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KNOWN ABANDONED UNDERGROUND MINES OF OHIO

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PURPOSE OF THIS MAP

Underground mining of rock and mineral resources in the Ohio region began more than 200 years ago when the state was still a territory (Crowell, 1995a). Thousands of abandoned underground mines (AUMs) have resulted from this resource extraction and pose a major geologic hazard, especially in the historic coal- and clay-mining districts of eastern and southeastern Ohio (Slucher and others, 2006). The locations of a large number of these mines are known; however, mining and geologic-resource professionals believe that several thousand additional small AUMs with unknown locations are likely to exist because a large number of mines were created before mine-reporting laws were enacted. This map, Known Abandoned Underground Mines of Ohio, provides information about the geographic distribution of known AUM areas (several are part of active underground mines). AUMs where the extent of mining is partially known, and the location of entryways associated with AUMs of unknown size and area.

One of the most significant hazards of AUMs is mine subsidence, which is when a subsurface collapse of bedrock or unconsolidated material into voids left by mining causes the ground surface to lower. When mines are abandoned, roof-support timbers and other mine structures can deteriorate over time and increase the risk of collapse. Even though deterioration takes place over a number of decades, mine roof collapse can occur in a short period of time without warning. A collapse can create hazardous conditions, such as small pit openings or broad depressions on the surface that result in damage to building foundations, underground utilities, and roadways (Crowell, 2001).

Abandoned underground mines have been located in approximately half of Ohio's 88 counties (fig. 1). In order to reduce property damage and other losses caused by mine subsidence, the professional and technical community and general public can use this map to help ascertain the location of mine openings and the areal extent of AUMs when planning for residential and commercial developments, highway infrastructures, underground mining operations, and water, oil, and natural-gas wells.

The Ohio Department of Natural Resources (ODNR) Division of Mineral Resources Management (DMRM) governs all mine developments in Ohio; however, the ODNR Division of Geological Survey (DGS) maintains the map and database records of AUMs. The Division of Geological Survey has acquired more than 25,000 mine maps (some are annual maps of the same mines), including detailed abandonment maps of 4,786 AUMs. The Division of Geological Survey has compiled these abandonment data into images available to the public in open-file and GIS formats; thus far, more than 3,033 of the abandonment maps have been georeferenced and indexed. It is an ongoing goal of DGS and its public and private partners to standardize, update, and maintain AUM information for Ohio citizens.

OHIO'S MINING HISTORY

Most AUMs in Ohio were used for coal production, which has a long history in the state. The first reported commercial extraction of coal occurred in 1800, prior to statehood in 1803; by 1908, approximately 50,000 workers were operating more than 1,000 underground mines in the state (Crowell, 1995a). From 1800 to 2006, approximately 2.25 billion tons of coal was produced from underground mines located in northeastern, eastern, and southeastern Ohio (Wolfe, 2007). Much of the early mining occurred near cultural centers or points of coal utilization that, over time, have been enveloped by urban expansion.

The advent of post-World War II mechanization technologies made large-scale surface mining feasible and reduced the number of mines using underground mining methods for coal extraction. In the past two decades, however, as the availability of coal extractable by surface methods has declined, the volume of coal produced by underground methods has increased from approximately 35% to more than 60% of the yearly coal production in Ohio (Lopez, 1988; Wolfe, 2007). Knowing the locations of AUMs is essential when planning new underground operations.

Underground mines have also been used in Ohio to produce the industrial minerals–clay, limestone, salt, shale, gypsum, iron ore, and sandstone. In 2006, only three industrial-mineral underground-mining operations were active: two produced salt and one produced limestone (Wolfe, 2007).

UNDERGROUND MINING METHODS

Three types of underground mines are found in Ohio, each named for the type of opening workers use to gain access to the commodity being extracted (fig. 2). A drift mine extends horizontally from the surface into the resource being extracted. Most abandoned underground coal mines and many industrial-mineral mines in Ohio are drift mines. A shaft mine has a vertical opening that extends downward from the surface, and a slope mine has an inclined shaft opening. Shaft and slope mines are generally used when surface mining is not economically feasible or where surface features such as towns or rivers make surface mining impractical. Shaft and slope mines in Ohio, particularly those developed to extract coal, typically extend no more than 500 feet below the surface. However, mines of greater depths have been excavated for production of industrial minerals (e.g., the abandoned Pittsburgh Plate Glass limestone mine near the city of Norton in Summit County is a shaft mine that extends more than 2,200 feet below the surface).

