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The contents are provisional and will be superseded by a paper in the DMT'11 Proceedings.

See also earlier Proceedings (1997-2010)
http://ngmdb.usgs.gov/info/dmt/

Mapping Abandoned Mines Using Imagery and LiDAR from the Ohio Statewide Imagery Program

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INTRODUCTION

Underground mining for coal in Ohio first was reported in 1800 (Crowell, 1995). The majority of underground mining takes place in coal- and clay-mining areas of eastern and southern Ohio (fig. 1). Other commodities have been mined underground within Ohio, such as salt, gypsum, limestone, shale, and even peat. Geologists have estimated that over 8,000 mines have been in operation over the last 200 years (Delong, 1988). With such a large number of mines occurring over a long period of time, there is an increasing probability that mines will collapse and subside as they age and deteriorate and as development occurs across the Ohio landscape.

Mine subsidence in Ohio has been a problem that only has been recognized in the last 40 years. In 1977, a mine shaft collapsed beneath a garage in Youngstown, Ohio. A car located in the garage fell 110 feet down a 230 feet shaft. Since this incident, the ODNR Division of Geological Survey began detailed mapping of locations of abandoned-underground mines (DeLong, 1988; Fuller and Sturgeon, 2011). Other prominent incidents have occurred in Ohio, such as the collapse of Interstate I-70 near Cambridge (Crowell, 1995) and the recent subsidence beneath a house in Sugarcreek. The costs associated with remediation of abandoned mines are high. The repair of the collapse of I-70 near Cambridge cost approximately $3.8 million (Crowell, 1995). As of 2005, the Ohio Department of Transportation had spent approximately $14.3 million to repair highway damage caused by mine subsidence. In 2008, the ODNR Division of Mineral Resources Management invested more than $1.3 million to complete 32 projects related to abandoned-underground mines (Gordon, 2009). As abandoned-underground mines age and deteriorate, remediation costs are expected to increase.

MAPPING CONVENTIONS

One method being investigated to detect unmapped, abandoned-surface mines and abandoned-underground mines is Light Detection and Ranging (LiDAR). Airborne LiDAR, also known as *laser altimetry,* uses a laser to measure the precise distance between the aircraft and the ground surface. The laser—which is mounted pointing downward in the aircraft—is fired, and the time that the laser light pulse travels between the ground surface and the aircraft elevation is measured. Using differential kinematic GPS and inertial navigation systems (INS), the location and elevation of the ground surface is computed for the thousands of laser pulses that are fired every second (Harding, 2000). The large number of data points generated using the LiDAR technique produces a high-resolution model of the surface topography.

The State of Ohio has a program to provide high-resolution digital imagery and LiDAR datasets for state government entities and the general public. The program, known as the Ohio Statewide Imagery Program (OSIP), imaged the state with high-resolution imagery in 2006 and 2007. The color imagery dataset was produced at either at 1-foot pixel or 6-inch resolution. The LiDAR dataset was produced with an average laser pulse spacing of 7 feet, with an accuracy of 1 foot (OGRIP, 2006). These two datasets, along with the other datasets produced as part of this program, have a wide range of utility, from parcel mapping to local and regional planning to responding to man-made and natural disasters.

As part of our continuing work to map abandoned-underground mines, a pilot project was undertaken to examine the suitability of using the OSIP high-resolution imagery and LiDAR datasets to find indications of abandoned mines. Six study areas around the state were selected in areas where mining had occurred or mine subsidence problems have been identified. Three of the sites include an area south of Byesville, Guernsey County (figs. 2a–2d); an area near Mulga, Jackson County (figs. 3a–3b); and an area near Wadsworth, Medina and Summit counties (figs. 4a–4b). The area near Byesville has been known as a location of pit subsidence failures for over 50 years (Norell, 1970). The LiDAR and digital-aerial photo imagery clearly show pit subsidence locations, some of which are next to I-77 and a rest area along the Interstate Highway. The area near Mulga has experienced underground and surface mining for coal. The OSIP imagery clearly shows the origin point for acid mine drainage as being the drift entry or the neighboring air shaft for an abandoned-underground mine. In addition, the LiDAR dataset shows a highwall for an unmapped surface mine. The area near Wadsworth is located within a Summit County Metropark. The OSIP imagery readily shows a disturbance in the field associated with the slope entry to an abandoned mine. In addition, there are two other disturbed areas within the field that may indicate that the underground mine has extended beyond the mapped area. These three examples demonstrate the usefulness of OSIP imagery and LiDAR datasets for locating unmapped mining areas throughout Ohio.

