Utah Coal Studies II

UTAH COAL STUDIES II

COAL DRILLING, NORTH HORN MOUNTAIN, EAST MOUNTAIN AREAS, WASATCH PLATEAU, UTAH

by Archie D. Smith

GEOLOGIC EVALUATION OF A CENTRAL UTAH COAL PROPERTY WASATCH PLATEAU, EMERY COUNTY, UTAH

by John M. Mercier, and Thomas W. Lloyd

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by A. D. Smith[1]

ABSTRACT

The primary statements of this report concern a description of drilling, quality of the coal encountered (trace elements and methane content included), and the indicated and inferred reserves calculated from the data developed from drilling. Other elements such as geography, physiography, stratigraphy, and structure are given less exposition because of adequate treatment by other authors.

Eighteen drill holes were successfully drilled through the Lower Blackhawk Formation coal zones into the Star Point Sandstone where total depth was achieved. Fourteen of the drill holes are located on North Horn Mountain, three are located on East Mountain, and one in Meetinghouse Canyon. The average drill hole depth is 1,394 feet. Thirteen of the drill holes were spudded in the Price River Formation while four were spudded in the North Horn Formation and one in the Blackhawk Formation. Each drill hole is described by its location, collar elevation, drilling method and time required. Also, each has its spud in formation identified as well as the succeeding units including thickness and percentage of rock types contained within the unit. The minable coal encountered in each drill hole is identified by the depth interval, including the lithology and thickness of roof and floor rock; also, both coal and rock are graphically represented in a column.

Quality and trace elements of the drilled coal was analyzed in both Blind Canyon (MC-56A-TC) and Hiawatha (MC-48-MP & MC-56A-TC) coal zones. The as received/dry basis ultimate analysis for the Blind Canyon coal zone is: moisture 6.68/XXX, carbon 67.69/72.56, hydrogen 5.01/5.37, nitrogen 1.09/1.17, chlorine 0.01/0.01, sulfur 0.35/0.37, ash 7.89/8.43, and oxygen 11.28/12.09. The average as received/dry basis analysis for the Hiawatha coal zone is: moisture 5.75/XXX, carbon 66.79/70.87, hydrogen 4.92/5.25, nitrogen 1.34/1.43, chlorine 0.03/0.03, sulfur 0.68/0.72, ash 9.69/10.34, and oxygen 9.74/10.38. Sulfur forms (pyritic, sulfate, and organic) as well as trace elements are tabularized. No adverse results were determined in either sulfur forms or trace elements. Methane content of the coal cores was determined by the U. S. Bureau of Mines "Direct Method" to be less than one cubic centimeter per gram of coal.

Reserve calculations for the drilled area show a total in-place indicated and inferred tonnage of 312,583,533 short tons. Not all of this coal is recoverable because there are several areas where the coal beds are split and only one bench can be considered for mining. The areas of reserve calculations are delineated for Blind Canyon and Hiawatha coal zones on page size maps. Calculated reserves are tabularized to show coal zone, location, bed configuration (upper, lower split or not split), indicated, inferred and total tonnage. If unminable benches are excluded from reserve calculations, the total tonnage is diminished by 69,783,533 short tons. Further, if an arbitrary recovery factor of 55% is applied to the remaining reserves, a total recoverable reserve of 133, 500,000 short tons remains.

Channel samples of limestone collected on The Cap, North Horn Mountain were analyzed and are within specification for the parameters tested for use as rock dust in coal mines.

INTRODUCTION

The Utah Geological and Mineral Survey (UGMS), under contract with the United States Geological Survey (USGS), Conservation Division, conducted an exploratory coal drilling program on North Horn Mountain and East Mountain in the Wasatch Plateau, Utah to determine preliminary coal reserves for future leasing or lease exchange activities.

The drilling program was accomplished through USGS contract 14-08-0001-17861 based on a cost sharing arrangement with UGMS. Total funding for the project was about $1,012,000, of which the UGMS share was 1.5 percent. UGMS and USGS personnel planned the drilling of 18 test holes in the area, the actual drilling and evaluation of the drilling was the responsibility of UGMS personnel.

The North Horn Mountain-East Mountain area is part of the Manti-LaSal National Forest of the U. S. Department of Agriculture. This agency issued exploration and road use permits after proper environmental

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assessment reports for the drill-sites had been prepared. UGMS subcontracted the drilling to Iron Clad Drilling Co., Inc. of Craig, Colorado and the exploration drilling was accomplished under the definitions and regulations contained in 43 Code of Federal Regulation 3400, "Coal Management of Federally Owned Coal."

The purpose of the project was to obtain new quantitative, qualitative, and correlative data on the coal beds of the Blackhawk Formation in the project area. The demand for such information is from federal and state agencies, private industry, and the public in response to the national energy crisis and the need for national self-sufficiency in energy. Surface mapping alone is not adequate for a proper evaluation of coal character in the Wasatch Plateau field. The true character of the coal is difficult to evaluate at outcrop, because the beds are normally thinned by oxidation and weathering. In most areas where the coal is expected to crop out, the seams are covered by a mantle of soil or regolith.

Of the 18 holes drilled, 14 were on North Horn Mountain, 3 on the south end of East Mountain, and 1 in Meetinghouse Canyon, a tributary to Huntington Canyon north of the main project area. Holes were spaced about a mile apart and sited to give maximum information complementary to previously drilled holes. The program's purpose was (1) to determine the existence of minable coal and (2) to delineate, if possible, inferred or indicated reserves.

GEOGRAPHY AND PHYSIOGRAPHY

The North Horn Mountain-East Mountain area is located in Emery County in central Utah. The two features are separated by Straight Canyon and Utah State Highway 29 as shown on the index map, figure 1. The area is about 38 road miles southwest from Price, Utah and 8 miles west of Orangeville, Utah. The area is bounded on the north by Huntington Canyon and on the south by Ferron Canyon, while the Sanpete County line and Trail Mountain border the area on the west. The coal outcrop marks the escarpment front of the mountains and serves as the eastern boundary. Both North Horn Mountain and East Mountain are mesa-like and physiographically are parts of the Wasatch Plateau of Utah.

Adjacent and to the east of the Wasatch Plateau is Castle Valley, or the Mancos Lowland, on which the towns of Huntington, Orangeville, Castle Dale, and Ferron are found in succession from north to south. Utah State Highway 10 links these towns and State Highway 29 gives access from Orangeville to the North Horn Mountain-East Mountain drilling area and the Joes Valley Reservoir. The elevations on the North Horn Mountain-East Mountain drilling area range from 7800 to 9300 feet. Those in Castle Valley below range from 5600 to 5900 feet. In the drilling areas the various benches are covered with sagebrush or scrub-forest.

STRATIGRAPHY AND STRUCTURE

The stratigraphic units of concern in the drilling area are Tertiary and Cretaceous in age and are listed and described in figure 2. A more detailed description of the units can be obtained from Spieker (1930) or Doelling (1972, p. 59-243).

Stratigraphic units drilled include the North Horn Formation, Price River Formation, Castlegate Sandstone, Blackhawk Formation and the Star Point Sandstone, in descending order. The Flagstaff Limestone is present on the highest parts of the mesa-like mountains, but no holes were spudded in that unit. The valuable coals are contained in the lower 200-300 feet of the Blackhawk Formation. The target for each hole was the underlying Star Point Sandstone to insure that all valuable coal beds had been penetrated.

Four drill holes were spudded in the North Horn Formation, so that a direct thickness of that unit was not obtained. The Price River Formation thickness was obtained from these holes, three drilled on East Mountain, the other on North Horn Mountain. The average thickness of the Price River Formation drilled on East Mountain is 271 feet, while the North Horn Mountain hole indicated the formation to be 528 feet thick. The average composition of the formation in both areas is 48 percent sandstone, 28 percent shale, and 24 percent siltstone.

Thirteen of the 18 drill holes were spudded in the Price River Formation and penetrated complete intervals of the Castlegate Sandstone along with those spudded in the North Horn Formation. The average thickness of the Castlegate Sandstone on East Mountain is 270 feet and the overall average thickness in all holes is 263 feet. The maximum deviation from this average is 35 feet. The Castlegate Sandstone has an average composition of 87 percent sandstone, 7 percent siltstone and 6 percent shale.

The Blackhawk Formation was completely penetrated in all but 2 holes; the average thickness of the

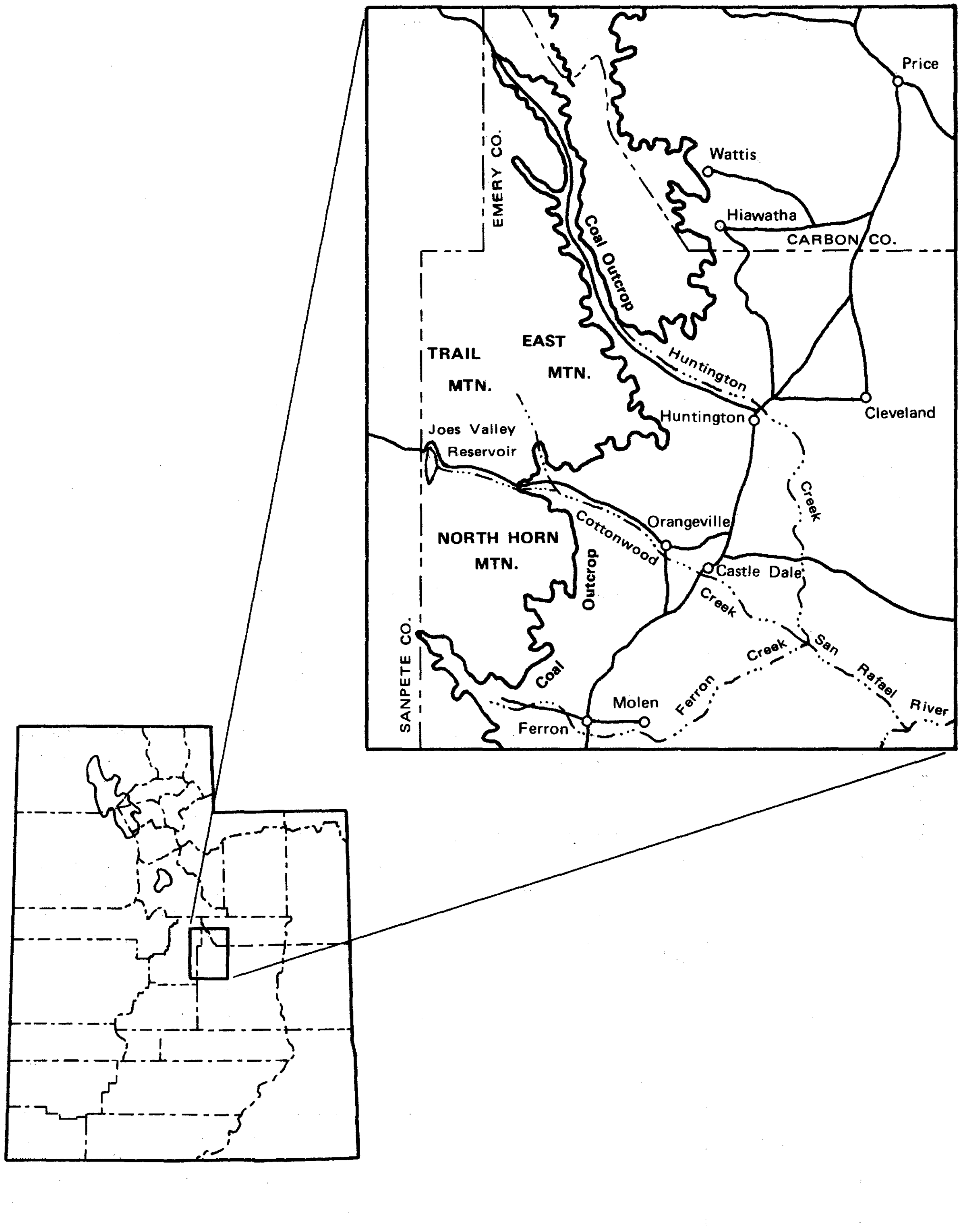


Figure 1. North Horn Mountain-East Mountain exploratory drilling and resource evaluation area.

Generalized Section of Rock Formations Wasatch Plateau Coal Field, Utah

System	Series	Group	Stratigraphic unit	Thickness Feet	Description
TERTIARY	Eocene				
TERTIARY	Paleocene	Wasatch Group	Flagstaff Limestone	200-1500	Dark yellow-gray to cream limestone, evenly bedded with minor amounts of sandstone, shale, and volcanic ash, ledge-former.
TERTIARY / CRETACEOUS	?	Wasatch Group	North Horn Formation (Lower Wasatch)	500-2500 slope-fo	Variegated shales with subordinate sandstone, conglomerate and fresh-water limestone, thickens to north, slope-former.
CRETACEOUS	Maestrichthian	Mesaverde Group	Price River Formation	600-1000	Gray to white gritty sandstone interbedded with subordinate shale and conglomerate, ledge and slope-former.
CRETACEOUS	Campanian	Mesaverde Group	Castlegate Sandstone	150-500	White to gray, coarse-grained often conglomeratic sandstone, cliff-former, weathers to shades of brown.
CRETACEOUS	Campanian	Mesaverde Group	Blackhawk Formation MAJOR COAL SEAMS	700-1000	Yellow to gray, fine- to medium-grained sandstone, interbedded with subordinate gray and carbonaceous shale, several thick coal seams.
CRETACEOUS	Campanian	Mesaverde Group	Star Point Sandstone	90-1000	Yellow-gray massive cliff-forming sandstone, often in several tongues separated by Masuk Shale, thickens westward.
CRETACEOUS	Santonian		Masuk Shale	300-1300	Yellow to blue-gray sandy shale, slope-former, thick in northern and central plateau area thins southward.

Figure 2. Generalized section of rock formations Wasatch Plateau coal field, Utah.

coal-bearing unit is 822 feet. The deviation from this norm does not exceed 95 feet. The Blackhawk Formation has an average composition of 45 percent siltstone, 38 percent sandstone, 14 percent shale and 3 percent coal. An attempt was made to drill at least 50 feet of the Star Point Sandstone before completing the hole.

Tectonically, the Wasatch Plateau is in a transition zone between the relatively stable Colorado Plateau on the east side and the relatively complex and unstable Basin and Range Province on the west side. Structurally, the west side of the area is terminated against the Joes Valley fault zone, a 1-2 mile-wide zone of north-south faulting. The strata dip gently to moderately toward the fault zone. The beds sag in the center of the area between Huntington Canyon and Ferron Creek in what is known as the Straight Canyon syncline (figure 3). Most of the drilled area exhibits northwesterly dipping beds. The area is bounded on the east by the Pleasant Valley fault zone.

DESCRIPTIONS OF DRILLING

A summary of the holes drilled for the project, indicating elevation, depth drilled, geographic location and formation tops is listed in table 1. A narrative description of each drill hole, including data on minable seams, roof rock and floor rock follows:

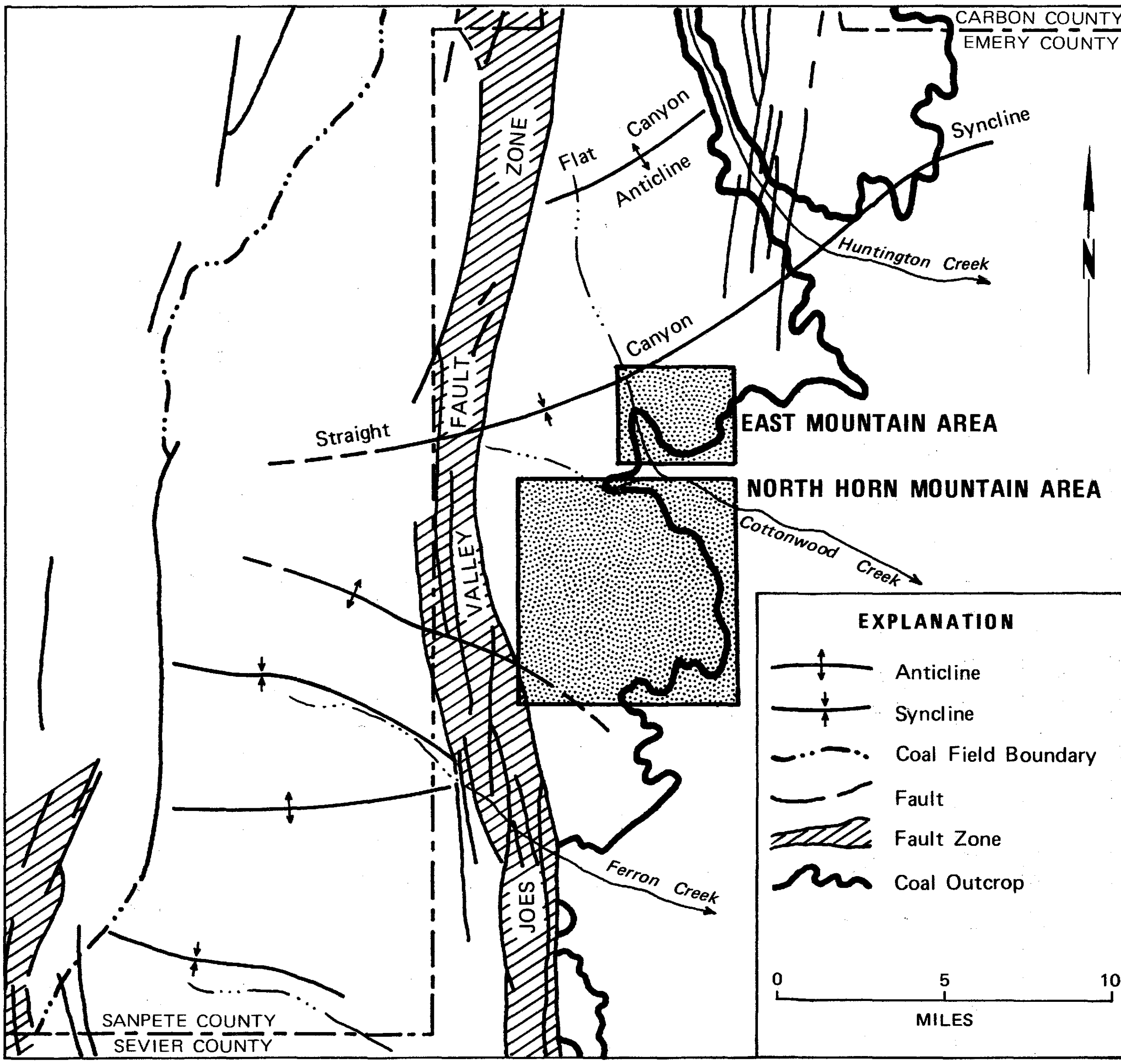


Figure 3. Principal structural features surrounding the North Horn Mountain-East Mountain drilling area.