After a geologic commodity has been reached through a drift, slope, or shaft opening, either the room-and-pillar or longwall mining method is used to extract the resource from the rocks. Since mining in Ohio began, the room-and-pillar method has been the primary underground-mining system used. In a room-and-pillar mine, large areas of a resource are extracted, creating openings (rooms), and intervening blocks (pillars) of the resource are left in place to serve as roof support for the mine (fig. 3). In some instances, a large percentage of the remaining pillars are systematically removed during a final phase of mining, termed pulling pillars or stumps, to maximize resource recovery. If pillars are not removed, only 50–70% of the resource is recoverable (Crowell, 2002).

In a longwall mine, large resource areas called panels, which can reach several thousands of feet in length and width, are mined in a continuous process (fig. 4). As mining progresses through a panel, no roof-supporting pillars are left in the extraction areas; instead, the roof-rock is allowed to collapse into the mined-out areas in a relatively controlled process. Up to 80% of a mineral resource can be recovered using the longwall mining system. Even though there are more room-and-pillar mines than longwall mines in Ohio, longwall mining is currently the predominant means of large-scale underground coal extraction in Ohio (Wolfe, 2007).

Both room-and-pillar and longwall mining systems are subject to subsidence, which is discussed in detail in the 'Purpose of This Map' section of this text. For specific details on mine subsidence, see Crowell (2001).

THE HISTORY OF MAPPING ABANDONED UNDERGROUND MINES FOR THE STATE OF OHIO

Historical records indicate that underground mining in the Ohio territory occurred as early as 1800; however, it was not until 1874 that mine operators were required by law to prepare and submit maps of their respective operations to the Ohio Office of the State Inspector of Mines—an office that was later incorporated into the Ohio Department of Industrial Relations, Division of Mines (DOM). The 1874 law required every operator of an underground mine having an excavation of "not less than 15,000 cubic yards" to file an annual mining activity report and updated mine map as long as the mine was active (Roy, 1888). As underground mines were closed or abandoned, either an abandonment map or a copy of the final annual map was to be submitted to the designated state authority.

The annual and abandonment maps submitted to the State of Ohio were engineering drawings focused upon underground mining operations. However, on selected maps, the location of surface features (e.g., roads, streams, etc.) that aid in determining the location of the mine are absent or poorly documented, especially for operations that existed before the 1950s when more stringent mining regulations were enacted. During the late 1960s, DGS began addressing this information gap by documenting the location and extent of known AUMs in the state. These initial AUM maps, completed in 1968, show mine outlines on planimetric maps (1:62,500-scale, approximately 1 inch equals 1 mile). Later, in 1973, the U.S. Bureau of Mines (USBM) microfilmed all abandonment and final-annual mine maps on file with DOM; DGS was entrusted with one archival set of this microfilm collection and later with the abandonment and final-annual mine maps on file with DOM.

In 1980, after several significant events involving underground mines had occurred in Ohio, DGS initiated a project, with cooperation from DOM and DMRM, to create a dataset of standardized, reproducible AUM maps and an Abandoned Underground Mine Map Series. The map series would depict underground-mine outlines and entry locations on 7.5-minute quadrangle topographic maps (1:24,000-scale, 1 inch equals 2,000 feet). To produce these maps, original final-annual or abandonment mine maps were first photographically reduced to 1:4,800-scale (1 inch equals 400 feet), and then mylar copies of these images were placed on open-file for public use. Next, the 1:4,800-scale maps were further photographically reduced to 1:24,000-scale, and the photographic images of the individual mines were plotted on mylar versions of U.S. Geological Survey 7.5-minute quadrangle topographic maps. These reduced-scale images, which included mine outlines and related features such as adits and air shafts, were geographically positioned on the 7.5-minute quadrangle maps by comparing the locations of cultural and topographic features on the original mine maps with corresponding features on the 7.5-minute topographic maps. During this part of the project, historic U.S. Geological Survey 15-minute series topographic maps provided supplemental information for locating features that no longer exist and are not shown (or have been relocated) on the 7.5-minute maps (e.g., railroads, highways, street intersections, bridges, streams, etc.). The newly created 1:24,000-scale AUM maps displayed the following features:

- -AUM outlines
- -AUMs where extent of mining is partially known
- -Mine-related entry points (i.e., drift adits, air shafts, hoisting shafts, or slope entries)
- -Locations of known abandoned-mine entries for which mine maps are not available
- -Elevations of mines relative to local drainage elevations
- -Ground surface areas underlain by multiple but separate mining horizons
- -Political boundaries
- -Streams
- -Roads, railroads, and fence lines

Next, the 1:24,000-scale Abandoned Underground Mine Map Series was photographically reduced into a series of 1:62,500-scale county-index maps. Both the 1:24,000- and 1:62,500-scale map series have been invaluable to DGS when providing AUM information to the public and other government agencies.

