August 9, 1982

Memo to File:

RE: West Appa Coal Company
Exploration Drilling
CEP/015/002
Emery County, Utah

On August 5, 1982, Tom Tetting, Cy Young, Barton Kale and Mary Boucek of the Division inspected planned drilling sites and sites of seismic exploration by West Appa Coal Company on East Mountain. They were accompanied by Jerry Vaninetti, Norwest Resource Consultants, Inc., who is in charge of exploration for West Appa.

Planned drill sites R1 and R4 are located in State Section 36, T. 16 S., R. 6 E. Northwest Carbon Corporation had originally (and unsuccessfully) drilled these sites during 1980-81 but has since cancelled their plans to open a coal mine in Rilda Canyon and has assigned rights to West Appa. The latter plans to drill five holes on East Mountain, including the aforementioned and three others, those being R3 in Section 31, T. 16 S., R. 7 E. (federal lease) and R5 and R6 in Section 32, T. 16 S., R. 7 E. (federal land).

During the inspection, it was noted that old drill sites R1 and R4 had been properly regraded but had not been revegetated by Northwest Carbon Corporation as was supposed to have been done. It is assumed that the other drill sites have not been revegetated either. Most of these previously disturbed sites will be redisturbed by West Appa during drilling operations; however, R4 will be relocated somewhat north of the present disturbance. On August 9, Mary Boucek contacted Leonard Witkowski of West Appa to question whether his Company had any agreement with Northwest Carbon concerning revegetation of these sites. Mr. Witkowski said that West Appa had agreed to reclaim (including revegetation) all drill sites previosuly disturbed by Northwest Carbon in Sections 31, 32, T. 16 S., R. 7 E., and Section 36, T. 16 S., R. 6 E.

MARY M. BOUCEK
RECLAMATION BIOLOGIST

cc: Allen Klein, OSM
Tom Tetting, DOGM
Joe Helfrich, DOGM
File INA/015/004, Northwest Carbon Corporation

MMB/btb

Statistics:

Vehicle: #EX 45428--330 miles
Per Diem: 4 people x 1 day = $203.12
Grant: A & E

Utah Geological and Mineral Survey, Bulletin 118, 1982
Proceedings — 5th ROMOCO Symposium, 1982

HIGH-RESOLUTION SEISMIC: A PRACTICAL APPROACH TO COAL EXPLORATION

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INTRODUCTION

The use of high-resolution seismic survey has been extremely effective in defining the geologic structure and stratigraphy of a developed coal property located within the Wasatch Plateau Coal Field, Emery County, Utah (Figure 1). The coal property, which is the East Mountain property owned by Utah Power and Light Company, contains five underground coal mines that collectively produce about 4 million tons of coal annually.

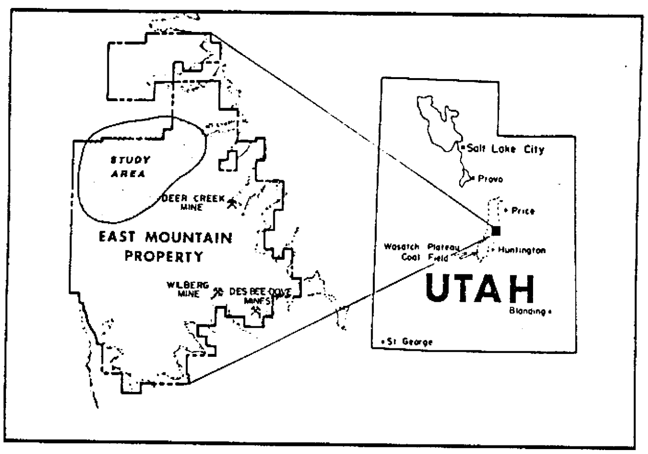

Figure 1. Location of study area.

The high-resolution seismic surveys were conducted in 1980 and 1981 to define the geologic structure in areas where data collected by geologic mapping and drilling resulted in questionable interpretations regarding the geologic structure. These surveys produced data which allow the identification of the geologic structure, the continuity and thickness trends of the coal seams present, and the location of fluvial channel sandstones superimposed on these coal seams.

GENERAL GEOLOGY

The coal seams present within the East Mountain property are located within the deltaic upper Cretaceous Blackhawk Formation. Two minable coal seams have been identified by mapping and drilling. These seams are the Hiawatha, which rests on the Starpoint Sandstone, and the Blind Canyon, which is located about 80 ft above the Hiawatha seam (Figure 2).