Table 1. NORTH HORN/EAST MOUNTAIN DRILL HOLES

Table 1. NORTH HORN/EAST MOUNTAIN DRILL HOLES

Drill Hole	Collar Elevation	Drillers Total Depth	Geophysical Logged Total Depth	Geographic Location	Tops: Formation	Tops: (Ft.) Elevation
MC-35-TC	8,313	1,640	1,640	NE SE, Sec. 4, T. 19 S., R. 6 E.	North Horn	Spud in
					Price River	
					Castlegate	7,963
					Blackhawk	7,687
					Star Point	6,757
MC-43-MP	7,840	1,580	1,584	SE SE, Sec. 10, T. 18 S., R. 6 E.	Price River	Spud in
					Castlegate	7,539
					Blackhawk	7,225
					Star Point	6,335
MC-45-MP	9,220	1,900	1,900	NE NW, Sec. 32, T. 17 S., R. 7 E.	North Horn	Spud in
					Price River	8,756
					Castlegate	8,452
					Blackhawk	8,173
					Star Point	7,423
MC-46-MP	9,220	1,645	1,644	NE SE. Sec. 32, T. 17 S., R. 7 E.	North Horn	Spud in
					Price River	8,802
					Castlegate	8,554
					Blackhawk	8,298
MC-47-MP	9,250	1,743	1,743	SW SW, Sec. 28, T. 17 S., R. 7 E.	North Horn	Spud in
					Price River	8,791
					Castlegate	8,524
					Blackhawk	8,246
					Star Point	7,532
MC-48-MP	7,550	359	359	NE SW, Sec. 3, T. 17 S., R. 7 E.	Colluvium	Spud in
					Blackhawk	7,474
					Star Point	7,301
MC-49-MP	8,031	1,526	1,526	NE SE, Sec. 11, T. 18 S., R. 6 E.	Price River	Spud in
					Castlegate	7,810
					Blackhawk	7,550
					Star Point	6,620

MC-51A-TC	8,360	1,140	1,131	Center, Sec. 19, T. 18 S., R. 7 E.	Price River	Spud in
					Castlegate	8,264
					Blackhawk	8,014
					Star Point	7,275
MC-53-TC	9,060	1,800	1,799	SW SW, Sec. 31, T. 18 S., R. 7 E.	North Horn	Spud in
					Price River	8,907
					Castlegate	8,382
					Blackhawk	8,087
					Star Point	7,294
MC-55A-TC	8,101	1,240	1,239	SE SE, Sec. 3, T. 19 S., R. 6 E.	Price River	Spud in
					Castlegate	7,949
					Blackhawk	7,704
					Star Point	6,911
MC-56A-TC	8,566	1,160	1,156	SE NW, Sec. 32, T. 18 S., R. 7 E.	Price River	Spud in
					Castlegate	8,389
					Blackhawk	8,166
					Star Point	7,466
MC-57B-TC	8,286	1,155	1,153	SW NW, Sec. 30, T. 18 S., R. 7 E.	Price River	Spud in
					Castlegate	8,120
					Blackhawk	7,897
					Star Point	7,173
MC-58-TC	8,100	1,340	1,337	SE SE NW, Sec. 24, T. 18 S., R. 6 E.	Price River	Spud in
					Castlegate	7,870
					Blackhawk	7,604
					Star Point	6,849
MC-59-TC	8,031	1,480	1,464	SW NW, Sec. 13, T. 18 S., R. 6 E.	Price River	Spud in
					Castlegate	7,884
					Blackhawk	7,610
					Star Point	6,668
MC-60-MP	8,072	1,740	1,671	SE SW, Sec. 14, T. 18 S., R. 6 E.	Price River	Spud in
					Castlegate	7,714
					Blackhawk	7,465
					Star Point	6,443
MC-63-TC	8,311	1,400	1,396	NE SE NW, Sec. 10, T. 19 S., R. 6 E.	Price River	Spud in
					Castlegate	8,117
					Blackhawk	7,849
					Star Point	6,984
MC-64-TC	8,595	1,163	1,164	SE SW, Sec. 29, T. 18 S., R. 7 E.	Price River	Spud in
					Castlegate	8,462
					Blackhawk	8,238
					Star Point	7,465

TOTAL FOOTAGE DRILLED - 25,303

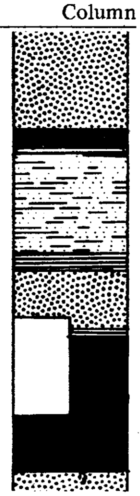
TOTAL FOOTAGE LOGGED - 25,080

MC-35-TC. This drill hole is located on North Horn Mountain just southwest of Baseball Springs in NE¼ SE¼ Sec. 4, T. 19 S., R. 6 E. The elevation of the collar is 8,313 feet and the hole was drilled by the rotary method to a total depth of 1,640 feet. Drilling commenced on September 3, 1979 and was completed September 26, 1979.

The hole was spudded in a thin remnant of the North Horn Formation after which 350 feet of the Price River Foramtion was intersected. The Price River is mostly siltstone (50 percent) with 38 percent sandstone and 12 percent shale. The Castlegate is 276 feet thick and 91 percent sandstone, 6 percent shale and 3 percent siltstone. The Blackhawk Formation is about 930 feet thick with 52 percent siltstone, 35 percent sandstone and 11 percent shale. Coal makes up 2 percent of the unit at this location. A total of 6 coal beds were intersected of which only one is of sufficient thickness to be profitably mined. The Star Point Sandstone beneath the lowest coal consisted of 100 percent sandstone and was penetrated a distance of 84 feet.

The 14-foot minable coal seam was located at the very base of the Blackhawk Formation immediately above the Star Point Sandstone. This coal bed is assigned to the Lower Hiawatha seam on the basis of its position in the column.

Coal, roof rock and floor rock for MC-35-TC are shown below:

Interval (ft)	Lithology	Thickness (ft)	Column
1517-1542 (Roof Rock)	Sandstone	10½	
	Coal	2	
	Siltstone	11	
	Shale	2	
	Sandstone	5	
	Shale	1	
1542-1556	Coal (Lower Hiawatha)	14	
1556-1566 (Floor Rock	Sandstone	10+	

MC-43-MP. This hole was drilled on the Clay Banks, just south of Straight Canyon and Cox Swale in SE¼ SE¼ Sec. 10, T. 18 S., R. 6 E. The elevation of the collar was 7,840 feet. Drilling commenced on November 9, 1979 and completed on November 17, 1979 when a total depth of 1,584 feet was reached by the rotary method.

The hole was spudded in the Price River Formation and penetrated 301 feet of the unit which is equally composed of sandstone (43 percent) and siltstone (45 percent), with a lesser amount of shale (12 percent). The Castlegate Sandstone is about 314 feet thick in this hole and composed of 92 percent sandstone, 6 percent siltstone and 2 percent shale. The Blackhawk Formation is 890 feet thick and is composed of 58 percent sandstone, 21 percent siltstone, 10 percent shale, and 2 percent coal. The 71 feet of Star Point Sandstone drilled beneath the Blackhawk consisted of 97 percent sandstone and 3 percent siltstone.

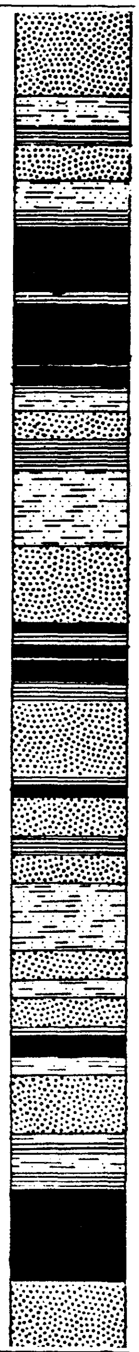
Ten coal beds were intersected, but none were of minable thickness. The usually minable Lower Hiawatha coal just above the Star Point Sandstone is only 1 foot thick and 21 feet of sandstone separate it from its upper component. A thin 2-foot coal bed marks the probable Blind Canyon coal. The thicknesses of all intersected coal beds range from 0.5 to 3.0 feet.

MC-45-MP. This drill hole is located on East Mountain immediately southwest of Snow Lake in NE¼ NW¼ Sec. 32, T. 17 S., R. 7 E., at an elevation of 9,220 feet. Drilling began on October 1979 and was completed on October 13, 1979 by the rotary method; a total depth of 1,900 feet was reached.

The hole encountered 451 feet of North Horn Formation, 304 feet of Price River Formation, 279 feet of Castlegate Sandstone, 750 feet of Blackhawk Formation and 103 feet of the Star Point Sandstone. The North Horn Formation consisted of 36 percent siltstone, 29 percent sandstone, 22 percent shale, and 13 percent limestone. The Price River beds were 59 percent sandstone, 21 percent shale, and 20 percent siltstone. The Castlegate consists of 62 percent sandstone, 23 percent siltstone, and 15 percent shale in this hole. The Blackhawk Formation consists of 58 percent sandstone, 21 percent siltstone, 18 percent shale and 3 percent coal and all of the penetrated Star Point Sandstone is sandstone.

In this hole the Blind Canyon seam consists of two benches, 7 and 8 feet thick, separated by a foot of shale and the Lower Hiawatha is 9 feet thick.

Interval (ft)	Lithology	Thickness (ft)	Column
1661-1686 (Roof Rock)	Sandstone	13+	
	Siltstone	3	
	Shale	2	
	Sandstone	4	
	Siltstone	3	
	Shale	2	
1686-1704 (Blind Canyon)	Coal	7	
	Shale	1	
	Coal	8	
1704-1714 (Floor Rock)	Siltstone	3	
	Sandstone	3	
	Shale	3	
1714-1763 (Rock Interval)	Siltstone	8	
	Sandstone	8	
	Interbedded coal and shale	8	
	Sandstone	8	
	Interbedded sand-stone, shale, and coal	11	
	Siltstone	7	
1763-1788 (Roof Rock)	Sandstone	3	
	Siltstone	2	
	Sandstone	3	
	Shale	1	
	Coal	2	
	Siltstone	2	
	Sandstone	6	
	Interbedded shale and siltstone	6	
1788-1797 (Lower Hiawatha)	Coal	9	
1797-1807 (Floor Rock)	Sandstone	10+	

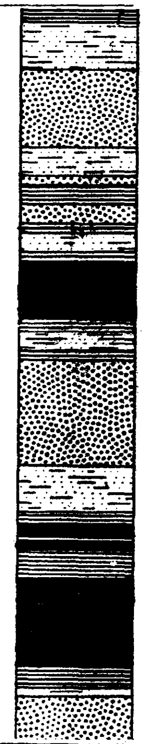


MC-46-MP. This hole was drilled on East Mountain southwest of Snow Lake in NE¼ SE¼ Sec. 32, T. 17 S., R. 7 E., at an elevation of 9,220 feet. Drilling commenced September 8, 1979 by the rotary method and was completed on September 19, 1979 when the tri-cones from the bit were lost in the hole at a depth of 1,644 feet.

The hole was spudded in the North Horn Formation and intersected 418 feet of that unit, a 248-foot Price River Formation, a 256-foot Castlegate Sandstone and 722 feet of the Blackhawk Formation. The latter was not drilled in its entirety because of the aforementioned drilling problems. The North Horn Formation consists of alternating sandstone, siltstone, shale, and limestone, however, limestone is not present in the lower 123 feet. The Price River Formation is composed of alternating sandstone (43 percent), siltstone (51 percent) and shale (6 percent). The Castlegate is principally sandstone (93 percent) with 4 percent shale and 3 percent siltstone. The Blackhawk Formation is an alternating sequence of sandstone and siltstone with lesser amounts of shale and about 3 percent coal.

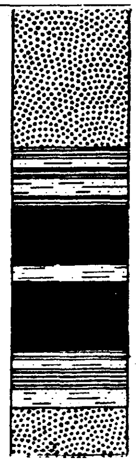
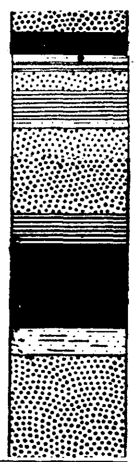
A total of six coal beds were intersected in the hole, but only two exceeded 4 feet in thickness, the lower of which is believed correlatable to the Blind Canyon coal seam.

Interval (ft)	Lithology	Thickness (ft)	Column
1531-1556 (Roof Rock)	Siltstone	5	
	Sandstone	8	
	Siltstone	3	
	Interbedded sand-stone, shale and siltstone	9	
1556-1562	Coal	6	
1562-1589 (Rock Interval)	Shale & siltstone	4	
	Sandstone	11	
	Siltstone	5	
	Interbedded shale and coal	7	
1589-1598 (Blind Canyon)	Coal	2.3	
	Shale split	0.2	
	Coal	6.5	
1598-1608 (Floor Rock)	Shale	2	
	Siltstone	1	
	Sandstone	7+	



MC-47-MP. This hole was drilled on East Mountain directly south of Snow Lake in SW¼ SW¼ Sec. 28, T. 17 S., R. 7 E., the elevation of the collar was 9,250 feet. Drilling was conducted from October 3 until November 3, 1979 and a total depth of 1,743 feet was reached.

A total of seven coal beds were intersected of which two were over 4 feet in thickness. These include the Blind Canyon and Lower Hiawatha seams.

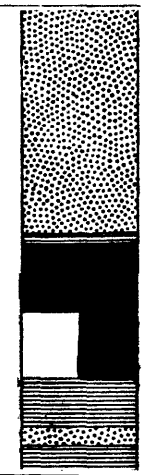
Interval (ft)	Lithology	Thickness (ft)	Column
1551-1576 (Roof Rock)	Sandstone	19+	
	Shale	1	
	Siltstone	1	
	Shale	1	
	Siltstone	3	
1576-1592	Coal	6	
(Blind Canyon)	Siltstone split	2	
	Coal	7	
1591-1601	Siltstone	2	
(Floor Rock)	Shale	2	
	Siltstone	2	
	Sandstone	4+	
1601-1681 (Rock Interval)		80	
1681-1706	Sandstone	3+	
(Roof Rock)	Coal	1	
	Siltstone	1	
	Shale	1	
	Sandstone	2	
	Shale	3	
	Siltstone	1	
	Sandstone	10	
	Shale	3	
1706-1715	Coal	9	
(Lower Hiawatha)			
1715-1725	Siltstone	3	
(Floor Rock)	Sandstone	7+	

Drilling encountered 451 feet of North Horn Formation (in which the drilling was spudded), 267 feet of Price River Formation, 278 feet of Castlegate Sandstone and 714 feet of Blackhawk Formation. The hole was ended in 25 feet of Star Point Sandstone. The North Horn Formation consists of alternating sandstone, siltstone, shale, and limestone, but no limestone is found in the lower 135 feet. The Price River Formation in this hole is 54 percent sandstone, 24 percent shale and 22 percent siltstone. The Castlegate Sandstone is mostly sandstone (92 percent) with siltstone (5 percent) and shale (3 percent) partings. The Blackhawk Formation consists of alternating sandstone (50 percent), shale (26 percent), siltstone (19 percent, and 5 percent coal. The penetrated Star Point was 100 percent sandstone.

MC-48-MP. This hole was drilled in Meetinghouse Canyon, a southwesterly tributary of Huntington Canyon, in NE¼ SW¼ Sec. 3, T. 17 S., R. 7 E. and the collar elevation was 7,550 feet. Drilling commenced on October 27, 1979 by the rotary method to a depth of 152.6 feet after which the hole was cored to a total depth of 359.4 feet on October 31, 1979.

Approximately 76 feet of colluvial cover was penetrated before the erosional surface of the Blackhawk Formation was intersected. The single discovered minable seam is under only 182 feet of cover. The drill passed through 173 feet of Blackhawk Formation and 110 feet of the Star Point Sandstone. The latter consisted of 100 percent sandstone.

A total of five coal beds were discovered in drill hole MC-48-MP, but only one was of minable thickness. That coal bed is believed to be the Lower Hiawatha.

Interval (ft)	Lithology	Thickness (ft)	Column
157-182 (Roof Rock)	Sandstone	24+	
	Shale	1	
182-194 (Lower Hiawatha)	Coal	12	
194-204 (Floor Rock)	Shale	5	
	Sandstone	2	
	Shale	3+	

MC-49-MP. This hole was drilled on the Clay Banks just south of the Oliphant Mine and east of Reid and Nielsen Swale in NE¼ SE¼ Sec. 11, T. 18 S., R. 6 E. from a collar elevation of 8,031 feet. Drilling occurred from September 14 to October 3, 1979 by the rotary method to a total depth of 1,526 feet.

Seven coal beds were intersected in the Blackhawk Formation in this hole, but none were more than 4 feet thick. The coal beds range in thickness from 0.5 to 2.4 feet.

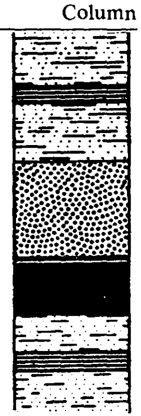
The hole was spudded in and passed through 216 feet of the Price River Foramtion. The hole continues through 260 feet of Castlegate Sandstone, 930 feet of Blackhawk Formation, and 114.5 feet of the Star Point

Sandstone. Of the footage drilled, about 41 percent of the Price River Formation was sandstone, along with 33 percent siltstone and 12 percent shale. The Castlegate is mostly sandstone (96 percent) with shale partings amounting to 4 percent. The Blackhawk consists of alternating siltstone (46 percent), sandstone (37 percent), shale (15 percent) and coal (2 percent). The Star Point is 97 percent sandstone with the remainder appearing as shale partings.

MC-50-MP. This hole was drilled on Mahogany Point immediately south of Straight Canyon in NE¼ NW¼ Sec. 18, T. 18 S., R. 7 E. The elevation of the collar was 8,410 feet. Drilling by the rotary method commenced on August 19 and ended on August 31, 1979 when a total depth of 1,174 feet was reached.

Six coal beds were found in the Blackhawk, but only one was thicker than 4 feet.

Interval (ft)	Lithology	Thickness (ft)	Column
1014-1039	Siltstone	6	
(Roof Rock)	Shale	2	
	Siltstone	6	
	Sandstone	10	
	Shale	1	
1039-1044	Coal	5	
1044-1054	Siltstone	4	
(Floor Rock)	Shale	2	
	Siltstone	4+	



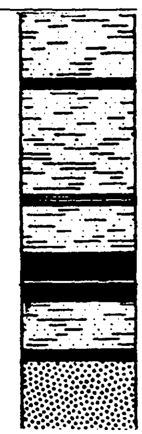
The hole was spudded in the Price River Formation and reached total depth in the Star Point Sandstone. Penetrated were 65 feet of Price River, 235 feet of the Castlegate, 855 feet of Blackhawk Formation and 45 feet of the Star Point. The drilled Price River consisted of 67 percent sandstone, 22 percent shale, and 11 percent siltstone. The Castlegate is 90 percent sandstone with 7 percent siltstone and 3 percent shale partings. The Blackhawk consists of alternating sandstone (52 percent), siltstone (28 percent), shale (18 percent) and coal (2 percent). Only 9 feet of the Star Point Sandstone was geophysically logged, but the cuttings indicate the unit is predominantly sandstone.

MC-51A-TC. Located on the Clay Banks just south of Mahogany Point and east of the Clay Banks Swale in the center of Sec. 19, T. 18 S., R. 7 E., this hole was drilled by the rotary method to 1,000 feet and then cored to a total depth of 1,140 feet. The collar elevation was 8,360 feet and the hole was drilled from August 9 to August 25, 1979.

The hole was spudded in the Price River Formation which consisted of 85 percent sandstone and 15 percent shale. Only the lower 96 feet were drilled. The Castlegate is about 250 feet thick and is mostly sandstone (89 percent) with 7 percent shale and 3 percent siltstone as partings. The Blackhawk Formation is about 739 feet thick and composed of alternating sandstone (31 percent), siltstone) (53 percent), shale (14 percent), and coal (3 percent). Geophysical logging of 46 feet of the Star Point Sandstone indicates that the unit is 98 percent sandstone with the remainder made up of shale partings.

