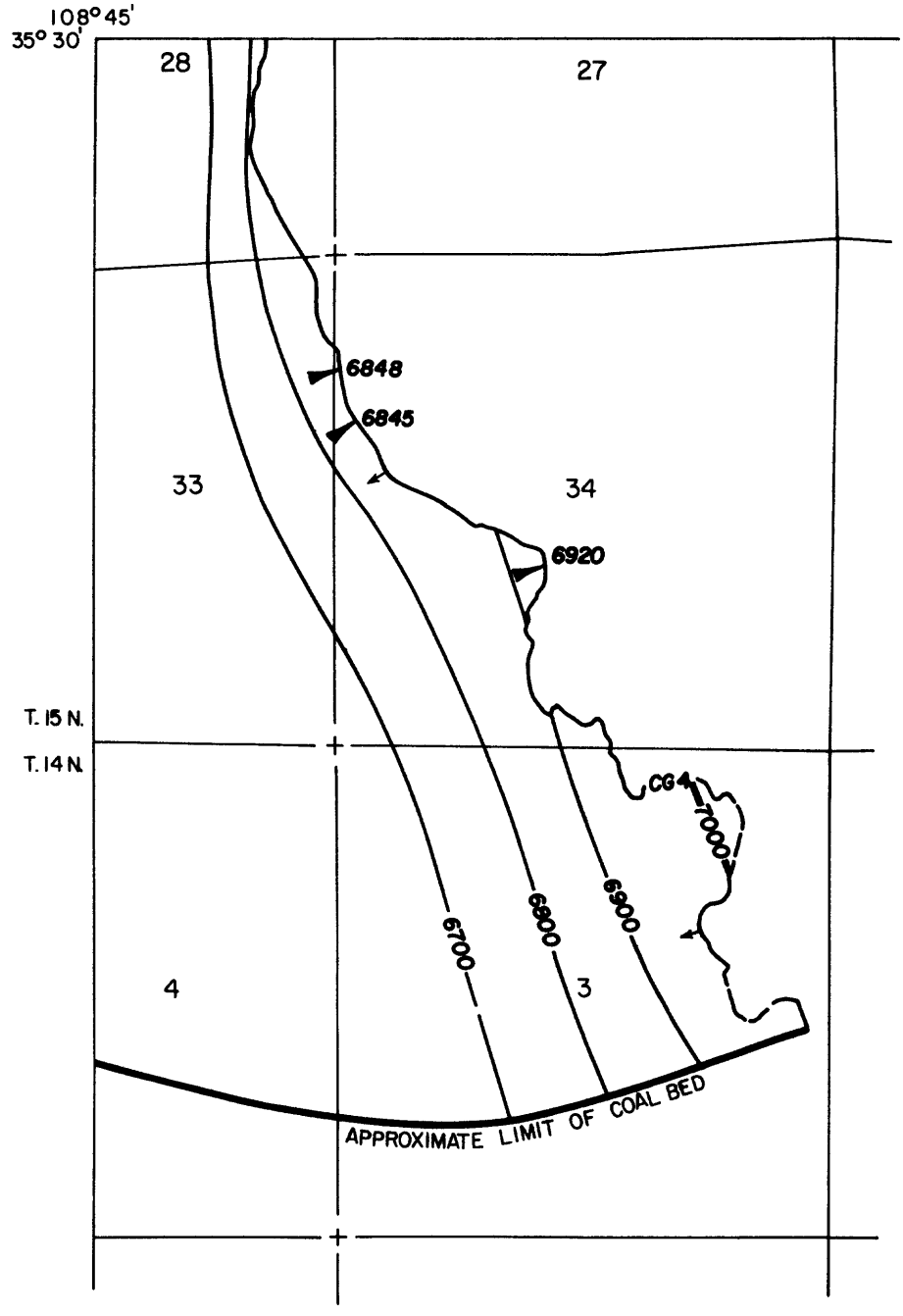


SCALE 1:24,000

Figure 4

STRUCTURE CONTOUR MAP OF THE CREVASSE CANYON GIBSON NO. 4 COAL BED

(See explanation p. 20)

