Explor97 Master Page | Author Index
Explor97 Contents | Section Contents
Previous Paper
GOTO

Seismic/Borehole Mapping of an Abandoned Coal Mine, Scott Air Force Base, Illinois

Anderson, N.[1], Shoemaker, M.[1], Lambert, D.[2], Roark, M.[1], Baker, J.[1], and Hinds, R.[1]

1. Department of Geology and Geophysics, University of Missouri-Rolla, Rolla, Missouri, U.S.A.
2. Geotechnology, Inc., St. Louis, Missouri, U.S.A.

ABSTRACT

Old mine location maps (1958 vintage) indicate that the northwestern part of an undeveloped property near Scott Air Force Base (SAB), St. Clair County, Illinois, is situated above an abandoned and now water-filled, room-and-pillar type coal mine. The central and southeast parts of the SAB property are shown as overlying intact (non-mined) coal. The coal unit mined at the SAB site, the Herrin #6 is Pennsylvanian in age and about 2.5 m thick at a depth of around 40 m.

The current owners of the SAB property want to construct a large building on the central and southeast parts of the site, but have been concerned about the accuracy of the old mine location maps because of recent mine-related surface subsidence in areas designated on the maps as not mined. To ensure that the proposed new development is located on structurally stable ground, a grid of ten high-resolution reflection seismic lines was acquired on-site. On these reflection seismic data, mined-out areas can be visually identified and differentiated from non-mined areas. Interpretation of the reflection seismic data was constrained and validated by 15 test boreholes. These seismic and borehole data confirm that the central and southeast parts of the property have not been mined extensively. Development of the SAB site has proceeded with confidence.

INTRODUCTION

The owners of an undeveloped property (approximately 300 m by 375 m) near Scott Air Force Base (SAB), St. Clair County, Illinois (Figure 1) want to erect a large non-residential building on-site, but have been concerned about long-term structural stability because of recent and substantive, mine- related surface subsidence in the general area.

To determine whether their property was suitable for development, the owners initially reviewed old (1958 vintage) regional mine location maps. These maps indicated that coal mining activity was restricted to the northwestern section of the SAB property, and that there was sufficient room to erect the planned building on areas designated as non-mined (central and southeast parts of the site; Figure 1). While the old mine map were encouraging (with respect to the suitability of the property from a developmental perspective), there was concern about their reliability because surface subsidence has occurred in areas designated on the old mine location maps as not mined (Figure 1).

To establish conclusively whether the central and southeast area of the property was structurally sound and suitable for development, a grid of ten high-resolution reflection seismic lines was acquired across the site and 15 test boreholes were drilled (Figure 1). These seismic and borehole data established that the central and southeast areas of the SAB site have not been mined extensively. The conclusions are that mine-related surface subsidence will not occur in these areas and that they are suitable for development from the perspective of long-term structural stability.

GEOLOGIC AND MINING BACKGROUND

Herrin #6, the coal unit mined in the SAB study area, is stratigraphically situated within the Pennsylvanian Carbondale Group (Figure 2). Locally, the Herrin #6 unit attains thicknesses on the order of 2.5 m, at a depth of about 40 m (Figure 2; Smith, 1958). In the study area, the Carbondale Group is overlain by the Pennsylvanian McLeansboro Group (bedrock unit), about 7 m of till, and about 9 m of unconsolidated alluvium (Figure 2).

In the SAB study area, the Herrin #6 coal was mined using room and pillar techniques. Initial room heights were on the order of 3 m. However, present-day room heights are variable because of post-mining processes

In "Proceedings of Exploration 97: Fourth Decennial International Conference on Mineral Exploration" *edited by* A.G. Gubins, 1997, p. 965–968