Twelve coal beds were intersected in this drill hole, but only one split seam was present that totalled more than 4 feet in thickness.

Interval (ft)	Lithology	Thickness (ft)	Column
900-925	Siltstone	7	
(Roof Rock)			
	Coal	1	
	Siltstone	11	
	Shale	1	
	Siltstone	5	
925-930	Coal	2.5	
(Coal)	Bony coal	0.5	
	Coal	2.0	
930-940	Siltstone	5	
(Floor Rock)	Coal	1	
	Sandstone	4+	



MC-53-TC. This hole was drilled on North Horn Mountain just southwest of the radio tower on Long Ridge in SW¼ NW¼ Sec. 31, T. 18 S., R. 7 E. at an elevation of 9,060 feet. Drilling commenced on September 4, 1979 by the rotary method and was completed to a total depth of 1,800 feet on September 22, 1979.

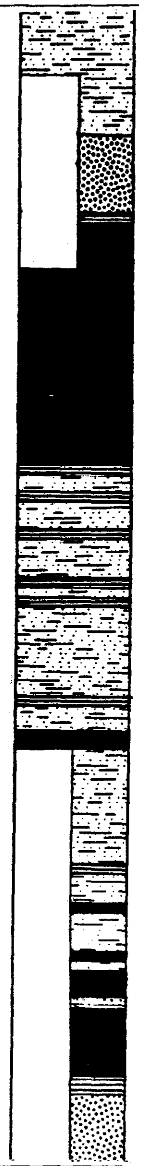
The hole was spudded in the North Horn Formation in which about 138 feet of alternating limestone, shale, and sandstone were penetrated. The limestones were confined to the first 36 feet. The Price River Formation is 525 feet thick and is composed mainly of shale (60 percent), sandstone (37 percent) and siltstone (3 percent). The Castlegate is about 295 feet thick, consisting mainly of sandstone (94 percent) with siltstone (5 percent) and shale (3 percent) partings The

Blackhawk Formation is about 793 feet thick and is composed of 45 percent sandstone, 40 percent siltstone, 9 percent shale and 6 percent coal. Thirty-four feet of Star Point Sandstone completed the hole and consisted entirely of sandstone.

Six coal beds were intersected, but only the Blind Canyon and the Lower Hiawatha were of minable thickness.

Interval (ft)	Lithology	Thickness (ft)
1650-1675 (Roof Rock)	Siltstone	16
	Sandstone	8
	Shale	1
1675-1700 (Blind Canyon)	Coal	25
1700-1710 (Floor Rock)	Shale	1
	Siltstone & shale	28
1710-1726 (Rock Interval)		
1726-1751 (Roof Rock)		
	Coal	2
	Siltstone	12
	Shale	1
	Siltstone	3
	Coal	1
	Siltstone	4
1751-1764	Coal	1
(Lower Hiawatha)	Siltstone	1
	Coal	3
	Siltstone	1
	Coal	7
1764-1774	Shale	2
(Floor Rock)	Sandstone	8

Column:



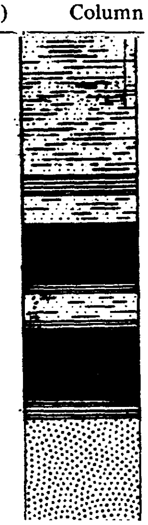
MC-55A-TC. This hole was drilled just south of Baseball Spring on North Horn Mountain adjacent to main road in SE¼ SE¼ Sec. 3, T. 19 S., R. 6 E., at a collar elevation of 8,101 feet. Drilling began on August 3 and was completed on August 11, 1979 by the rotary method to a total depth of 1,240 feet. This hole was drilled adjacent to the site of UGMS Rock Canyon drill hole No. 6 which was drilled in 1975. Twelve coal beds were intercepted in the most recent drilling, all were thin, as reported in the 1975 hole (Davis and Doelling, 1977), except one. The 1975 hole was terminated at 1158.3 feet and the minable coal was found at 1170 feet.

The hole was spudded in the Price River Formation and passed through 142 feet of that unit, 245 feet of Castlegate Sandstone, 793 feet of Blackhawk Formation, and 50 feet of the Star Point Sandstone to the total depth. The penetrated Price River is mostly sandstone (95 percent) with shale partings (5 percent) 1 to 6 feet thick. The Castlegate is 85 percent sandstone, 14 percent siltstone with 1 percent shale partings. The Blackhawk is alternating siltstone (37 percent), sandstone (36 percent), shale (23 percent), with 4 percent coal. The Star Point Sandstone is entirely sandstone.

The Lower Hiawatha coal zone in this hole consists of two benches, 6 and 7 feet thick, separated by 5 feet of shale and siltstone. The Blind Canyon and other zones are not developed in this area.

Interval (ft)	Lithology	Thickness (ft)
1145-1170 (Roof Rock)	Siltstone	20
	Shale	2
	Siltstone	3
1170-1188	Coal 6	
(Lower Hiawatha)	Shale	1
	Siltstone	3
	Shale	1
	Coal 7	
1188-1198	Shale	2
(Floor Rock)	Sandstone	8+

Column:

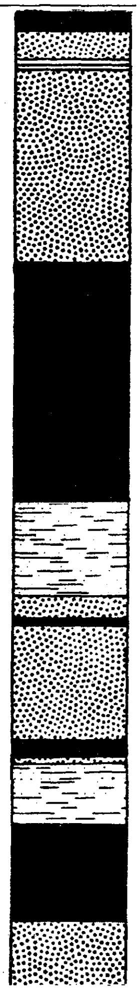


MC-56A-TC. This hole was drilled just southeast of Long Ridge on North Horn Mountain in SE¼ NW¼ Sec. 32, T. 18 S., R. 7 E., at a collar elevation of 8,566 feet. Drilling began on July 27, 1979 by the rotary method to 988 feet and then cored to 1,102 feet and then drilled again by the rotary method until the hole was completed on August 2, 1979, when a total depth of 1,156 feet was reached.

The hole penetrated 122 feet of Price River Formation, 223 feet of Castlegate Sandstone, about 700 feet of the Blackhawk Formation, and 9 feet of the Star Point Sandstone. The Price River is 83 percent sandstone, 17 percent shale, the latter being present as partings 1 to 6 feet thick. The Castlegate is principally sandstone (19 percent) with 7 percent shale and 2 percent siltstone as partings. The Blackhawk is mostly siltstone (60 percent) with 23 percent sandstone, 11 percent shale and 6 percent coal. The Star Point was completely sandstone.

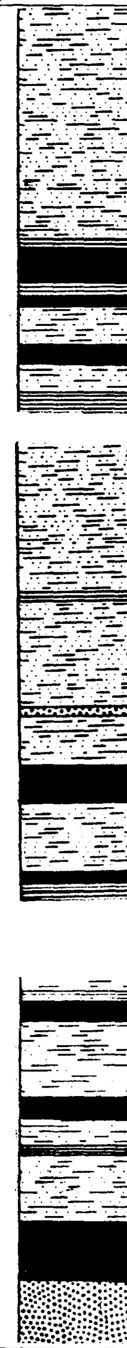
A total of ten coal beds were discovered, but only two, the Blind Canyon and the Lower Hiawatha are of minable thickness.

Interval (ft)	Lithology	Thickness (ft)	Column
997-1022	Coal	3	
(Roof Rock)	Sandstone	3	
	Shale	1	
	Sandstone	20	
1022-1047	Coal	25	
(Blind Canyon)			
1047-1057	Siltstone	10	
(Floor Rock)			
1057-1060	Sandstone	2	
(Interval)	Coal	1	
1060-1085	Sandstone	12	
(Roof Rock)			
	Coal	2	
	Sandstone	1	
	Siltstone	10	
1085-1095	Coal	10	
(Lower Hiawatha)			
1095-1105	Sandstone	10+	
(Floor Rock)			



MC-57B-TC. This hole was drilled on the Clay Banks just north of Long Ridge on North Horn Mountain in SW¼ NW¼ Sec. 30, T. 18 S., R. 7 E., and the collar elevation was 8,286 feet. Drilling commenced on October 15, 1979 by the rotary method and was completed October 20, 1979 when a depth of 1155 feet was reached. Twelve coal beds were discovered, but only three were of minable thickness.

Interval (ft)	Lithology	Thickness (ft)	Column
935-960	Siltstone	24	
(Roof Rock)			
	Shale	1	
960-966	Coal	3.5	
(Upper coal)	Shale	1	
	Coal	1.5	
966-976	Siltstone	4	
(Floor Rock)	Coal	2	
	Siltstone & shale	4+	
976-1019	Rock Interval	43	
1019-1044			
(Roof Rock)			
	Siltstone	7	
	Shale	1	
	Siltstone	11	
	Sandstone	1	
	Siltstone	5	
1044-1048	Coal		
(Middle coal)		4	
1048-1058	Siltstone	7	
(Floor Rock)	Coal	1	
	Shale	2	
1058-1082			
(Rock Interval)			
1082-1107	Siltstone	1	
(Roof Rock)	Shale	1	
	Coal	2	
	Siltstone	8	
	Coal	2	
	Siltstone	3	
	Shale	1	
	Siltstone	7	
	Coal	6	
1107-1113			
(Lower Hiawatha			
1113-1123	Sandstone	10+	
(Floor Coal)			



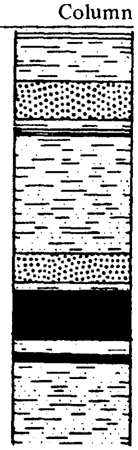
The hole was spudded in the Price River Formation which consisted of 145 feet of sandstone (68 percent), siltstone (17 percent), and shale (15 percent). It then passed through the Castlegate Sandstone (223 feet thick), which is mainly sandstone (91 percent) with siltstone (9 percent) partings. The Blackhawk Formation is 724 feet thick and consists of alternating sandstone (31 percent), siltstone (57 percent), shale (9 percent) and coal (3 percent). The 42 feet of the penetrated Star Point were completely sandstone.

MC-58 TC. This hole was drilled on the Clay Banks southwest of Clay Banks Swale in SE¼ NW¼ Sec. 24, T. 18 S., R. 6 E., on North Horn Mountain. The collar elevation was 8,100 feet. Drilling began on October 6 and was completed October 8, 1979 by the rotary method when a total depth of 1,340 feet was reached.

The hole began in the Price River Formation and passed through 230 feet of that unit, 266 feet of Castlegate Sandstone, 755 feet of the Blackhawk Formation and 86 feet of the Star Point Sandstone. In this hole the Price River is alternating sandstone (60 percent), siltstone (27 percent) and shale (13 percent). The Castlegate is principally sandstone (72 percent) with 19 percent siltstone and 9 percent shale. The Blackhawk has alternating siltstone (52 percent), sandstone (38 percent), shale (7 percent) and coal (3 percent). The Star Point is 96 percent sandstone with the remainder present as shale partings. A minor coal parting occurs about 47 feet below the top of the unit.

Nine coal beds were discovered but only one has a thickness exceeding 4 feet.

Interval (ft)	Lithology	Thickness (ft)	Column
1085-1110	Siltstone	3	
(Roof Rock)	Sandstone	4	
	Siltstone	1	
	Shale	1	
	Siltstone	12	
	Sandstone	3	
	Siltstone	1	
1110-1115	Coal	5	
(Coal	Siltstone	1	
1115-1125	Coal bed	1	
	Siltstone	8+	



MC-59-TC. This hole was drilled on the Clay Banks between Reid and Nielsen Swale and Clay Banks Swale on North Horn Mountain in SW¼ NW¼ Sec. 13, T. 18 S., R. 6 E. The collar elevation was 8,031 feet. Drilling began on October 23, 1979 and was completed November 6, 1979 by the rotary method when a total depth of 1,464 feet was reached.

The hole was spudded in the Price River Formation and passed through 139 feet of that unit, 274 feet of Castlegate Sandstone, 942 feet of the Blackhawk Formation, and 101 feet of the Star Point Sandstone. The upper unit is mostly sandstone (77 percent) with lesser amounts of siltstone (10 percent) and shale (13 percent). The Castlegate is also mostly sandstone (86 percent) with shale (14 percent) breaks ranging from 1 to 8 feet in thickness. The Blackhawk is alternating sandstone (50 percent), siltstone (37 percent), shale (12 percent) and coal (1 percent). All of the Star Point is sandstone, except for three 1-foot shale partings.

The Blackhawk has 8 coal beds at this location, but none of them are of minable thickness. The coal beds range in thickness from 1.0 to 1.4 feet.

MC-60-MP. This hole is located on the Clay Banks just southwest of Reid and Nielsen Swale in SE¼ SW¼ Sec. 14, T. 18 S., R. 6 E. on North Horn Mountain. The collar elevation was 8,072 feet and drilling began on October 30 and was completed on November 15, 1979 by the rotary method to a total depth of 1,740 feet.

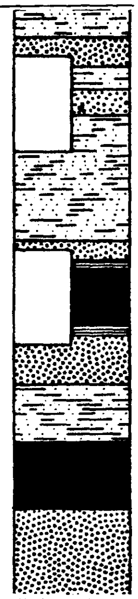
Seven coal beds were intersected, but none were of minable thickness. The coal beds range from 0.5 to 2.5 feet in thickness. Drilling began in the Price River Formation (358 feet) and passed through 239 feet of Castlegate Sandstone 1,022 feet of Blackhawk Formation and 43 feet of the Star Point Sandstone.

The Price River consists of alternating shale, sandstone, and siltstone (49, 35, and 16 percent respectively). The Castlegate is 99 percent sandstone with minor shale (1 percent) partings. The Blackhawk Formation consists of alternating siltstone, sandstone, shale, and coal (59, 30, 10, and 1 percent respectively). The Star Point Sandstone is entirely that.

MC-63-TC. This hole is located on South Horn Mountain just northeast of Bull Hollow in SE¼ NW¼ Sec. 10, T. 19 S., R. 6 E. and has a collar elevation of 8,311 feet. Drilling began on October 2, 1979 and completed October 4, 1979 when a total depth of 1,400 feet was reached by the rotary method.

Five coal beds were intersected in this hole of which 2 exceed 4 feet in thickness. Both are correlated with the Lower Hiawatha zone and are separated by 12 feet of rock.

Interval (ft)	Lithology	Thickness (ft)	Column
1277-1302 (Roof Rock)	Siltstone	1	
	Sandstone	3	
	Siltstone	2	
	Sandstone	3	
	Siltstone	13	
	Sandstone	2	
	Shale	1	
1302-1308 (Upper bed)	Coal	6	
1308-1320 (Rock interval)	Shale	1	
	Sandstone	5	
	Siltstone	6	
1320-1327 (Lower bed)	Coal	7	
1327-1337 (Floor Rock)	Sandstone	10+	



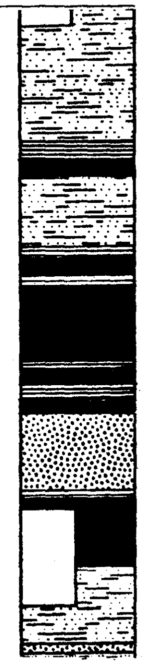
The hole was spudded in the Price River Formation and passed through 175 feet of it before penetrating 268 feet of Castlegate Sandstone, 865 feet of Blackhawk Formation, and 69 feet of the Star Point Sandstone. The Price River is alternating siltstone, sandstone, and shale (55, 26, and 19 percent) at this location. The Castlegate is 77 percent sandstone, 13 percent siltstone and 10 percent shale. The Blackhawk Formation is composed of alternating sandstone, siltstone, shale, and coal (34, 52, 12 and 2 percent respectively) at this location. Most of the Star Point penetrated is sandstone with a few shale partings.

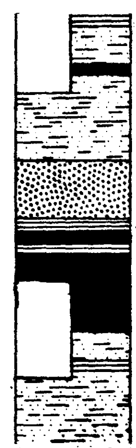
MC-64-TC. This hole was drilled just northeast of Long Ridge on North Horn Mountain in SE¼ SW¼ Sec. 29, T. 18 S., R. 7 E., at a collar elevation of 8,595 feet. Drilling began November 18 and was completed December 1 1979 when a total depth of 1,164 feet was reached by the rotary method.

The hole was spudded in the alternating sandstone (57 percent), shale (30 percent) and limestone (13 percent) of the Price River Formation (133 feet penetrated). The Castlegate is 224 feet thick, composed of sandstone (80 percent), siltstone (8 percent) and shale 1 percent. The Blackhawk Formation is approximately 773 feet thick and consists of alternating sandstone, siltstone, shale, and coal (19, 62, 14, and 3 percent respectively). The 34 feet of the Star Point that were penetrated in the hole consisted of 91 percent sandstone with 9 percent shale.

Eight coal beds were intersected and 3 were of minable thickness. The upper two are part of the Blind Canyon zone and are only separated by 14 feet of rock and coal intervals. Only 31 feet separate the lower Blind Canyon seam from the lower Hiawatha bed.

Interval (ft)	Lithology	Thickness (ft)	Column
1012-1037 (Roof Rock)	Siltstone	10	
	Shale	2	
	Coal	2	
	Siltstone	7	
	Shale	1	
	Coal	2	
	Shale	1	
1037-1045 (Upper Blind C.)	Coal	8	
1045-1059 (Interval)	Shale	1	
	Coal	1.5	
	Shale	1.5	
	Coal	1	
	Sandstone	8	
	Shale	1	
1059-1066 (Lower Blind C.)	Coal	7	
1066-1076			
	Siltstone	8	
	Sandstone	1	
	Siltstone	1	
1076-1082 (Rock Interval)		6	
1082-1107 (Roof Rock)	Shale	1	
	Siltstone	4	
	Coal	1	
	Siltstone	9	
	Sandstone	6	
	Shale	1	
	Coal	2	
	Shale	1	
1107-1115 (Lower Hiawatha)	Coal	8	
1115-1125 (Floor Rock)	Siltstone	3	
	Shale	1	
	Siltstone	6+	





DRILLING OBSERVATIONS

The average depth of the 18 drilled holes was 1,478 feet and it was found that round-the-clock drilling was best because of hole instability (breakdown of weak rock formations and water-sensitive units). A drill hole does not generally stand well in this area. Water for drilling is a problem on both North Horn and East Mountain and one should be prepared to haul water from Joes Valley Reservoir to a central storage point, such as an equidistant 500 barrel storage tank. Permission must be obtained for the use of all water in the area. Early in the season, water may be obtained from Sawmill Springs on North Horn Mountain.

Distances are great and drillers should maintain a mechanic's truck with a welder, cutting torch, and commonly used parts. An "overshot," "trash basket," and magnet for down hole problems are good to have on hand.

There are several viable approaches to drilling in this area, one in particular is worth mentioning. This system has been used successfully on East Mountain and consists of the following steps. A 6-inch hole is drilled with air to a point below any surface water. The hole is then thoroughly washed and cased to bottom, then cemented. Drilling is then continued with air until it becomes necessary to inject. A stiff foam system is used for injection that combines gel with a foaming agent in 2,500 gallons of water. A bag of high molecular weight polymer (Drispac) is also added. Air pressure of 250 psi is used with a capability of boosting the air pressure to 400-500 psi. Drilling is then continued to a point where drilling mud is required. The use of mud requires strict adherence to the "mud engineer's" recipe and regular determination of viscosity and mud weight parameters, etc.

