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Evaluating Mine Subsidence Using a GIS Software Application

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ABSTRACT

Subsidence due to the collapse of abandoned underground mines is a geologic hazard that can affect highways and buildings, potentially endangering lives and property. Damages from mine subsidence can cost millions of dollars. In 2008, the Ohio Department of Natural Resources (ODNR), Division of Mineral Resources Management invested more than $1.3 million to complete 32 projects related to abandoned underground mines. As of 2005, the Ohio Department of Transportation had spent approximately $14.3 million to repair highway damage caused by mine subsidence. The costs of mine subsidence will continue to rise as abandoned underground mines age and deteriorate and further development occurs across the Ohio landscape.

Homeowners are particularly at risk because most homeowner insurance policies do not cover cost of damages from mine subsidence. In Ohio, the Mine Subsidence Insurance Fund gives property owners the opportunity to purchase mine subsidence insurance. When officials from the Ohio Mine Subsidence Insurance Underwriting Association (OMSIUA) receive a claim from a property owner, the claim is forwarded to geologists at the ODNR Division of Geological Survey for further evaluation. Geologists use a geographic information system (GIS) application that automatically gathers all digital geologic maps and documents for the claim location. When all the digital geologic maps and documents are gathered into the GIS, geologists first evaluate the potential of an underground mine to underlie a property and then write a claim report that is submitted to a consulting engineering company for further evaluation and potential remediation. The OMSIUA GIS application provides easy access to digital geologic information, for faster insurance claim processing and property remediation.

INTRODUCTION

Underground mining for coal in Ohio was first reported in 1800 (Crowell, 1995). The majority of the underground mining takes place in coal- and clay-mining areas of eastern and southern Ohio (fig. 1). Other commodities, such as salt, gypsum, limestone, shale, and even peat, have been mined underground in Ohio. 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 developed 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.

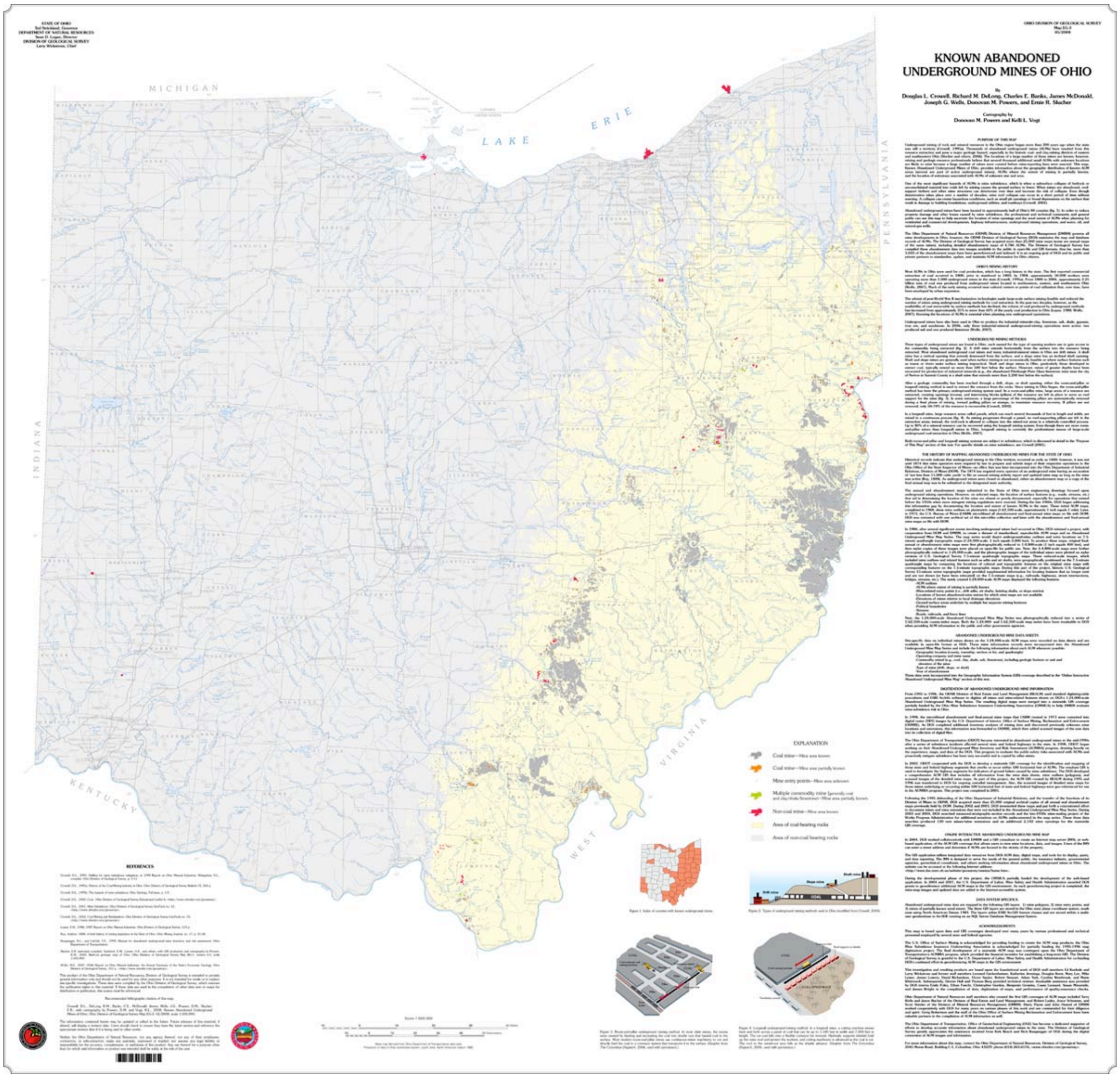

Figure 1. Known abandoned underground mines of Ohio (Crowell and others, 2008). The majority of abandoned underground mines are associated with coal and clay mining in eastern Ohio.

In Ohio, mine subsidence has been a problem that has been recognized only in the last 40 years. In 1977, a mine shaft collapsed underneath a garage in Youngstown, Ohio (fig. 2). This incident led the ODNR Division of Geological Survey to map the detailed locations of abandoned underground mines (DeLong, 1988). Other prominent incidents have occurred throughout the state, such as the collapse of Interstate 70 (I-70) near Cambridge (fig. 3; Crowell, 1995), and the recent subsidence beneath a house in

Sugarcreek (fig. 4). The costs associated with the remediation of abandoned mines are high. The repairs 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, the ODNR Division of Geological Survey expects remediation costs associated with abandoned mines to increase.

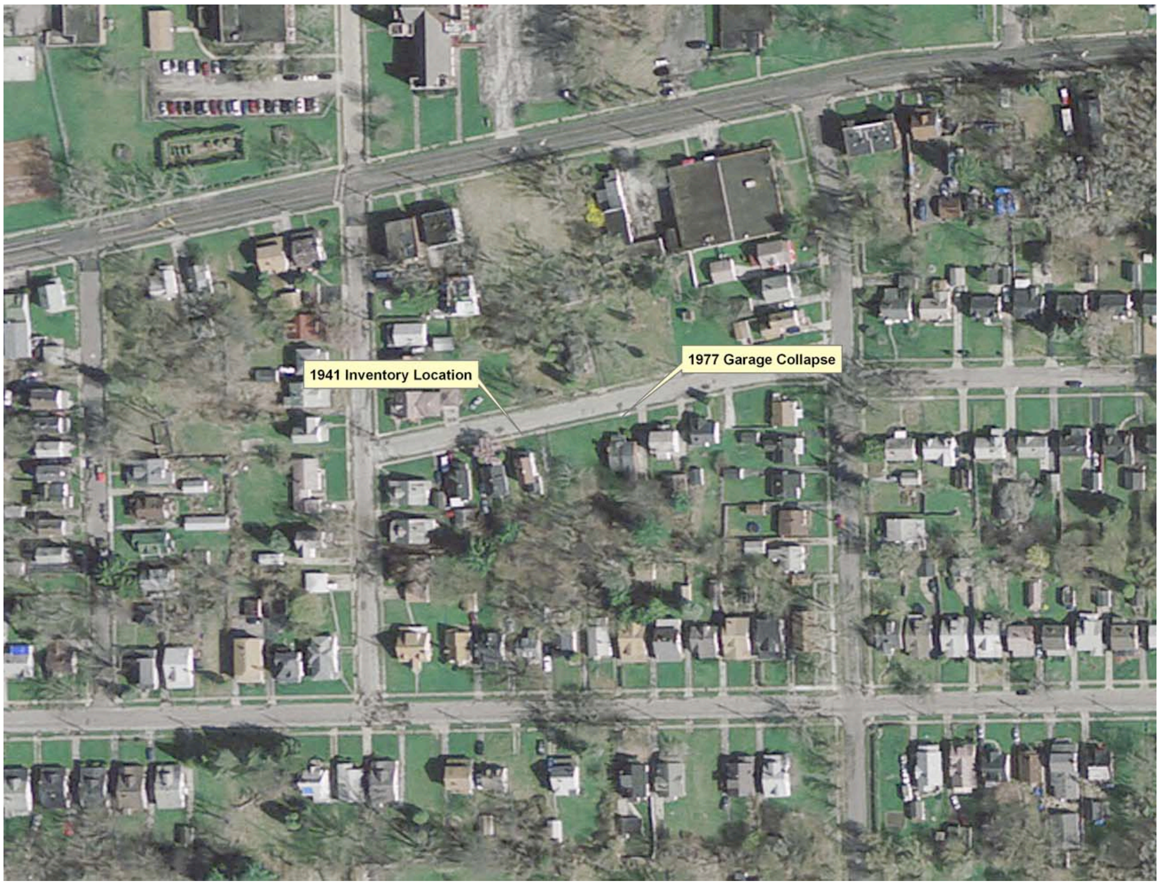

Figure 2. Aerial photograph showing location of mine subsidence. In 1941, a property was inventoried by Fuller and Sturgeon (1941) as containing an abandoned mine shaft of the Foster #1 mine, which was abandoned in 1884. In 1977, a garage collapsed into a mine shaft on a nearby property (Crowell, 1980; DeLong, 1988).

