OHIO GEOLOGY

GEOFACTS No. 12

OHIO DEPARTMENT OF NATURAL RESOURCES • DIVISION OF GEOLOGICAL SURVEY

MINE SUBSIDENCE

Mine subsidence, like an earthquake, is a geologic hazard that can strike with little or no warning and can result in very costly damage. However, unlike an earthquake, mine subsidence generally affects very few people. But, if a mine collapses under an interstate highway, many lives and industries are affected. Mine subsidence in March 1995 caused a portion of the eastbound lane of Interstate Route 70 (I-70) in Guernsey County to collapse. This subsidence event and the ensuing repair work closed the eastbound and westbound lanes of I-70 for several months, and the cost of the repair work was estimated at $3.6 million. From 1995 through 2001, the Ohio Department of Transportation has spent $26.6 million to repair mine-subsidence damage on eight highway projects.

Mine subsidence also can cause foundation damage to buildings, disrupt underground utilities, and be a potential risk to human life. Several Ohio communities, such as Wellston (Jackson County) and North Canton (Stark County), have been plagued with numerous mine-subsidence problems.

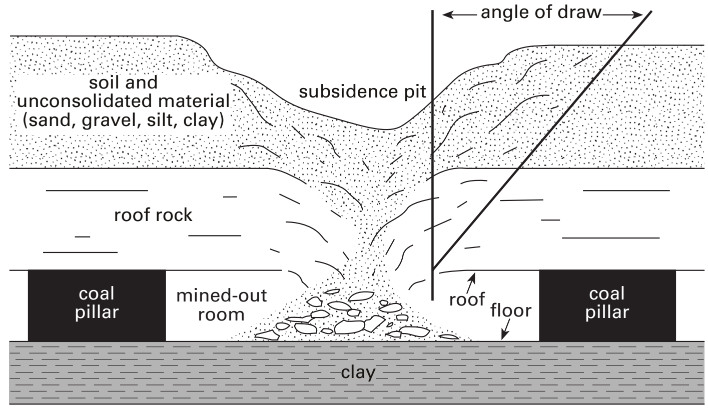
Abandoned underground mines are found in 35 counties in Ohio. Tuscarawas County has the most known abandoned underground mines at 419. Although clay, shale, limestone, iron ore, gypsum, and salt also have been mined underground, most of Ohio's estimated 6,000 abandoned underground mines are coal mines. As a result, Ohio has had a history of coal-mine subsidence problems dating to at least 1923.

This subsidence pit behind a residence in North Canton, Stark County, was 35 feet across and 25 feet deep. Photo courtesy of Ohio Division of Mineral Resources Management.

MECHANICS OF MINE SUBSIDENCE

Subsidence, in the context of underground mining, is the lowering of the Earth's surface due to collapse of bedrock and unconsolidated materials (sand, gravel, silt, and clay) into underground mined areas.

There are two types of subsidence: (1) pit, also called sinkhole or pothole, and (2) sag or trough. (The term "sinkhole" more properly refers to solution-collapse features in limestone.) Pit subsidence is characterized by an abrupt sinking of the surface, resulting in a circular steep-sided, craterlike feature that has an inward drainage pattern. It is associated with roof collapse of mines that have total overburden (overlying unconsolidated material and rock) of less than 165 feet, weak roof rock of shale or mudstone, and a ratio of unconsolidated-material thickness to rock thickness of less than 1.2. Pit subsidence does not occur where the thickness of the unconsolidated overburden is more than 90 feet. Sag subsidence is a gentle, gradual settling of the surface. It is associated with pillar crushing or pillar punching (discussed below) of deeper mines (overburden of more than 75 feet). Sag-subsidence features may fill with water if the surface of the subsidence intersects the water table. Pit-subsidence features generally do not hold water because the pit drains into the underlying mine.



Diagrammatic cross section of typical subsidence resulting from mine-roof collapse. No scale implied.

Mine subsidence is controlled by many factors, including height of mined-out area, width of unsupported mine roof, thickness of overburden, competency (strength) of bedrock, pillar dimensions, hydrology, fractures/joints, and time. The vertical component of subsidence is proportional to the height of the extraction area. Generally, the vertical component of subsidence does not exceed the height of the mine void. However, piping (subsurface erosion by water washing away fine-grained soil) of unconsolidated material can create a cavity deeper than the height of the mined area.