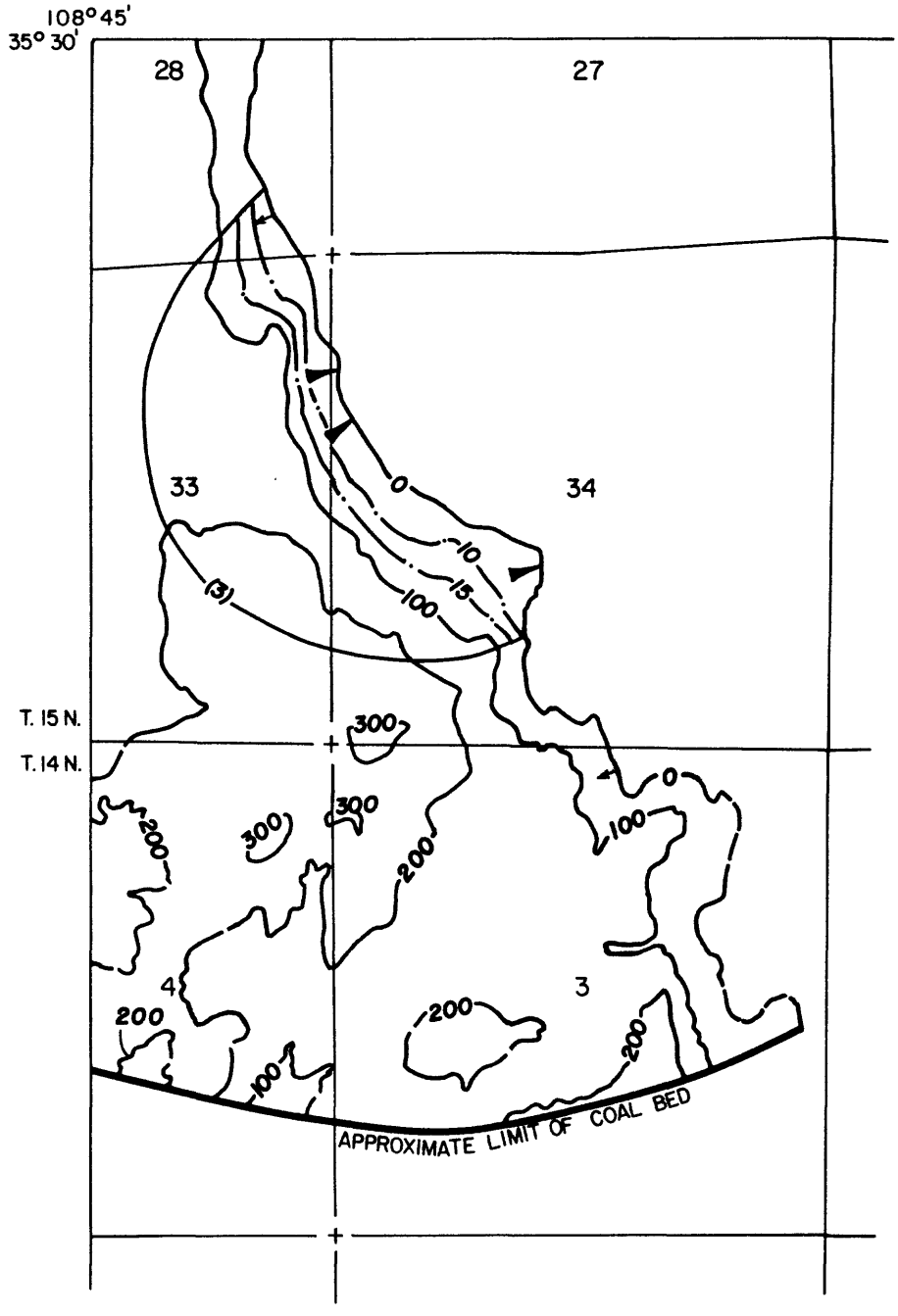


SCALE 1:24,000

Figure 5

ISOPACH MAP OF OVERBURDEN OF THE CREVASSE CANYON GIBSON NO. 4 COAL BED

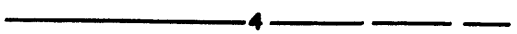
(See explanation p. 20)



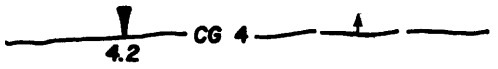
SCALE 1:24,000

Figure 3

EXPLANATION



ISOPACHS OF THE CREVASSE CANYON GIBSON NO. 4 COAL BED-Showing thickness in feet. Isopach interval 1 foot (0.3 meter). Isopachs dashed where inferred.

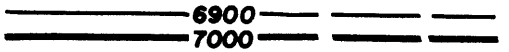


TRACE OF COAL BED OUTCROP-Showing coal thickness, in feet, measured at triangle. Arrow points toward the coal-bearing area. Dashed line indicates inferred outcrop.

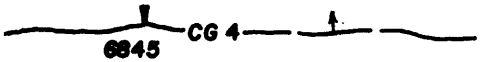
To convert feet to meters, multiply feet by 0.3048.

Figure 4

EXPLANATION



STRUCTURE CONTOURS-Drawn on top of the Crevasse Canyon Gibson No. 4 coal bed. Contour interval 100 feet (30 meters). Datum is mean sea level. Contours dashed where inferred.

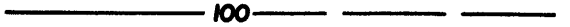


TRACE OF COAL BED OUTCROP-Showing altitude, in feet, measured at triangle. Arrow points toward the coal-bearing area. Dashed line indicates inferred outcrop.

To convert feet to meters, multiply feet by 0.3048.