ABANDONED UNDERGROUND MINE DATA SHEETS

Site-specific data on individual mines shown on the 1:24,000-scale AUM maps were recorded on data sheets and are available in open-file format at DGS. These mine information records were incorporated into the Abandoned Underground Mine Map Series and include the following information about each AUM whenever possible:

- -Geographic location (county, township, section or lot, and quadrangle)
- -Operating company and mine name
- -Commodity mined (e.g., coal, clay, shale, salt, limestone), including geologic horizon or unit and elevation of the mine
- -Type of mine (drift, slope, or shaft)
- -Year of abandonment

These data were incorporated into the Geographic Information System (GIS) coverage described in the "Online Interactive Abandoned Underground Mine Map" section of this text.

DIGITIZATION OF ABANDONED UNDERGROUND MINE INFORMATION

From 1995 to 1996, the ODNR Division of Real Estate and Land Management (REALM) used standard digitizing-table procedures and ESRI ArcInfo software to digitize all mines and mine-related features shown on DGS's 1:24,000-scale Abandoned Underground Mine Map Series. The resulting digital maps were merged into a statewide GIS coverage partially funded by the Ohio Mine Subsidence Insurance Underwriting Association (OMSIUA) to help DMRM evaluate mine-subsidence risk in Ohio.

In 1998, the microfilmed abandonment and final-annual mine maps that USBM created in 1973 were converted into digital raster (TIFF) images by the U.S. Department of Interior, Office of Surface Mining, Reclamation and Enforcement (OSMRE). As DGS completed additional inventory analyses of mining data and discovered previously unknown mine locations and extensions, this information was forwarded to OSMRE, which then added scanned images of the new data into its collection of digital files.

The Ohio Department of Transportation (ODOT) became interested in abandoned underground mines in the mid-1990s after a series of subsidence incidents affected several state and federal highways in the state. In 1998, ODOT began working on their Abandoned Underground Mine Inventory and Risk Assessment (AUMIRA) program, drawing heavily on the experience, maps, and data of the DGS. This program to evaluate the public-safety risks associated with AUMs and proactively mitigate subsidence has been very successful and is copied by other states.

In 2002, ODOT cooperated with the DGS to develop a statewide GIS coverage for the identification and mapping of those state and federal highway segments that overlie or occur within 500 horizontal feet of AUMs. The resultant GIS is used to investigate the highway segments for indicators of ground failure caused by mine subsidence. The DGS developed a comprehensive AUM GIS that includes all information from the mine data sheets, mine outlines (polygons), and scanned images of the detailed mine maps. As part of this project, the AUM GIS created by REALM during 1995 and 1996 was transferred to DGS for ongoing custodial management. Also, the scanned images of detailed mine maps for those mines underlying or occurring within 500 horizontal feet of state and federal highways were geo-referenced for use in the AUMIRA program. This project was completed in 2005.

Following the 1995 disbanding of the Ohio Department of Industrial Relations, and the transfer of the functions of its Division of Mines to ODNR, DGS acquired more than 25,000 original archival copies of all annual and abandonment maps previously held by DOM. During 2002 and 2003, DGS inventoried these maps and put forth a concentrated effort to document mines and mine extensions that were not included in the Abandoned Underground Mine Map Series. During 2003 and 2004, DGS searched measured-stratigraphic-section records and the late-1930s mine-sealing project of the Works Progress Administration for additional notations on AUMs undocumented in the map series. These three data searches produced 130 new mines/mine extensions and an additional 2,142 mine openings for the statewide GIS coverage.

ONLINE INTERACTIVE ABANDONED UNDERGROUND MINE MAP

In 2004, DGS worked collaboratively with DMRM and a GIS consultant to create an Internet map server (IMS), or web-based application, of the AUM GIS coverage that allows users to view mine locations, data, and images. Users of the IMS can enter a street address and determine if AUMs are located in the vicinity of the property.

The GIS application utilizes integrated data resources from DGS AUM data, digital maps, and tools for its display, query, and data reporting. The IMS is designed to serve the needs of the general public, the insurance industry, governmental agencies, geotechnical consultants, and others seeking information about abandoned underground mines in Ohio. The website can be accessed at the following Internet address:
<http://www.dnr.state.oh.us/website/geosurvey/omsiua/home.htm>.

During the developmental phase of this project, the OMSIUA partially funded the development of the web-based application. In 2004 and 2007, the U.S. Department of Labor, Mine Safety and Health Administration awarded DGS grants to georeference additional AUM maps in the GIS environment. As each georeferencing project is completed, the mine-map images and updated data are added to the Internet-accessible system.

DATA SYSTEM SPECIFICS

Abandoned underground mine data are mapped in the following GIS layers: 1) mine polygons, 2) mine entry points, and 3) mines of partially known areal extent. The three GIS layers are stored in the Ohio state plane coordinate system, south zone using North American Datum 1983. The layers utilize ESRI ArcGIS feature classes and are stored within a multi-user geodatabase in ArcSDE running on an SQL Server Database Management System.