The penetration rate in the Price River Formation, which consists of sandstone alternating with equal amounts of shale and siltstone, is generally good to fair. Lost circulation zones can sometimes be expected. Significant caving and washover zones are to be expected in the unit so that casing the full interval is strongly recommended to avoid downhole problems. Some holes have been successfully drilled uncased with air to TD.

Generally, the medium- to coarse-grained Castlegate Sandstone drills well (penetration rate is about 20 feet per hour), but washover zones can be encountered in the shale partings. The Castlegate carries a large water flow in the Clay Banks portion of the area during the spring season, and drilling in this area should be planned for the late summer-early fall.

The Blackhawk Formation is predominantly siltstone alternating mostly with sandstone and with lesser amounts of shale. The lower 250 feet of the unit contain most of the coal. The penetration rate is generally about 16 feet per hour. Lost circulation zones can be expected in this unit. In a general sense, the Blackhawk Formation drills well if uphole problems have been properly eliminated. Washover zones occur at the shale partings, especially if fluid loss is not controlled.

The Star Point Sandstone is a massive fine-grained sandstone with minor siltstone or shale partings. The penetration rate in this unit is usually excellent. The Star Point usually presents no drilling problems, but there can be a recognition problem. The Lower Hiawatha coal seam is normally found at the base of the Blackhawk Formation or is followed by a few feet of siltstone and sandstone or sandstone alone. The Hiawatha seam is often split and Star Point appearing sandstone can occur in the split. To preclude the potential for an early TD the practice of drilling at least 50 feet into the Star Point appears to be prudent.

QUALITY OF THE COAL

Quality data were obtained from only two holes, MC-48-MP in Meetinghouse Canyon, and from MC-56A-TC on North Horn Mountian. Quality data were not obtained from other drill holes because they were drilled by the rotary method. The available coal cores were measured and described at the drill site, sealed in plastic sleeving, and sent to Commercial Testing and Engineering Co. (CT & E) in Denver, Colorado to be run for proximate and ultimate analyses. The overall rank of the seams was determined to be high volatile B bituminous by the Parr Formula as given by the American Society for Testing Materials (ASTM-388D), p. 77-84. The proximate and ultimate analyses, as received and dry bases, are given in tables 2 and 3. Forms of sulfur and trace element determinations are given in tables 4 and 5.

The methane content of each collected core was measured by the direct method as outlined in U. S. Bureau of Mines' Reports of Investigation 7767 and 8043, and a summary of test results is contained in table 6. A coal core sample was collected from hole MC-48-MP at a depth interval of 182.0 to 195.0 feet. Between October 30, 1979 to November 12, 1979 the sample desorbed 130 cubic centimeters and the sample gave up no residual gas. The total gas content was therefore 451 cubic centimeters, the weight of the sample was 1 326.4 grams, so that the bed contained 0.34 centimeters per gram equivalent to 10 9 cubic feet of methane per ton of coal in place. The long range forecast for mine gas emissions where the coal contains that amount of

Table 2. Proximate analyses of coal cores obtained from the MC-48-MP and MC-56A-TC drill holes.

Drill-Hole Number	Drilling Interval (ft)	Proximate Analysis (%) As Received/Dry Basis: Moisture	Ash	Volatile	Fixed Carbon	Btu/lb	Sulfur	MMF Btu	ASTM Rank
MC-48-MP	182.0- 195.0	6.12/XXXXX	8.70/ 9.27	41.24/43.93	43.94/46.80	12,422/13,232	0.57/0.61	13,726	hvBb
MC-48-MP	242-245	5.11/XXXXX	10.86/11.44	41.51/43.75	42.52/44.81	12,302/12,965	0.66/0.70	13,957	hvBb
MC-56A-TC	1019.5-1020	6.52/XXXXX	7.33/ 7.84	38.69/41.39	47.46/50.77	12,039/12,879	0.89/0.95	13,095	hvBb
MC-56A-TC	1020.0-1021.9	5.71/XXXXX	5.00/ 5.30	44.31/46.99	44.98/47.71	12,847/13,625	0.41/0.44	13,591	hvBb
MC-56A-TC	1021.9-1023.8	6.44/XXXXX	4.49/ 4.80	45.37/48.49	43.70/46.71	12,699/13,573	0.24/0.26	13,352	hvBb
MC-56A-TC	1023.8-1025.7	5.97/XXXXX	4.78/ 5.08	46.07/48.99	43.18/45.93	12,908/13,727	0.24/0.25	13,617	hvBb
MC-56A-TC	1025.7-1027.5	5.73XXXXX	4.27/ 4.53	47.31/50.19	42.69/45.28	13,087/13,882	0.26/0.28	13,727	hvBb
MC-56A-TC	1027.5-1029.4	6.97/XXXXX	7.34/ 7.89	41.30/44.39	44.39/47.72	12,147/12,057	0.22/0.24	13,198	hvBb
MC-56A-TC	1029.4-1031.3	6.68/XXXXX	13.19/14.13	41.24/44.19	38.89/41.68	10,231/10,963	0.15/0.16	11,933	hvCb
MC-56A-TC	1031.3-1033.1	7.88/XXXXX	8.98/ 9.75	39.01/42.35	44.13/47.90	11,626/12,620	0.22/0.24	12,880	hvCb
MC-56A-TC	1033.1-1035.1	7.95/XXXXX	6.27/ 6.81	38.61/41.95	47.17/51.24	11,682/12,691	0.21/0.23	12,535	hvCb
MC-56A-TC	1035.1-1036.9	6.26/XXXXX	5.64/ 6.02	43.46/46.36	44.64/47.62	12,704/13,552	0.42/0.45	13,539	hvBb
MC-56A-TC	1036.9-1038.8	5.90XXXXX	6.46/ 6.86	46.35/49.26	41.29/43.88	12,740/13,539	0.28/0.30	13,703	hvBb
MC-56A-TC	1038.8-1039.6	5.59/XXXXX	4.74/ 5.02	43.80/46.39	45.87/48.59	12,898/13,662	0.33/0.35	13,603	hvBb
MC-56A-TC	1039.6-1040.5	10.27/XXXXX	4.90/ 5.46	41.91/46.71	42.92/47.83	12,117/13,504	0.34/0.38	12,801	hvCb
MC-56A-TC	1040.5-1043.7	7.47/XXXXX	4.95/ 5.35	43.24/46.73	44.34/47.92	12,600/13,617	0.51/0.55	13,324	hvBb
MC-56A-TC	1043.7-1044.5	4.91/XXXXX	30.05/31.60	33.24/34.96	31.80/33.44	9,172/9,646	0.48/0.51	13,597	hvBb
MC-56A-TC	1019.5-1044.5	6.68/XXXXX	7.89/ 8.43	42.26/45.29	43.16/46.28	12,100/12,969	0.35/0.37	13,236	hvBb
MC-56A-TC	1087.-1095.3	6.39/XXXXX	10.67/11.40	40.62/43.39	42.32/45.21	11,824/12,631	0.78/0.83	13,385	hvBb

Table 3. Ultimate analyses of coal cores obtained from the MC-48-MP and MC-56A-TC drill holes.

Drill Hole Number	Drilling Interval	Ultimate Analysis (%) As Received/Dry Basis							
		Moisture	Carbon	Hydrogen	Nitrogen	Chlorine	Sulfur	Ash	Oxygen
MC-48-MP	182.0- 195.0	6.12/XXXXX	68.53/73.00	5.03/5.36	1.46/1.56	0.05/0.05	0.57/0.61	8.70/ 9.27	9.54/10.15
MC-48-MP	242.0- 245.0	5.11/XXXXX	67.39/71.02	5.14/5.42	1.52/1.60	0.04/0.04	0.66/0.70	10.86/11.44	9.28/ 9.78
MC-56A-TC	1019.5-1020.0	6.52/XXXXX	68.17/72.93	4.68/5.01	1.18/1.26	0.02/0.02	0.89/0.95	7.33/ 7.84	11.21/11.99
MC-56A-TC	1020.0-1021.9	5.71/XXXXX	71.61/75.95	5.29/5.61	1.10/1.17	0.02/0.02	0.41/0.44	5.00/ 5.30	10.86/11.51
MC-56A-TC	1021.9-1023.8	6.44/XXXXX	71.79/76.73	5.21/5.57	0.94/1.01	0.00/0.00	0.24/0.26	4.49/ 4.80	10.89/11.63
MC-56A-TC	1023.8-1025.7	5.97/XXXXX	71.30/75.83	5.43/5.77	1.16/1.23	0.01/0.01	0.24/0.25	4.78/ 5.08	11.11/11.83
MC-56A-TC	1025.7-1027.5	5.73/XXXXX	71.05/75.37	5.55/5.89	1.22/1.29	0.00/0.00	0.26/0.28	4.27/ 4.53	11.92/12.64
MC-56A-TC	1027.5-1029.4	6.97/XXXXX	68.21/73.32	4.90/5.27	1.01/1.09	0.01/0.01	0.22/0.24	7.34/ 7.89	11.34/12.18
MC-56A-TC	1029.4-1031.3	6.68/XXXXX	60.54/64.87	4.15/4.45	0.85/0.91	0.01/0.01	0.15/0.16	13.19/14.13	14.43/15.47
MC-56A-TC	1031.3-1033.1	7.88/XXXXX	65.39/70.98	4.67/5.07	1.02/1.11	0.00/0.00	0.22/0.24	8.98/ 9.75	11.84/12.85
MC-56A-TC	1033.1-1035.1	7.95/XXXXX	67.40/73.22	4.67/5.07	1.04/1.13	0.01/0.01	0.21/0.23	6.27/ 6.81	12.45/13.53
MC-56A-TC	1035.1-1036.9	6.26/XXXXX	70.51/75.22	5.29/5.64	1.13/1.21	0.01/0.01	0.42/0.45	5.64/ 6.02	10.74/11.45
MC-56A-TC	1036.9-1038.8	5.90/XXXXX	70.45/74.87	5.39/5.73	1.11/1.18	0.00/0.00	0.28/0.30	6.46/ 6.86	10.41/11.06
MC-56A-TC	1038.8-1039.6	5.59/XXXXX	71.77/76.02	5.38/5.70	1.16/1.23	0.00/0.00	0.33/0.35	4.74/ 5.02	11.03/11.68
MC-56A-TC	1039.6-1040.5	10.27/XXXXX	67.28/74.98	5.09/5.67	1.20/1.34	0.00/0.00	0.34/0.38	4.90/ 5.46	10.92/12.17
MC-56A-TC	1040.5-1043.7	7.47/XXXXX	69.68/75.31	5.41/5.85	1.27/1.37	0.01/0.01	0.51/0.55	4.95/ 5.35	10.70/11.56
MC-56A-TC	1043.7-1044.5	4.91/XXXXX	50.16/52.75	4.07/4.28	0.96/1.01	0.01/0.01	0.48/0.51	30.05/31.60	9.36/ 9.84
MC-56A-TC	1019.5-1044.5	6.68/XXXXX	67.69/72.56	5.01/5.37	1.09/1.17	0.01/0.01	0.35/0.37	7.89/ 8.43	11.28/12.09
MC-56A-TC	1087.0-1095.3	6.39/XXXXX	66.19/70.71	4.81/5.14	1.22/1.30	0.01/0.01	0.78/0.83	10.67/11.40	9.93/10.61

Table 4. Forms of sulfur analyses of coal obtained from the MC-48-MP and MC-56A-TC drill holes.

Drill-Hole Number	Drill-Hole Interval	Sulfur Forms As Received/Dry Basis			
		Pyritic %	Sulfate %	Organic %	Total
MC-48-TC	182.0- 195.0	0.08/0.09	0.00/0.00	0.49/0.52	0.57/0.61
MC-48-TC	242.0- 245.0	0.04/0.04	0.00/0.00	0.62/0.66	0.66/0.70
MC-56A-TC	1019.5-1020.0	0.30/0.32	0.00/0.00	0.59/0.63	0.89/0.95
MC-56A-TC	1020.0-1021.9	0.10/0.11	0.00/0.00	0.31/0.33	0.41/0.44
MC-56A-TC	1021.9-1023.8	0.02/0.02	0.00/0.00	0.22/0.24	0.24/0.26
MC-56A-TC	1023.8-1025.7	0.02/0.02	0.00/0.00	0.22/0.23	0.24/0.25
MC-56A-TC	1025.7-1027.5	0.02/0.02	0.00/0.00	0.24/0.26	0.26/0.28
MC-56A-TC	1027.5-1029.4	0.01/0.01	0.00/0.00	0.21/0.23	0.22/0.24
MC-56A-TC	1029.4-1031.3	0.03/0.03	0.00/0.00	0.12/0.13	0.15/0.16
MC-56A-TC	1031.3-1033.1	0.02/0.02	0.02/0.02	0.18/0.20	0.22/0.24
MC-56A-TC	1033.1-1035.1	0.02/0.02	0.00/0.00	0.19/0.21	0.21/0.23
MC-56A-TC	1035.1-1036.9	0.02/0.02	0.00/0.00	0.40/0.43	0.42/0.45
MC-56A-TC	1036.9-1038.8	0.03/0.03	0.00/0.00	0.25/0.27	0.28/0.30
MC-56A-TC	1038.8-1039.6	0.01/0.01	0.00/0.00	0.32/0.34	0.33/0.35
MC-56A-TC	1039.6-1040.5	0.02/0.02	0.00/0.00	0.32/0.36	0.34/0.38
MC-56A-TC	1040.5-1043.7	0.06/0.07	0.00/0.00	0.45/0.48	0.51/0.55
MC-56A-TC	1043.7-1044.5	0.03/0.03	0.00/0.00	0.45/0.48	0.48/0.51
MC-56A-TC	1019.5-1044.5	0.05/0.05	0.00/0.00	0.30/0.32	0.35/0.37
MC-56A-TC	1087.0-1095.3	0.27/0.29	0.02/0.02	0.49/0.52	0.78/0.83

Table 6. Coal Core *Methane Content – North Horn Mt/ Meetinghouse Canyon

Drill-Hole Number	Drill-Hole Interval	Lost gas cm^3	Desorbed gas cm^3	Residual gas cm^3	Sample Weight grams	Total gas cm^3/gram	ft^3/Ton Coal in place	Long Range Mine Gas Emmissions ft^3/ton produced /day
MC-56A-TC	1019.5-1044.5	95.0	430.0	00.0	947.4	0.6	17.7	106.0
MC-56A-TC	1087.0-1095.3	12.9	95.0	00.0	1012.5	0.2	7.1	42.5
MC-48-MP	182.0- 195.0	32.1	130.0	00.0	1326.4	0.3	10.9	65.3

* Determined in accordance with U. S. Bureau of Mines Report of Investigation R. I. 7767 and 8043.

Table 5. Trace element determinations of coal obtained from the MC-48-MP and MC-56A-TC drill holes.

	MC-56A-TC	MC-56A-TC	MC-48-MP	Drill Hole No.
	1019.5-1044.5	1087.0-1095.3	182.0-195.0	Drill Hole Interval
Element	CONC. PPM WT			
Uranium	<3	3	4	
Thorium	<3	4	<8	
Bismuth				
Lead	2	<2	4	
Thallium				
Mercury	*0.12	*0.13	*0.07	
Gold				
Platinum				
Iridium				
Osmium				
Rhenium				
Tungsten				
Tantalum				
Hafnium				
Lutetium				
Ytterbium				
Thulium				
Erbium				
Holmium				
Dysprosium				
Terbium				
Gadolinium				
Europium				
Samarium			<2	
Neodymium	0.5	4	2	
Prsaeodymium	1	5	2	
Cerium	11	2	26	
Lanthanum	9	28	37	
Barium	200	44	120	
Cesium	<0.1	200	0.7	
Iodine	0.4	1	0.9	
Tellurium		0.9		
Antimony				
Tin				
Cadmium	0.6	1	1	
Silver				
Palladium				
Rhodium				
Ruthenium				
Molybdenum	2	1	2	
Niobium	***4	4	10	
Zirconium	12	25	73	
Yttrium	6	6	15	
Strontium	76	240	160	
Rubidium	1	2	4	
Bromine	4	7	2	
Selenium	0.6	2	.1	
Arsenic	1	2	<0.4	
Germanium				
Gallium	3	5	15	
Zinc	3	31	30	
Copper	***11	26	15	
Nickel	0.8	<2	5	
Cobalt	0.6	0.6	<0.7	
Manganese	21	8	6	
Chromium	5	10	11	
Vanadium	14	14	34	
Scandium	3	3	3	
Fluorine	**88	**148	**69	All elements not detected <0.2ppm
Boron	79	18	42	* Flameless Atomic Absorption
Beryllium	<0.1	0.1	0.3	** Specific Ion Electrode
Lithium	12	21	16	*** Heterogeneous

methane is 65.3 cubic feet of gas per ton of coal produced per day.

Two coal core samples were obtained from the MC-56A-TC drill hole. The first was collected from a depth interval of 1019.5 to 1044.5 feet. From July 30 to August 15, 1979, the coal core sample desorbed 430 cubic centimeters of gas. Lost gas was calculated to be 95 cubic centimeters and there was no residual gas. Therefore, the total gas content of the 947.4 gram sample was 525 cubic centimeters which computes to 0.6 cubic centimeters per gram. This is equivalent to 17.6 cubic feet of gas per ton of coal in place and the long range forecast for mine gas emissions is 105 cubic feet of gas per ton of coal produced per day.

The second coal core sample from this hole (MC-56A-TC) was collected at a depth interval of 1087.0 to 1095.3 feet. From July 31 to August 17, 1979 the sample desorbed 95 cubic centimeters of methane, lost gas was calculated to be 129 cubic centimeters and there was no residual gas. The total gas content of the 1012.5-gram sample was 224 cubic centimeters computing 0.22 cubic centimeters per gram of coal. This is equivalent to 7.0 cubic feet of gas per ton of coal in place and the long range forecast for mine emissions is 42.5 cubic feet of gas per ton of coal produced per day.

RESERVES

Reserve calculations for the drilled area were made in accordance with the criteria contained in U. S. Geological Survey Bulletin 1450-B, 1976. A predetermined geometric grid, i.e., 1-mile centers to maximize measured reserves, was not used, but drill hole locations were placed to take advantage of topography, existing roads, and constraints, of obtaining permits. A circle with a radious of ½-mile was drawn around each drill hole and the enclosed area was used to determine the indicated reserve. Experience in this area dictates that drill holes must be placed at least on ½-mile centers to determine a measured reserve. A circle with a radius of 2¼ miles was drawn around each drill hole and the enclosed area minus that considered for the indicated reserve was utilized to calculate the inferred reserve. A planimeter was used on U. S. Geological Survey 7½-Minute (1:24,000) topographic maps to determine the areas. The outer circular boundaries were modified to conform to surveyed boundaries; i.e., to conform with section lines. The areas for which reserves were calculated are shown on figures 4 and 5. Figure 4 indicates the area of Blind Canyon coal considered and figure 5 indicates the area of Lower Hiawath coal considered.