Figure 3. Collapse of Interstate 70, near Cambridge, Ohio, caused by mine subsidence (Crowell, 1995).

Figure 4. A home damaged by mine subsidence, in Sugarcreek Township, Tuscarawas County, Ohio.

Most homeowner insurance policies do not cover damages from mine subsidence. In Ohio, the Mine Subsidence Insurance Fund gives property owners the opportunity to purchase mine subsidence insurance. In order to assist the Ohio Mine Subsidence Insurance Underwriting Association (OMSIUA) with the evaluation of insurance claims, the ODNR Division of Geological Survey has entered into an agreement with OMSIUA to provide geologic information and preliminary evaluation of the validity of the mine subsidence claims. When OMSIUA officials receive a claim from a property owner, geologists at the ODNR Division of Geological Survey are given the claim for further evaluation. Geologists use a geographic information system (GIS) application that automatically gathers all digital geologic maps and documents for the claim location. When all the digital geologic maps and documents are gathered into the GIS, geologists first evaluate the potential of an underground mine to underlie a property and then write a claim report. The claim report is submitted to a consulting engineering company for further evaluation and potential remediation. The GIS application provides easy access to digital geologic information to speed up insurance claim processing and property remediation.

DATA ARCHIVES, GIS DATASETS, AND ACCESS

The ODNR Division of Geological Survey is the legally defined repository of geologic data in the State of Ohio and has been collecting geologic data since it was first organized in 1837 as the Ohio Geological Survey. In its archives, there are over 17,000 measured stratigraphic-measured sections (Carlton, 2001), over 4,000 core descriptions, and thousands of draft project maps and open-file maps. Starting in the mid-1980s, the division created project databases for individual projects. Systematic GIS dataset and database creation and data archiving started in 1996 with the creation of the oil- and gas-well GIS dataset (McDonald and others, 2005). The systematic conversion of the 1:24,000-scale bedrock geology and bedrock topography open-file maps was completed in 2003 (McDonald and others, 2003). Other datasets have been converted since 2003, as part of the various projects funded to map the locations of abandoned underground mines. These datasets include the scanning and georeferencing of low-resolution abandoned-mine maps, the scanning of abandoned-mine maps at high resolution, and the conversion of the bedrock-geology structure-contour maps to a GIS dataset. Currently, the division is in the process of digitally archiving all of the records and converting all of the spatially referenced information to GIS datasets, which can be accessed by the staff and eventually by the public.

One challenge inherent in creating digital archives of statewide GIS datasets is discovery and access of information at the desktop. Traditionally, with paper records at the ODNR Division of Geological Survey, identifying records and maps that contain information for a particular site involves searching through each collection, which could be organized by county/township/section or by U.S. Geological Survey quadrangle. Even if a staff member or member of the public is successful in examining the entire collection for information, other collections may be missed due to the person not knowing about them. These types of searches through paper records and archives are typically slow, taking days to weeks to undergo. As a mine subsidence report comes into the ODNR Division of Mineral Resources Management, a geologist will visit the Geologic Records Center (at the ODNR Division of Geological Survey) and will examine measured sections, core descriptions, 1:24,000-scale abandoned-underground mine maps, bedrock geology maps, and other records collections. Such searching and examination can take many hours to research a particular mine subsidence claim (Tim Jackson, ODNR Division of Mineral Resources Management, oral commun., 2010). Because the ODNR Division of Geological Survey is still in the process of scanning and digitizing all of its collections of paper records, allowing access to these digital data is difficult. If there are hundreds of different types of datasets, then knowing what relevant datasets to add to an analysis is a time-consuming task. More importantly, if there are written documents that support a GIS analysis, then adding these written documents to the project is almost impossible.

OMSIUA GIS APPLICATION

Application Design

Many different types of geologic information can be used for geologic-hazards analysis. Types of geologic information produced by geologists and engineers include published and open-file reports; miscellaneous documents, such as core descriptions and measured-stratigraphic section descriptions; published and draft working maps; and vector and raster GIS datasets representing digital geologic maps. All of these types of geologic information form a voluminous archive. In order to locate geologic information about a specific site, geologic maps and documents need to be scanned or digitized, digitally indexed, and spatially referenced. Indexing involves recoding within a database table the existence and location of a record on the computer network. Spatial referencing involves attaching geographic-location information to the geologic record. By associating with each geologic record the location on the computer network and the geographic location, a geologic record can be easily retrieved for any geographic location within a GIS.

The basic concept of the OMSIUA application is to easily locate all pertinent geologic records and maps and load them into the GIS for a user to evaluate the mine-subsidence potential of a site. The information that is then loaded into ESRI ArcMap is driven by reading records from multiple tables in a database. The basic information indexed into database tables can be categorized into vector GIS layers, scanned maps and digital orthophoto images, and scanned paper records. These database tables record the file name and the network path of the geologic information record, which provides the information necessary to locate the digital geologic record on the computer network. The tables also contain geographic information indexes describing the county, township, or U.S. Geological Survey 7.5-minute or 15-minute quadrangle in which the record is located.

The vector GIS layers are loaded by reading the records in the table that index the vector layers. The table contains attribute fields that record various types of information related to how the layer will be loaded into ArcMap (fig. 5). The attribute fields include the name of the layer, the location of the layer file, the group name in the ArcMap table of contents (TOC), the location of the group in the TOC, and the order in which both the layers in the groups, and the groups within the TOC, are loaded into ArcMap. For example, there are nine layers associated with abandoned underground mines. Each of the nine layers has a group-order attribute value and a TOC attribute value. These values determine where the group of abandoned-mine vector layers is loaded and displayed in the TOC in ArcMap. Inside the group, the order of the layers is specified using the TOC order attributes. All of the vector layers are loaded at the statewide level; the display of the vector layers is not limited to the zoomed-in area of interest.

Attributes of ODGSLAYERS

ID	LAYERNAME	PATH	GROUPORDER	GROUPNAME	GROUPTOCORDER	GROUPVISABLE	GROUPPDFEXPORT
1	BG Facies.lyr	S:\AUM\OMSIUA\Layer_Files	8	Bedrock Geology Layers	6	0	0
2	BG Mines Line.lyr	S:\AUM\OMSIUA\Layer_Files	6	Bedrock Geology Layers	6	0	0
3	BG Mines Ply.lyr	S:\AUM\OMSIUA\Layer_Files	10	Bedrock Geology Layers	6	0	0
4	BG Mines Pnt.lyr	S:\AUM\OMSIUA\Layer_Files	1	Bedrock Geology Layers	6	0	0
5	BG Misc Pnt.lyr	S:\AUM\OMSIUA\Layer_Files	2	Bedrock Geology Layers	6	0	0
6	BG Structure Line.lyr	S:\AUM\OMSIUA\Layer_Files	5	Bedrock Geology Layers	6	0	0
7	BG Structure Pnt.lyr	S:\AUM\OMSIUA\Layer_Files	3	Bedrock Geology Layers	6	0	0
8	BG Units Contacts.lyr	S:\AUM\OMSIUA\Layer_Files	9	Bedrock Geology Layers	6	0	0
9	BG Units Line.lyr	S:\AUM\OMSIUA\Layer_Files	7	Bedrock Geology Layers	6	0	0
10	BG Units Ply.lyr	S:\AUM\OMSIUA\Layer_Files	11	Bedrock Geology Layers	6	0	0
11	BG Units Pnt.lyr	S:\AUM\OMSIUA\Layer_Files	4	Bedrock Geology Layers	6	0	0
13	BT Contours.lyr	S:\AUM\OMSIUA\Layer_Files	2	Surface and Bedrock Topography Layers	5	0	0
14	BT Data Points.lyr	S:\AUM\OMSIUA\Layer_Files	1	Surface and Bedrock Topography Layers	5	0	0
15	Coal Geochemistry Samples.lyr	S:\AUM\OMSIUA\Layer_Files	2	Coal Layers	2	1	0
19	Directional drilled wellbore.lyr	S:\AUM\OMSIUA\Layer_Files	2	Oil and Gas Layers	4	1	0
20	DMRM Strip Mines.lyr	S:\AUM\OMSIUA\Layer_Files	4	Coal Layers	2	1	0
24	Mine Location - Extent Unknown.lyr	S:\AUM\OMSIUA\Layer_Files	5	AUM Layers	3	1	0
25	Mine Opening from Topographic Maps.lyr	S:\AUM\OMSIUA\Layer_Files	3	AUM Layers	3	1	0
26	Mine Opening.lyr	S:\AUM\OMSIUA\Layer_Files	4	AUM Layers	3	1	0
28	NCRDS_PTS.lyr	S:\AUM\OMSIUA\Layer_Files	1	Coal Layers	2	1	0
29	OGWELLS.lyr	S:\AUM\OMSIUA\Layer_Files	1	Oil and Gas Layers	4	1	0
36	Superimposed Underground Mine.lyr	S:\AUM\OMSIUA\Layer_Files	8	AUM Layers	3	1	0
37	Underground Mine - Extent Partially Unknown.lyr	S:\AUM\OMSIUA\Layer_Files	7	AUM Layers	3	1	0
38	Underground Mine.lyr	S:\AUM\OMSIUA\Layer_Files	9	AUM Layers	3	1	0
39	Wayne NF - Gob Piles and Spoil Points.lyr	S:\AUM\OMSIUA\Layer_Files	1	Wayne National Forest	7	0	0
40	Wayne NF - Mine Openings.lyr	S:\AUM\OMSIUA\Layer_Files	2	Wayne National Forest	7	0	0
41	Wayne NF - Mine Seepages.lyr	S:\AUM\OMSIUA\Layer_Files	3	Wayne National Forest	7	0	0
42	Wayne NF - Mine Subsidence Locations.lyr	S:\AUM\OMSIUA\Layer_Files	4	Wayne National Forest	7	0	0
43	Wayne NF - Parcel Ownership.lyr	S:\AUM\OMSIUA\Layer_Files	11	Wayne National Forest	7	0	0
44	Wayne NF - PH and Water Sampling Points.lyr	S:\AUM\OMSIUA\Layer_Files	6	Wayne National Forest	7	0	0
45	Wayne NF - Ponds.lyr	S:\AUM\OMSIUA\Layer_Files	7	Wayne National Forest	7	0	0
46	Wayne NF - Rubbish.lyr	S:\AUM\OMSIUA\Layer_Files	8	Wayne National Forest	7	0	0
47	Wayne NF - Slumps Associated with Mines.lyr	S:\AUM\OMSIUA\Layer_Files	9	Wayne National Forest	7	0	0
48	Wayne NF - Structures.lyr	S:\AUM\OMSIUA\Layer_Files	10	Wayne National Forest	7	0	0
49	Wayne NF - Surface Mine Highwall Locations.lyr	S:\AUM\OMSIUA\Layer_Files	5	Wayne National Forest	7	0	0
50	Bedrock Topography 500K.lyr	S:\AUM\OMSIUA\Layer_Files	5	Surface and Bedrock Topography Layers	5	0	0
51	Drift Thickness.lyr	S:\AUM\OMSIUA\Layer_Files	6	Surface and Bedrock Topography Layers	5	0	0
52	Water Wells.lyr	S:\AUM\OMSIUA\Layer_Files	1	Water Wells	1	1	0
53	Pittsburgh No. 8 Isopach.lyr	S:\AUM\OMSIUA\Layer_Files	2	Regional Coal Maps - Pittsburgh No. 8	8	0	0
54	Pittsburgh No. 8 Structure Contours.lyr	S:\AUM\OMSIUA\Layer_Files	1	Regional Coal Maps - Pittsburgh No. 8	8	0	0
55	Pittsburgh No. 8 Structure Grid.lyr	S:\AUM\OMSIUA\Layer_Files	3	Regional Coal Maps - Pittsburgh No. 8	8	0	0
56	Pittsburgh No. 8 Overburden Grid.lyr	S:\AUM\OMSIUA\Layer_Files	4	Regional Coal Maps - Pittsburgh No. 8	8	0	0
57	Upper Freeport No. 7 Isopach.lyr	S:\AUM\OMSIUA\Layer_Files	2	Regional Coal Maps - Upper Freeport No. 7	9	0	0
58	Upper Freeport No. 7 Structure Contours.lyr	S:\AUM\OMSIUA\Layer_Files	1	Regional Coal Maps - Upper Freeport No. 7	9	0	0
59	Upper Freeport No. 7 Structure Grid.lyr	S:\AUM\OMSIUA\Layer_Files	3	Regional Coal Maps - Upper Freeport No. 7	9	0	0
60	Upper Freeport No. 7 Overburden Grid.lyr	S:\AUM\OMSIUA\Layer_Files	4	Regional Coal Maps - Upper Freeport No. 7	9	0	0
61	Lower Freeport No. 6a Isopach.lyr	S:\AUM\OMSIUA\Layer_Files	2	Regional Coal Maps - Lower Freeport No. 6a	10	0	0
62	Lower Freeport No. 6a Structure Contours.lyr	S:\AUM\OMSIUA\Layer_Files	1	Regional Coal Maps - Lower Freeport No. 6a	10	0	0
63	Lower Freeport No. 6a Structure Grid.lyr	S:\AUM\OMSIUA\Layer_Files	3	Regional Coal Maps - Lower Freeport No. 6a	10	0	0

