Reflection Seismic and Ground-Penetrating Radar Study of Previously Mined (Lead/Zinc) Ground in Joplin, Missouri

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ABSTRACT

A geophysical survey was conducted for the Missouri Department of Transportation (MoDOT) across previously mined (lead/zinc) ground along a proposed interstate route near Joplin, Missouri. A total of 6 000 m of high-resolution reflection seismic data, 3 000 m of ground-penetrating radar (GPR) data, and nine seismic check shots were acquired.

The geophysical survey was successful. It established that high-resolution reflection seismic data can be used to identify and map bedrock structure, abandoned mine access shafts, paleosinkholes, and areas of probable shallow mining activity, and that surface shafts can be located using GPR, even where such shafts are overlain by a thin veneer of surficial "chat".

INTRODUCTION

A geophysical survey was conducted for the Missouri Department of Transportation (MoDOT) across previously mined (lead/zinc) ground along a proposed interstate route (Alternate "E") near Joplin, Missouri. In total, 6 000 m of high-resolution reflection seismic data, 3 000 m of ground-penetrating radar data, and nine seismic check shots were acquired. The survey was conducted with two specific objectives in mind:

1. to determine whether high-resolution reflection seismic profiling could be used to map Mississippian bedrock, and locate paleosinkholes, abandoned and infilled open pit mines, and abandoned mine access shafts; and
2. to determine whether ground-penetrating radar (GPR) techniques could be used to locate abandoned mine access shafts in areas that were overlain by a thin (up to 3 m) veneer of "chat" (milled rock).

The geophysical survey was successful. Bedrock structure, abandoned mine access shafts, paleosinkholes, and areas of possible shallow mining activity were imaged on the high-resolution reflection seismic data. Mine access shafts were located using the GPR tool, even where such shafts were overlain by a thin veneer of surficial chat. These geophysical interpretations were transferred onto existing mine location maps as an aid to MoDOT engineers involved in route planning, hazards assessment, and site remediation.

GEOLOGICAL/MINING OVERVIEW OF STUDY AREA

Bedrock in the Joplin area (Figure 1) is comprised mostly of Mississippian carbonates and cherts. Bedrock is typically located at depths of between 3 m and 10 m, and is overlain by a veneer of soil, excavated rock, and chat. In places, the Mississippian carbonates have been leached extensively and paleosinkholes have formed. These paleosinkholes are typically elongate (oriented north-northwest along pre-existing fracture planes) and infilled with Pennsylvanian shales, siltstones, sandstones, limestones and coals. Some of the paleosinkholes contain in excess of 50 m of Pennsylvanian strata.

Lead/zinc ore in the Joplin area was preferentially deposited along pre-existing fractures and the margins of the paleosinkholes, and as sheet ground deposits within the Mississippian carbonates and cherts at depths on the order of 50 m. The former deposits are shallower and were recovered first (1850–1900) using shallow interconnected shafts and open-pit mining techniques. The latter deposits were mined later (1900–1950) using more conventional room and pillar methods.

From the perspective of a highway engineer, there are two principal mining hazards in the study area. These are associated with shallow mining activity, and the access shafts to the deeper room and pillar mines, respectively. (The deeper room and pillar mines themselves are not considered to be a significant risk due to the likelihood that stoping

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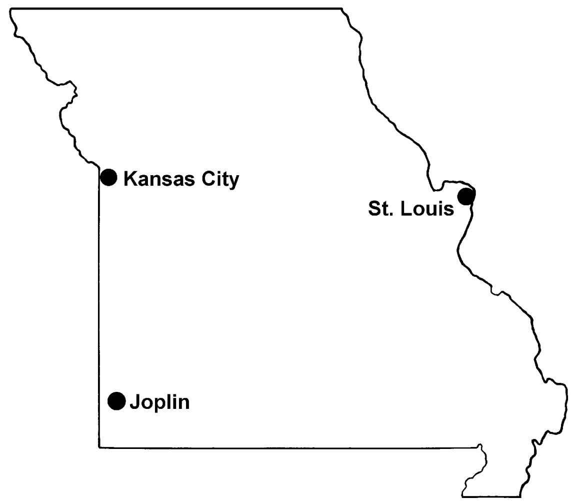

Figure 1: *Map of Missouri showing the location of the city of Joplin.*

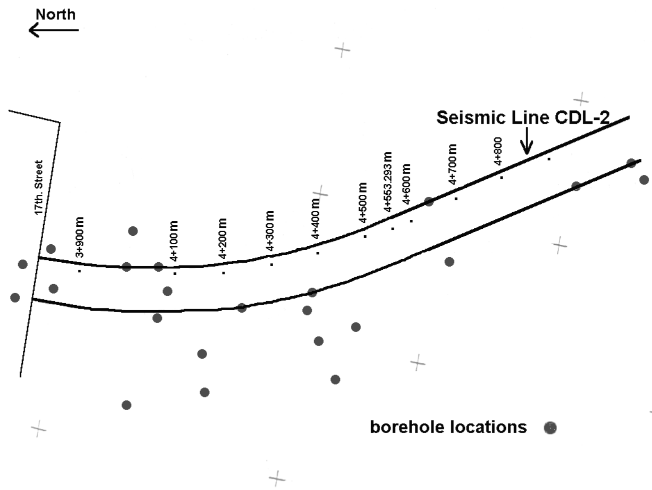

Figure 2: *Map of CDL study area showing location of Seismic Line CDL-2. Seismic Line CDL-2 was acquired along the interior edge of pavement on the south-bound lane of the proposed Interstate. Borehole locations are depicted as small dots.*