The coal seams within the property are covered by a regressive continental sedimentary sequence which is about 2,200 ft thick. The strata immediately above the coal zone consists of interbedded mud, silt and sandstones. The Blackhawk Formation is approximately 700 ft thick and generally coarsens upward. The fluvial Castlegate sandstones rests sharply on top of the Blackhawk Formation. This unit consists of fine to medium-grained well-sorted sandstone and is 200 ft thick. The Price River Formation which conformably overlies the Castlegate Sandstone is comprised of medium to coarse-grained sandstones with subordinate amounts of pebble conglomerates and mudstones. This unit averages approximately 500 ft in thickness. The Price River Formation is overlain by the North Horn Formation. Mudstones and siltstones comprise the majority of the North Horn strata but sandstones and limestones are also present, particularly near the top of the formation. The thickness of the North Horn Formation averages 700 ft. The youngest formation found within the property is the Flagstaff Limestone.

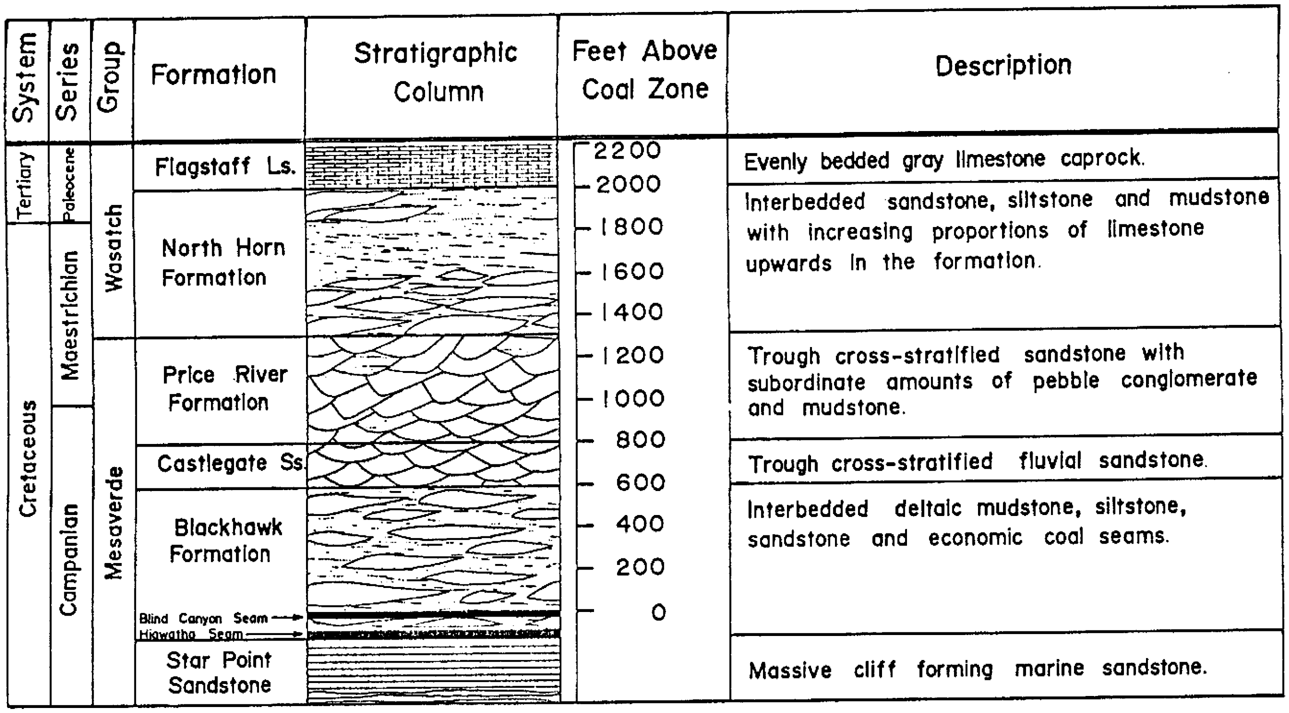

Figure 2. Stratigraphic section-east mountain.

An erosional remant of the lower 200 ft of the limestone caps the top of the East Mountain area.

The sedimentary rocks present have been cut by a series of north-south trending faults. An early investigation of the area documented the location and extent of these faults and is now considered to be a classic work of the stratigraphy and structure of the Wasatch Plateau Coal Field (Speiker, 1931). Generally, the faults mapped by Speiker are easily recognized on outcrop, particularly where they intersect the steep cliff escarpments flanking the eastern edge of the Wasatch Plateau.

