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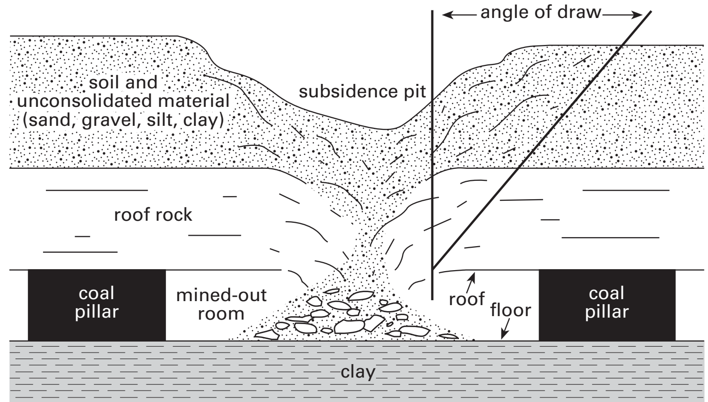
MINE SUBSIDENCE

Like an earthquake, mine subsidence 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 an underground mine collapses beneath 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.

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 41 counties in Ohio. Tuscarawas County has the most known abandoned underground mines at 455. Although clay, shale, limestone, iron ore, gypsum, and salt also have been mined underground, most of Ohio's estimated 8,000 abandoned underground mines are coal mines. As a result, Ohio has a history of coal mine subsidence problems, dating back to at least 1923.

This home in Sugarcreek, Tuscarawas County, was damaged by the collapse of an underground mine. July 9, 2009.



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

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 ground 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 that is less than 1.2:1. Pit subsidence does not occur where the thickness of the unconsolidated overburden is more than 90 feet. Sag subsidence occurs as a gentle, gradual settling of the ground surface and is associated with roof collapse, 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.

Mine subsidence is controlled by many factors, including height of a mined-out area, width of an unsupported mine roof, overburden thickness, bedrock competency (strength), 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 caused by water washing away fine-grained soil—of unconsolidated material can create a cavity deeper than the height of the mined area.

The total area of mine subsidence increases proportionally with increasing width of unsupported roof rock. The potential area of subsidence is equal to the area of collapse in the mine plus an area surrounding the collapsed area measured by an angle (called the *angle of draw*) up to 35° from the vertical at the edge of the collapsed area. For example, roof collapse in a mine 160 feet deep could cause subsidence more than 75 feet beyond the edge of the mine. Thus 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 can withstand greater loads than shales and mudstones and therefore 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 in turn 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 pillar and it is crushed. *Pillar punching* occurs 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 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 a mine roof. *Fractures* or *joints* are natural planes of weakness where mine roof collapse is likely to occur. Fractures also may allow subsidence to extend beyond the limit of a mined area.

The length of time for mine subsidence to occur increases with increasing depth of mining and increasing competency of overburden. In addition to pillars of coal left in the mine, the type and amount of roof support also affect subsidence. Most early underground mines in Ohio used wooden timbers as additional roof support. Beginning in the early twentieth century, steel I-beams were used in Ohio mines as roof support. 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, creating conditions for subsidence to occur. Because of the complexity of the variables that contribute to mine-related subsidence, no acceptable system exists that is capable of accurately predicting the time or amount of subsidence in a variety of geologic settings, especially for mines that have an irregular pattern of room-and-pillar mining.

In addition to subsidence above a mine, collapse of improperly stabilized mine openings presents great risk to public property and safety. The depth of collapse of an improperly sealed shaft may be less than or equal to 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-feet-deep opening. The shaft was originally 230 feet deep. Fortunately, no loss of life or personal injury was associated with this collapse, but this incident illustrates the potential for life-threatening situations due to collapse of mine openings.

OHIO ABANDONED MINE LOCATOR

In 2004 the ODNR Division of Geological Survey, along with the Ohio Mine Subsidence Insurance Underwriting Association and the ODNR Division of Mineral Resources Management, released an interactive Web site, the *Ohio Abandoned Underground Mine Locator*, which gives property owners, developers, and transportation officials the ability to determine if a mine is located underneath a property. The locator is designed to improve public access to abandoned underground mine records. These records include original abandonment maps, turned into the state upon closing of the mine, and details about the mine. Such information can aid in quantifying and categorizing the hazard potential and includes but is not limited to the commodity being mined (coal, limestone, sandstone, gypsum, clay, etc.); past operator(s) of the mine; year(s) of operation; and notes about the condition of the mine when abandoned, such as roof collapse. All information found on the maps and related documents are compiled into the abandoned underground mine database (made available to the public through the *Ohio Abandoned Underground Mine Locator*). The locator contains an address locator system and displays aerial photography and topographic maps as references. Locator users also can download detailed mine maps and can compare a map in their possession with mine maps archived by the ODNR Division of Geological Survey. Visit **www.OhioGeology.com** to access the *Ohio Abandoned Underground Mine Locator*.

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 insurance coverage allowed for the principal dwelling is $300,000. Of the 1,750 mine subsidence claims filed between 1988 and October 2010, only 117 were documented to be a result of mine subsidence. The Ohio Mine Subsidence Insurance Underwriting Association (OMSIUA) estimates the cost of the damage payments for the 117 claims totaled nearly $3.5 million. In addition to the cost of mine subsidence insurance claims, since 1980 the ODNR Division of Mineral Resources Management and the U.S. Office of Surface Mining, Reclamation and Enforcement have treated 359 acres of mine subsidence at an estimated cost of more than $23 million.

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 OMSIUA at 1-800-282-1772 or (614) 839-6446 or visit its Web site: **www.ohiominesubsidence.com**. 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 ODNR Division of Mineral Resources Management at (614) 265-6633.

FURTHER READING

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• This GeoFacts compiled by Douglas L. Crowell • Revised December 2010 •