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Exploration of Abandoned Mine Shafts by means of Seismic Refraction, Electrical Resistivity Tomography, and Ground Penetrating Radar: Case study at Centralia, PA

Jackson Long

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Exploration of Abandoned Mine Shafts by means of Seismic Refraction, Electrical Resistivity Tomography, and Ground Penetrating Radar: Case study at Centralia, PA.

Jackson Long & Ahmed Lachhab Ph.D.

Introduction

- Electrical Resistivity is effective in finding subsurface voids due to their high resistance (Biswa et. al., 2005; Negri et al., 2015; Cardarelli et al., 2019).
- Ground Penetrating Radar has high resolution and accuracy to detect abandoned mine structures (Munk and Sheets, 1997; Biswas et. al., 2005).
- Seismic Refraction Tomography is traditionally used for Geological exploration (Cardarelli et al., 2009; Sheehan et al., 2005).
- A combination of geophysical techniques have been found to be most effective over individual techniques (Munk and Sheets, 1997; Cardarelli et al., 2009).
- This study combines ERT, SRT & GPR to identify mine shafts

Methodology

- Centralia, PA was selected as the main sample site for this experiment, due to the plethora of subsurface structure under the town (Figure 1 & 2)
- Located on the Locust Mountain Anticline in the Llewellyn Formation
- The Buck Mountain Coal Vein (bottom and middle splits) was mined at the sample site, with beds dipping at 12 degrees towards the south
- Room and pillar was the primary technique of mining at the sample site

Figure 1: Sample site at Centralia
Figure 2: GIS image of mines at the sample site

Shot Points and Geophone Spacing

- Figure 3 represent the 24 geophones Seismic Refraction array deployed in this project. The first and the last two geophones had 2 m spacing
- One ERT survey was performed with 56 electrodes with 0.5 m spacing; using both Wenner and dipole-dipole configurations.
- A 100 MHz GPR survey was performed over the same transect for the ERT and Seismic refraction line.
- Two model surveys were also conducted over a known culvert with SR both using 24 geophones. The first survey performed 1 m spacing. And the second 0.5 m spacing. Both surveys had 7 shots.

Figure 3: SR geophone spacing

Centralia Results

- Figure 4: Comparative analysis of the geophysical methods

- ERT contains areas of high resistivity shown in both the Wenner and Dipo-Dipole, indicative of subsurface void spaces.
- Several times (Figure 6) the signature of void spaces in time-distance plots is an unanticipated delay in arrival times (Ballard, 1982). This was replicated in the model (Figure 7).

Discussion

- Significant noise on the GPR 2D transect made identification of the shafts hard. Instead, a point by point survey was used. The 5 shafts detected by the survey are shown by the dotted lines in Figure 4.
- ERT contained areas of high resistivity shown in both the Wenner and Dipole-Dipole, indicative of subsurface void spaces (Figure 4).
- The signature of void spaces for SRT are depressions in the 2D transect between 800 – 1000 m/s (Mariano et al., 2014; Riddle et al., 2010). This was replicated in the model (Figure 7).
- The signature of void spaces in time-distance plots is an unanticipated delay in arrival times (Ballard, 1982). This was replicated in the model several times (Figure 6).
- SR and ERT were the preferred methods of mine structure detection, as they revealed the most information about the detection of the 4 voids and their respective placement.

References