The area of mine subsidence increases proportionally with increasing width of unsupported roof rock. The potential area of subsidence is equal to the extraction area plus an area surrounding the extraction area measured by an angle up to 35°, called the angle of draw, from the vertical at the edge of the extraction area. For example, roof collapse in a mine 160 feet deep could cause subsidence more than 75 feet beyond the edge of the mine. The deeper the mine, the larger the area potentially affected by mine subsidence at the surface.

The vertical component of subsidence decreases with increasing depth or thickness of overburden, especially bedrock. As the roof rock sags, ruptures, and eventually collapses into a mined-out area, the roof rock rotates, twists, splinters, or crumbles as it falls, resulting in incomplete compaction. In other words, the mine void is not completely filled during a mine-roof collapse. Because bedrock collapses with incomplete compaction, the deeper the extraction area, the smaller the vertical component is at the surface.

Mine subsidence is related to the strength or competency of bedrock, which is a measure of a rock's load-bearing capacity. Sandstones and limestones are capable of withstanding greater loads than are shales and mudstones. Therefore, sandstones and limestones can span larger unsupported distances or support thicker amounts of overburden before failing.

Mine subsidence increases as the size of the supporting pillars decreases. In room-and-pillar mining, the most common style of underground mining in Ohio, about 50 percent of the seam is left in place as pillars for roof support. However, coal operators in the nineteenth and early twentieth centuries commonly mined the pillars, partially or wholly, as an area of the mine was abandoned. Complete mining of a pillar is called pillar robbing. Reducing the size of a pillar is called pillar slicing. Creating small, multiple pillars out of a single, large pillar is called pillar splicing. Mining the pillar increases the width of unsupported roof, which increases the likelihood of subsidence. Also, diminishing the size of a pillar increases the chance of pillar crushing or pillar punching and increases the chance of mine-roof collapse. Pillar crushing results when the weight of the overburden exceeds the load-bearing capacity of the

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pillar and it is crushed. Pillar punching results when the weight of the overburden exceeds the load-bearing capacity of the floor rock, and the pillar is pushed downward into the floor. In pillar punching, the floor rock is generally a soft, plastic clay that flows upward into the mine void, a phenomenon miners term a "squeeze."

Mine subsidence is affected by water circulation or the fluctuation of water level in a mine. Some underground mines remain dry after abandonment; many others fill with water. Circulating water in an underground mine can deteriorate roof support or the roof rock. Because of its incompressibility, water provides support to the roof of a mine that is filled with water. However, the likelihood of roof collapse may be enhanced or accelerated in mines where the roof rock is repeatedly saturated then left unsupported by fluctuating water levels (either by seasonal weather conditions or intentional pumping) and where the pillars of coal are eroded by flowing water.

The likelihood of subsidence increases where fractures (joints) intersect the mine roof. Fractures or joints are natural planes of weakness where collapse of the mine roof is likely to occur. Fractures also may allow the subsidence to extend beyond the limit of the mined area.

The length of time for mine subsidence to occur increases with increasing depth of mining and increasing competency of overburden. The type and amount of roof support in addition to pillars of coal left in the mine also affect subsidence. Most early underground mines in Ohio used wooden timbers as additional roof support. Steel I-beams were used in Ohio mines as roof support beginning in the early twentieth century. By the mid-twentieth century, roof bolting was another type of roof support being used in Ohio mines. With time following abandonment of an underground mine, these types of roof support eventually rot or deteriorate, allowing subsidence to occur. Because of the complexity of the variables which contribute to mine-related subsidence, no acceptable system exists which is capable of accurately predicting the time or amount of subsidence in a variety of geological settings, especially for mines that have an irregular pattern of room-and-pillar mining.

In addition to subsidence above a mine, the collapse of improperly stabilized mine openings presents a great risk to public property and safety. The collapse of an improperly sealed shaft may equal the original depth of the shaft. In 1977, an improperly stabilized shaft to a coal mine abandoned in 1884 collapsed underneath a garage in a residential neighborhood in Youngstown, leaving a 115-foot-deep opening. This shaft was originally 230 feet deep. Fortunately, there was no loss of life or personal injury associated with this collapse, but this shaft collapse illustrates the potential for life-threatening situations due to collapse of mine openings.