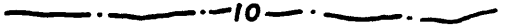
Figure 5

EXPLANATION



OVERBURDEN ISOPACHS-Showing thickness of overburden, in feet, from the surface to the top of the Crevasse Canyon Gibson No. 4 coal bed. Isopach interval 100 feet (30.5 meters). Isopachs dashed where inferred. Stripping limit is 200 feet (61 meters).

TRACE OF COAL BED OUTCROP-Showing no overburden at triangle. Arrow points toward the coal-bearing area. Dashed line indicates inferred outcrop.



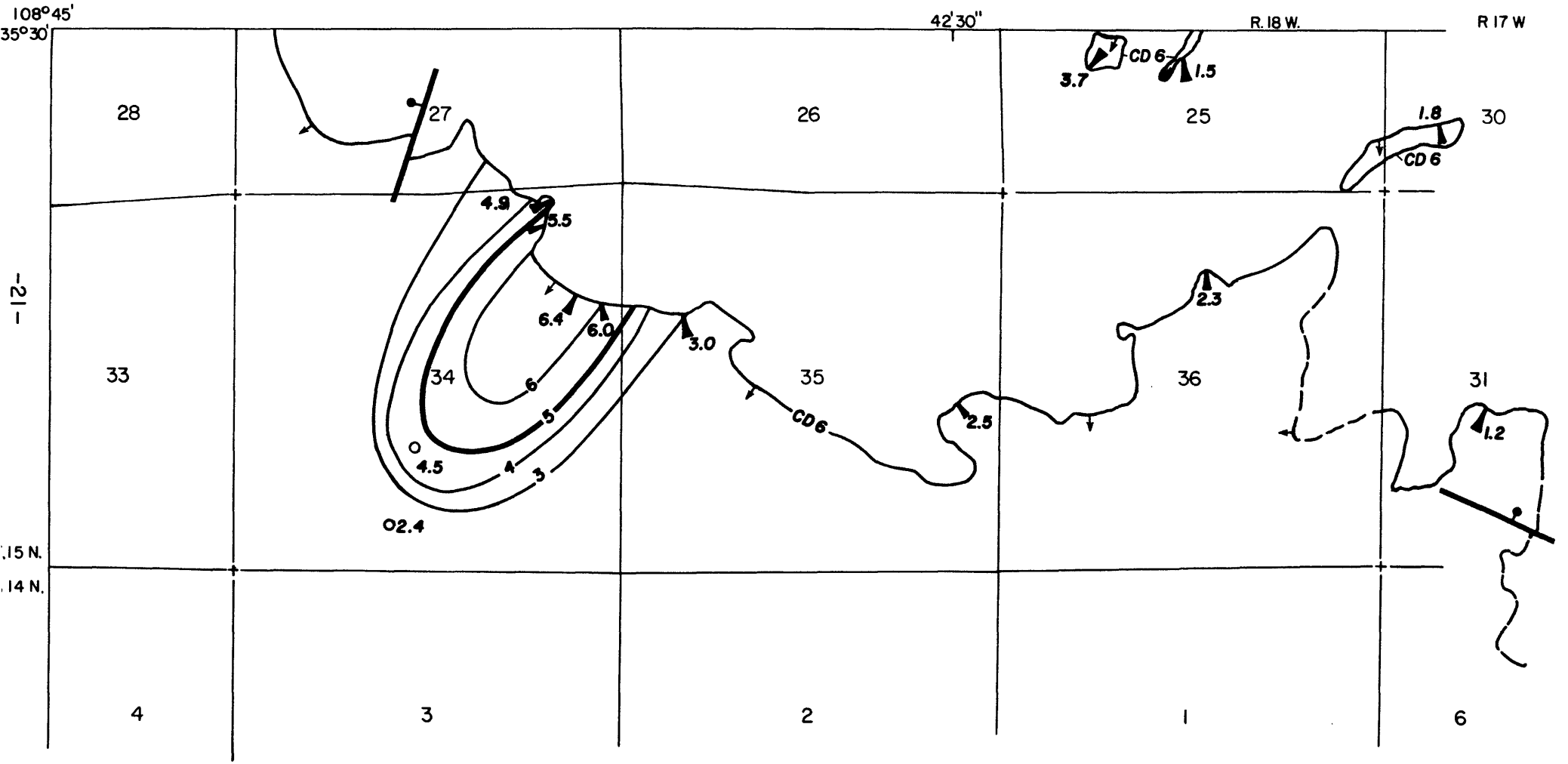
MINING RATIO CONTOUR FOR THE CREVASSE CANYON GIBSON NO. 4 COAL BED-Number indicates cubic yards of overburden per ton of recoverable coal by surface-mining methods. Contours shown only in areas suitable for surface mining within the stripping limit, less than 200 feet (61 meters) of overburden.

To convert feet to meters, multiply feet by 0.3048.