Record: 1 Show: All Selected Records (0 out of 86 Selected) Options

Figure 5. Portion of the table used for loading the vector layers into the ESRI ArcMap documents. The fields in the table contain information on the vector layers to be loaded into the table of contents (LAYERNAME), location of the layer file (PATH), the order in which the vector layer is loaded into the group layer (GROUPORDER), the group layer name (GROUPNAME), the location of the group layer in the table of contents (GROUPTOCORDER), whether the group layer display is turned on or off in the ArcMap (GROUPVISABLE), and whether the group can be exported into the PDF maps during the automated map production process (GROUPPDFEXPORT).

The scanned paper maps, Digital Raster Graphic (DRG) maps, digital orthophoto images, and the scans of the abandoned-underground mine maps have the same type of table associated with them. The table contains the file name, the location of the file on the network drive and full path name (i.e., network location and file name), and an index location. The index location can be a county, civil township, U.S. Geological Survey 7.5-minute or 15-minute quadrangle name, or the identification number for the abandoned underground mine (fig. 6). In figure 6, the table contains information about the scanned 15-minute thematic geologic maps. These are maps that have been used to record geologic information, such as the locations of coal samples or the draft mapping of the bedrock geology for a particular 1:62,500-scale topographic quadrangle. The index location is the 15-minute quadrangle name.

Attributes of QUADMAPS15MIN

ID *	QUADNAME15MIN	PATH	FILENAME	COMMENTS
1	<Null>	Z:\IMAGES\MAPS	7.5 min index.TIF	Index map
2	AKRON	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Miscellaneous	Akron_BG.TIF	<Null>
3	AKRON	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Miscellaneous	Akron_MC.TIF	<Null>
4	AKRON	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Miscellaneous	Akron_ML-MC.TIF	<Null>
5	AKRON	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Miscellaneous	Akron_MS.TIF	<Null>
6	AKRON	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Miscellaneous	Akron_NA.TIF	<Null>
7	AKRON	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Miscellaneous	Akron_SG-BG.TIF	<Null>
8	ALEXANDRIA	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Formations	Alexandria_ED.TIF	<Null>
9	ALEXANDRIA	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Miscellaneous	Alexandria_MS.TIF	<Null>
10	ALGER	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Miscellaneous	Alger_MS.TIF	<Null>
11	ALGER	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Miscellaneous	Alger_ST.TIF	<Null>
12	<Null>	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Formations	Allegheny Series.TIF	<Null>
13	ALLIANCE	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Coal	Alliance_BR.TIF	<Null>
14	ALLIANCE	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Formations	Alliance_BS.1.TIF	<Null>
15	ALLIANCE	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Formations	Alliance_BS.TIF	<Null>
16	ALLIANCE	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Miscellaneous	Alliance_CS.2.TIF	<Null>
17	ALLIANCE	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Miscellaneous	Alliance_CS.3.TIF	<Null>
18	ALLIANCE	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Miscellaneous	Alliance_CS.TIF	<Null>
19	ALLIANCE	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Coal	Alliance_LK.2.TIF	<Null>
20	ALLIANCE	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Coal	Alliance_LK.TIF	<Null>
21	ALLIANCE	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Miscellaneous	Alliance_MC.TIF	<Null>
22	ALLIANCE	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Coal	Alliance_MK.TIF	<Null>
23	ALLIANCE	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Miscellaneous	Alliance_MS.2.TIF	<Null>
24	ALLIANCE	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Miscellaneous	Alliance_MS.TIF	<Null>
25	ALLIANCE	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Miscellaneous	Alliance_NA.TIF	<Null>
26	ALLIANCE	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Miscellaneous	Alliance_ST.2.TIF	<Null>
27	ALLIANCE	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Miscellaneous	Alliance_ST.TIF	<Null>
28	ALLIANCE	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Coal	Alliance_UF.2.TIF	<Null>
29	ALLIANCE	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Coal	Alliance_UF.TIF	<Null>
30	ALLIANCE	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Contacts	Alliance_VM.TIF	<Null>
31	ANDOVER	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Miscellaneous	Andover_MS.2.TIF	<Null>
32	ANDOVER	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Miscellaneous	Andover_MS.TIF	<Null>
33	ANTRIM	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Miscellaneous	Antrim_CS.2.TIF	<Null>
34	ANTRIM	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Miscellaneous	Antrim_CS.3.TIF	<Null>
35	ANTRIM	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Miscellaneous	Antrim_CS.TIF	<Null>
36	ANTRIM	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Miscellaneous	Antrim_GW.TIF	<Null>
37	ANTRIM	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Coal	Antrim_LK.TIF	<Null>
38	ANTRIM	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Coal	Antrim_ME.2.TIF	<Null>
39	ANTRIM	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Coal	Antrim_ME.TIF	<Null>
40	ANTRIM	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Coal	Antrim_MK.2.TIF	<Null>
41	ANTRIM	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Coal	Antrim_MK.TIF	<Null>
42	ANTRIM	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Miscellaneous	Antrim_MS.TIF	<Null>
43	ANTRIM	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Coal	Antrim_PI.2.TIF	<Null>
44	ANTRIM	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Coal	Antrim_PI.TIF	<Null>
45	ANTRIM	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Miscellaneous	Antrim_ST.TIF	<Null>
46	ANTRIM	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Coal	Antrim_UF.2.TIF	<Null>
47	ANTRIM	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Coal	Antrim_UF.TIF	<Null>
48	ARLINGTON	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Miscellaneous	Arlington_MS.TIF	<Null>
49	ARLINGTON	Z:\IMAGES\MAPS\15_Min_Thematic_Maps\Formations	Arlington_TR-MC.TIF	<Null>

Record: 0 Show: All Selected Records (0 out of *2000 Selected) Options

Figure 6. Portion of the table used for loading the raster map images into the ESRI ArcMap documents. The fields in the table contain information on the index identification number for the file (QUADNAME15MIN), the location of the raster image (PATH), the name of the raster image (FILENAME), and a comments field (COMMENTS). The raster images listed in this table are for the 15-minute quadrangle thematic maps. The index identification numbers in this figure refer to the 15-minute quadrangle names.

In order to load the raster map images, a point location first must be identified. The point location, identified using a standard ESRI ArcObjects VBA function, is then passed along to a VBA class method that will process the location. A temporary half-mile, circular buffer is then applied to the point. Using the 15-minute thematic maps as an example, a spatial intersection is then performed between the buffer of the point and the 15-minute quadrangle map index feature class. The spatial intersection will identify all the 15-minute quadrangles that intersect the buffered point location. Once the list of 15-minute quadrangles is obtained, then a search is executed against the 15-minute quadrangle thematic maps table. All the georeferenced 15-minute quadrangle thematic maps selected from the table will then be loaded into the ArcMap application.