ACKNOWLEDGMENTS

This map is based upon data and GIS coverages developed over many years by various professional and technical personnel employed by several state and federal agencies.

The U.S. Office of Surface Mining is acknowledged for providing funding to create the AUM map products; the Ohio Mine Subsidence Insurance Underwriting Association is acknowledged for partially funding the 1995-1996 map digitization project. The final development of a statewide AUM map was contingent upon the Ohio Department of Transportation's AUMIRA program, which provided the financial incentive for establishing a long-term GIS. The Division of Geological Survey is grateful to the U.S. Department of Labor, Mine Safety and Health Administration for co-funding DGS's continued effort in georeferencing AUM maps in the GIS environment.

This investigation and resulting products are based upon the foundational work of DGS staff members Ed Ruehnle and Larry Wickstrom and former staff members Leonard Guckenheimer, Katherine Jennings, Douglas Keen, Mary Lee, Mike Lester, James Lowery, David Richardson, Victor Saylor, Robert Stewart, Adam Turk, Cynthia Westbrook, and Marie Whitenack. Subsequently, Dennis Hull and Thomas Berg provided technical reviews. Invaluable assistance was provided by DGS interns Emily Foley, Ethan Fuecht, Christopher Gordon, Benjamin Growley, Casey Leonard, Susan Minamide, and James Wright in the compilation of data, digitization of maps, and performance of quality-assurance checks.

Ohio Department of Natural Resources staff members who created the first GIS coverages of AUM maps included Terry Wells and Jason Bucher of the Division of Real Estate and Land Management, and Robert Lasley, Joyce Schramm, and Scott Sitteler of the Division of Mineral Resources Management (DMRM). Harry Payne and John Husted of DMRM worked cooperatively with DGS for many years on various phases of this work and are commended for their diligence and spirit. Greig Robertson and the staff of the Ohio Office of Surface Mining Reclamation and Enforcement have been valuable partners in the compilation of AUM information as well.

The Ohio Department of Transportation, Office of Geotechnical Engineering (OGE) has become a dedicated supporter of efforts to develop accurate information about abandoned underground mines in the state. The Division of Geological Survey greatly appreciates the assistance received from Kirk Beach and Rick Ruegsegger of OGE during the digital conversion of AUM images and information.

For more information about this map, contact the Ohio Department of Natural Resources, Division of Geological Survey, 2045 Morse Road, Building C-1, Columbus, Ohio 43229; phone (614) 265-6576; <www.ohiodnr.com/geosurvey>.

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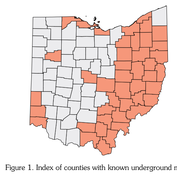

Figure 1. Index of counties with known underground mines.

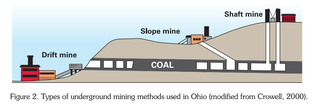

Figure 2. Types of underground mining methods used in Ohio (modified from Crowell, 2000).

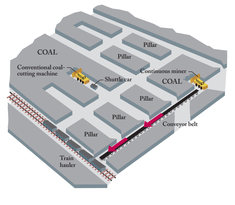

Figure 3. Room-and-pillar underground mining method. In most older mines, the rooms were created by blasting and excavating the coal into shuttle cars that hauled coal to the surface. Most modern room-and-pillar mines use continuous-miner machinery to cut and directly feed the coal to a conveyor system that transports it to the surface. (Graphic from *The Columbus Dispatch*, 2006, used with permission.)

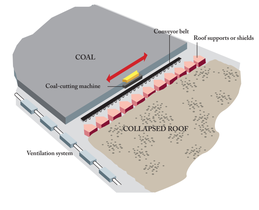

Figure 4. Longwall underground-mining method. In a longwall mine, a cutting machine moves back and forth across a panel of coal that can be up to 1,100 feet in width and 7,000 feet in length. The cut coal falls onto a flexible conveyor for removal. Hydraulic supports (shields) hold up the mine roof and protect the workers, and cutting machinery is advanced as the coal is cut. The roof in the mined-out area falls as the shields advance. (Graphic from *The Columbus Dispatch*, 2006, used with permission.)

EXPLANATION

- Coal mine—Mine area known
- Coal mine—Mine area partially known
- Mine entry points—Mine area unknown
- Multiple commodity mine (generally coal and clay/shale/limestone)—Mine area partially known
- Non-coal mine—Mine area known
- Area of coal-bearing rocks
- Area of non-coal bearing rocks

10 0 10 20 30 40 Miles
10 0 10 20 30 40 50 Kilometers

Base map derived from Ohio Department of Transportation data sets.
Projection of data is Ohio coordinate system, south zone, North American Datum 1983.