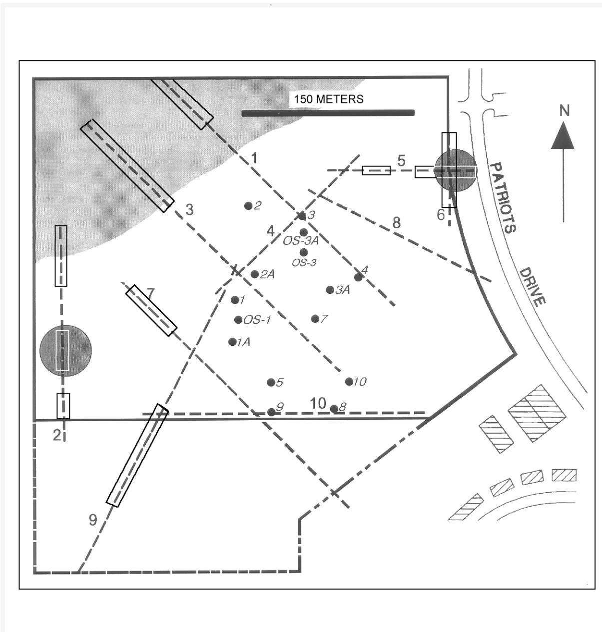

Figure 1: *Map of the SAB study area (after Smith, 1958). Areas denoted on old (1958 vintage) regional mine location maps as mined-out have been highlighted. The locations of the reflection seismic lines, the test boreholes, areas of recent surface subsidence, and areas interpreted as mined-out are also shown.*

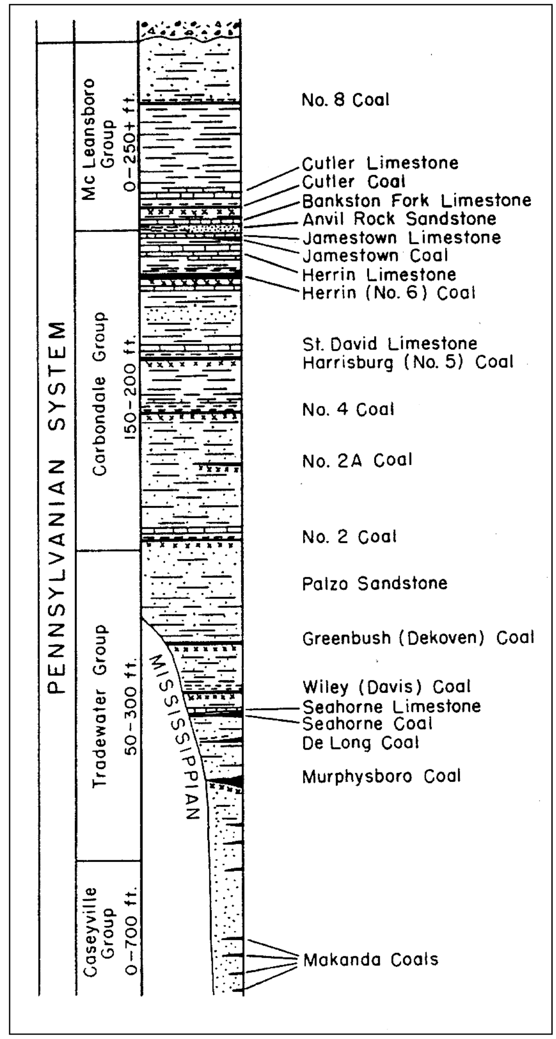

Figure 2: *Generalized section of Pennsylvanian rocks in Jackson, Perry, Randolph, and St. Clair counties, Illinois (after Smith, 1958); top of the Pennsylvanian McLeansboro Group*

including floor buckling, the crushing of pillars, and roof failure. In places in the SAB area, these processes have resulted in the gradual to catastrophic collapse of post-coal strata and surface subsidence (Figure 1).

COREHOLE CONTROL

To constrain the interpretation of the reflection seismic data, 15 boreholes were drilled into the SAB site (Figure 1). All of the boreholes, except #3, encountered intact Herrin #6 coal. Borehole #3 was drilled into a mined area and encountered less than a meter of void. Drilling was terminated at the base of the void and cuttings were not extracted.

Bedrock elevation at the borehole sites (Figure 1) varies by 8 m in the study area, from a high of 123.5 m (borehole #1) to a low of 115.5 m (borehole #5). Intact Herrin #6 coal was encountered in all boreholes (except #3) indicating that structural relief at bedrock (at the test borehole sites) is erosional or tectonic in origin (as opposed to differential mining-related subsidence). Mining activity did occur at the borehole #3 site, however bedrock is relatively high (122.8 m) compared to 122.6 m in adjacent boreholes #OS-3A and OS-3 indicating that there has been little, if any, mining-related subsidence of bedrock at borehole #3.

The elevation of the top of the Herrin #6 coal at the borehole locations varies by 3 m, from a high of 100.1 m (borehole #OS-1) to a low of 97.1 m (borehole #10). Estimated coal thicknesses (based on cuttings and drill rates) vary between 1.5 m and 2.5 m. The top of the 0.6 m high void (borehole #3) was encountered at 99.8 m. This value is not anomalous indicating that there has been little, if any, subsidence of the roof rock at this site. It is unfortunate that borehole #3 was not extended below the void. If the void is underlain by one or more meters of coal, the inference would be that the coal was not completely mined-out at this location, and that neither appreciable roof caving or subsidence, nor floor buckling has occurred.