The application uses the similar table format for the 1:24,000-scale DRG topographic maps; the 1:1,200- and 1:600-scale digital-orthophotography images that are supplied from the Ohio Statewide Imagery Program (OSIP; OGRIP, 2006); and the low-resolution (72 dpi) abandoned-underground mine maps. These three types of index tables use different spatial indexing schemes. The U.S. Geological Survey DRG topographic maps and the OSIP imagery have been compiled into county-level tiles across the state. Therefore, these tables use a county index identifier for each record. The low-resolution abandoned-underground mine maps use the new 12-digit identifier that has been modified from the American Petroleum Institute identifier (API no.) for oil and gas wells. In order to load the DRGs and the OSIP imagery, ArcMap needs to contain an Ohio county index map feature class. In order to load the scans of the abandoned-underground mine maps, ArcMap needs to contain the abandoned-underground-mine polygon feature class. The same procedure is used to locate the index polygons, to find the index identifier, which is then used to select the records in the raster index table, and then to load the selected raster maps and georeferenced images into ArcMap.

The scanned records have a similar type of table schema as the raster maps tables (fig. 7). In the table, there is a unique identifier associated with each record, which could be a core description number or a measured stratigraphic section number. In addition, the file name for the document, the location of the file on the network, and the full path name for the file are included each as attribute fields for the record. The unique identifier is used to join the scanned records index table with the scanned documents GIS feature class. Currently, each document is located via a point location within a feature class. The feature class is loaded into ArcMap and the scanned records table is joined to the document feature class using an attribute table join. When the user wants to display the document for a particular location in ArcMap, the user uses the hyperlink tool to display the document. The full path and file name for the document are used for displaying the document as a hyperlink within ArcMap.

Attributes of ODGSDOCLOCATIONS

OBJECTID	ODGSDOCID *	PATH	FILENAME	FULLNAME
1	MS00001	Z:\IMAGES\DOCUMENTS\StratSections	MS00001.pdf	Z:\IMAGES\DOCUMENTS\StratSections\MS00001.pdf
2	MS00010	Z:\IMAGES\DOCUMENTS\StratSections	MS00010.pdf	Z:\IMAGES\DOCUMENTS\StratSections\MS00010.pdf
3	MS00100	Z:\IMAGES\DOCUMENTS\StratSections	MS00100.pdf	Z:\IMAGES\DOCUMENTS\StratSections\MS00100.pdf
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5	MS10000	Z:\IMAGES\DOCUMENTS\StratSections	MS10000.pdf	Z:\IMAGES\DOCUMENTS\StratSections\MS10000.pdf
6	MS10001	Z:\IMAGES\DOCUMENTS\StratSections	MS10001.pdf	Z:\IMAGES\DOCUMENTS\StratSections\MS10001.pdf
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8	MS10003	Z:\IMAGES\DOCUMENTS\StratSections	MS10003.pdf	Z:\IMAGES\DOCUMENTS\StratSections\MS10003.pdf
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44	MS10035A	Z:\IMAGES\DOCUMENTS\StratSections	MS10035A.pdf	Z:\IMAGES\DOCUMENTS\StratSections\MS10035A.pdf
45	MS10036	Z:\IMAGES\DOCUMENTS\StratSections	MS10036.pdf	Z:\IMAGES\DOCUMENTS\StratSections\MS10036.pdf
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48	MS10039	Z:\IMAGES\DOCUMENTS\StratSections	MS10039.pdf	Z:\IMAGES\DOCUMENTS\StratSections\MS10039.pdf
49	MS01004	Z:\IMAGES\DOCUMENTS\StratSections	MS01004.pdf	Z:\IMAGES\DOCUMENTS\StratSections\MS01004.pdf

Record: 1 Show: All Selected Records (0 out of *2000 Selected) Options

Figure 7. Portion of the table used for loading and accessing the scanned records into the ESRI ArcMap documents. The fields in the table contain information on the index identification number for the file (ODGSDOCID), the location of the raster image (PATH), the name of the raster image (FILENAME), and the full path and name of the raster image (FULLNAME). The scanned records in this figure refer to the measured stratigraphic sections, and the index identification numbers refer to the measured stratigraphic section ID.

During an earlier project, GeoDecisions, Inc., created the initial database design for the abandoned-underground mines database. The attribute database for the abandoned underground mines includes a number of different tables, all of which are tied together using the new 12-digit identifiers (fig. 8). The primary table is the Abandoned Underground Mine polygon feature-attribute table, which is part of the abandoned-underground-mine polygon feature class. Associated with the primary table are a number of tables that record the attribute information concerning the underground mines. These tables include basic information on the underground mines (TBLMINES), information on the operator and the name of the mine (TBLOPERATOR), information on the location (TBLCOUNTY, TBLTOWNSHIP, TBLQUAD), information on the type of commodity being mined (TBLCOMMODITY), the name of the coal bed or geologic unit being mined (TBLSEAM), and general information about the mine (TBLCOMMENT). Some of the tables have a one-to-one relationship with the polygon feature-attribute table (for example, TBLMINES). Other tables have a one-to-many relationship with the polygon feature-attribute table. Examples of these types of relationships include the tables TBLOPERATOR and TBLSEAM. With the one-to-many relationship, a mine can have more than one record associated with those particular attributes. For example, a mine can have one or more owners over the life span of the mine. Or, a mine can produce coal from one or more coal beds. In order to display all of these attributes, relationships are set up in either the database or in ESRI ArcGIS between the polygon feature class and all the attribute tables.

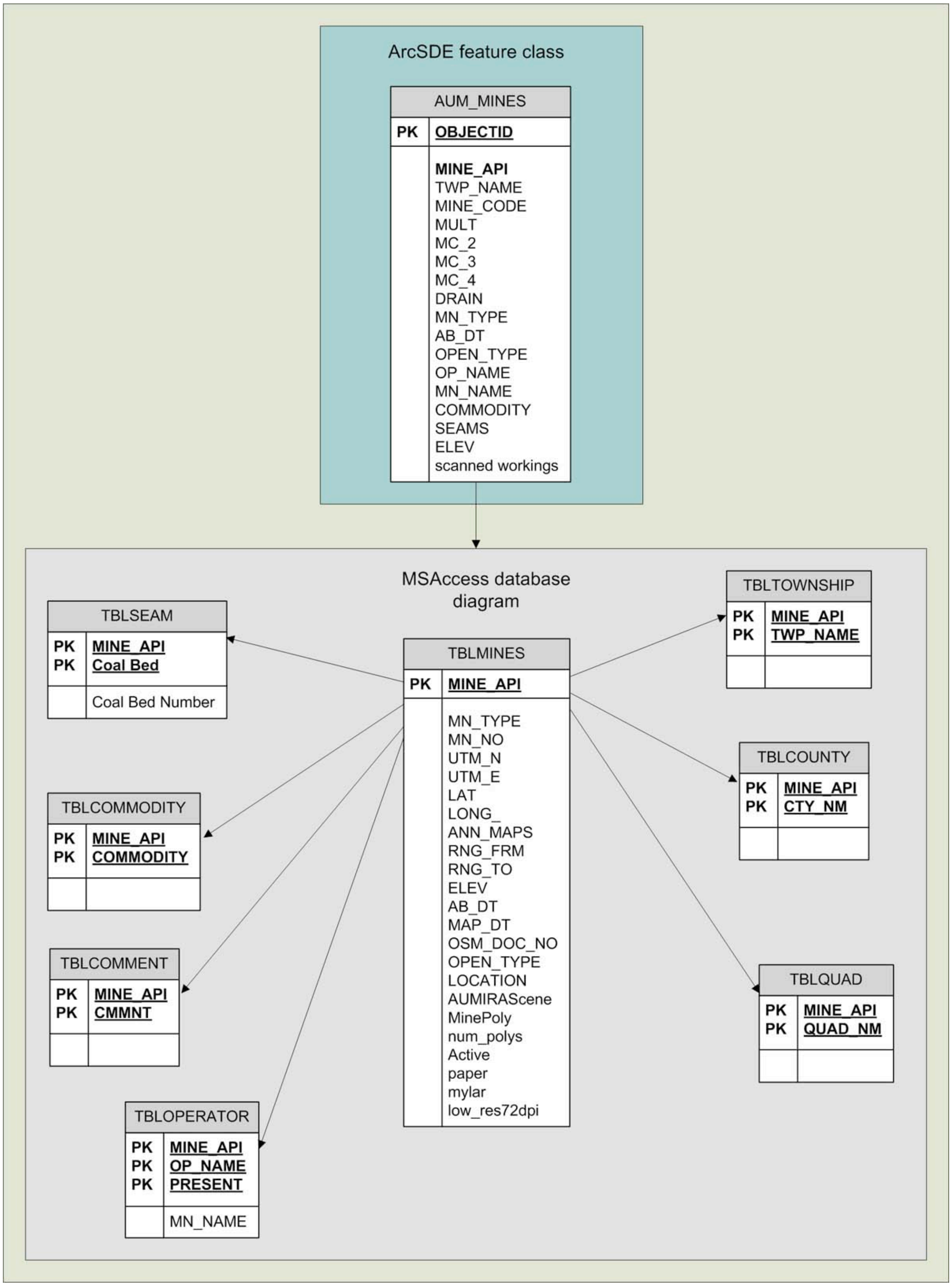

Figure 8. Entity relationship diagram of the Abandoned Underground Mines database. This diagram shows the relationships between all the tables describing the attribute information associated with the abandoned underground mines.

To easily display all the attributes associated with an underground mine, a VBA form was created. When a mine is selected with the tool associated with the form, the 12-digit identifier is read from the polygon feature class. The identifier is then used to create SQL statements within the ArcObjects environment. The SQL statements are in turn applied to each of the related tables, gathering information about the selected mine. Finally, the information is presented in the VBA form for a user to examine.

The final portion of the application involves the creation of simple PDF maps from all the vector layer groups. A code snippet, in the VBA language, was downloaded from the ESRI Web site (http://www.esri.com) that exports PDF maps from ArcMap. The code snippet was modified to automatically generate many PDF maps, based upon the vector groups that had been loaded into ArcMap. The modified code reads the vector layers table and then creates a PDF map for all the groups specified in the vector layers table.