The reserve estimates are presented in several ways. Table 7 presents the in-place reserves for the Blind Canyon seam on North Horn Mountain by location (section, township and range) and by split; US = upper split, LS = lower split, and NS = not split. In most places only one bench or split will be minable. Table 8 does the same for the Lower Hiawatha. Tables 9 and 10 give the same approach for the East Mountain area. Tables 11-14 consider the reserve with respect to general seam thickness; low seam 4 to 8 feet, medium seam 8 to 14 feet and high seam greater than 14 feet. No reserve was calculated for the Meetinghouse Canyon area.

The total in-place indicated and inferred tonnage for North Horn and East Mountain is calculated to be 312,583,533 short tons. Not all of this coal will be recoverable. There are several areas in which the coal beds are split and only one bench can be considered for mining. Removing the coal contained in the unminable benches from the calculations leaves 242.8 million tons; about 62.7 million tons on East Mountain and 180.1 million tons on North Horn Mountain. If an arbitrary recovery of 55 percent is applied to the minable beds then this figure is further reduced to 133.5 million tons; 34.5 million tons on East Mountain and 99 million tons on North Horn Mountain, considering only those areas outlined on figures 4 and 5. If no other reductions are deemed necessary this drilling project has established a recoverable reserve of 133.5 million short tons in the outlined areas of figures 4 and 5 (see table 15).

LIMESTONE

Some interest has been expressed in using the limestone of the Flagstaff Limestone exposed on North Horn Mountain (The Cap) as rock dust in the coal mines. Three channel samples were taken at the locations on the Cap as shown on figure 6, to be analyzed. The Federal Mine Safety and Health Act of 1977, Public Law 91-173 as amended by Public Law 95-164 states "rock dust means pulverized limestone. . . . . .and does not contain more than 5 per centum of combustible matter or more than a total of 4 per centum of free and combined silica (SiO_2). . ."

The samples analyzed were all within the silica content specified for rock dust, however, other physical parameters were not tested. The descriptions of the channel samples is given in Appendix 2, the results of the analyses are given in table 16.

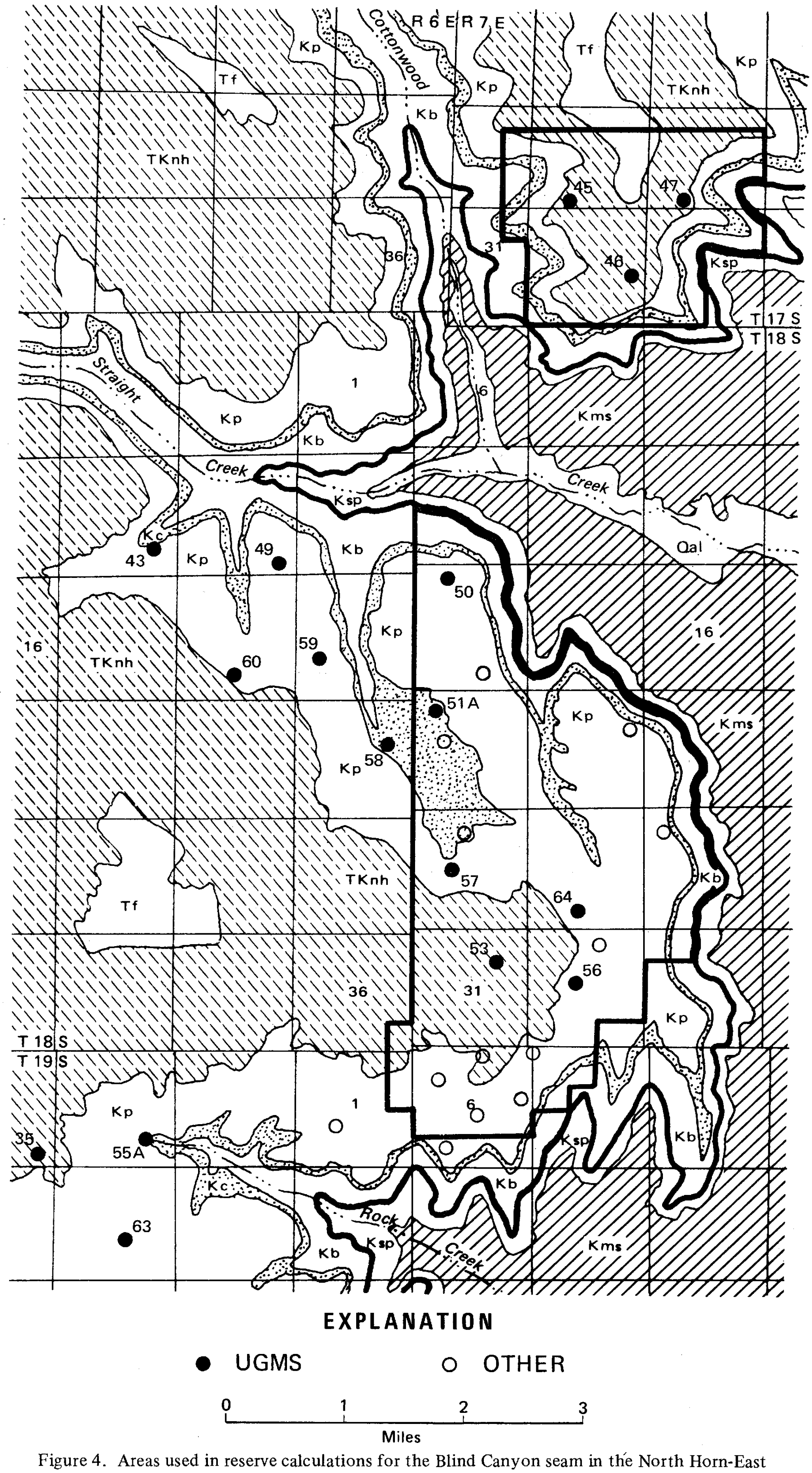


Figure 4. Areas used in reserve calculations for the Blind Canyon seam in the North Horn-East Mountain areas and locations of drill holes.

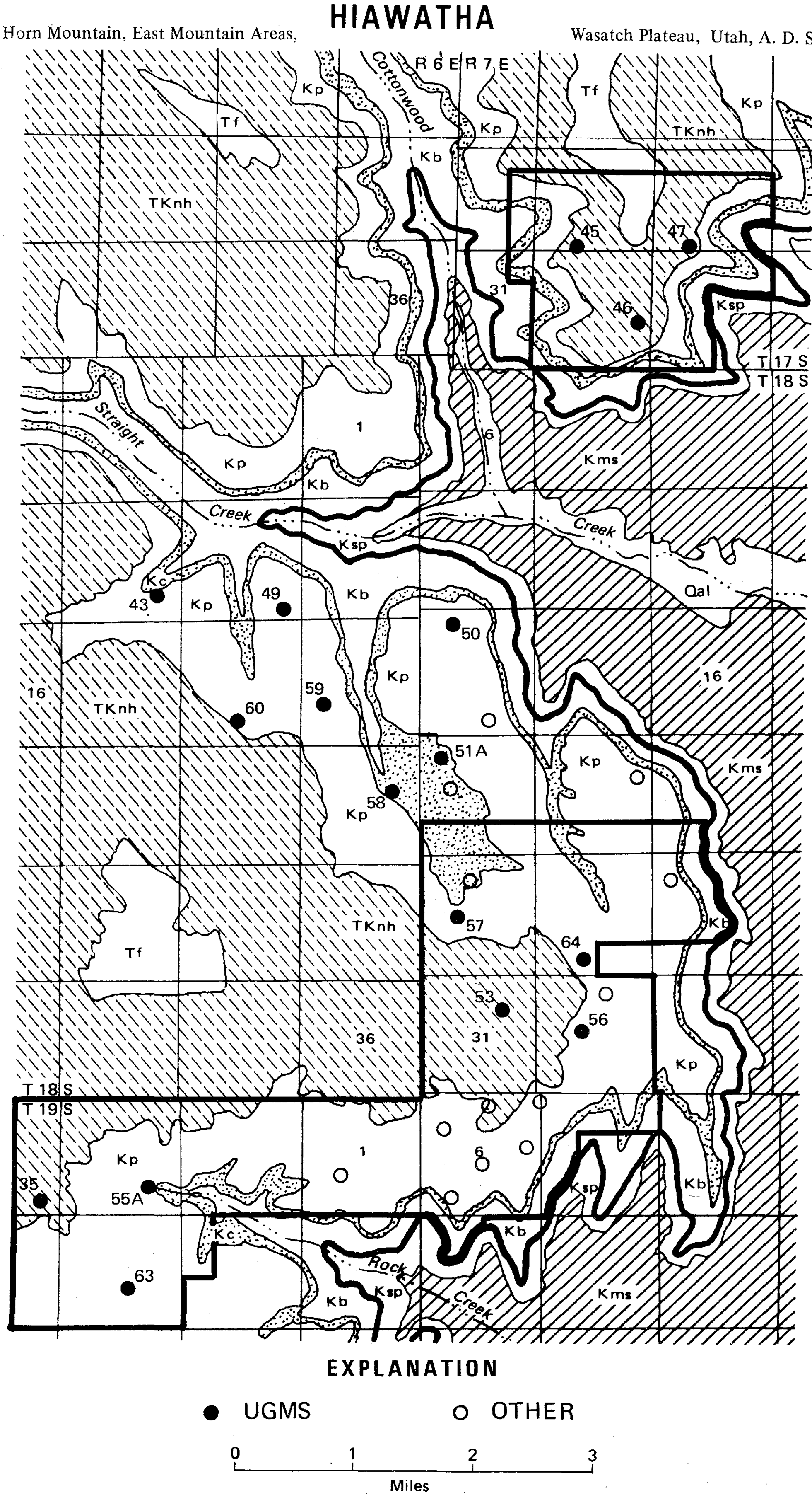


Figure 5. Areas used in reserve calculations for the Lower Hiawatha seam in the North Horn-East Mountain areas and locations of drill holes.

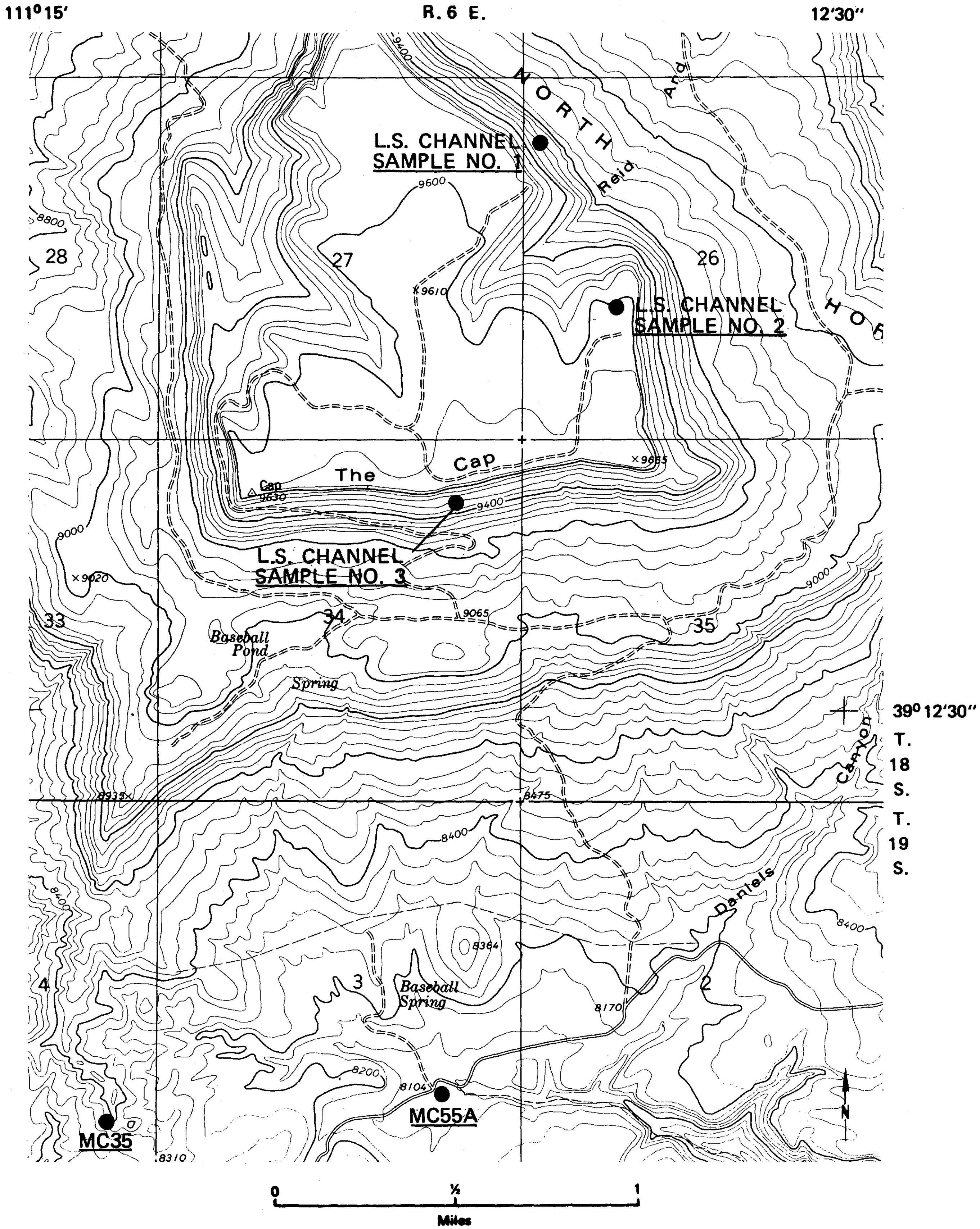


Figure 6. Map showing where limestone channel samples were taken for analysis.

Table 7. In Place Coal Reserves, Blind Canyon Seam, North Horn Mountain Area.

Location		Split	Indicated	Inferred	Total Tons
T1 8S, R 7 E.					
S½	7	US		370,309	370,309
S½	17	LS	105,803	1,491,826	1,597,629
		US	15,076	491,234	506,310
			(120,879)	(1,983,060)	(2,103,939)
all	18	LS	2,153,855		2,153,855
		US	1,375,439	1,980,029	3,355,468
			(3,529,294)	(1,980,029)	(5,509,323)
all	19	LS	3,796,819	2,521,145	6,317,964
		US	3,932,859	2,623,922	6,556,781
			(7,729,678)	(5,145,067)	(12,874,745)
all	20	NS	2,366,973	40,808	2,407,781
		LS	554,712	4,789,867	5,344,579
		US	1,062,578	5,746,637	6,809.215
			(3,984,263)	(10,577,312)	(14,561,575)
W½	21	NS	1,319,519	27,200	1,346,719
		LS	906,885	559,248	1,466,133
		US	1,532,638	961,306	2,493,944
			(3,759,042)	(1,547,754)	(5,306,796)
W½	28	LS	1,957,358	1,178,949	3,136,307
		US	2,974,585	1,481,260	4,455,845
			(4,931,943)	(2,660,209)	(7,592,152)
all	29	LS	4,880,552	2,043,510	6,924,062
		US	8,730,288	3,027,481	11,757,769
			(13,610,840)	(5,070,991)	(18,681,831)
all	30	LS	2,575,554	1,730,638	4,306,192
		US	3,527,607	2,450,098	5,977,705
			(6,103,161)	(4,180,736)	(10,283,897)
all	31	NS	15,779,304	2,954,617	18,733,921
		LS	83,134	400,540	483,674
		US	185,918	923,503	1,109,421
			(16,048,356)	(4,278,660)	(20,327,016)
N½, SW, N½ SE	32	NS	13,143,792	3,061,611	16,205,403
		LS	1,216,731		1,216,731
		US	2,814,373		2,814,373
			(17,174,896)	(3,061,611)	(20,236,507)
T1 8S, R 7 E					
N½ NW	33	LS	241,833	483,674	725,507
		US	406,590	634,820	1,041,410
			(648,423)	(1,118,494)	(1,766,917)
T1 9S, R 7 E					
N½ NW, SW NW	5	NS	3,257,252	185,905	3,443,157
N½, N½ S½	6	NS	4,614,528		4,614,528
T1 8s, R 6 E					
SESE	36	NS	104,288	563,781	668,069
T 19 S, R 6 E					
E½ NE	1	NS	65,494	25,190	90,684
Totals		NS	40,651,150	6,859,112	47,510,262
		LS	18,473,236	15,199,397	33,672,633
		US	26,557,951	20,690,599	47,248,550
GRAND TOTAL			85,682,337	42,749,108	128,431,445

Table 8. In Place Coal Reserves, Hiawatha Seam, North Horn Mountain Area.