Figure 6

ISOPACH MAP OF THE CREVASSE CANYON DILCO NO. 6 COAL BED

(See explanation p. 24)

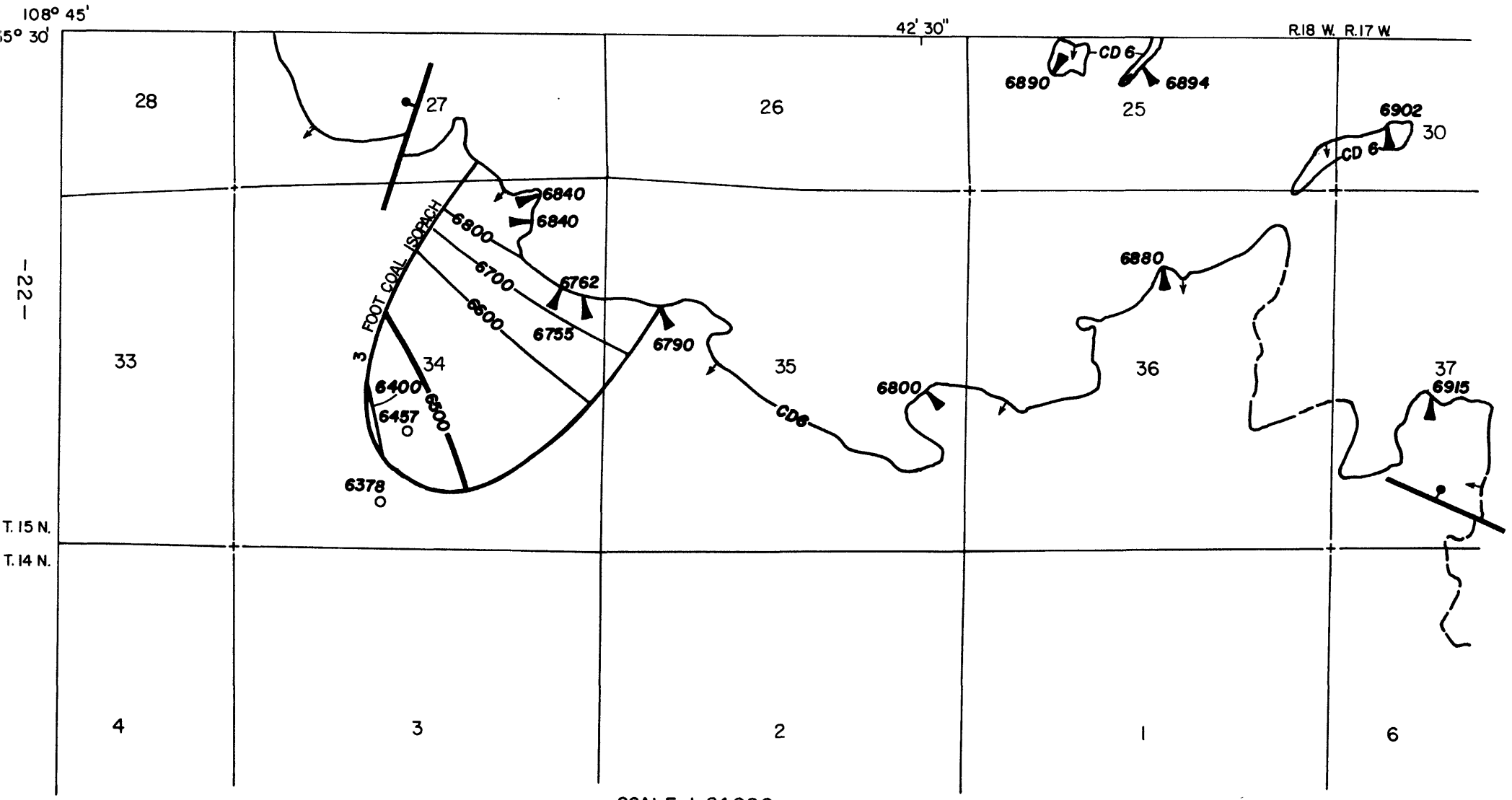


SCALE 1: 24,000

Figure 7

STRUCTURE CONTOUR MAP OF THE CREVASSE CANYON DILCO NO. 6 COAL BED

(See explanation p. 24)