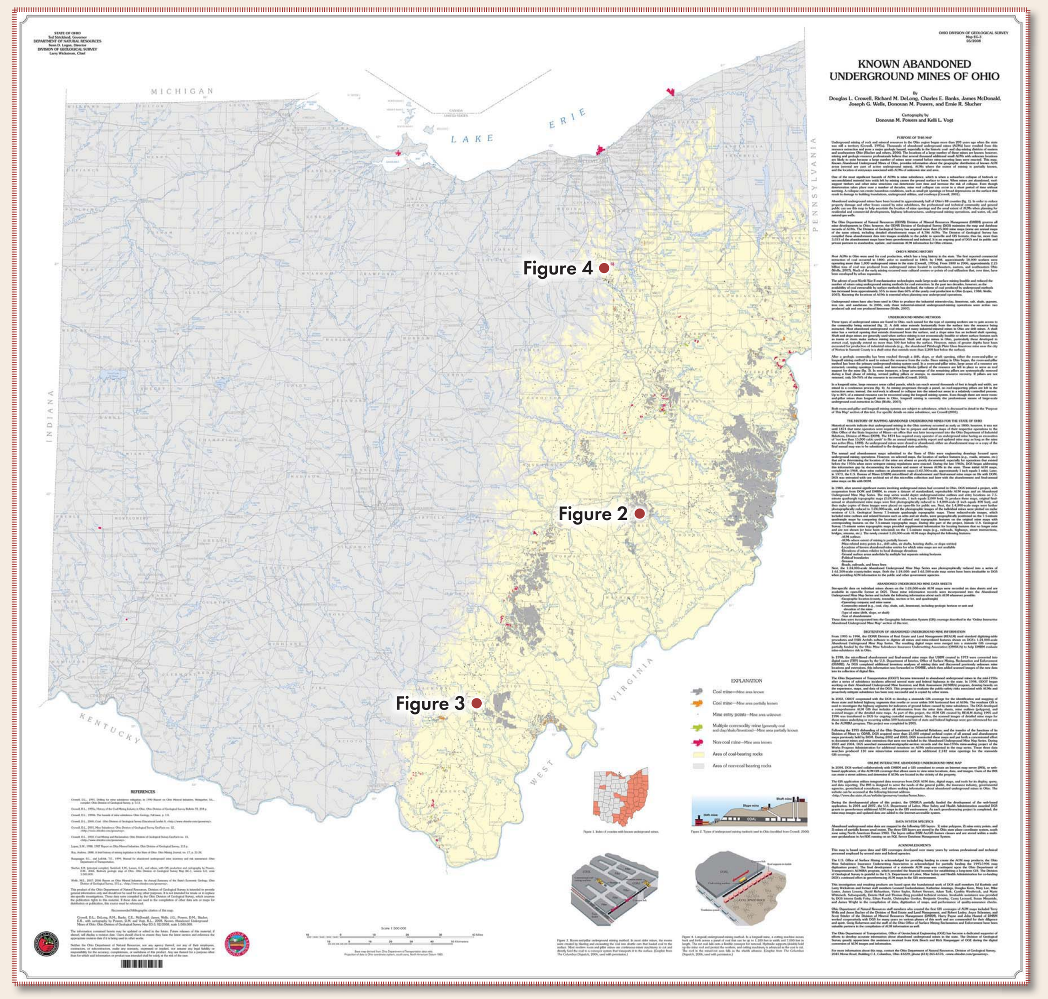

FIGURE 1.—Known abandoned-underground mines of Ohio (modified from Crowell and others, 2008). The majority of abandoned-underground mines are associated with coal- and clay-mining in eastern Ohio. Shown on the map are the locations of the three study areas discussed in this poster.