Location		Split	Indicated	Inferred	Total Tons
T 18 S, R 7 E					
S½ S½	19	NS	287,184	990,019	1,277,203
S½ S½	20	NS	720,972	1,528,100	2,249,072
S½ SW	21	NS	1,311,979		1,311,979
NW, N½ SW	28	NS	3,573,129	1,062,559	4,635,688
N½, SW, N½, SE	29	NS	6,422,248	2,985,164	9,407,412
all	30	NS	5,139,010	3,233,041	8,372,051
all	31	NS	7,019,299	2,753,924	9,773,223
		LS	702,835		702,835
		US	211,610		211,610
			(7,933,744)	(2,753,924)	(10,687,668)
all	32	NS	4,818,590		4,818,590
		LS	264,513		264,513
			(5,083,103)		(5,083,103)
T 19 S, R 6 E					
all	1	US	4,762,655	2,110,019	6,872,674
all	2	LS	922,005	1,484,268	2,406,273
		US	1,301,384	4,746,038	6,047,422
			(2,223,389)	(6,230,306)	(8,453,695)
all	3	NS	645,713	1,110,926	1,756,639
		LS	3,491,507	3,618,466	7,109,973
		US	2,471,263	2,622,410	5,093,673
			(6,608,483)	(7,351,802)	(13,960,285)
E½	4	NS	3,672,874	2,887,500	6,560,374
E½	9	NS	2,017,811	2,289,893	4,307,704
		LS		899,334	899,334
		US		642,381	642,381
			(2,017,811)	(3,831,608)	(5,849,419)
all	10	LS	6,224,258	1,349,754	7,574,012
		US	5,509,331	1,019,223	6,528,554
			(11,733,589)	(2,368,977)	(14,102,566)
W½ NW	11	LS	287,184	196,490	483,674
		US	349,160	662,025	1,011,185
			(636,344)	(858,515)	(1,494,859)
T 19 S, R 7 E					
N½ N½, W½ SW, SWNW	5	LS	1,118,495	30,231	1,148,726
		US	506,345		506,345
			(1,624,840)	(30,231)	(1,655,071)
all	6	NS	2,181,051		2,181,051
		LS	4,990,890	166,259	5,157,149
		US	1,723,085		1,723,085
			(8,895,026)	(166,259)	(9,061,285)
NW	7	LS	1,079,193		1,079,193
Totals		NS	37,809,860	18,841,126	56,650,986
		LS	19,080,880	7,744,802	26,825,682
		US	16,834,833	11,802,096	28,636,929
GRAND TOTAL			73,725,573	38,388,024	112,113,597

Table 9. In Place Coal Reserves, Blind Canyon- -East Mountain

Location
Table 9. In Place Coal Reserves, Blind Canyon- -East Mountain

Location		Split	Indicated	Inferred	Total Tons
T 17 S, R 7 E					
S½, S½ N½	28	LS	2,193,915	196,492	2,390,407
		US	1,980,030	388,448	2,368,478
		NS	1,955,090	795,795	2,750,885
			(6,129,035)	(1,380,735)	(7,509,770)
S½, S½ N½	29	LS	3,310,130	1,248,477	4,558,607
		US	1,024,031	1,050,481	2,074,512
		NS		766,322	766,322
			(4,334,161)	(3,065,280)	(7,399,441)
E½ SE, SE NE	30	LS	132,260	860,785	993,045
		US	58,193	597,040	655,233
			(190,453)	(1,457,825)	(1,648,278)
NE NE	31	LS	152,657	359,737	512,394
		US	279,631	16,622	296,253
			(432,288)	(376,359)	(808,647)
all	32	LS	6,386,740	2,201,467	8,588,207
		US	2,368,478	115,629	2,484,107
			(8,755,218)	(2,317,096)	(11,072,314)
SW, N½	33	LS	4,111,972	1,748,038	5,860,010
		US	1,143,427	271,315	1,414,742
			(5,255,399)	(2,019,353)	(7,274,752)
Total		LS	16,287,674	6,614,996	22,902,670
		US	6,853,790	2,439,535	9,293,325
		NS	1,955,090	1,562,117	3,517,207
GRAND TOTAL			25,096,554	10,616,648	35,713,202

Table 10. In Place Coal Reserves, Hiawatha- - East Mountain

Location		Split	Indicated	Inferred	Total Tons
T 17 S, R 7 E					
S½, S½ N½	28	NS	5,903,819	1,647,505	7,551,324
S½, S½ N½	29	NS	4,697,657	3,626,029	8,323,686
E½ SE, SE NE	30	NS	229,741	1,730,635	1,960,376
NE NE	31	NS	215,394	445,134	660,528
all	32	NS	3,991,812	6,754,783	10,746,595
SW, N½	33	NS	3,044,104	4,038,676	7,082,780
TOTAL			18,082,527	18,242,762	36,325,289

Table 11. North Horn– – Blind Canyon Coal Seam

Location			Indicated Tons (Thickness in Feet) 4–8	8–14	14	Total	Inferred Tons (Thickness in Feet) 4–8	8–14	14	Total
T 1 8 S, R 7 E	S½	7					370,309			370,309
	S½	17	120,879			120,879	1,983,060			1,983,060
	all	18	3,529,294			3,529,294	1,980,029			1,980,029
	all	19	7,729,678			7,729,678	5,145,067			5,145,067
	all	20	724,002	3,260,261		3,984,263	7,980,594	2,596,718		10,577,312
	W½	21	1,446,485	2,312,557		3,759,042	1,098,848	448,906		1,547,754
	W½	28	3,163,518	1,768,425		4,931,943	21,184,086	476,123		2,660,209
	all	29	4,880,552	8,730,288		13,610,840	2,350,336	2,720,655		5,070,991
	all	30	5,527,276	575,885		6,103,161	3,134,798	1,045,938		4,180,736
	all	31	83,134	2,348,340	13,616,882	16,048,356	637,837	974,601	2,666,222	4,278,660
	N½, SW, N½ SE	32	1,216,731	2,853,662	13,104,503	17,174,896			3,061,611	3,061,611
	N½ NW	33	294,741	353,682		648,423	1,118,494			1,118,494
T 19S, R 7 E	N½ NW, SW NW	5		2,184,105	1,073,147	3,257,252		185,905		185,905
	N½, N½ S½	6	1,886,323	2,728,205		4,614,528				
T 18 S, R 6 E	SE SE	36	63,480	40,808		104,288	163,238	400,543		563,781
T 19 S, R 6 E	E½ NE	1	65,494			65,494	25,190			25,190
TOTALS	Not Split		2,015,297	10,841,321	27,794,532	40,651,150	188,428	942,851	5,727,833	6,859,112
	Lower Split		18,473,236			18,473,236	15,199,397			15,199,397
	Upper Split		10,243,054	16,314,897		26,557,951	12,784,061	7,906,538		20,690,599
GRAND TOTAL			30,731,587	27,156,218	27,794,532	85,682,337	28,171,886	8,849,389	5,727,833	42,749,108
								TOTAL BLIND CANYON		128,431,445

Table 12. North Horn––Hiawatha Coal Seam

Location			Indicated Tons (Thickness in Feet) 4-8	8-14	14	Total	Inferred Tons (Thickness in Feet) 4-8	8-14	14	Total
T 18 S, R 7 E	S½S½	19	287,184			287,184	990,019			990,019
	S½S½	20		720,972		720,972	983,969	544,131		1,528,100
	S½SW	21		1,311,979		1,311,979				
	NW, N½ SW	28		3,573,129		3,573,129	169,283	893,276		1,062,559
	N½, SW, N½ SE	29		6,422,248		6,422,248	634,820	2,350,344		2,985,164
	all	30	3,394,778	1,744,232		5,139,010	811,662	2,421,379		3,233,041
	all	31	914,445	7,019,299		7,933,744		2,753,924		2,753,924
	all	32	264,513	4,818,590		5,083,103				
T 19 S, R 6 E	all	1	4,762,655			4,762,655	2,110,019			2,110,019
	all	2	2,223,389			2,223,389	6,230,306			6,230,306
	all	3	5,962,770		645,713	6,608,483	6,240,876		1,110,926	7,351,802
	E½	4			3,672,874	3,672,874			2,887,500	2,887,500
	E½	9			2,017,811	2,017,811	1,541,715		2,289,893	3,831,608
	all	10	11,733,589			11,733,589	2,368,977			2,368,977
	W½ NW	11	636,344			636,344	858,515			858,515
T 19 S, R 7 E	N½N½, W½SW,SWNW	5	1,624,840			1,624,840	30,231			30,231
	all	6	6,713,975	2,181,051		8,895,026	166,259			166,259
	NW	7	1,079,193			1,079,193				
TOTALS	Not Split		3,681,962	27,791,500	6,336,398	37,809,860	3,589,753	8,963,054	6,288,319	18,841,126
	Lower Split		19,080,880			19,080,880	7,744,802			7,744,802
	Upper Split		16,834,833			16,834,833	11,802,096			11,802,096
GRAND TOTAL			39,597,675	27,791,500	6,336,398	73,725,573	23,136,651	8,963,054	6,288,319	38,388,024

TOTAL HIAWATHA 112,113,597

Table 13. Blind Canyon Coal Seam--East Mountain

Location			Indicated Tons (Thickness in Feet) 4-8	8-14	Total	Inferred Tons (Thickness in Feet) 4-8	8-14	Total
T 17 S, R 7 E	S½, S½ N½	28	6,129,035		6,129,035	1,380,735		1,380,735
	S½, S½ N½	29	4,334,161		4,334,161	3,065,280		3,065,280
	E½ SE, SE NE	30	190,453		190,453	1,457,825		1,457,825
	NE NE	31	432,288		432,288	376,359		376,359
	all	32	5,774,595	2,980,623	8,755,218	2,317,096		2,317,096
	SW, N½	33	2,929,990	2,325,409	5,255,399	1,184,256	835,097	2,019,353
TOTALS	Lower Split		10,981,642	5,306,032	16,287,674	5,779,899	835,097	6,614,996
	Upper Split		6,853,790	0	6,853,790	2,439,535	0	2,439,535
	Not Split		1,955,090	0	1,955,090	1,562,117	0	1,562,117
GRAND TOTAL			19,790,522	5,306,032	25,096,554	9,781,551	835,097	10,616,648
					TOTAL BLIND CANYON--EAST MOUNTAIN			35,713,202

Table 14. Hiawatha--East Mountain

Location			Indicated Tons (Thickness in Feet) 4-8	8-14	Total	Inferred Tons (Thickness in Feet) 4-8	8-14	Total
T 17 S, R 7 E								
T 17 S, R 7 E	S½, S½ N½	28		5,903,819	5,903,819		1,647,505	1,647,505
	S½, S½ N½	29		4,697,657	4,697,657		3,626,029	3,626,029
	E½ SE, SE NE	30		229,741	229,741		1,730,635	1,730,635
	NE NE	31		215,394	215,394		445,134	445,134
	all	32		3,991,812	3,991,812		6,754,783	6,754,783
	SW, N½	33		3,044,104	3,044,104		4,038,676	4,038,676
TOTALS				18,082,527	18,082,527		18,242,762	18,242,762
						TOTAL HIAWATHA--EAST MOUNTAIN		36,325,289

Table 15. Recoverable reserves, North Horn Mountain, East Mountain project area, in millions of short tons.

	East Mtn.	North Horn Mtn.
Blind Canyon Bed	14.5	52.1
Lower Hiawatha Bed	20.0	46.9
Totals:	34.5	99.0
Grand Total:	133.5	

Table 16. Rock analyses for limestone samples collected on The Cap, North Horn Mountain in percentages.

Sample:	1		2		3	
Units:	1-4	5-8	1	2-4	1	2-5
SiO_2	3.60	2.40	3.30	2.80	2.70	3.20
Al_2O_3	0.70	0.43	0.62	0.53	0.45	0.60
Fe_2O_3	0.29	0.24	0.27	0.27	0.21	0.23
MgO	0.76	1.70	0.81	2.40	0.71	1.70
CaO	31.60	51.90	51.50	50.90	52.20	51.50
P_2O_5	0.07	0.07	0.07	0.05	0.05	0.07
S	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Moist.	0.20	0.10	0.10	0.20	0.10	0.20

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GEOLOGIC EVALUATION OF A CENTRAL UTAH COAL PROPERTY WASATCH PLATEAU, EMERY COUNTY, UTAH

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ABSTRACT

A multi-seam coal property located in Utah's Wasatch Plateau has been studied by a wide variety of geologic methods. Evaluation of collected data has proven valuable in the planning and development of underground mines.

Data from detailed mapping, sampling, and monitoring in mines; interpretation of depositional features, drilling, and outcrop mapping are used to predict normal or anomalous conditions in advance of mining.

The location of predicted channeling and rolling of seams, hydrologic problems, unstable roof conditions, and rock splits in coal have been substantiated during continued mining advance. The ability to delineate such features permits increased confidence in projected mine design and equipment purchase while allowing for optimum resource management and safety.

INTRODUCTION

In 1976, a large coal property was acquired by Utah Power and Light Company for the expressed objective of supplying existing and proposed coal-fired electric generating plants on a long-term basis. At the time of purchase, the coal reserves, depositional pattern, and physical properties of the coal and enclosing strata of the area to be mined were very poorly known.

An extensive geologic mapping and evaluation program was undertaken to gain insight into the mining conditions present on the property. This paper will emphasize geologic criteria important to roof control and to the predicition of undesirable features.

LOCATION

The coal property investigated in this report is located in the Wasatch Plateau area of central Utah (figure 1) and contains a total of five active mines including the Deer Creek and Wilberg Mines. The study area is located in Emery County, Utah about 40 km (25 miles) south of Price and approximately 240 km (150 miles) from Salt Lake City, Utah.

GEOLOGIC SETTING

The geology and stratigraphy of the area was first mapped and described in detail by Spieker (1931). The

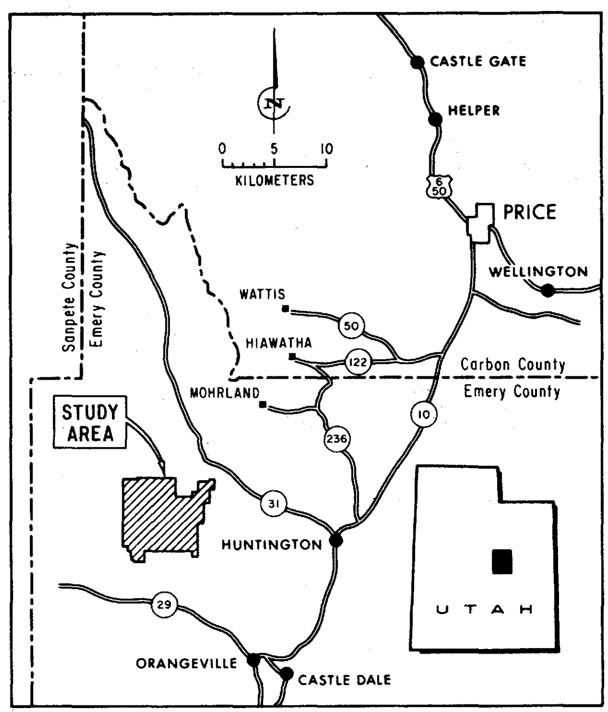


Fig. 1 - Location map of coal property study area.

[1] Coal Geologist, Getty Oil Company
[2] Mine Geologist, Utah Power and Light Company

main stratigraphic units exposed are (in ascending order), the Mancos Shale, Starpoint Sandstone, Blackhawk Formation, and the North Horn Formation. These rocks are well exposed in cliffs along the eastern and southern margins of the coal property.

All economic reserves are contained in two coal seams, the Hiawatha and the Blind Canyon, which are in the basal part of the Blackhawk Formation (figure 2). Both coal seams are high volatile Bituminous C in rank and are characterized by a low sulfur content.

The Hiawatha seam (the basal seam) is quite consistent and well developed over most of the area studied, is generally over 2.5 m thick and is being worked by the Wilberg Mine. This seam rests on a very distinctive beach sandstone (Starpoint Sandstone) which forms the lower boundary of coal accumulation. The overlying Blind Canyon coal seam is less uniform in thickness because of the variable nature of the substrate upon which it accumulated and subsequent differential compaction. The Blind Canyon coal, which is being developed by the Deer Creek Mine, averages about 2.5 m thick.

As shown in figure 2, Blackhawk strata enclosing the two coal seams consist of lenticular sandstone, mudstone, siltstone, and thin-bedded sandstones which are discontinuous in nature, variable in thickness, and exhibit rapid lateral changes in composition. The lenticular sandstones were deposited in meandering delta plain channels and the mudstone, siltstone, and thin-bedded sandstone intervals were formed as interchannel (overbank) deposits.

Figure 3 shows the locations of current mine workings, drill holes, and outcrops of the coal property, which are located on the flanks of the northeast-southwest trending Straight Canyon Syncline. Dips of the limbs of the structure are minor (2° - 3°). Workings of the Deer Creek and Wilberg Mines cross the Pleasant Valley Fault which decreases progressively in offset to a

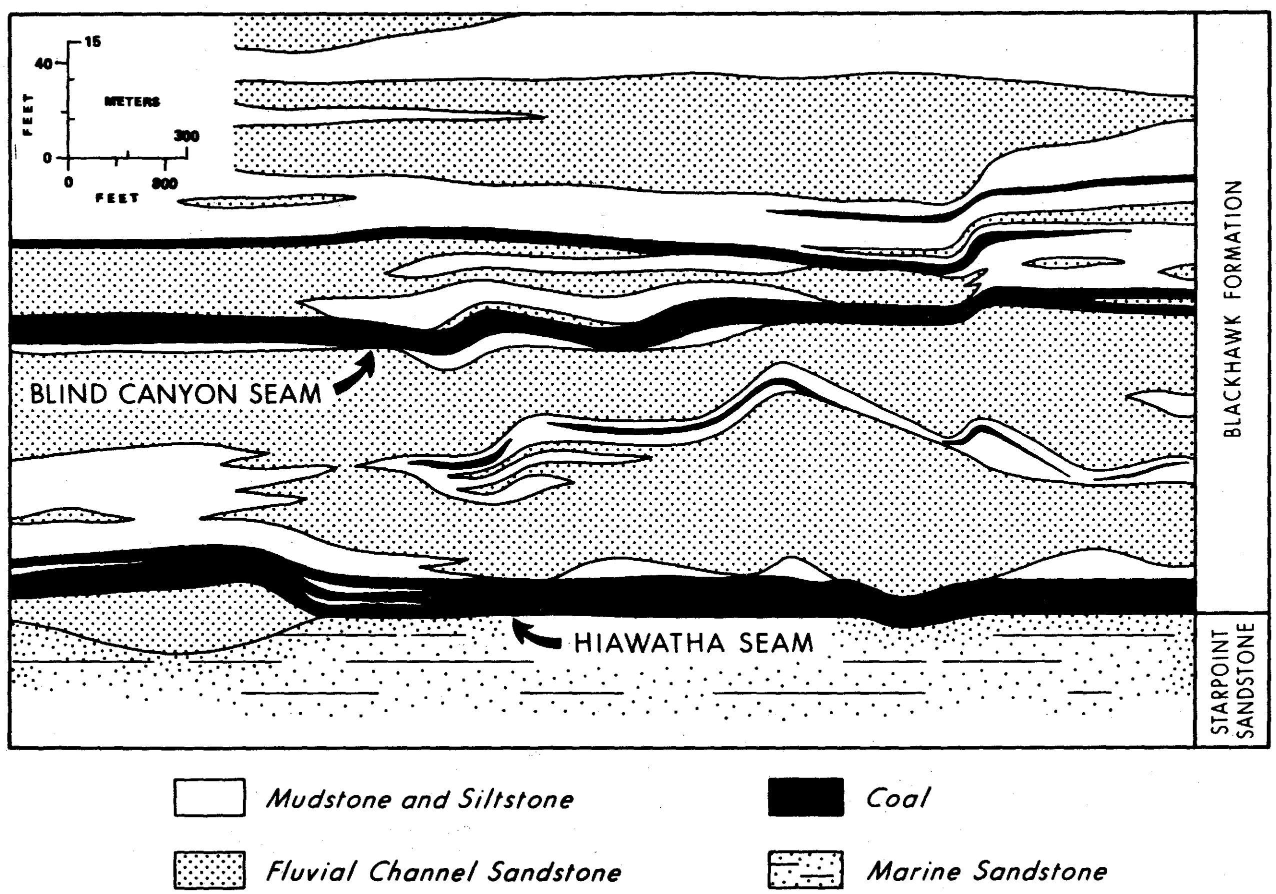


Figure 2. Partial stratigraphic cross section illustrating general relationship of principal coal seams and enclosing strata.