A fault trending in a northeast direction has been identified in the northern portion of the property. Geologic mapping failed to produce data regarding the fault's displacement or lateral extent because of the lack of outcrops in that area.

The Straight Canyon syncline, a northwest trending structural feature, crosses the northern portion of the East Mountain property. The axis of the syncline roughly coincides with the north-east trending fault previously mentioned.

Prior to conducting the seismic surveys, the geologic structure was interpreted as shown in Figure 3. Although the interpretation was based on data collected from drill holes spaced roughly on .5 mi centers, aerial photo interpretation, and geologic mapping, many questions were left unanswered in the area of the syncline. The lack of outcrops in this area plus the fact that a fault was identified but its displacement could not be determined from the available data forced the Utah Power and Light Company to investigate this area using high-resolution seismic techniques.

SEISMIC SURVEYS

The primary objectives of the seismic surveys were to: 1) identify the displacement of the northeast trending fault at the depth of the coal seams, 2) locate any additional faulting present, and 3) substantiate the continuity of the coal seams adjacent to the fault zone. To accomplish these objectives, seismic data

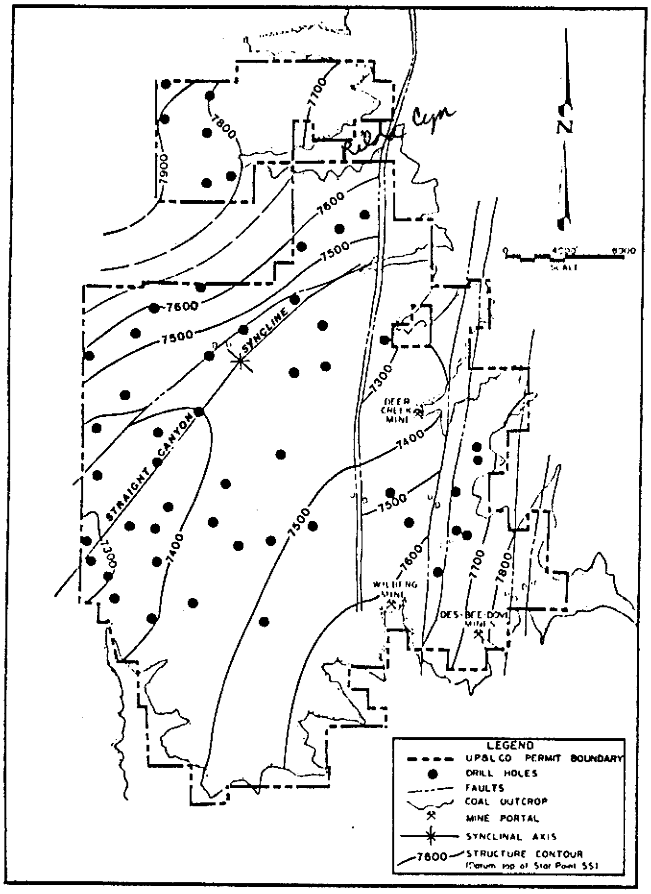

Figure 3. Preseismic structural interpretation.