ABANDONED-UNDERGROUND-MINE MAPS

The Division of Geological Survey has detailed abandonment maps (scale: 1 inch equals 400 feet) for 4,138 mines, most of which are coal mines. In addition to those mines for which detailed maps are available, the Division estimates there are approximately 2,000 mines for which no detailed maps of the mine workings are available. The Division's extensive database on abandoned underground mines includes mine-information sheets, detailed maps of individual abandoned underground mines, and an Abandoned Underground Mine Map Series. The maps in this series are plotted on U.S. Geological Survey 7.5-minute topographic quadrangle bases (scale: 1:24,000, or 1 inch equals 2,000 feet) and show the areal extent of mapped abandoned underground mines, the location and type of mine openings (air shaft, drift, slope, and hoisting shaft) for mapped mines, and the location of openings to abandoned underground mines for which no mine maps exist. Copies of the quadrangles in the Abandoned Underground Mine Map Series can be purchased from the Division for $4.00 per map, plus tax and shipping. To order an abandoned-mine map or to find out more about abandoned underground mines in Ohio call the Division of Geological Survey at 614-265-6576. The accompanying sheet shows the location of 7.5-minute quadrangles in Ohio for which abandoned-underground-mine maps are available.

Subsidence pit, about 6 feet across and 8 to 10 feet deep, on I-70 resulting from roof collapse of a mine in March 1995. Photo courtesy of Gannett Fleming, Inc.

MINE SUBSIDENCE INSURANCE

The Ohio Mine Subsidence Insurance Law mandates mine-subsidence coverage for all basic homeowner insurance policies in 26 Ohio counties: Athens, Belmont, Carroll, Columbiana, Coshocton, Gallia, Guernsey, Harrison, Hocking, Holmes, Jackson, Jefferson, Lawrence, Mahoning, Meigs, Monroe, Morgan, Muskingum, Noble, Perry, Scioto, Stark, Trumbull, Tuscarawas, Vinton, and Washington. The insurance is available on an optional basis for 11 Ohio counties: Delaware, Erie, Geauga, Lake, Licking, Medina, Ottawa, Portage, Preble, Summit, and Wayne. The maximum amount of coverage for the principal dwelling allowed by the insurance is $50,000. Of the 1,070 mine-subsidence claims filed between 1988 and October 2001, only 50 were documented to be a result of mine subsidence. The Ohio Mine Subsidence Insurance Underwriting Association estimates the cost of the damage payments for the 50 claims totalled $1,189,000. In addition to the cost of mine-subsidence insurance claims, since 1980 the Ohio Division of Mineral Resources Management and the U.S. Office of Surface Mining, Reclamation and Enforcement have treated 74.4 acres of mine subsidence at an estimated cost of $8,111,000.

Subsidence seems to be increasing owing to the age of underground mines. The ultimate extent of mine-subsidence problems in Ohio is uncertain. For information concerning mine-subsidence insurance, call the Ohio Fair Plan, Mine Subsidence Insurance Underwriting Association at 1-800-282-1772 or 614-839-6446. To have damage to a site from a known or suspected underground mine evaluated, or to have a potentially life-threatening mine opening sealed, call the Ohio Division of Mineral Resources Management at 614-265-6633.

FURTHER READING

Crane, W. R., 1931, Essential factors influencing subsidence and ground movement: U.S. Bureau of Mines Information Circular 6501, 14 p.

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DeLong, R. M., 1988, Coal-mine subsidence in Ohio: Ohio Division of Geological Survey, Ohio Geology, Fall, p. 1-4.

Hoffman, A. G., Clark, D. M., and Bechtel, T. D., 1995, Abandoned deep mine subsidence investigation and remedial design, Interstate 70, Guernsey County, Ohio, *in* 46th Highway Symposium: Charleston, West Virginia, May 14-18, 1995, 15 p.

• This GeoFacts compiled by Douglas L. Crowell • Revised November 2001 •

The Division of Geological Survey GeoFacts Series is available on the World Wide Web: http://www.ohiodnr.com/geosurvey/