Application User Interface

The user interface of the OMSIUA GIS application features a number of toolbar tools, including native ArcGIS tools and tools custom-designed using VBA for ArcObjects (fig. 9).

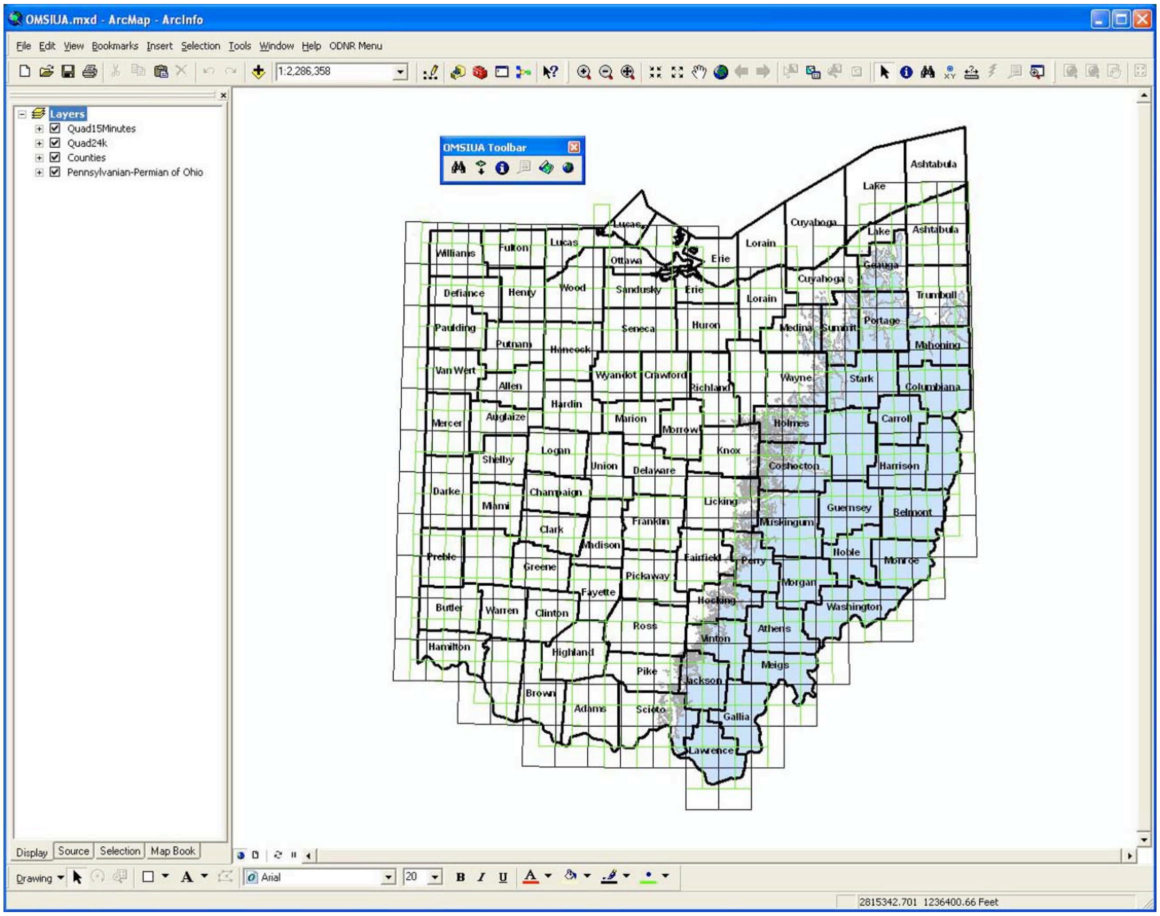

Figure 9. OMSIUA Toolbar. The toolbar, built using ESRI ArcMap customization tools, contains a set of native ArcMap commands and custom-built VBA commands.

To locate mine subsidence claims, two tools are used to zoom into the claim location and load all geologic maps and documents. The toolbar contains the native ArcGIS Find tool (fig. 10). This tool is used to locate insurance claims based upon the Address Locator function in the Find tool. The second tool on the toolbar is the mine-subsidence location Select Location tool (fig. 11). This tool will load all known digital geologic maps and all geologic GIS data into the ArcMap document for that location. Some of the GIS datasets include abandoned underground mines, permitted surface mines, the 1:24,000-scale bedrock geology, and the 1-foot-resolution digital orthophotography. One of the most important historical records is the set of 15-minute thematic geologic maps. The Select Location tool will identify all the scanned maps within a half-mile radius and load them into ArcMap (fig. 12).

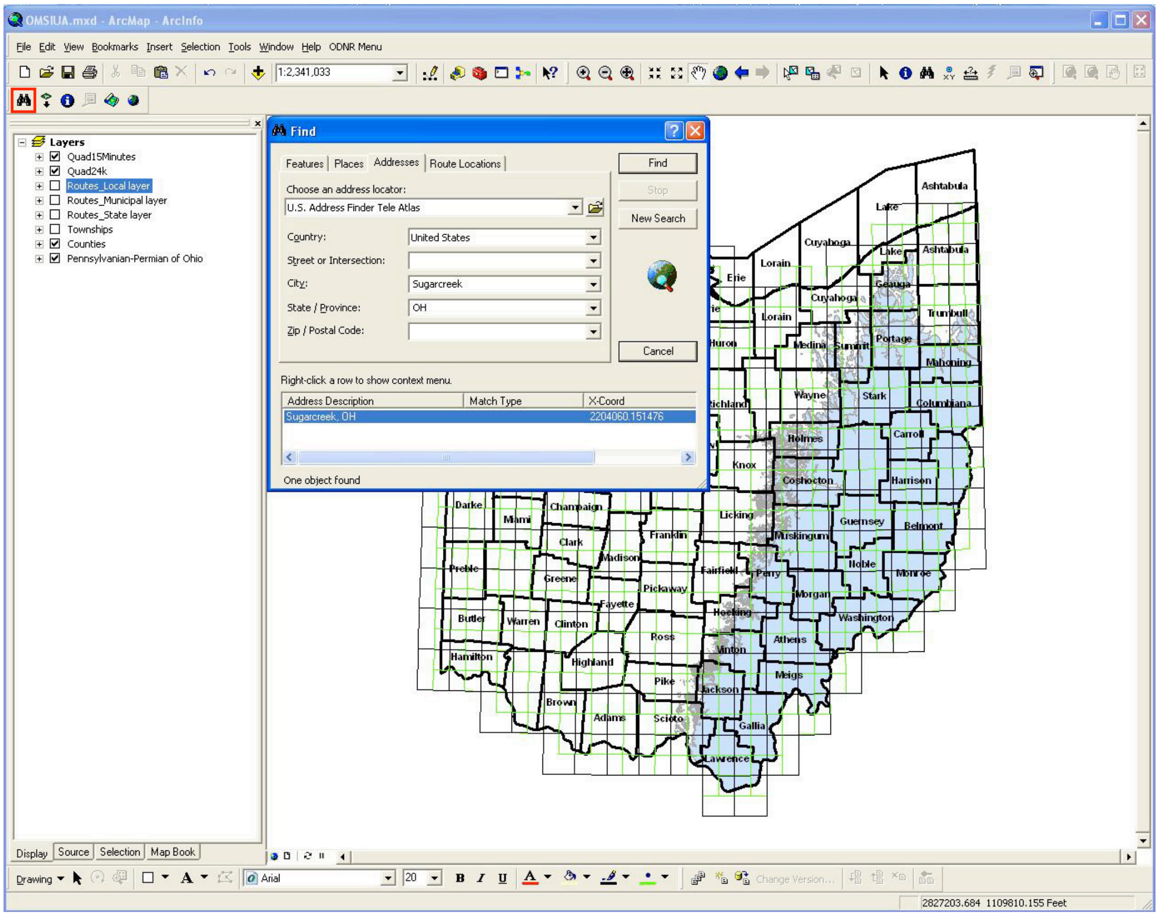

Figure 10. The "Find" tool on the OMSIUA Toolbar. This tool and the ESRI Address Locator are used to locate an insurance claim based upon the claim address. The "Find" tool is highlighted in RED on the OMSIUA Toolbar.