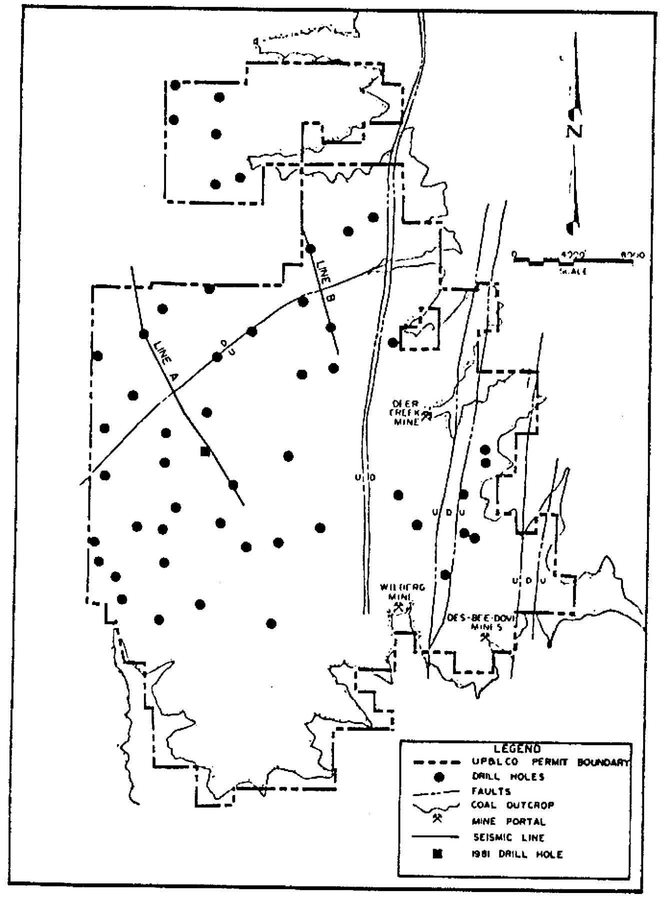

Figure 4. Location map-seismic lines.

were collected on two lines (Figure 4): one in 1980 (Line A), and in 1981 an extension made to that line as well as the implacement of a second line (Line B). The location of these lines was chosen based on the presence of coal exploration drill holes (used for interpretation control points) located at each end of the lines and viable access routes along the lines.

The seismic work was performed by Engineering Specialties, Inc., Conroe, Texas, under the direction of Emerald Exploration Consultants, Inc. The data processing was performed by Applied Research Concepts, Houston , Texas. These companies were chosen because of their proven expertise in high-resolution seismic data collection, processing and interpretation.

Data collection - The seismic data was collected using a Texas Instrument DFS-V seismic recorder which was mounted in a four-wheel drive vehicle. This system was capable of recording on 48 channels simultaneously. Each channel was connected to a series of six or twelve high-resolution Mark Product MP-L-28E geophones. These instruments were used to collect seismic data using the common depth point "CDP" method.

Prior to collecting the seismic data the energy source parameters had to established. To do this, shot holes four inches in diameter and 160 ft deep were drilled at each end of the Lines A and B. Tests were performed on both lines due to the variation in near surface rock characteristics. Line A was located stratigraphically on top of the Flagstaff Limestone while Line B was located in the upper part of the Price River Formation and lower part of the North Horn Formation. After drilling the holes, several one and five pound explosive charges were then placed at various intervals within the holes. As these charges were fired one at a time, data were recorded by the spread of geophones placed on the ground. This work demonstrated that a five pound explosive charge located at a depth of 60 ft would provide optimum results on both lines. However, on Line B it was determined that a three pound charge located at a depth of six feet would also produce adequate data. The shallow holes would not work on Line A because the Flagstaff Limestone on the surface required a deeper energy source to achieve acceptable reflected signals.

In addition to establishing the source parameters, measurements were also taken of the time required for the direct arrival of acoustic waves from the shot to a geophone on the surface immediately above the shot point. This information, termed the uphole time, relates to the velocity of the near surface strata, and was utilized in the data processing and interpretation stages.

After establishing the source parameters shot holes were drilled on the various lines. The shot holes on Line A were drilled on 100 ft intervals to a depth of 60 ft over the south half of this line and loaded with five pound charges (after initial data were collected on this line it was determined that the shot hole interval could be increased to 200 ft without sacrificing the quality of the data). Shot holes on the north half of Line A were completed at 200 ft intervals. These shot holes were drilled with a truck mounted Garner-Denver 1,000 drill rig.

On Line B shot holes were drilled in groups of three, with each hole spaced 25 ft apart. The center hole in each group was located at the surveyed shot point stations which were located at 100 ft intervals. These holes were drilled six feet deep and loaded with a one pound explosive charge. Much of this line was located in areas of rugged, roadless terrain. The shot hole drilling was done using an all-terrain vehicle mounted auger drill, where access permitted, and a hand-held gas-powered auger in the more rugged terrain.

Following the completion of the shot holes the seismic data were collected on the various lines using 50 ft trace spacing with a geophone array spread over 25 ft. On the south half of Line A the array consisted of six geophones. On the north half of Line A and all of Line B, 12 geophones made up the array. This array pattern was selected as a compromise between the desire for a long array or traces for noise reduction (by cancelling waves traveling along the surface) and a short array which provides maximum resolution. As the shots were fired the geophone arrays, 24 on each side of the shot point, spaced 50 ft apart, sensed the incoming acoustic wave and transmitted the data to the recorder where it was stored on magnetic tape. Before the next shot was fired some geophone arrays on one end of the line were dropped from the system and new arrays were added on the other end of the line. This was done from the recorder truck with the use of a roll-along switch and was necessary to maintain 24 geophone arrays on each side of the shot point. This procedure continued until all shot points had been fired.