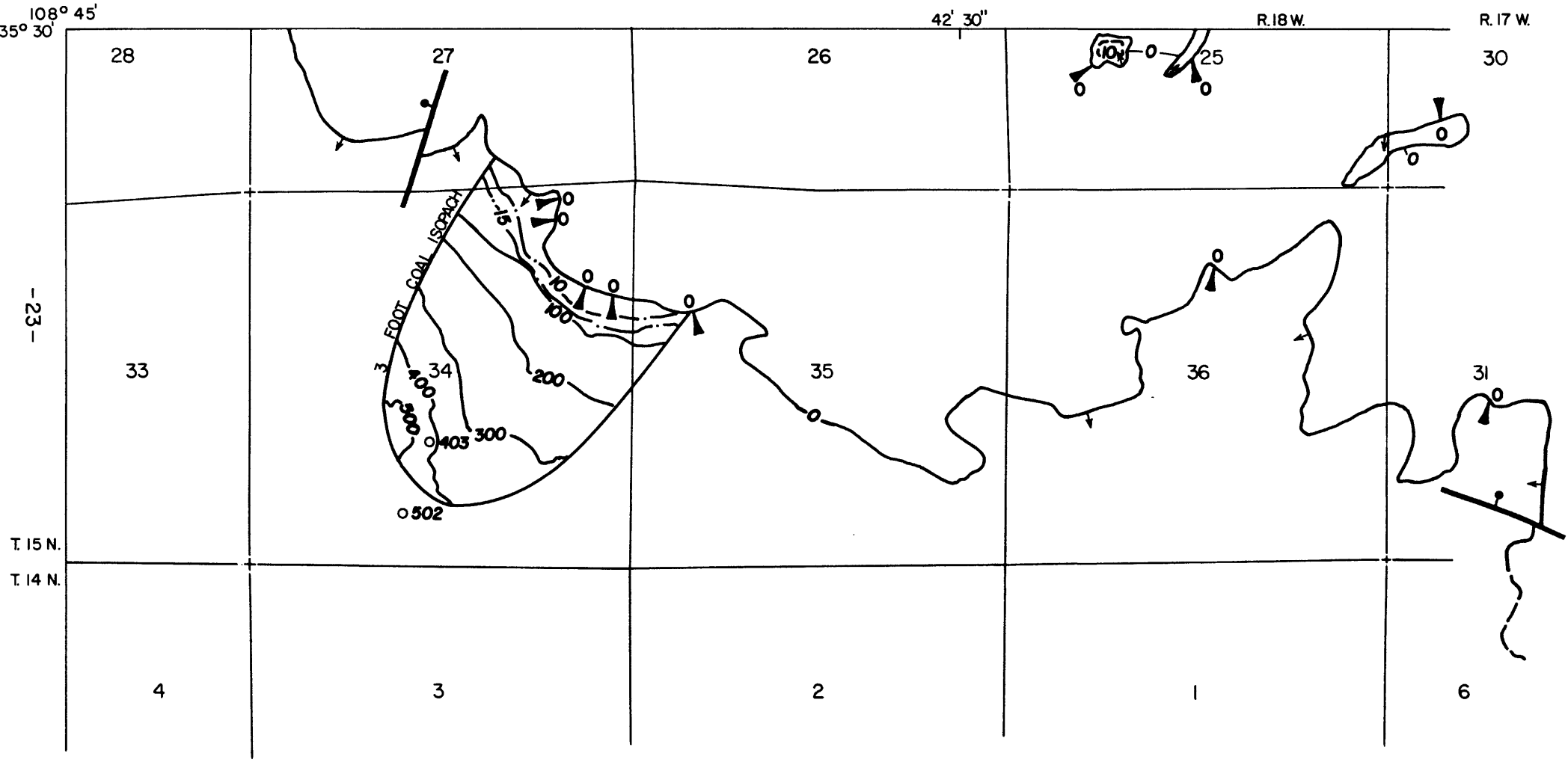


SCALE 1: 24,000

Figure 8

ISOPACH MAP OF OVERBURDEN OF THE CREVASSE CANYON DILCO NO. 6 COAL BED

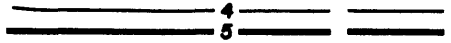
(See explanation p. 24)



SCALE 1: 24,000

Figure 6

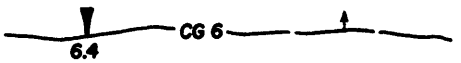
EXPLANATION



ISOPACHS OF THE CREVASSE CANYON DILCO No. 6 COAL BED-Showing thickness in feet. Isopach interval 1 foot (0.3 meter). Isopachs dashed where inferred.

o4.5

DRILL HOLE-Showing thickness of the Crevasse Canyon Dilco No. 6 coal bed in feet.



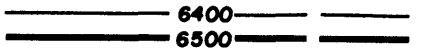
TRACE OF COAL BED OUTCROP-Showing coal thickness, in feet, measured at triangle. Arrow points toward the coal-bearing area. Dashed line indicates inferred outcrop.

FAULT-Bar and bell on downthrown side.

To convert feet to meters, multiply feet by 0.3048.

Figure 7

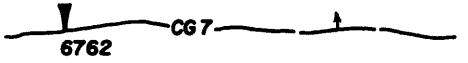
EXPLANATION



STRUCTURE CONTOURS-Drawn on top of the Crevasse Canyon Dilco No. 6 coal bed. Contour interval 100 feet (30.5 meters). Datum is mean sea level. Contours dashed where inferred.

o6457

DRILL HOLE-Showing altitude at top of the Crevasse Canyon Dilco No. 6 coal bed in feet.