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FIGURE 2a.—Locations of historic mine subsidence features south of Byesville, Ohio.

FIGURE 2b.—Zoomed-in view of the mine subsidence features south of Byesville, Ohio.

FIGURE 2c.—Hill shade overlay of the gridded LiDAR dataset. Some of the pit subsidence features can be easily identified, especially if the pit subsidence feature has a vertical resolution of greater than the LiDAR accuracy.

FIGURE 2d.—Overlay of the detailed abandoned mine map. Some of the pit subsidence features lie outside of the mapped mine workings, possibly indicating that the detailed mine map does not completely show the full extent of the mine workings.

FIGURE 4a.—Silver Creek Metro Park, near Wadsworth, Ohio. The high-resolution imagery shows some unusual patterns (red arrows) within the mowed field.

FIGURE 4b.—Overlay of the abandoned-mine map and the gridded LiDAR hill shade. The overlay clearly shows that the unusual pattern on the left side of the figure is due to slope entry to the mine. The other unusual patterns in the center of the figure may be caused by collapse of unmapped entries from an extension of the abandoned-underground mine. Further field work is necessary to confirm or refute this hypothesis.

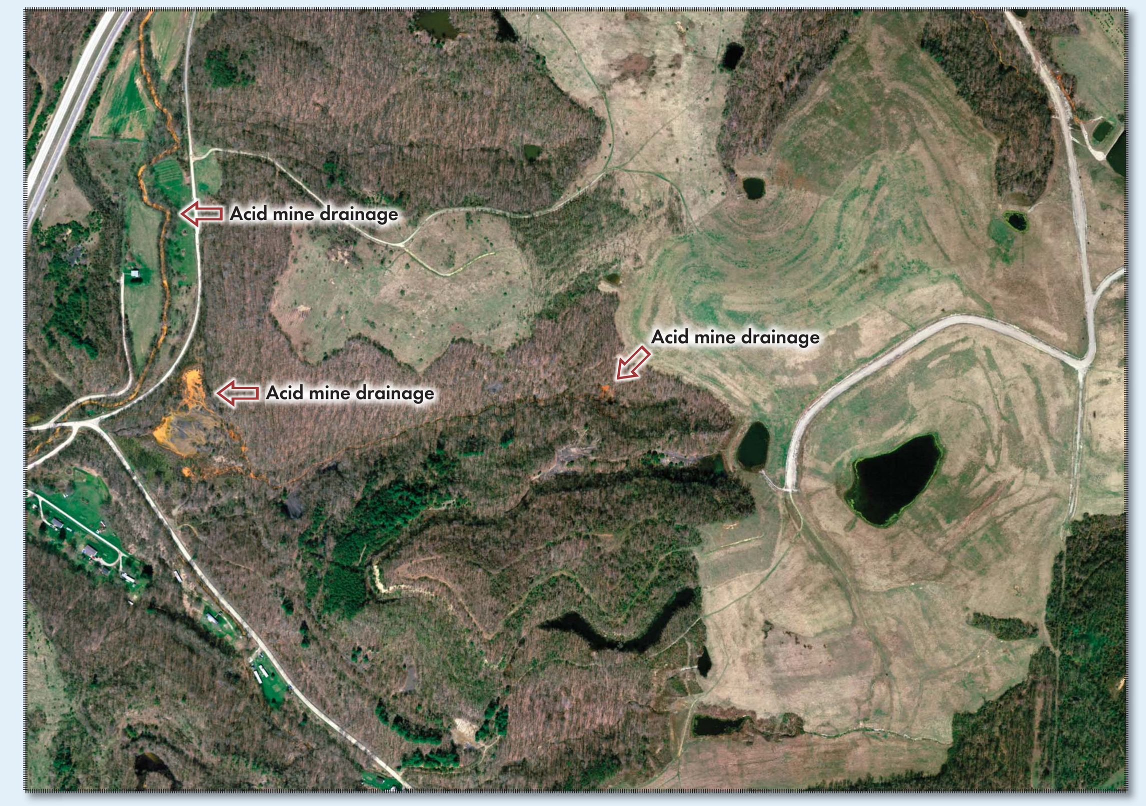

FIGURE 3a.—Locations of abandoned-underground and surface mines near Mulga, Ohio. The orange discoloration is acid mine drainage.