Where the shot points were spaced on 100 ft intervals the data were collected twelve-fold, or in other words, events were recorded on each trace from twelve different shot locations. Where the shot points were located on 200 ft intervals the data were collected six-fold. The number of fold is a function of the number of traces being recorded, the shot point interval, and the trace spacing interval.

Data Processing - In recent years the seismic exploration industry has developed many computer software programs used to manipulate, mathematically adjust, and graphically plot seismic data. The processing of the quantity of data collected in this project would be impossible without the use of this computer technology. In all, ten processes were applied to the data collected which include: 1) demultiplexing, 2) CDP gathering, 3) filtering, 4) deconvolution 5) velocity analysis, 6) normal moveout correction, 7) mute, 8) stacking, 9) constant datum, and 10) equalization. A detailed description of the function performed by each individual step is beyond the scope of this report but can be found in other publications (Claerbout, 1976).

In the previous section on data collection, a discussion was made about the data being collected twelve and six-fold. In processing this data, many of the steps apply correction factors and manipulate the data so that when twelve or six traces are stacked together, the individual reflectors become superimposed. This produces reflectors that are amplified and the noise or meaningless data which stack randomly are cancelled.

Throughout the data processing the result of each intermediate step was examined carefully to ensure maximum data resolution at the depth of the coal seams. If a computer process is applied to the data incorrectly, the resolution of the data would be reduced. On the other hand, correct application of a process such as filtering can increase data resolution significantly. The higher frequency energy yields better resolution at shallow depths than do lower frequencies. The converse is true for deeper reflectors. By using filters to enchance the correct frequencies of recorded data, a high degree of resolution can be achieved at the depth of interest.

After all the data processing had been completed a final seismic profile can be made (Figure 5). The seismic profile is a graphical representation of processed data with the various traces plotted on the x-axis and the function of time plotted on the y-axis. Because the vertical position of a reflector is a funtion of its depth and the velocity the acoustic wave travels through the strata, the profile should not be interpreted the same way as a geologic cross-section.

Synthetic Seismograms - Unless the reflections shown on a seismic profile can be correlated to the various strata they represent, the profile is useless. An effective method to correlate the two data sets is to generate synthetic seismograms of control points, such as drill holes, located along the line. In this study, synthetic seismograms were developed using data from drill holes located at each end of both lines in addition to sonic velocity logs from nearby drill holes.

In compiling a synthetic seismogram of a drill hole, it is best to have a detailed lithologic log and a full suite of geophysical logs including sonic velocity and density. The synthetic seismogram is developed by a computer process that determines the reflection coefficient of the interface between the lithologies having different sonic velocities. This coefficient is further processed to generate a synthetic seismogram which should resemble the traces on the seismic profile at the drill hole location.

If hypothetical data are incorporated in a synthetic seismogram, for example, changing the thickness of the coal seam, the effect of that change can be observed. This procedure, synthetic seismogram modeling, was found useful in estimating coal thickness trends during the data interpretation phase of this study.

Data Interpretation -The data collected from the seismic surveys of the two lines produced profiles which show several reflectors: some are laterally continuous and some are intermittent. Figure 6 is the seismic profile in the central portion of Line A. The synthetic seismogram indicates that the reflectors shown at 0.35 and 0.37 seconds on the profile are the Blind Canyon and Hiawatha seams respectively.

The lateral termination of reflectors representing coal seams is interpreted as fault locations (Figure 6). Other reflectors are also useful in locating the faults such as the ones at 0.30, 0.64 and 1.15 which are interpreted as the tops of the Blackhawk Formation, Emery Sandstone and Ferron Sandstone, respectively. Similar interpretations can be made from the remaining portions of Line A and B.

A depression on the reflection representing the Blind Canyon seam on Figure 6 between traces 285 and 295 can be observed. This depression which coincides with an overlying lens-shaped reflector is interpreted as a fluvial sandstone channel. Data from adjacent drill holes support this interpretation.

By incorporating the seismic data with the data supporting the pre-seismic structural interpretation (Figure 3), a significantly different interpretation was made (Figure 7). The seismic study identified eight faults with displacements ranging from 20-180 ft. These faults were part of two graben systems not previously identified. In the pre-seismic structural interpretation the variation in coal seam elevation detected in drill hole data was assumed to be the effect of the Straight Canyon syncline. The seismic data proved this theory incorrect.