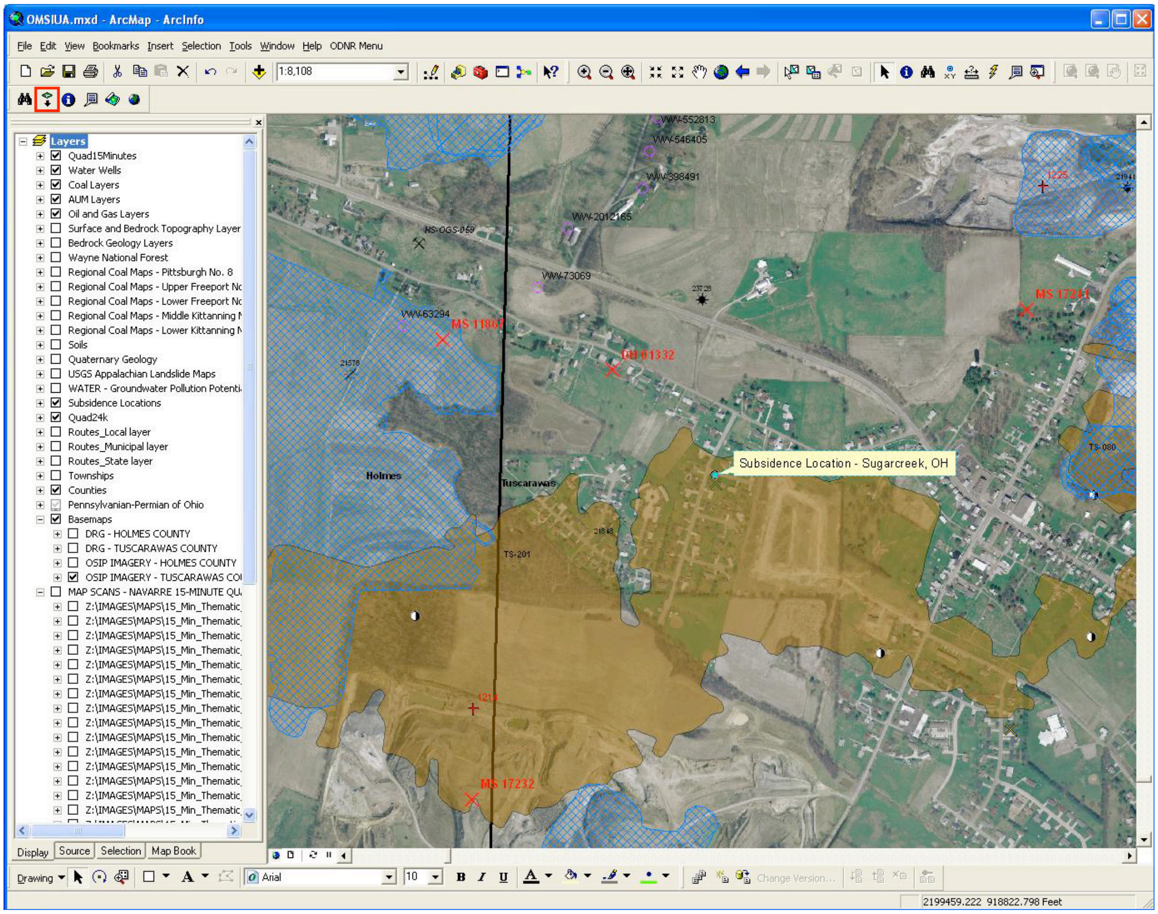

Figure 11. The “Select Location” tool on the OMSIUA Toolbar. All geologic information is loaded into ESRI ArcMap for the complainant location. The “Select Location” tool is highlighted in red on the OMSIUA Toolbar.

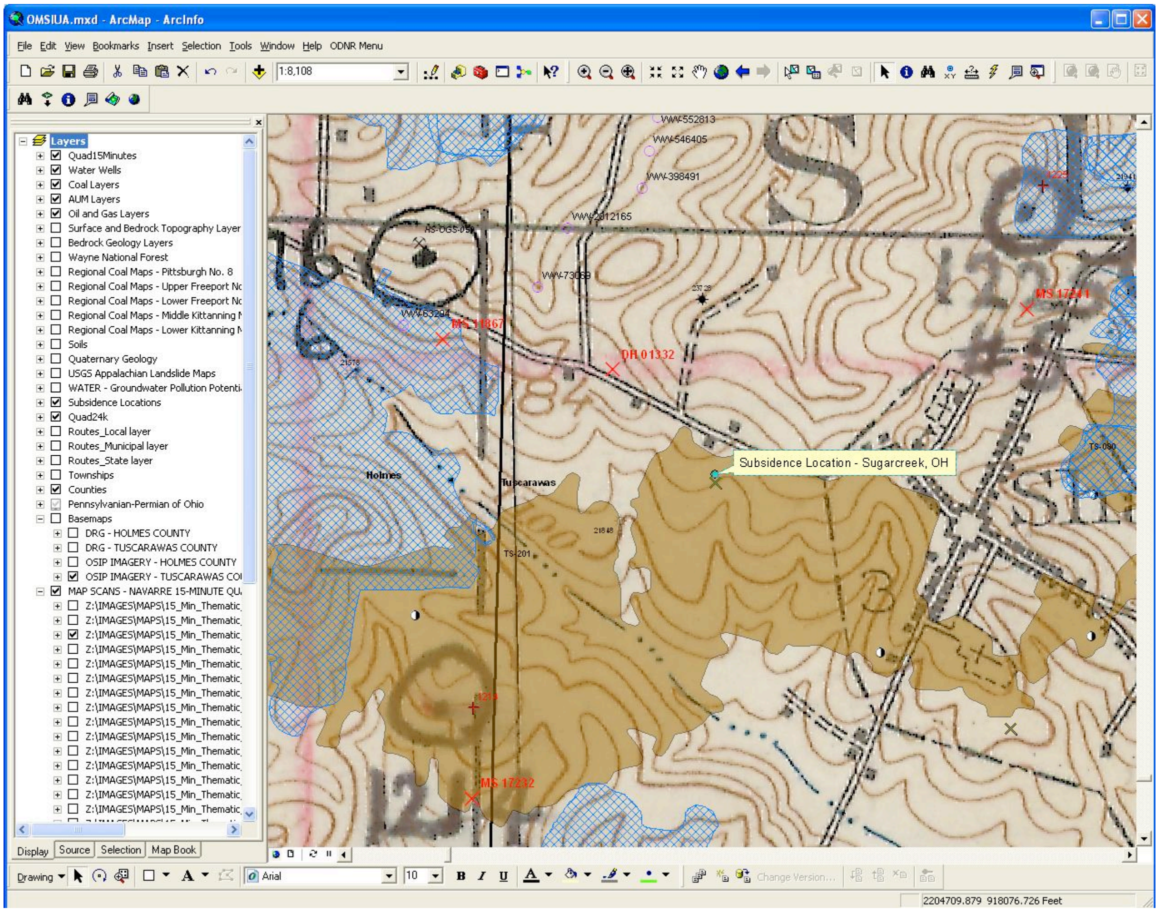

Figure 12. Historic thematic 15-minute topographic map as a base map. In the ArcMap TOC, 38 different thematic 15-minute topographic maps have been identified and loaded into the ArcMap project. The base map in this figure shows the coal sample locations mapped onto the thematic 15-minute topographic map.

Once the information is loaded, the geologist can conduct a preliminary mine-subsidence analysis. The Underground Mine Information Form (fig. 13A) will present the attribute information on abandoned underground mines. In addition, by using the form, the georeferenced abandoned mine maps can be loaded into ArcMap (fig. 13B). Documents can be accessed using the native ArcGIS Hyperlink tool (fig. 14). Some of the documents that can be accessed are measured stratigraphic sections, core descriptions, and oil- and gas-well completion cards. These three types of documents may contain a description of a coal bed, and possibly the notation that an underground mine is nearby.

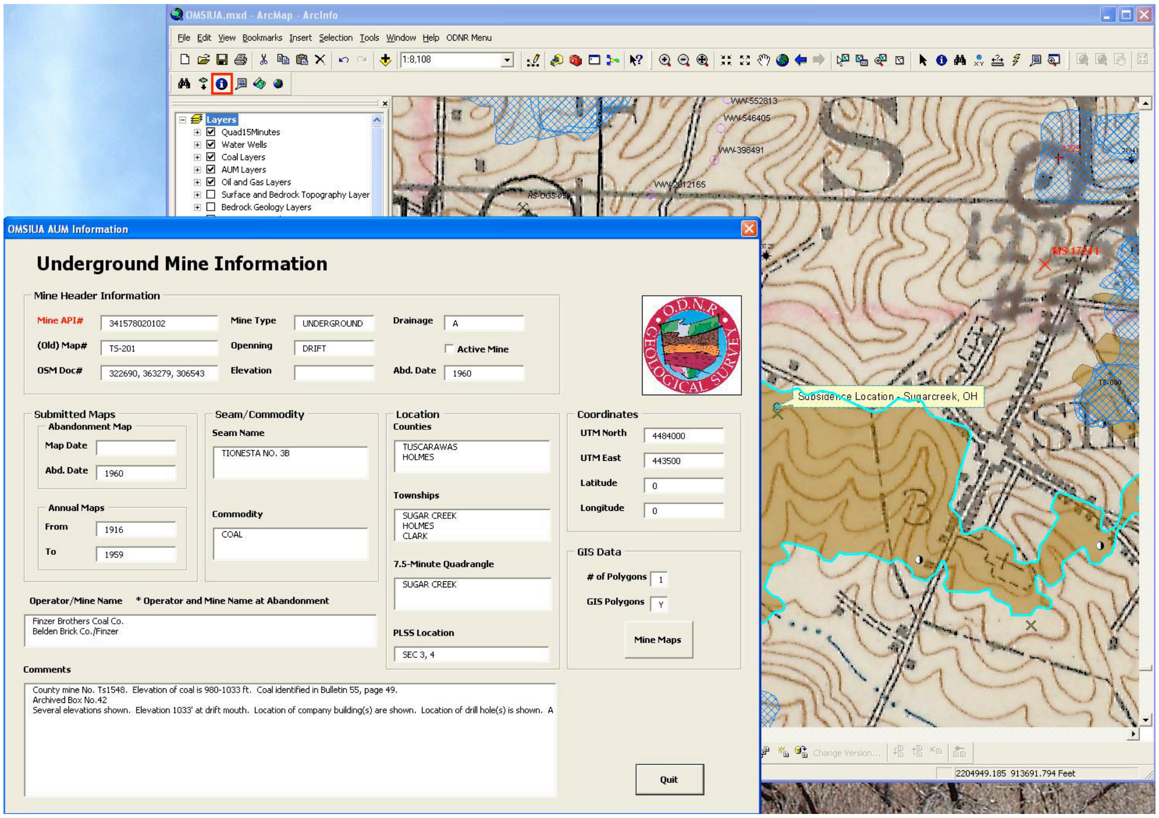

Figure 13A. Underground Mine Information Form. A VBA form was created that allows the selected mine attribute information to be loaded into the form for display. The Underground Mine Information Form is activated by selecting the "Underground Mine Information" tool on the OMSIUA Toolbar, which is highlighted in red.