TRACE OF COAL BED OUTCROP-Showing altitude, in feet, measured at triangle. Arrow points toward the coal-bearing area. Dashed line indicates inferred outcrop.

FAULT-Bar and bell on downthrown side.

To convert feet to meters, multiply feet by 0.3048.

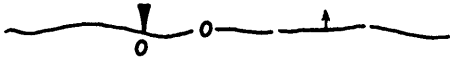
Figure 8

EXPLANATION

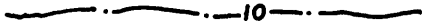
OVERBURDEN ISOPACHS-Showing thickness of overburden, in feet, from the surface to the top of the Crevasse Canyon Dilco No. 6 coal bed. Isopach interval 100 feet (30.5 meters). Isopachs dashed where inferred. Stripping limit is 200 feet (61 meters).

o393

DRILL HOLE-Showing thickness of overburden, in feet, from the surface to the top of the Crevasse Canyon Dilco No. 6 coal bed.



TRACE OF COAL BED OUTCROP-Showing no overburden at triangle. Arrow points toward the coal-bearing area. Dashed line indicates inferred outcrop.



MINING RATIO CONTOUR FOR THE CREVASSE CANYON DILCO NO. 6 COAL BED-Number indicates cubic yards of overburden per ton of recoverable coal by surface-mining methods. Contours shown only in areas suitable for surface mining within the stripping limit, less than 200 feet (61 meters) of overburden.

FAULT-Bar and bell on downthrown side.

To convert feet to meters, multiply feet to 0.3048.

sec, 27, T. 15 N., R. 18 W., and sec. 31, T. 15 N., R. 17 W. (see fig. 6). The author's Crevasse Canyon Dilco No. 6 coal bed is the same bed as Sears' (1925) Thatcher coal bed.

Crevasse Canyon Dilco No. 5 coal bed

The Crevasse Canyon Dilco No. 5 coal bed was identified in four coal test holes and numerous outcrop measured sections. Thickness of the bed ranges from 0.1 to 8.9 ft (0.1 to 2.7 m). The coal test hole in SE¼ NE¼ SW¼ sec. 34, T. 15 N., R. 18 W. (data point #23, plates 1 and 3) contains three benches of the Crevasse Canyon Dilco No. 5 coal bed, each separated by rock partings. The procedure prescribed by the U. S. Geological Survey regarding rock partings in coal beds overlain by greater than 200 ft (61 m) of overburden is the rock parting must be thicker than the coal bench to discount that bench from the total coal thickness. Following these guidelines, coal benches of 0.5 and 0.6 ft (0.2 and 0.2 m) were discounted, so the isopached thickness was 2.5 ft (0.8 m) (see plate 10). The mine samples from the Gallup Southwestern-Atherton mine (sample 4, table 2) is from the same coal bed as the author's Crevasse Canyon Dilco No. 5 coal bed (Black Diamond bed of Sears, 1925). The bed is inferred to pinch out toward the south (see plate 10).

COAL RESOURCES

The U. S. Geological Survey requested resource evaluations of the Crevasse Canyon Gibson No. 7 coal bed and Crevasse Canyon Dilco No. 8 and

No. 5 coal beds, where the beds are 3.0 ft (0.9 m) or more thick. The evaluation is restricted to Federal coal lands.