Synthetic seismogram models which represent different scenarios of coal thickness for the Blind Canyon and Hiawatha seam are shown in Figure 8. By carefully comparing changes in the character of the hypothetical reflections (Figure 8) with the Blind Canyon and Hiawatha seams (Figure 6), a general estimate of coal thickness trends can be made. The only significant discrepency found between the thickness estimations based on seimsic and drill hole data was at a point located in the southern portion of Line A. The seismic data indicated a thickness of 7.5 ft for the Hiawatha seam, but the drill hole data indicated a thickness of 2.5 ft. This point was centered between three drill holes located approximately one-half mile away. In the fall of 1981, a drill hole was completed in that area (Figure 4). The Hiawatha seam in that hole was measured to be 6.5 ft thick, one foot less than the seismic estimation.

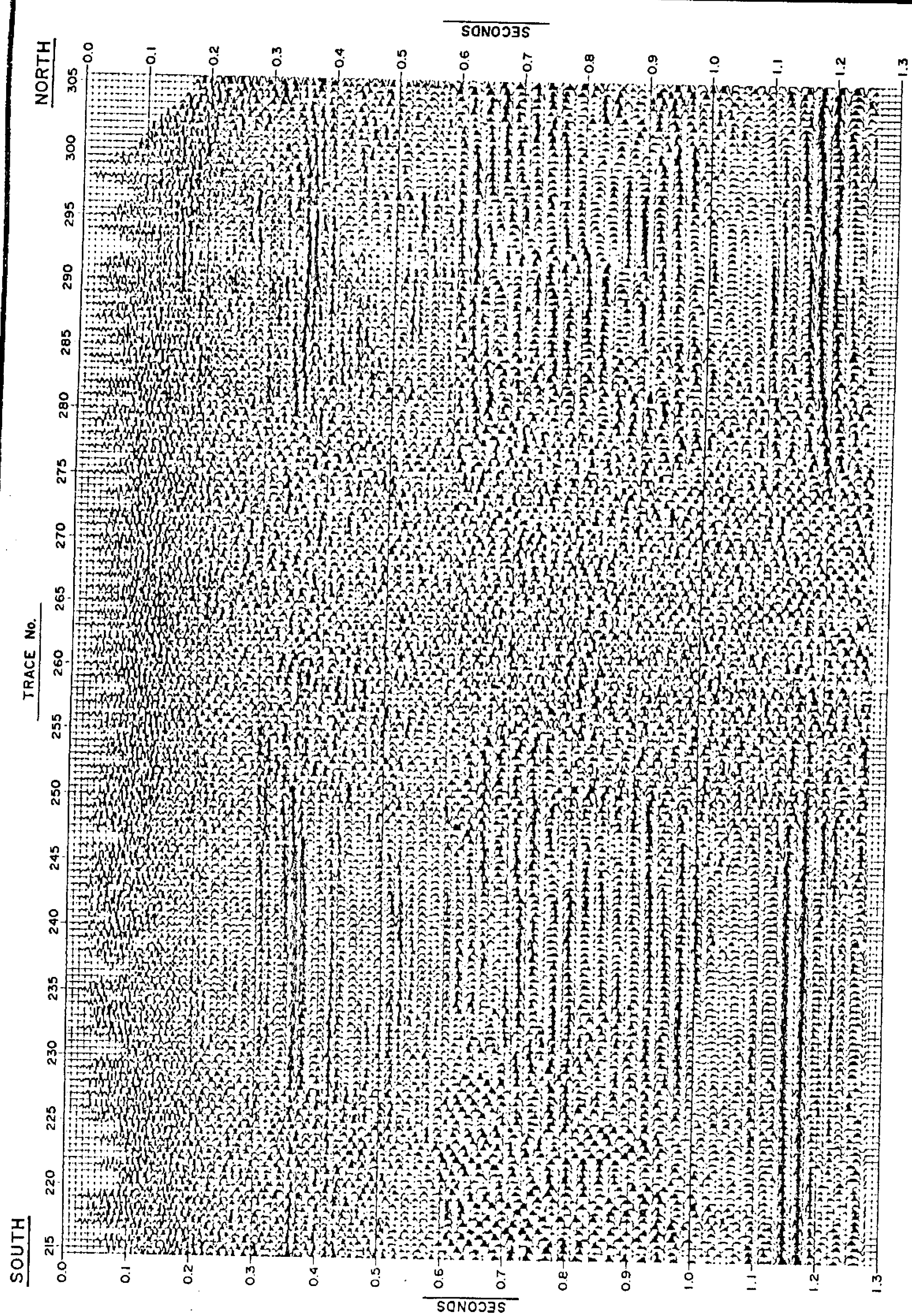

Figure 5. Seismic profile (central portion of line "A").