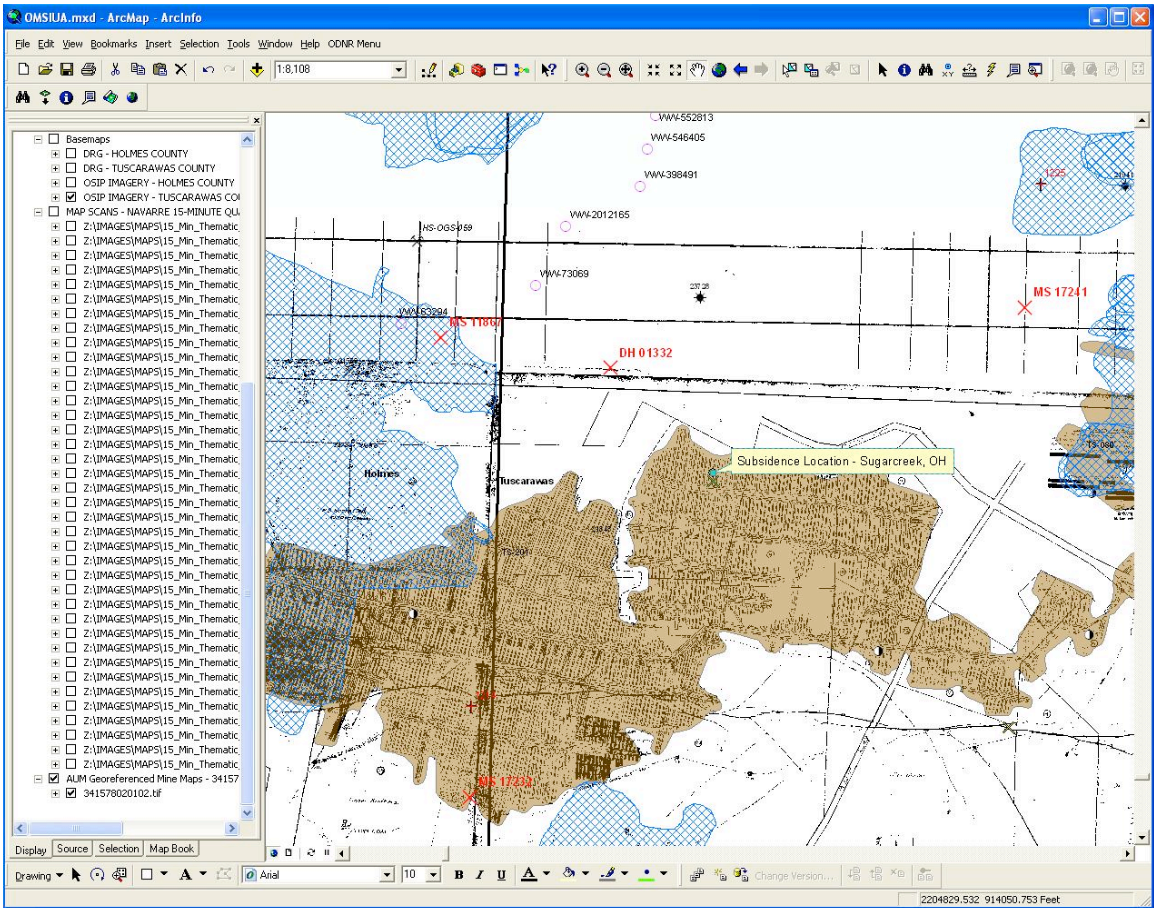

Figure 13B. Using the Mine Maps command on the Underground Mine Information Form, the georeferenced, detailed mine map can be loaded into ArcMap. The detailed mine maps show the room-and-pillar configuration within the abandoned underground mine.

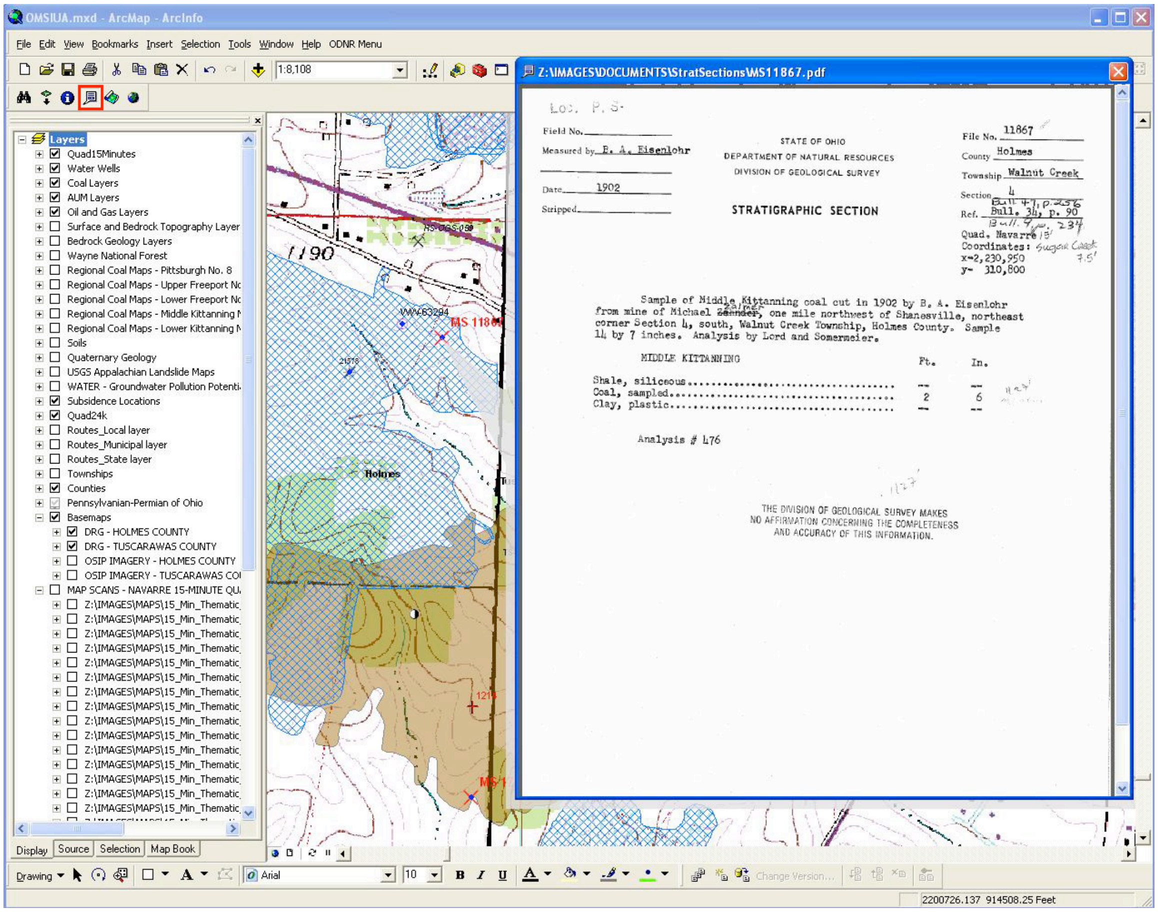

Figure 14. Example of using the ESRI ArcMap Hyperlink tool to access a scanned document. In this figure, the scanned document is a measured stratigraphic section. The ESRI ArcMap Hyperlink tool is highlighted in red on the OMSIUA Toolbar.

After the analysis is completed, portions of the preliminary mine subsidence report can be automated. A custom-designed tool will export thematic, page-sized PDF maps (fig. 15A). The page-size maps are generated with titles that are based upon the group layer names in the ArcMap TOC (fig. 15B). The PDF maps, along with all the geologic documents within a half-mile of the site, will be exported to a temporary directory (fig. 15C). The geologist can then compress the files and send them to the consulting engineering company for further analysis. These data allow the consulting engineering companies to have existing, publicly held geologic data about a site made available so that they arrive at the complainant's site with the appropriate data.

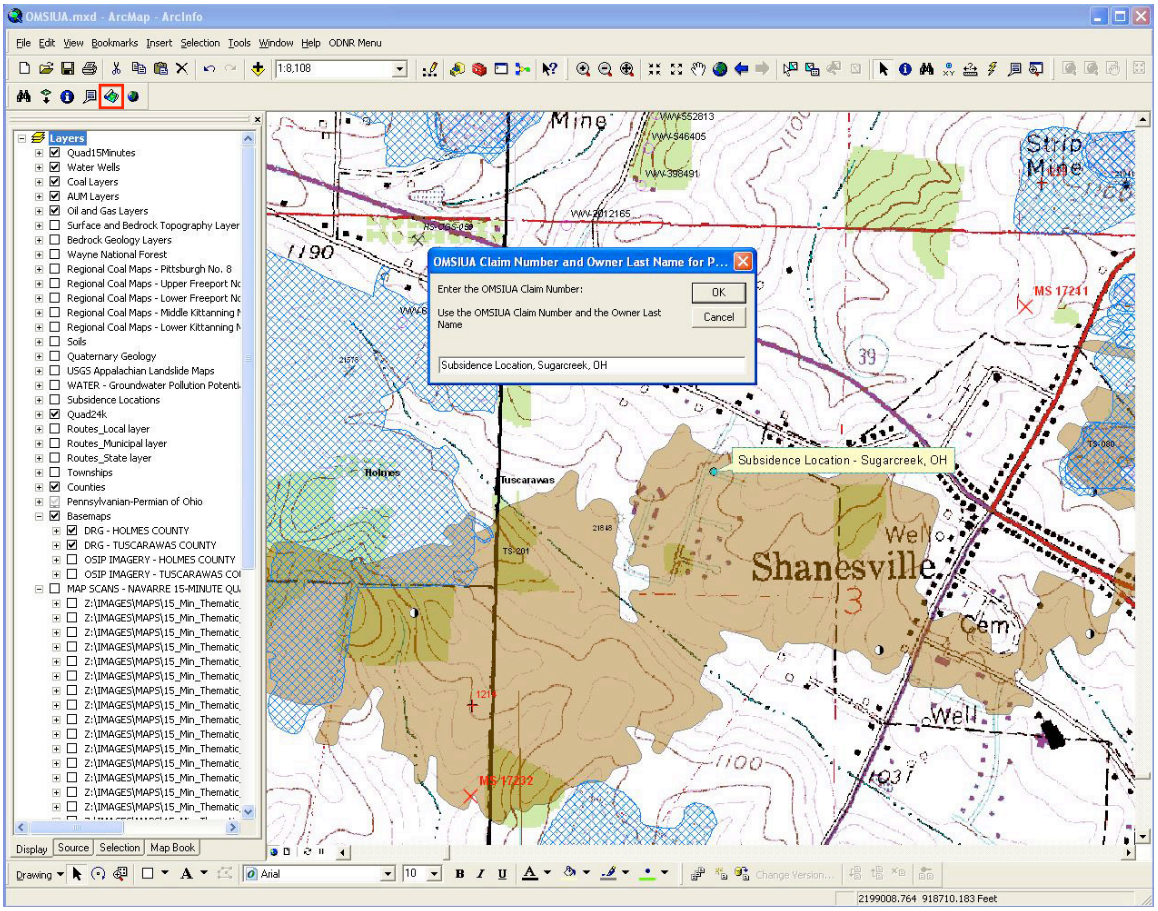

Figure 15A. The OMSIUA Toolbar contains a tool that automates exporting of PDF maps. The Export PDF tool is highlighted in red on the OMSIUA Toolbar.