REFLECTION SEISMIC DATA

To ensure that the southeast and central parts of the SAB property were not mined (and therefore suitable for development), a grid of high-resolution reflection seismic data was acquired using a 24-channel Bison seismograph with roll-a-long capabilities, single 40 hz geophones, and a Bison EWG weight drop source. The source was impacted six to ten times at each shotpoint, dependent upon visual inspection of background noise on the shot gathers. These nominally 12-fold data were acquired using source and receiver spacings of 3 m, and a near-offset of 6 m.

A standard processing runstream was applied to the data except that the ground surface was relatively planar, and elevation corrections were not applied. The processing routine consisted of: muting the first breaks and excessive ground roll, resorting the shot gathered traces into common midpoint (CMP) gathers, determining appropriate velocity/time functions along the seismic traverses, calculating and applying surface consistent statics, applying normal moveout (NMO) corrections to CDP gathered traces, stacking the NMO corrected data, applying residual statics, restacking statically corrected data, bandpass and F-K filtering of data.

In Figures 3 and 4, uninterpreted and interpreted versions of reflection seismic line 1 is presented, respectively. These data are interpreted as zero-phase and normal polarity. Borehole depths and stacking velocities were used to constrain the interpretation of these reflection seismic data.

Several prominent reflectors are interpreted on the reflection seismic profiles of Figure 4. The event labeled P represents the reflection from bedrock (base alluvium/top Pennsylvanian strata; Figure 2). The events (peaks) labeled C and S are the reflections from the tops of the Cutler Limestone and St. David Limestone, respectively. Event M (peak) is the reflection from the top of the Mississippian unconformity. The event (peak) labeled B is interpreted as the base of the mined zone (void or base rubble), and is present only where mining has occurred.

As indicated on the interpreted version, mining activity occurred beneath two segments of line 1 (between traces 70 and 85, and from trace 162 to the end of the line and beyond). Mining activity between traces 70 and 85 is confirmed by borehole #3 (Figure 1). Mining activity north of trace 162 is consistent with the old mine location maps. Boreholes #OS-3A, #OS-3 and #4 support the interpretation that mining activities did not occur elsewhere along the length of seismic Line 1.

The seismic image of the subsurface, in areas that were not mined (south of trace 70, and between traces 85 and 162), is characterized by a sequence of four prominent, high-amplitude, laterally continuous peaks (P, C, S, M) representing reflections from the tops of bedrock, Cutler Limestone, St. David Limestone, and Mississippian unconformity, respectively. Where mining has not occurred, events C and S are separated by the reflection (trough) from the top of the Herrin #6 Coal.