would prevent significant collapse-related surface subsidence.) Shallow mining activity represents a potential hazard because of the unstable nature of such ground. Such ground is unstable because of the density of interconnected shallow shafts (where such mining techniques were employed), and because the open-pit mines were infilled with under compacted material. The access shafts to the deeper room and pillar mines also pose a hazard because of the presence of void space and under compacted material fill.

REFLECTION SEISMIC PROFILING

A total of six seismic profiles (6 000 linear meters in total) were acquired along selected segments of the proposed interstate, with the objective of delineating potential mining-related hazards. These reflection seismic data were acquired using a 24-channel Bison engineering seismograph with roll-a-long capabilities, single 40 Hz geophones, and an EWG weight drop source. Source and receiver intervals were 10 ft. Each source location was used twice; once with a near offset of 20 ft, and a second time with a near offset of 40 ft (essentially providing two "shots records" per source location), and resulting in nominally 24-fold data. The weight drop source was impacted 6 to 10 times per shot record, dependent upon visual inspection of background noise on the shot gathers. Elevation control was acquired for each source and geophone location.

The reflection seismic data were processed on a Pentium PC using WINSEIS, a commercial processing package developed exclusively for high-resolution reflection seismic data. A fairly standard processing runstream was applied to the data. The processing routine consisted of: muting the first breaks and excessive ground roll, resorting the shot gathered traces into common midpoint (CMP) gathers, applying elevation corrections, determining appropriate velocity/time functions along the seismic traverses, calculating and applying surface consistent statics, applying normal moveout (NMO) corrections to CMP gathered traces, stacking the NMO corrected data, applying residual statics, restacking statically corrected data, and bandpass filtering.

An example seismic reflection profile is presented as Figure 3. The reflection from Mississippian bedrock, as correlated, is consistent with borehole and checkshot survey control (Figure 2). Note that a number of possible faults have been superposed on the seismic profile. The origin of these interpreted faults is uncertain. Some are probably deep-seated and related to regional tectonic deformation. Others are probably shallow and related to karst processes. Still others may be misinterpreted abandoned mine access shafts.

To facilitate the discussion of the interpretation of the example reflection seismic profile, it has been subdivided into four segments (1-4). Paleozoic bedrock across segments 1 and 3 is extensively leached and faulted, and is structurally low. The margins of the interpreted paleosinkholes are prospective sites for shallow mining activity. Mine shafts are interpreted at locations A, B, C, D, and E. As a result, segments 1 and 3 are areas classified as high risk for shallow mining activities. Paleozoic bedrock across Segment 2 and 4 is not extensively faulted, and is structurally high. The area is classified as low risk for shallow mining activities.

GROUND-PENETRATING RADAR PROFILING

A GSSI SIR-8 GPR unit equipped with a 500 MHZ monostatic antenna was used to acquire approximately 3 000 m of ground-penetrating radar data along segments of the proposed interstates. All of the areas surveyed were covered by a thin layer (1 to 3 m) of surficial chat. The principal objective was to locate mine access and ventilation shafts.

The data were acquired as suites of five parallel GPR profiles (spaced at 3 m). The central profile was located along the centerline of the respective interstate lane. The sampling interval was 30 scans/foot. The trace length was 100 ns, providing for depth penetration on the order of 5 m. The GPR data was processed on a Pentium PC using RADAN, a commercial processing package developed exclusively for ground-penetrating radar data. A fairly standard processing runstream was applied to the GPR data. The processing routine consisted of trace normalization, application of vertical gain, horizontal filtering, and vertical filtering.