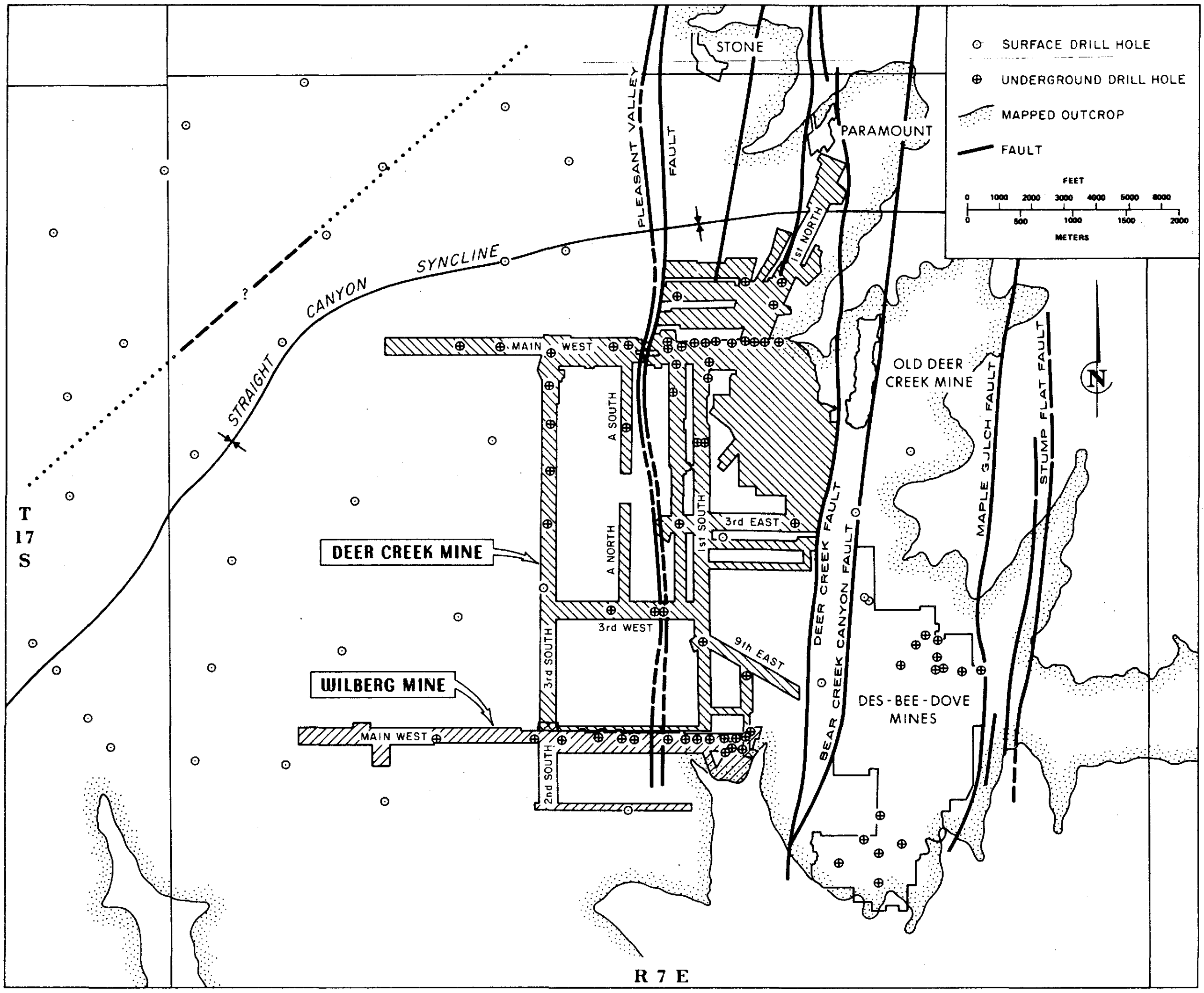


Figure 3. Generalized structure map of study area showing mines, drill holes, and outcrops.

termination point at the southern end of the area. Both mines are effectively bound by the Deer Creek Fault on the east. The influence of faulting is generally confined to about 30 m to each side of the displacement.

Joints in the enclosing strata strongly reflect local structural trends; the average orientation of the major joint set is about N 5° E. Face cleats for both seams are roughly oriented east-west and the butt cleats trend north-south.

MINING OPERATION

The coal property under study covers about 90 sq. km. Workings lie under an anverage overburden of 500 m.; overburden depths range from less than 100 m to over 600 m and may increase in abrupt increments in areas of rugged topography. Portals are in canyons cut into the property. Drift mining in both seams is in a north-south, east-west, pattern. The Deer Creek Mine (Blind Canyon Seam) is experiencing both development and production mining; the Wilberg Mine (Hiawatha Seam) is in a development phase at present.

Most coal has, until recently, been produced by continuous mining equipment used in room and pillar extraction. At present, one longwall unit is in operation on the first panel in the Deer Creek Mine. A second longwall unit is on order for the Deer Creek and two more units are proposed for eventual installation in the Wilberg Mine. Coal is carried out of the mines by belt conveyors. Extensive amounts of water needed for both mining operations and culinary purposes are mostly produced in the underground workings.

DATA GATHERING PROGRAMS

The small amount of data available at the time of purchase required that significant amounts of information be collected to improve mine design and to define and evaluate problem areas relating to mining. The data were collected in three phases: (1) exploratory phase, (2) development of data base, and (3) interpretation and prediction phase.

Exploratory Phase

The first phase, began during the acquisition of the property, consisted of the surface drilling of a small number of holes to verify the presence of coal in the interior parts of the leases. A geologic reconnaissance of the mines was made to establish the reliability of the existing data, and limited underground core drilling was done to probe strata above and below existing workings. A number of coal "grab" samples were collected to assess the general quality of the coal in the mines. Evaluation of the data collected in this phase confirmed the potential of the property and figured importantly in final purchase negotiations.

Development of Data Base

The second phase consisted of collecting the information necessary for mine planning and evaluation. Surface drilling tested most of the property on a 100m pattern (figure 3). Coal strata outcrops were mapped in detail to verify and supplement in-mine and surface drill hole measurements. This work essentially checked, and in places refined, early work by Spieker. The outcrop mapping provided detailed descriptions of coal stratigraphy and thickness, position of seams, interval descriptions and thicknesses, and cleat and joint orientations of both coal and the enclosing strata for over 72 km of outcrop, for a fraction of the cost of one surface drill hole.

At the same time, a systematic and detailed evaluation of the mines were conducted. The scope of this work was three-fold: (a) to describe and correlate underground coal stratigraphy and associated structures, (b) to sample and analyze "in-place" coal quality on a systematic basis, and (c) to monitor and sample the hydrologic regime encountered by the mine workings, for management and utilization as well as to comply with Federal regulations.

Exposed coal ribs were measured along traverses through major access and working sections; roof and floor exposures, including roof failures, over and undercast excavations, and faults were inspected and measured; and structural discontinuities (joints, cleats, faults), and roof and floor lithologies were mapped. Particular attention was paid to fluvial channel sandstones because of their common association with roof stability problems. (McCole and Pascoe, 1978). Features such as scouring and rolling of channel bases, proximity to coal seam, channel thickness, structural complications, paleocurrent direction and inferred dimensions were noted and mapped.

Roof bolters in each working section were visited on a regular basis and hole cuttings were logged from test holes to investigate the immediate roof rock. Underground diamond drilling on 150 m spacing was conducted to determine the strata above and below existing entries, when possible. Core descriptions were supplemented with a number of geophysical logs, made with a portable underground density and natural gamma probe. Composite and stratigraphic coal channel samples were collected at rib measurement sites for analysis. Many sites displaying anomalous or detrimental mineralogical values were resampled on close spacing.

Mine development data was plotted on panel cross-sections to illustrate coal thicknesses, rock splits, roof and floor lithologies, drill holes, monitoring sites, structures, and coal sample locations (figure 4).

Interpretation and Prediction

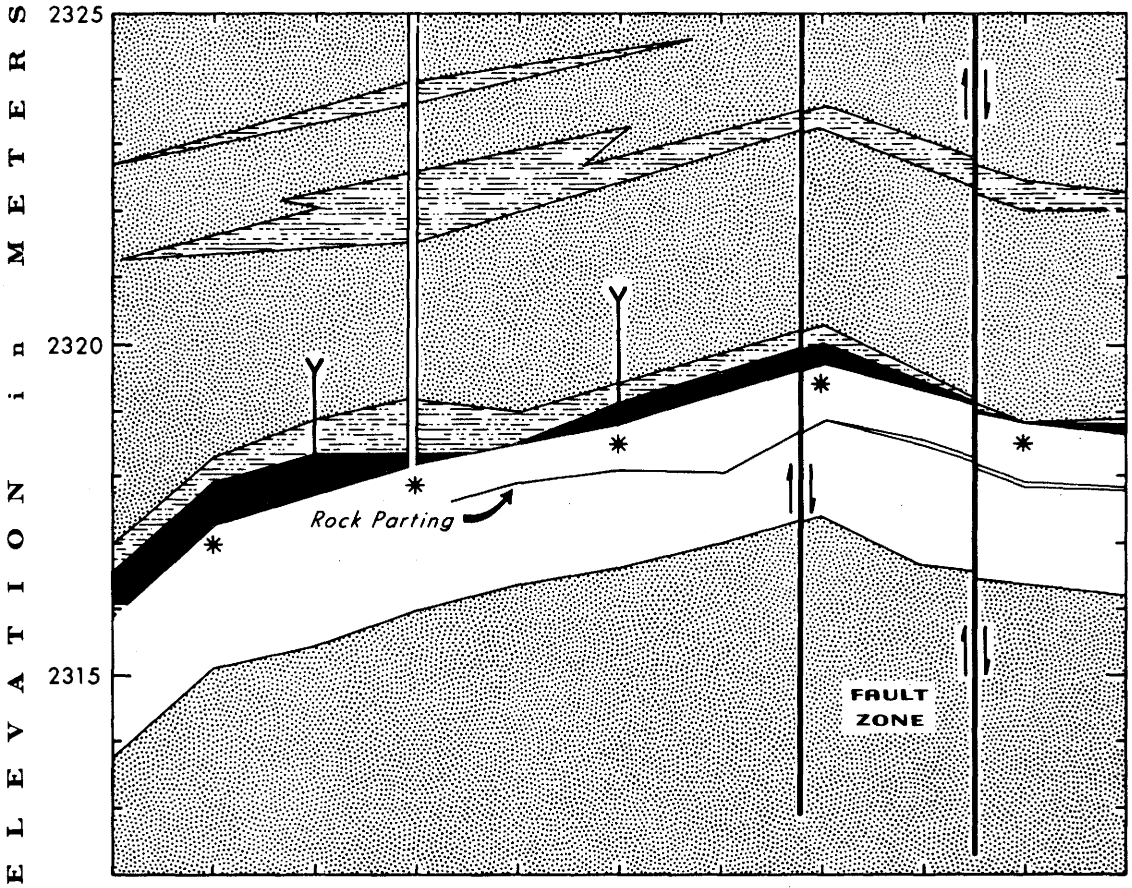
Phase three of the program, presently underway, includes: (a) evaluation of collected data, (b) updating of basic mine data upon advance, (c) prediction and/or projection of features into unmined areas, (d) stress monitoring in key areas, and (e) the refining of mine plans to conform to geologic conditions.

ROOF MAPPING PROGRAM

A broad survey of roof lithologies in previously mined areas was based on roof exposures, drill core and roof bolt hole data, and the memory of section foremen and crews. This information, plotted on distribution maps with surface drill hole and outcrop data, quickly revealed stratigraphic trends which figure importantly in mine development.

Roof Lithologies

The roof strata were divided into two main lithologies to simplify data collection under difficult con-



COAL THICKNESS	2.7	2.8	2.9	2.5	2.1	2.4	2.6	2.6	2.7	2.4	2.4
MINED THICKNESS	2.1	2.2	2.3	2.4	2.1	2.2	2.3	2.3	2.6	2.4	2.4
MINED SPLIT					0.03	0.06	0.03	0.03	0.06	0.06	0.06
CORE HOLE NO.				B118(2L-3L)							
CROSS-CUT NO.	X38B	X37B	X36B	X35B	X34B	X33B	X32B	X31B	X30B	X29B	X28B

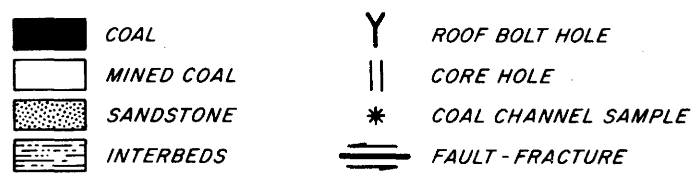


Figure 4. Idealized cross section illustrating underground mapping data.

ditions and to aid graphic presentation. The two lithologic divisions are (a) fluvial channel sandstones and (b) overbank deposits which consist of mudstones, siltstones and interbeds. General rock strengths for the different rock types are shown in table 1.

Fluvial Channel Sandstone

Fluvial channel sandstones included in this classification are ordinarily massive, cross-bedded, fine grained, moderately well-sorted sandstones. The sandstone is usually moderately cemented (calcite) and moderately indurated, although some areas, especially adjacent to faults, it consists of weathered, poorly cemented, friable beds. Rock cementation and strength increases upwards through the channel body.

Outcrop and underground work both show that the meandering and migrating fluvial channels locally form thick, blanket deposits (figure 2), lateral dimen-

Table 1. General Rock Strengths for Various Blackhawk Formation Lithologies

	Rock Strength psi		
Rock Type	Compressive	Tensile	Flexural
Mudstone*	2000-7000	200-500	300-800
Siltstone	8000-12000	450-900	600-1400
Sandstone (thin bed)	6500-12500	600-1150	900-1800
Sandstone (fluvial)	4000-9000	300-700	300-1400
Coal	1000-2500	50-250	150-350
Starpoint Sandstone (marine)	4000-6000	200-300	400-500

*wet clay-rich samples exhibit lower values

sions of these sandstone units are extremely variable, ranging from 10 m to over several km. The lenticular units generally range from 1 to 15 m in thickness, with an average of about 8-10 m. The fluvial channels may be stacked, creating a very thick sequence of sandstone. In most areas, paleocurrent structures at the base of the fluvial channels show a strong paleodrainage trend to the northeast. Joints in the sandstone are generally prominent, have spacings of approximately 3 m, and display continuities of about 20-30 m.

The sandstone at the base of a fluvial channel, where exposed by mining or revealed by drilling, is quite competent and solid (table 1). In general, the channel sandstones display food bridging characteristics and are desirable for roof material in long-term entries. This lithology does fail moderately easily along crossbedding or partings formed by muddy laminae in longwall panels. In addition, preliminary convergence monitoring around the longwall panel suggests that large blocks, rotating between north-south joints, can act as cantilevers and transfer potentially dangerous stresses to adjacent coal pillars.

The channel sandstones act as aquifers; permeability rates vary, with the greatest coefficient of transmission generally confined to the basal parts of the channel. Most of the water produced in the mines is suspected to originate from these "perched" aquifers.

Overbank Interchannel Deposits

Overbank interchannel deposits consist of mudstone, siltstone, and interbedded materials. These lithologies are formed in the interchannel areas as floodplain and overbank levee deposits and may display differential compaction features immediately adjacent to the fluvial channel sandstone bodies.

Carbonaceous mudstone (usually referred to by miners as "cap rock") may immediately overlie the coal seam, and is usually quite thin (less than 15 cm), fissile, weak, and separates easily along bedding laminae. The carbonaceous mudstone commonly exhibits fractures which can be traced into the underlying coal. Carbonaceous mudstone, as well as the non-carbonaceous variety, may be quite susceptible to air slacking.

Mudstones containing less carbonaceous material are generally featureless, dense, homogenous in nature, and, as shown in table 1, quite weak. The release of high residual stresses and moisture changes (wetting) during and after mining is very damaging to rock strength. The inherent multi-directional weakness of mudstone can be accentuated by stresses introduced by roof bolt tensioning (Packer, 1974). Natural discontinuities in this rock type may display very irregular patterns. Mudstones may be slickensided, especially in areas where coalified stumps protrude above the coal seam or along the margins of sandstone paleochannels. These slickensides were formed during compaction diagenesis (differential compaction) and are not continuous into coarser grained units.

Siltstones range from moderately fissile to well indurated, depending on clay content. They locally form dense, featureless units and are usually gradational into other rock types. Thin-bedded sandstones found in the overbank deposits are usually very fine grained to silty, dense, well indurated to mottled, and generally exhibit high rock strengths (table 1). These sandstones units can be expected to thicken towards stratigraphically equivalent fluvial channels. The strengths of the siltstones and thin bedded sandstones are high, but these lithologies interbedded with thinly layered (5 mm to 20 mm thick) mudstones and only moderately competent due to fractures or separations occurring along bedding planes. Shear failure of these units over a mined area is fairly common, with the break of the beds occurring at high angles. These units are difficult to rock bolt unless a competent anchor point is available.

Interpretation of Roof Mapping

This systematic study of roof features points out the intimate association of fluvial channel bodies with hazardous or difficult mining conditions. Maps of the roof of the Hiawatha Seam (figure 5) and of the Blind Canyon Seam (figure 6), prepared from these collected data, illustrate the dominant roof lithology in a 3 meter zone immediately above the coal seams and define hazardous areas present in these lithologies.

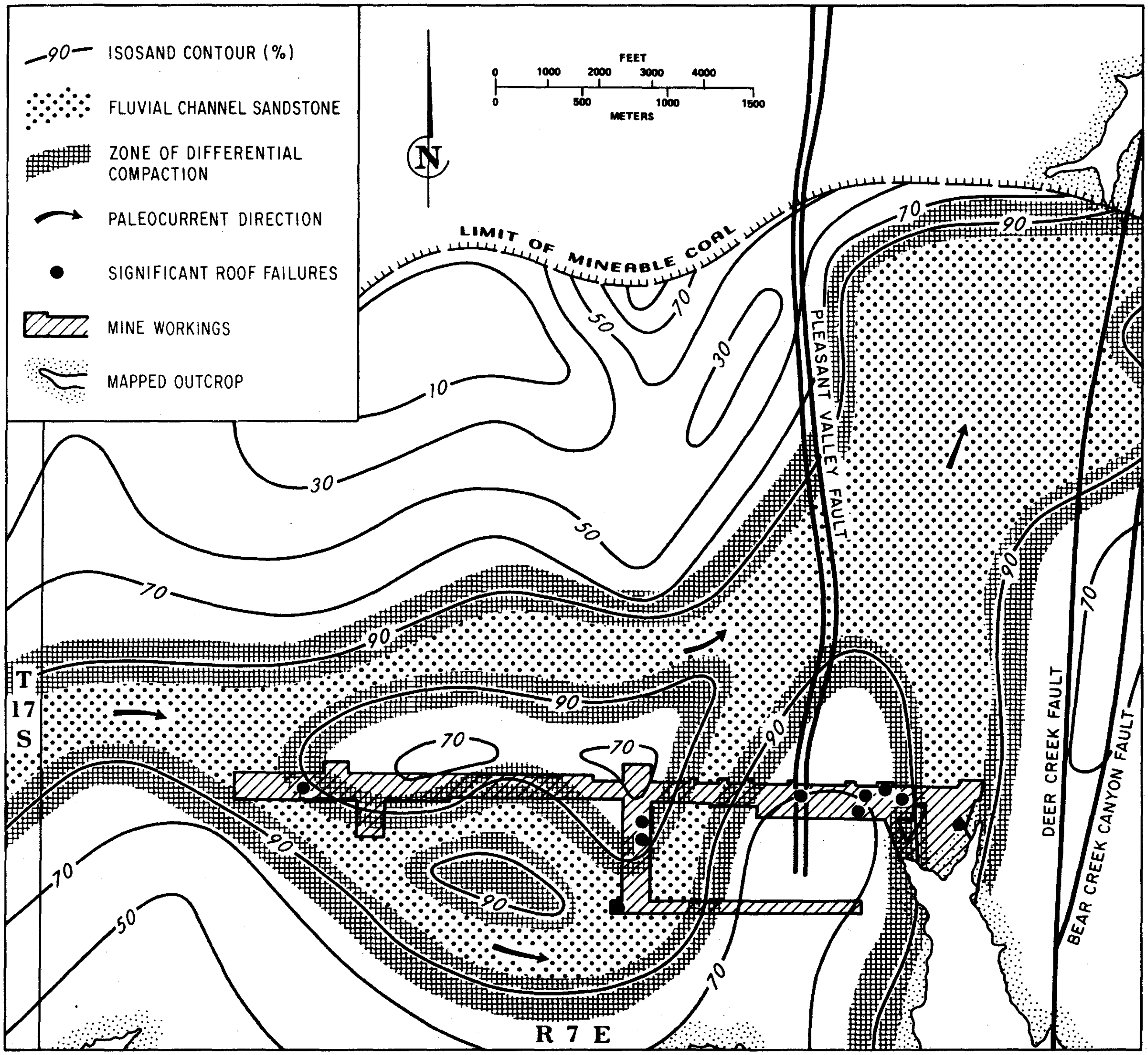


Figure 5. Roof control geology map of the Hiawatha Seam - Wilberg Mine (contoured interval is 3 m).