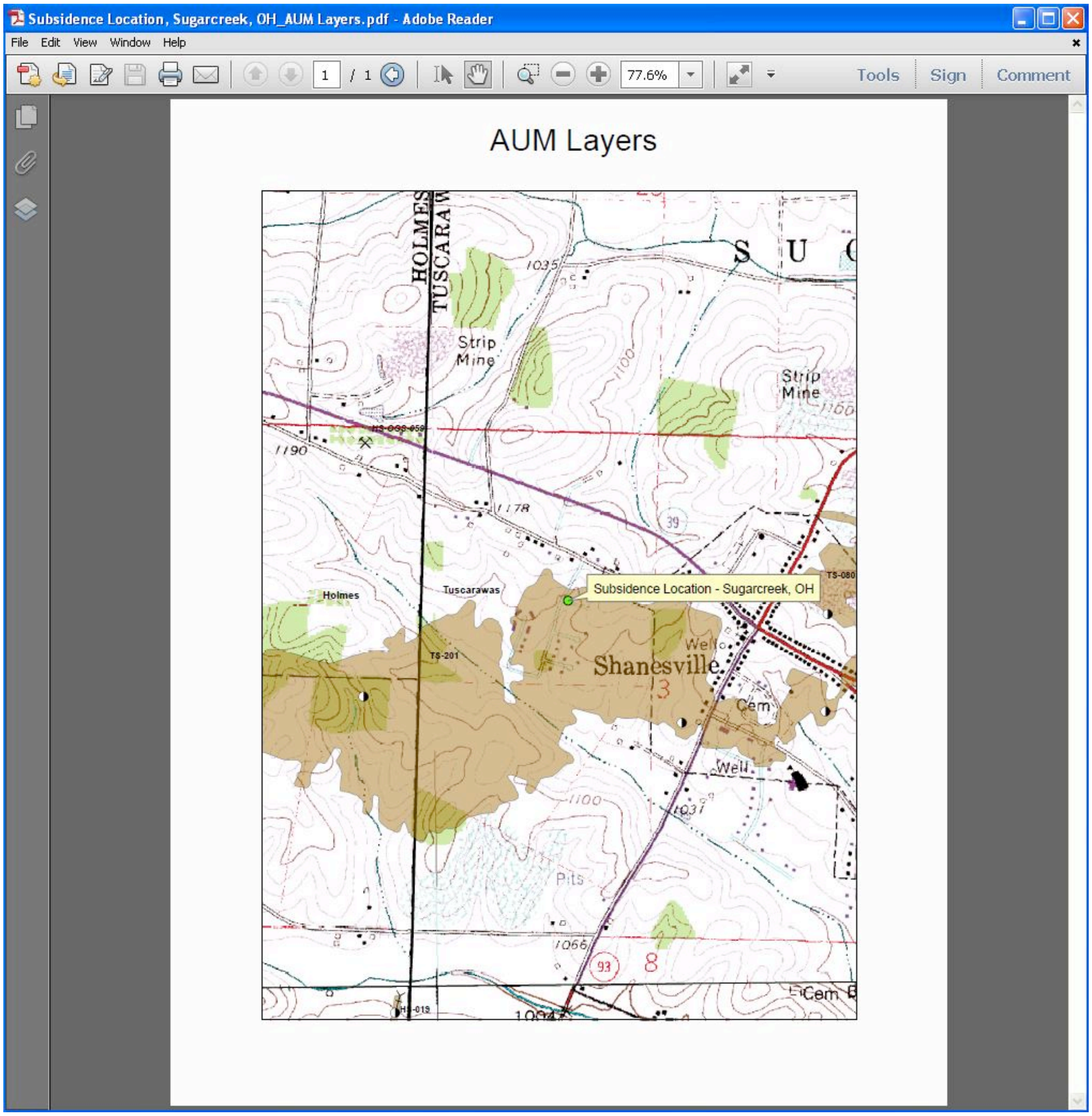

Figure 15B. Example of an automatically exported PDF map. Each automated PDF map is generated with a title based upon the group layer name in the ArcMap TOC.

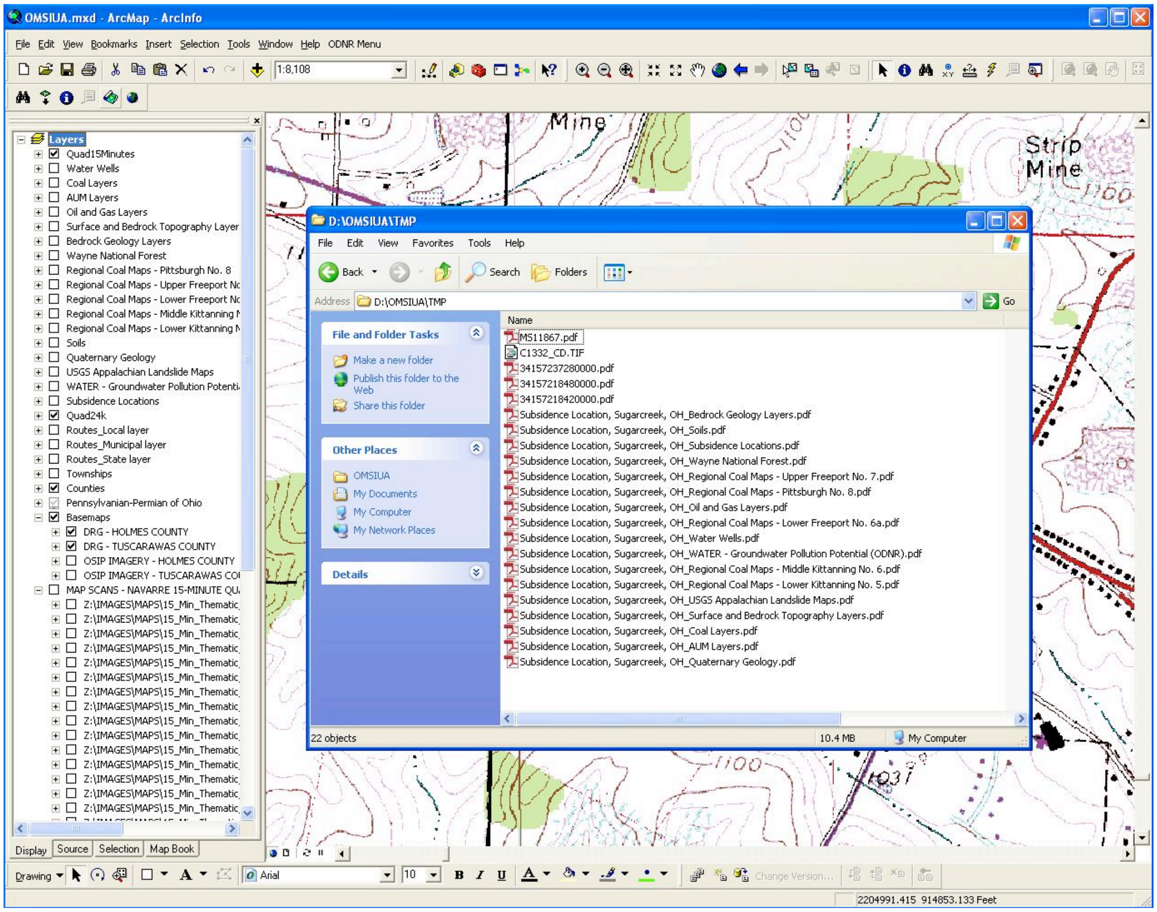

Figure 15C. Example showing the temporary directory that is specified to contain all the exported PDF maps and relevant scanned documents. The PDF figures and all documents within a half-mile radius are copied to this temporary directory, which then can be forwarded to the consultant for the site evaluation.

SUMMARY

The OMSIUA GIS application has proven to be extremely successful in its ability to gather all known geologic information for a specific location and present the information to GIS users within the ESRI ArcGIS Desktop environment. This application has significantly reduced the amount of time that a geologist takes to determine if the site of a mine subsidence claim is underlain by an abandoned underground mine. The application significantly speeds up the process of evaluating mine subsidence claims, thereby saving the State of Ohio and its citizens significant tax monies.

The application also proves to be very popular for nonsubsidence inquiries. Geologists have used the application to investigate potential karst sinkholes and the potential causes of landslides in Ohio. A modified version of the application has also been created to assist with the permitting of oil- and gas-well locations.

ACKNOWLEDGMENTS

The ODNR Division of Geological Survey thanks the Ohio Mine Subsidence Insurance Underwriting Association (OMSIUA) for providing funding to create the application and to perform the preliminary site assessments of mine subsidence insurance claims.

We also thank the many agencies that have allowed access to their GIS datasets for use in the OMSIUA GIS application. Within the Ohio Department of Natural Resources, the Division of Mineral Resources Management provides the surface-coal mine GIS datasets (MINEINFO dataset) and the Abandoned Mine Lands (AML) emergency locations, the Division of Soil and Water Resources provides access to the SSURGO soils GIS dataset and the DRASTIC GIS dataset, and the Office of Information Technology provides ESRI ArcSDE access and maintenance to the SURGO soils GIS dataset. The U.S. Department of Agriculture, Forest Service, provides access to the AIM dataset of abandoned-mine features located within Wayne National Forest.

The engineering consulting firms of Gannett Flemming and H.C. Nutting provide reviews of the output from the OMSIUA GIS application. These reviews provide information that makes the application more useful for mine-subsidence claim investigations. Finally, thanks to ODNR Division of Mineral Resources Management supervisor Tim Jackson and former chief John Husted for their support of the project.

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