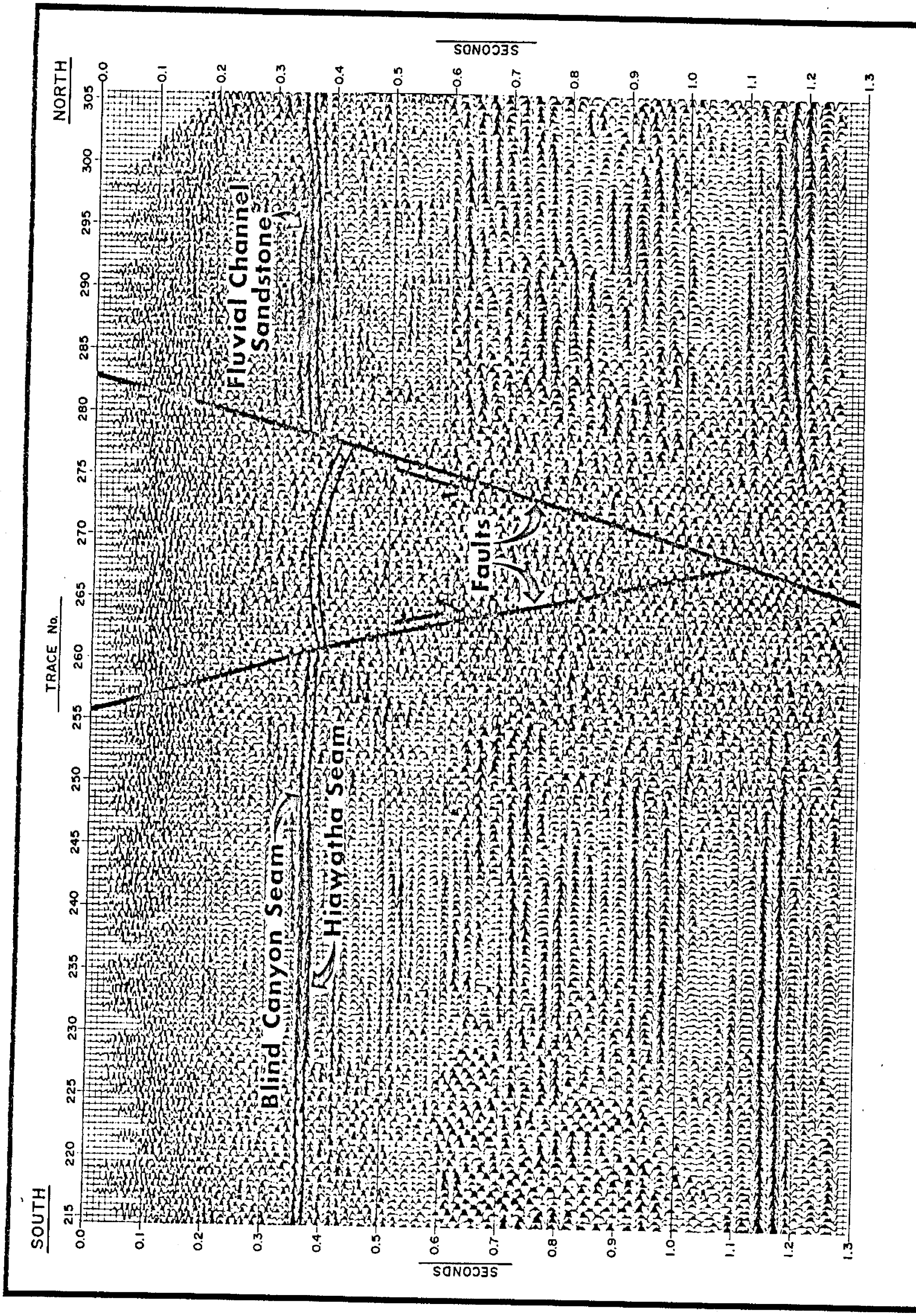

Figure 6. Interpreted seismic profile (central portion of line "A").