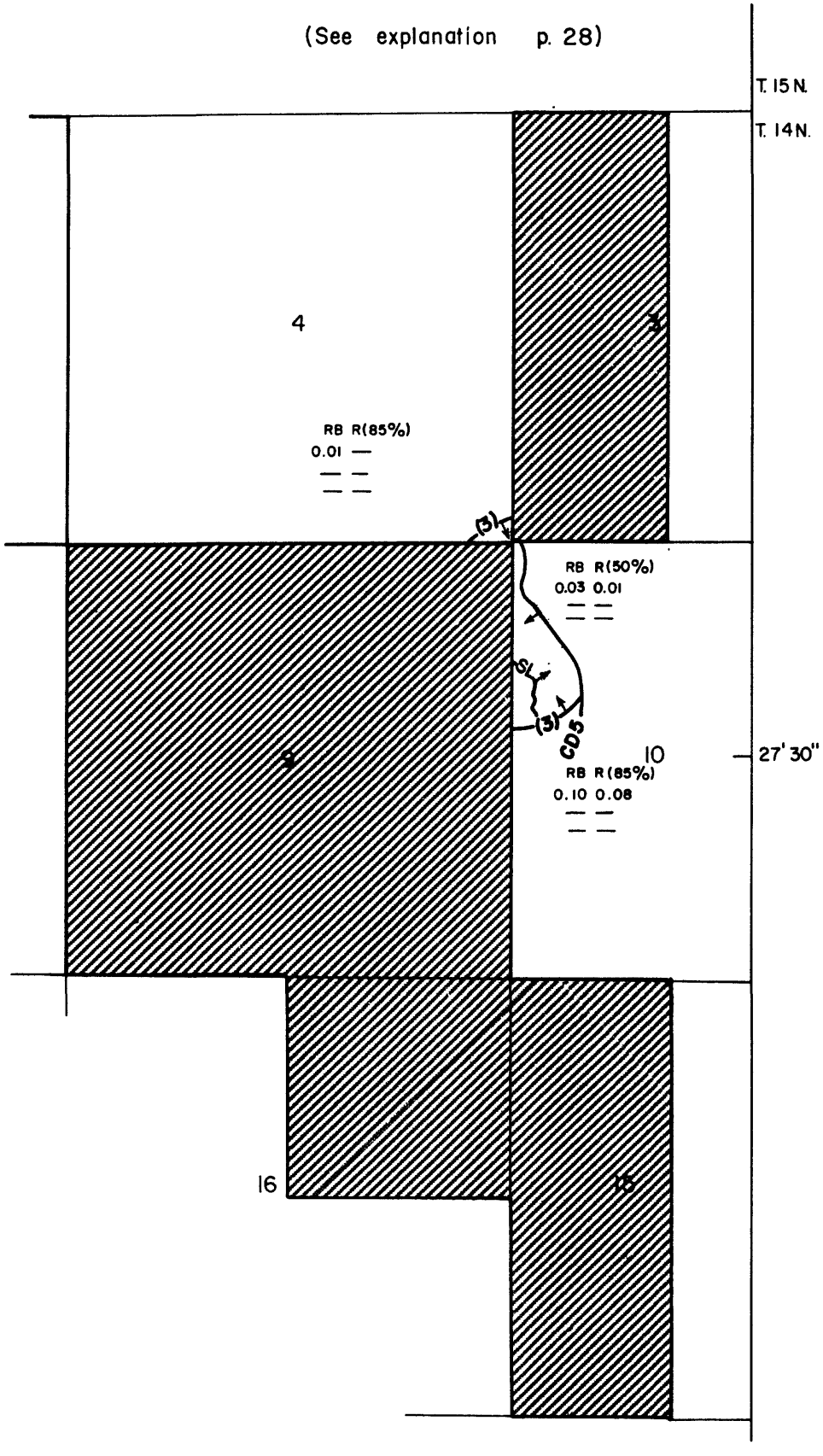
The following procedures were prescribed by the U. S. Geological Survey for the calculation of reserve base. Criteria established in U. S. Geological Survey Bulletin 1450-B were used to areally divide the bed into measured, indicated, and inferred reserve base categories. Reserve base was calculated for each category by section, using data from the isopach (plates 4, 7, and 10) and overburden maps (plates 6, 9, 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. 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, which include all reserve base categories, are shown by section on plate 2. Because of the limited areal extent of the Crevasse Canyon Dilco No. 5 coal bed, the areal distribution and identified resources map was included in this text as a page-sized map (fig. 9). Reserve base and reserve data in the various categories are shown on plates 13 and 14, and fig. 9.

Figure 9

AREAL DISTRIBUTION AND IDENTIFIED RESOURCES OF THE CREVASSE CANYON DILCO NO. 5 COAL BED

(See explanation p. 28)



SCALE 1:24,000

Figure 9

EXPLANATION

NON-FEDERAL COAL LAND-Land for which the Federal Government does not own the coal rights.

SL

STRIPPING LIMIT LINE-Boundary for surface mining (in this quadrangle, the 200 foot-61 meter-overburden isopach). Arrows point toward the area suitable for surface mining. Recovery factor of 85 percent used within the stripping limit.

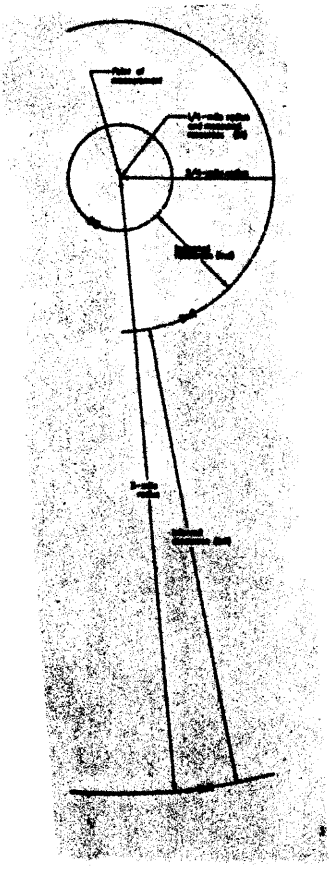
BOUNDARY OF IDENTIFIED RESERVE BASE COAL-Drawn along the coal outcrop (CD5) and the 3 foot (0.9 meter) coal isopach (3). Arrow points toward area of identified Reserve Base coal.