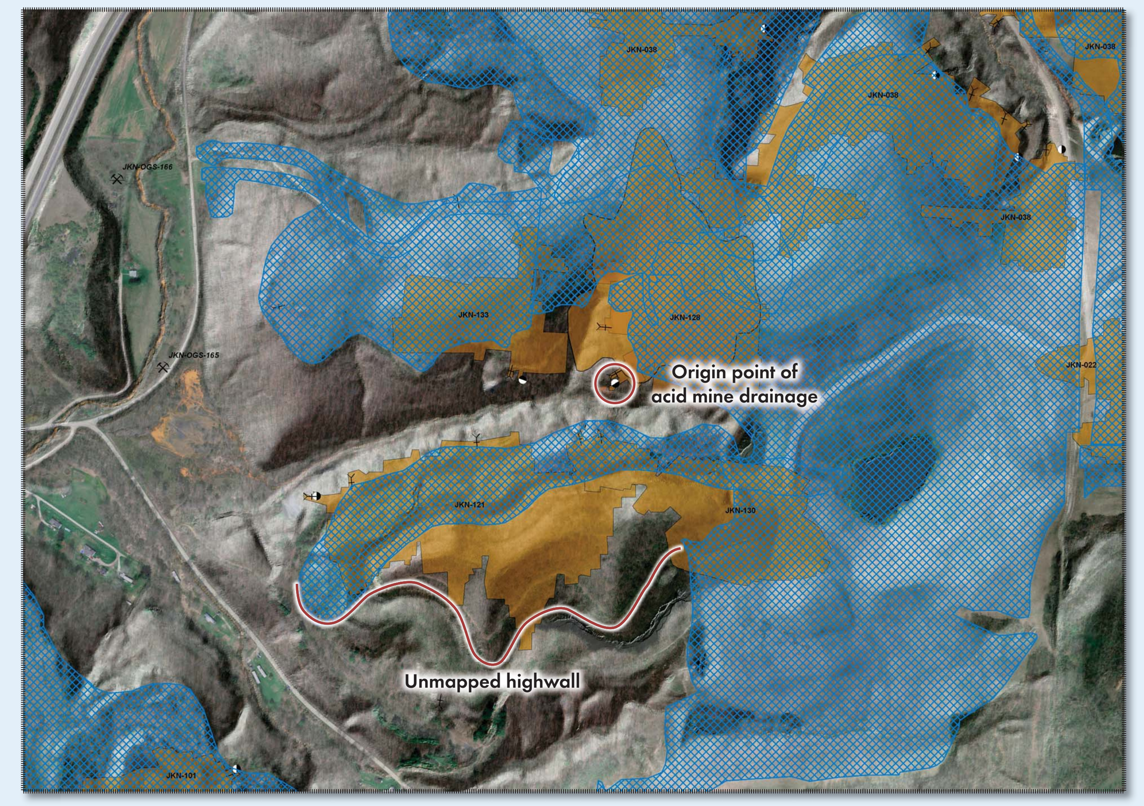

FIGURE 3b.—Overlay of the outlines of the abandoned-underground mines (brown) and abandoned-surface mines (blue hachure pattern). The origin point for the acid mine drainage can now be identified as coming from either the drift entry or the air shaft of the abandoned-underground mine. In addition, the LiDAR hill shade easily identifies an unreclaimed highwall from an unmapped surface mine.

ACKNOWLEDGMENTS

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