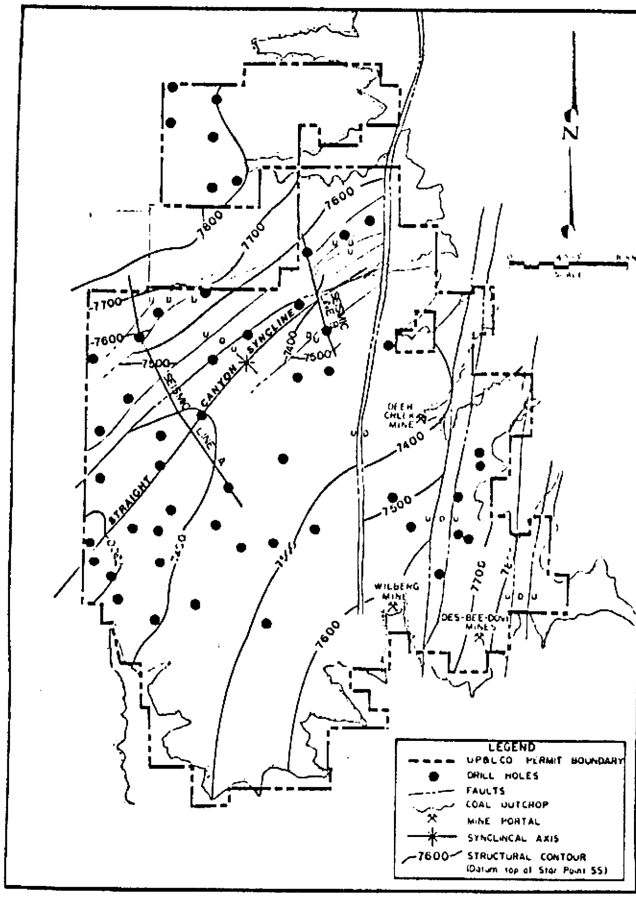

Figure 7. Postseismic structural interpretation.

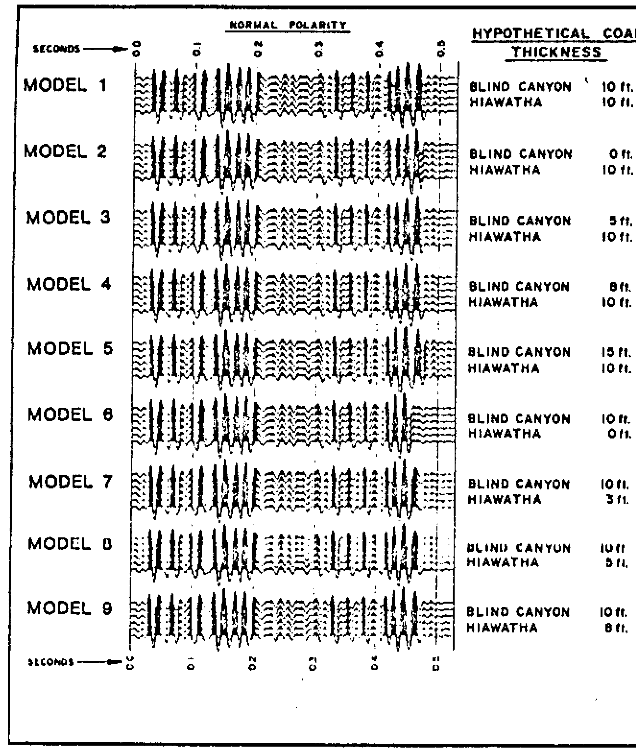

Figure 8. Synthetic seismogram models.

SUMMARY

High-resolution seismic surveys were effectively applied to the exploration of a coal property in central Utah. By utilizing this exploration method a better understanding of a complex geologic structure was accomplished. The method was also proven successful in the estimation of coal thickness trends and in identifying fluvial channel sandstones overlying the coal seam. These interpretations made an important contribution to mine planning.

ACKNOWLEDGEMENTS

The author wishes to thank the crews of Engineering Specialities, Inc., who collected the seismic data. Special thanks are given to the staff of Emerald Exploration Consultants, Inc. for their contributions in supervising the data collection and interpretation of the seismic information. It is through cooperation of the management of Utah Power and Light Company that the opportunity to publish this study is available. Appreciation is given to Robert Webster and Scott Child for preparation of the illustrations and editing suggestions made.

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