RB R(85%)
0.10 0.08 (Measured resources)
— — (Indicated resources)
— — (Inferred resources)

IDENTIFIED COAL RESOURCES-Showing totals for Reserve Base (RB) and Reserves(R), in millions of short tons, for each section of Federal coal land within the stripping limit line. Dash indicates no resources within that category. Reserve Base (RB) x the Recovery Factor (85 percent) = Reserves (R).

RB R(50%)
0.03 0.01 (Measured resources)
— — (Indicated resources)
— — (Inferred resources)

IDENTIFIED COAL RESOURCES-Showing totals for Reserve Base (RB) and Reserves (R), in millions of short tons, for each section of Federal coal land outside the stripping limit line. Dash indicates no resources in that category. Reserve Base (RB) x the Recovery Factor (50 percent) = Reserves (R).



BOUNDARY LINES-Enclosed areas of measured (M), indicated (Ind) and inferred (Inf) coal resources. Diagram not to scale.

To convert short tons to metric tons, multiply short tons by 0.9072.

To convert miles to kilometers, multiply miles by 1.609.

NOTE: BLM coal ownership data current as of Oct. 26, 1978.

NOTE: This plate does not show the areal distribution or quantity of subeconomic resources present in this quadrangle.

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 evalutaions.

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 and subsurface mining methods (plates 15 and 16,respectively) are defined

at the coal-bearing Gallup Sandstone with the underlying noncoal-bearing "main body" of the Mancos Shale. For coal development potential evaluations, the Dakota Sandstone is not considered potentially coal-bearing in the area by the U. S. Geological Survey. 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 component area. 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 Bread Springs quadrangle is shown on plate 15. Based on coal development potential criteria, all Federal coal lands have high, moderate, low,

unknown or no surface mining potentials. The areas of moderate development potential are not shown on plate 15 because they occupy less than half of a 40 acre lot. Refer to table 5 for reserves and planimetered acreage, by section, for Federal coal lands in the Bread Springs quadrangle with surface mining potential.

Development potential for subsurface mining methods and in situ gasification

The coal development potential for subsurface mining methods in the Bread Springs quadrangle is shown on plate 16. Based on coal development potential criteria, all Federal coal lands have high, unknown or no subsurface mining potentials. Refer to table 6 for reserves and planimetered acreage, by section, for Federal coal lands in the Bread Springs quadrangle with subsurface mining potential.

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 Bread Springs 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
Crevasse Canyon Gibson No. 7	100,000	50,000	180,000	330,000
Crevasse Canyon Dilco No. 8	260,000	200,000	680,000	1,140,000
Crevasse Canyon Dilco No. 5	20,000	30,000	70,000	120,000
Total	380,000	280,000	930,000	1,590,000

Table 4. - Reserve base data (in short tons) for subsurface mining methods for Federal coal lands in the Bread Springs 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
Crevasse Canyon Dilco No. 8	10,180,000	----	----	10,180,000
Crevasse Canyon Dilco No. 5	30,000	----	----	30,000
Total	10,210,000	----	----	10,210,000

Table 5. - Reserves and planimetered acreage, by section, for Federal coal lands in the Bread Springs 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)
High	Crevasse Canyon Gibson No. 7	22	14	17	4.0	less than 10,000
		27			12.2	40,000
		30			1.5	less than 10,000
		26	14	18	2.0	less than 10,000
	Crevasse Canyon Dilco No. 8	10	14	17	11.1	40,000
		22			21.8	140,000
		27			less than 1.0	less than 10,000
	Crevasse Canyon Dilco No. 5	4	14	17	1.5	less than 10,000
		10			1.5	less than 10,000
Moderate	Crevasse Canyon Gibson No. 7	22	14	17	4.0	less than 10,000
		27			3.0+	10,000
	Crevasse Canyon Dilco No. 8	10	14	17	8.1	30,000
		22			15.7	100,000
		27			1.0	less than 10,000
	Crevasse Canyon Dilco No. 5	4	14	17	1.0	less than 10,000
		10			3.0	10,000
Low	Crevasse Canyon Gibson No. 7	22	14	17	28.9	140,000
		27			1.5	less than 10,000
	Crevasse Canyon Dilco No. 8	10	14	17	41.1	210,000
		16			2.0	10,000
		22			39.5	260,000
		27			7.6	50,000
	Crevasse Canyon Dilco No. 5	10	14	17	13.5	50,000

Table 6. - Reserves and planimetered acreage, by section, for Federal coal lands in the Bread Springs 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	Crevasse Canyon Dilco No. 8	10	14	17	6.1	20,000
		16			317.7	1,190,000
		22			147.4	620,000
		28			526.0	1,720,000
		27			104.9	440,000
		33			101.8	310,000
		34			244.7	770,000
	Crevasse Canyon Dilco No. 5	10	14	17	4.6	10,000

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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.