Iso-sand contours of this 3 m zone were constructed to define and relate, by gross lithology, general stratigraphic trends in this key zone in which complex lateral variations are common. Mudstone was judged to contain less tha 10% sand, interbeds about 50%, and sandstones, 100%. The relative percentage of each lithologic type at known points in the zone determined the iso-sand values.

Areas within the 90% sand contours are interpreted to be fluvial channels within 0.5 m of the top of the coal seam. These channel bodies have been projected into unmined portions of the property. Areas immediately above the coal containing less than 90% sand are usually varying thicknesses of mudstones, siltstones, and thin-bedded sandstones, and represent areas of inter-channel deposition.

The hatched zones bordering the fluvial channels demark the areas affected by differential compaction of finer grained sediments. Zones away from mine openings or outcrop exposures are inferred. The large dots on both maps mark the general location of underground sites experiencing significant roof control problems.

Paleoflow directions (arrows), established from

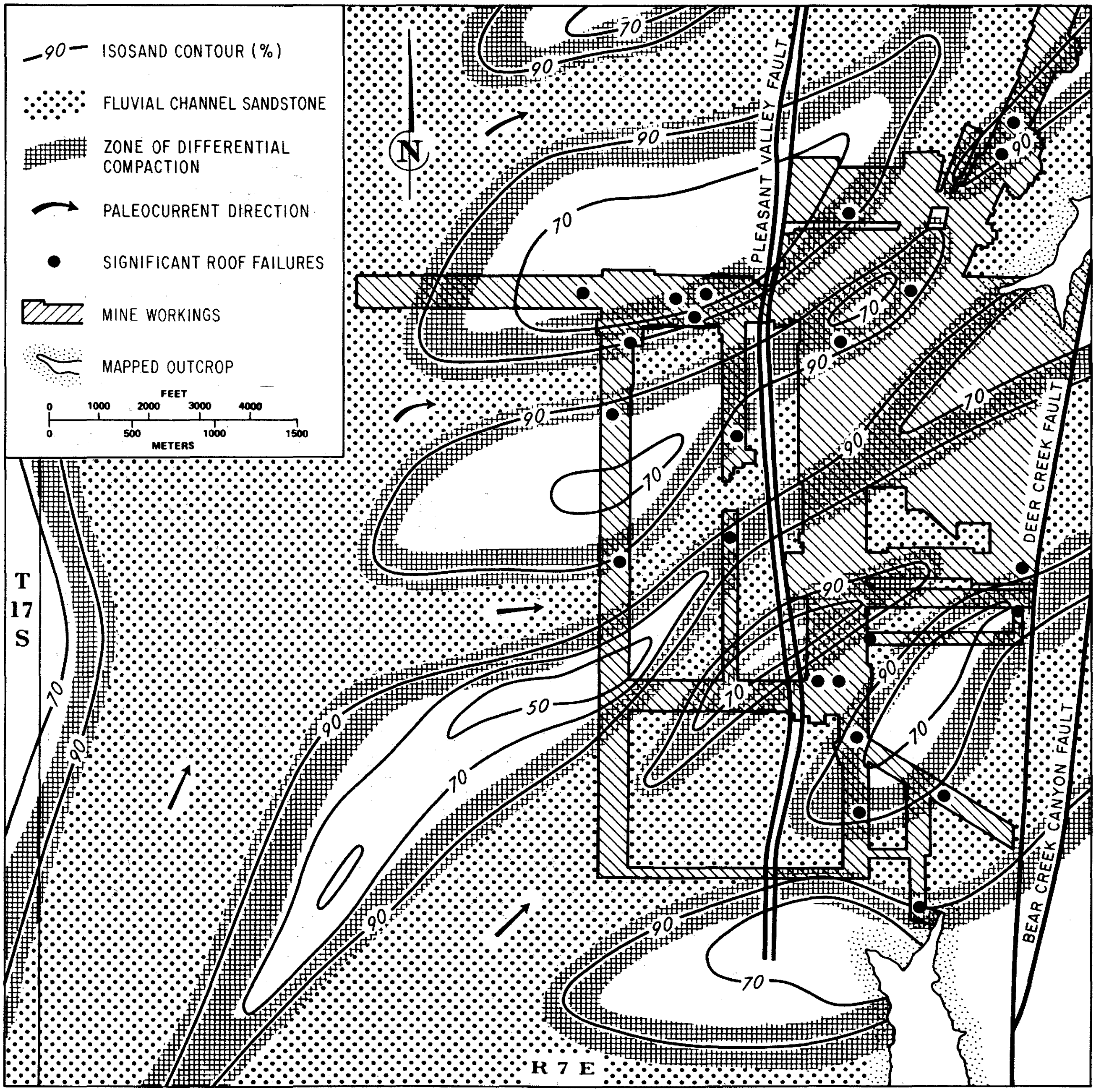


Figure 6. Roof control geology map of the Blind Canyon Seam - Deer Creek Mine (contoured interval is 3 m).

underground and surface exposures, were found to be useful tools for mapping and projecting the trends of the linear channel bodies.

Roof mapping of fluvial channels and associated features reveals these general conditions:

1. A zone of disturbed roof rock up to 150 m wide is found along fluvial channel flanks as shown in figure 7. The roof, is significantly weakened by an increased number of discontinuities caused by differential compaction around the sides of the channel sandstones.

2. A significant increase in water encountered by roof bolting operations is often climaxed by tapping the base of the fluvial channel with a resultant release of large volumes of water for short periods. This is particularly troublesome when found associated with seam undulations described below.

3. The coal seam commonly undulates in broad to

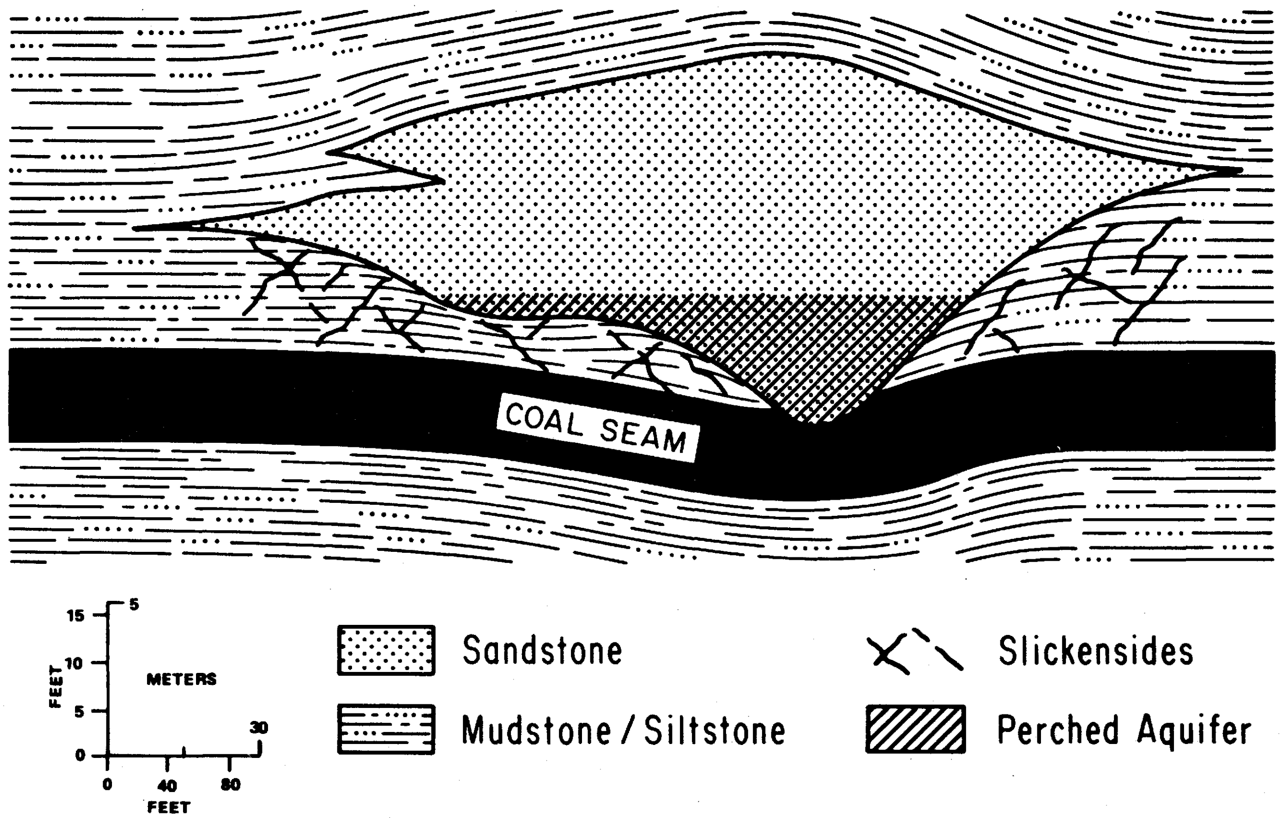


Figure 7. Cross section of Fluvial Channel illustrating commonly associated problem features.

tight rolls beneath the channeled sandstones (figure 7). Severe undulations of the seam are often found with major erosional sandstone rolls directly overlying.

4. Fluvial channels noted in the study area normally displace significant amounts of coal only at old fluvial meander bends, which occur at intervals in the sandstone belts. Where channels do scour into the coal and decrease the mining height, section production may be dramatically reduced and may require special equipment for removal.

Wilberg Mine

Development in the Wilberg Mine is advancing at present under a fairly stable fluvial channel sandstone top. In this area, undulations of the coal seam, possible scouring of the coal, and high water production are to be expected. Wet conditions should be experienced under the dominantly fluvial channelled top between the Pleasant Valley and Deer Creek faults (figure 5).

To the north and northwest of the present mine workings a significant area is immediately overlain by overbank deposits (less than 90% iso-sand value). The roof will become increasingly muddy and weak away from the channels as suggested by the areas of roof control problems shown on figure 5. Zones where differential compaction (shown by hachures) will be encountered may cause periodic problems before and during roof bolting operations. Caving, once started in the overbank mudstones and siltstones, may extend upwards to a competent roof, but will also provide an easily caving top for any longwall panels prepared in this area.

The lack of channel sandstone bodies in the immediate top strata in the northwest area may also provide less water than is being produced in the current mine workings. This could mean a potential water shortage for the two proposed longwall panels.

Deer Creek Mine

Much of the immediate top rock of the Blind Canyon seam contains complexly interconnected fluvial channels (figure 6). Channel trends, are dominantly to the northeast, indicated by numerous paleocurrent structures measured by underground exposures. As would be expected, areas inside the 90% iso-sand contours display generally good roof conditions during room and pillar mining operations. Occasional minor problems are experienced with the thin layer of carbonaceous mudstone, present at the seam's upper boundary, which tends to separate moderately easily from fluvial bases unless carefully supported. A number of rolling channel bases, scouring into the underlying coal, have been exposed by mining, especially in Main West east of the Pleasant Valley Fault, A South, 3rd South, and is 1st South. In each of these locations a combination of the earlier described problem features was associated with roof strata containing fluvial channels.

On the basis of early roof mapping data, two significant channel trends were projected into unmined portions of the Deer Creek Mine: one trend across the projected A South section and the other into the 3rd South section north of the 3rd West workings. Both of the suspected fluvial systems were encountered where expected, and each system had a detrimental impact on section development. In the A South section, the channel scoured almost completely through the coal seam; in 3rd South, undulations of the seam and increased water production significantly hampered regular advance.

Historically, the Deer Creek Mine has long experienced water production far in excess of operational requirements. Figure 6 reveals the source of this water in the fluvial channel bases that may act as perched aquifers and are often tapped during mining operations. The large areas of fluvial sandstone top yet untapped strongly suggest the high water inflow rates will continue for the life of the mine.

Hatched areas shown on figure 6 define actual or suspected zones of differential compaction along the flanks of the fluvial channels in the immediate roof of the Blind Canyon Seam. Locations of roof control problems plotted on the mine works in figure 6 coincide very strongly with zones of differential compaction. Similar and continued roof problems can be expected in the unmined areas in the zones of differential compaction.

In contrast to the Hiawatha Seam roof, overbank/interchannel deposits above the Blind Canyon Seam are limited in occurrence and extent and are strongly elongated between the fluvial sandstone channels. Overbank deposits in the roof may display rapid slaking of mudstones (especially Main West section, west of the Pleasant Valley Fault) or sagging and fracturing of thin interbedded sequences because of a lack of strong roof bolt anchor points. In general, overbank deposits offer inferior roofs for sections requiring access over long periods of time. Overbank deposits in the roof over the present longwall panel cave easily and yield desirable pressure abutment profiles for longwall mining.

COAL SEAM MAPPING

The detailed mapping, measurement and sampling of the coal seams recorded variations in coal lithology, thickness, mineralogical composition, and the occurrence of rock splits. The extensive sampling of the coal has also identified problem coals (coals, which by their composition would require special handling during combustion in power plants.

A variety of contemporaneous channels and rock splits are found in both seams. A large distributary fluvial channel, flowing to the east across the Starpoint Sandstone, creates a discontinuous pattern of coal deposition in the Hiawatha Seam in the north part of the area studied (see figure 5). The limits of this distributary system will have to be carefully defined before planning mine expansion in this area. Much of the data for this definition can be gathered by extensive underground drilling from sites in the Blind Canyon Seam, which is mined out in advance of the Hiawatha. An unexpected paleochannel, which may be related to the large channel to the north, was encountered in the Wilberg Mine Main West entries (figure 8). This feature is approximately 120 m in width and has created considerable anxiety over its possible impact on proposed longwall panels to the north and south. Development mining plans in the overlying Blind Canyon Seam have been altered to facilitate early delineation of this paleochannel by underground diamond drilling.

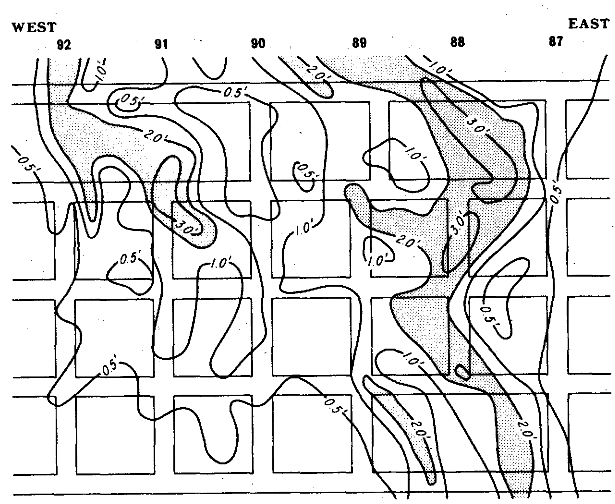


Figure 8. Isopach map of interseam paleochannel - Hiawatha Seam, Wilberg Main West entries.

Rock partings, located in the upper parts of the Hiawatha and Blind Canyon seams, are generally related to the overbank deposits or to shifting of adjacent fluvial channels and may cause roof support problems because they provide poor roof bolt anchor points. Other, generally intermittent, rock or ash bands throughout the seams are likely related to drought and/or fire occurrences during peat deposition. These bands are often used as stratigraphic guides for mining.

FLOOR LITHOLOGIES

The coal seam base or "floor" of the Hiawatha Seam rests on the beach sands of the Starpoint and enjoys the benefits of a solid, homogeneous, well indurated floor. Mining in the Hiawatha Seam advances on floor rock with no problems presented by heaving or muddy road conditions. On the other hand, advance in the Blind Canyon Seam, which has a predominantly muddy substrate of varying thickness, requires the careful exclusion of a basal 0.3 m of coal from mining, where possible, to maintain a useable working floor. Lack of care during mining or later breakthrough of the basal coal, has resulted in a number of rapidly enlarging "mudholes" which disrupt haulage and often necessitate graveling operations. In some areas of the Deer Creek Mine pillar pressures cause squeezing and deformation of incompetent floor rock and of mud bands in the lower part of the seam. In addition, high lateral stresses probably cause local buckling of the floor coal because of the different compressional characteristics of the coal and the "underclay" floor rock. Lateral stresses in both seams generally reflect the local structure with major compressive forces oriented northwest-southeast.

SUMMARY AND CONCLUSIONS

A three-phase investigation of a large two-seam coal property in central Utah which integrated a wide variety of data collecting methods has been successfully used to develop the means for the evaluation and prediction of adverse conditions in advance of mining. The study identifies a number of problem conditions in the underground mines such as: zones of unstable top strata, "wants" or areas of eroded coal, undulation of coal seams, high groundwater inflow rates, and rock splits or bands in coal which can be attributed to specific and predictable lithologic and depositional associations.

Significant conclusions resulting from the investigation include:

1. Coal seam roof strata can be roughly divided into two main lithologies - fluvial channel sandstones and overbank/interchannel deposits. The fluvial channel sandstones form moderately competent roof strata but are often associated with seam undulations, eroded coal, and wet mining conditions. Overbank deposits generally form weak to incompetent mine roofs because of low strengths, exhibit poor bridging characteristics and are in many places lacking in competent roof bolt anchor points.

2. The boundaries between the two lithologic types are commonly differentially compacted over a wide zone. The very strong correlation between existing unstable conditions in the mines and the differentially compacted zones indicates that the areas around the channel margins are potentially the most hazardous underground. Appropriate roof support measures should be implemented and long haulages avoided in these zones.

3. The development of long-term entries in areas containing interchannel mudstone for immediate roof rock should arrange for the exclusion of some top coal from mining to protect the interchannel mudstones from moisture and stress changes. The identification and use of competent roof strata by roof bolters in areas of mudstone or thin bedded tops should be emphasized.

4. While unexpected features may be encountered during future mining in the Blind Canyon Seam necessitating an evolving mine plan, underground diamond drilling on a 150 m spacing from the Deer Creek Mine workings down through the Hiawatha Seam can adequately define depositional patterns in and around that seam allowing for an exact and early depiction of problem areas.

5. In either seam, longwall mining progressing in a north-south direction under a fluvial sandstone top may experience severe cantilevering problems as large sandstone blocks fail differentially between north-south joint fractures.

6. Water production in the Wilberg Mine may decrease as mining progresses to the northwest and enters a large area lacking sandstone aquifers in the roof strata. The Deer Creek Mine will probably continue to experience wet conditions due to the presence of numerous fluvial channels in the immediate top strata of the Blind Canyon Seam.

7. A troublesome paleochannel appearing at midseam in the Wilberg Mine may be related to a large contemporaneous distributary channel to the north in the Hiawatha Seam. This feature should be traced and evaluated by drilling from the overlying Blind Canyon Seam.

8. Floor lithologies in the two mines are quite different and can result in radically different haulage

conditions.

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