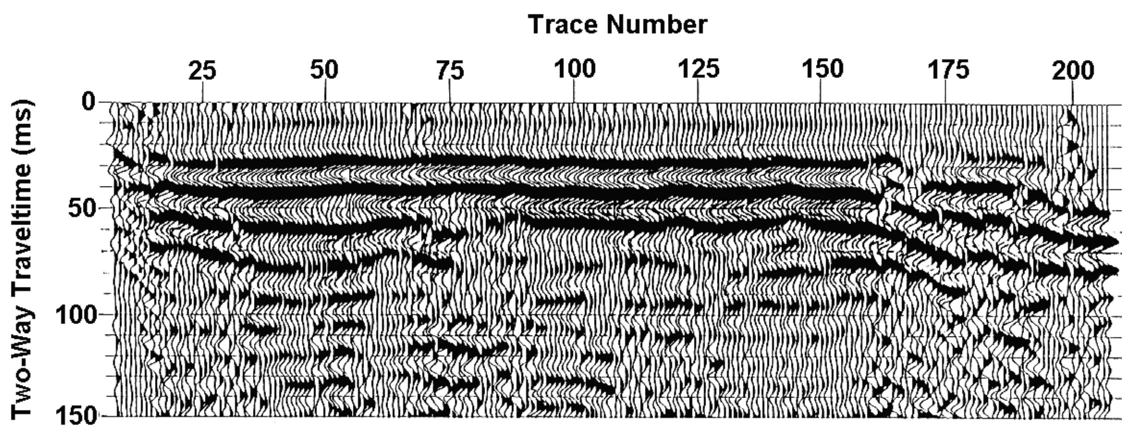

Figure 3: *Uninterpreted version of reflection seismic line 1.*

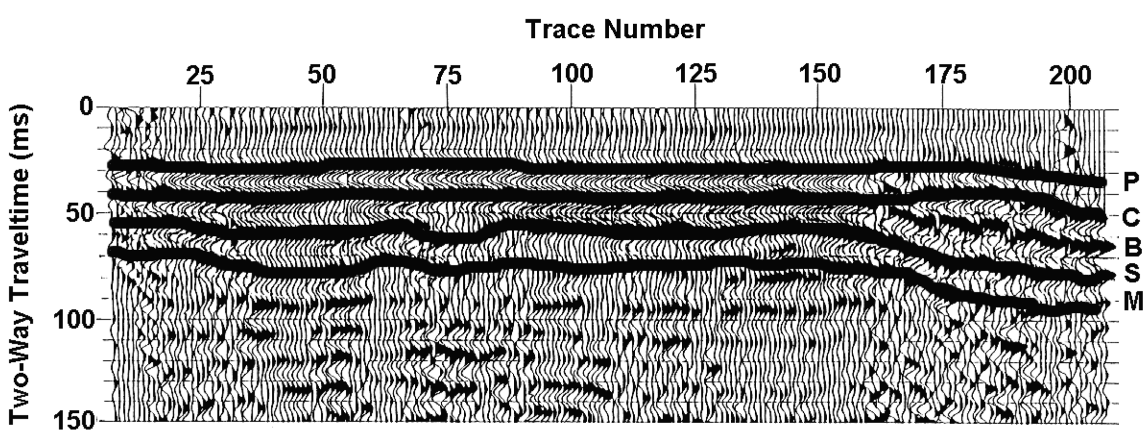

Figure 4: *Interpreted version of reflection seismic line 1.*

Areas that have been mined (traces 70-85, and north of trace 162), are characterized by a sequence of five peaks (P, C, B, S, M). Event B is the reflection from the base of the mined zone (void or base rubble), and is separated from event C by the reflection (trough) from the present-day base of intact rock (above the mined zone; i.e., void or rubble zone). Note that in places (traces > 195) events P and C are anomalously time-structurally low (about 5 ms) beneath mined areas (relative to non-mined areas), and dislocated in places. These time-structural and character anomalies are consistent with bedrock subsidence on the order of 2 to 3 m, in response to the collapse of the mine rooms.

The S (St. Peter's Limestone) and M (Mississippian) events are also anomalously time-structurally low beneath mined areas. This time-structural relief is not attributed to real structure, rather events S and M are interpreted to be "pushed down" beneath mined areas. The relative time-structural low (along events S and M) between traces 70 and 85 (on the order of 4 ms), for example, can be attributed partially (?~ 1.5 ms or about 30%) to the velocity contrast between remnant coal (V_p ~ 2500 m/s) and the 0.6 m void (V_p ~ 700 m/s). However, it must be caused also by processes such as caving, stress fracturing of the post-mine strata and/or the buckling of the floor. If the original mine ceiling had caved, there could be several meters of low velocity rubble beneath the void. Similarly stress fracturing or buckling would reduce the acoustic velocity of the strata above and below the mined zone, respectively. The relative time-structural low (on the order of 15 ms at the S and M levels north of trace 162) can also be attributed partially (? 8 ms or about 65%) to the velocity contrast between remnant coal (V_p ~ 2500 m/s) and a postulated 3 m void (V_p ~ 700 m/s). However, it must also be partially caused by processes such as caving, stress fracturing of the post- mine strata and/or the buckling of the floor.

Reflection seismic Lines 2 through 10 were interpreted in a similar manner. These data confirm that although the old mine maps are inaccurate in places, and that the central and southeast areas of the SAB property were not extensively mined. Areas along the lengths of the reflection seismic profiles that are interpreted as mined, are denoted in Figure 1. For the sake of clarity, the mined area at borehole #3 (on Line 1) has not been highlighted.

SUMMARY

A grid of ten high-resolution reflection seismic lines and 15 test boreholes were acquired on the SAB property with a view to differentiating mined and non-mined areas. The investigations were successful. Mined-out areas were identified and differentiated from non-mined areas, and the central and southeast parts of the site were determined to be suitable for development. The seismic and borehole data also confirmed the owner's suspicions regarding the accuracy of the old (1958 vintage) mine location. As evidenced by Figure 1, the old mine maps are regional with respect to detail, and are not suitable for specific detailed site evaluations.

REFERENCES

Smith, W. H., 1958, Strippable coal reserves in Illinois, Part 2—Jackson, Monroe, Perry, Randolph, and St. Clair counties: Illinois Geologic Survey Circular 260, 35p.