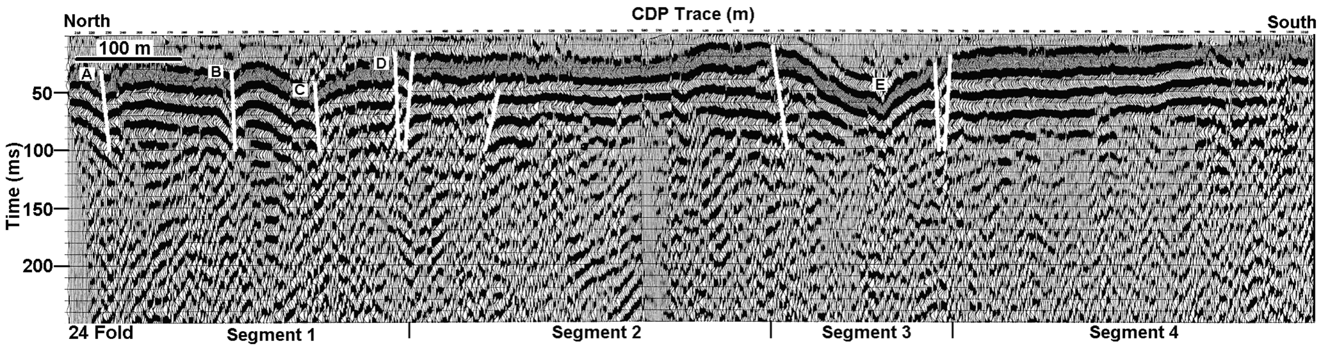

Figure 3: *Example seismic profile CDL-2. Bedrock is correlated across the seismic profile, and the locations of interpreted mine access shafts are designated by letter. Interpreted faults have been superposed on the seismic profile. This reflection seismic profile is one of six that were acquired in the study area.*

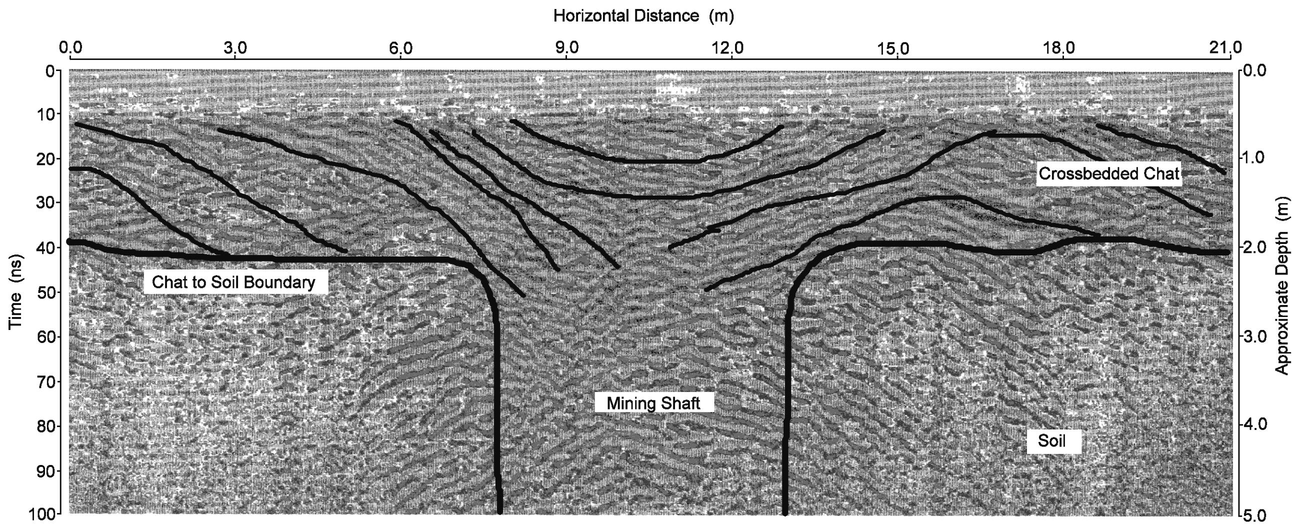

Figure 4: *Ground-penetrating radar profile 1. The surficial layer of milled chat is characterized by cross-bedding. The base of the chat (chat/soil contact) is highlighted. This contact is regular and continuous except where the GPR profile crosses the abandoned mine access shaft. The shaft is characterized by an anomalous thickness of infilled chat.*

An example ground-penetrating profile is shown as Figure 4. The GPR profile images an abandoned and infilled mine access shaft. The original ground surface is overlain by a thin veneer of chat (characterized by cross-bedding). The base of the chat (chat/soil contact) is correlated across GPR profile. This surface is regular in character and continuous except where the GPR profile crosses the mine access shaft. The mine shaft is characterized by an anomalous thickness of chat, which is consistent with the idea that abandoned shafts were infilled with chat. The chat within the shaft is cross-bedded, which is consistent with the idea that the chat was bulldozed into the shafts.

CONCLUSIONS

A geophysical survey was conducted for the Missouri Department of Transportation (MODOT) across previously mined (lead/zinc) ground along a proposed interstate route near Joplin, Missouri. A total of 6 000 m of high-resolution reflection seismic data, 3 000 m of ground-penetrating radar data, and 9 seismic check shots were acquired.

The reflection seismic data establish that high-resolution reflection seismic data can effectively image the shallow subsurface, and be used to identify and map Mississippian bedrock, abandoned room and pillar mine access shafts, paleosinkholes, and areas of probable shallow mining activity. The check shot survey data enabled the seismic data to be tied accurately to the subsurface geology. Such control is particularly important in the study area because of extreme structural relief and lateral velocity variations.

The GPR profiles demonstrate that mine access shafts can be located using the GPR tool, even where such shafts are overlain by a thin veneer of surficial chat. These data demonstrate that the GPR technique can be used effectively to image the shallow subsurface to depths of up to 15 m.