THE PITTSBURGH GEOLOGICAL SOCIETY

LAND SUBSIDENCE IN WESTERN PENNSYLVANIA

Civilization exits by geological consent, subject to change without notice.
Will Durant

Land subsidence is the sinking of the ground surface above an underground void or depression. This phenomenon can be caused by the collapse of an underground mine or cave, or by the compaction or deterioration of soils and fill materials beneath engineered structures such as buildings, bridges, and roads. If the subsidence occurs beneath or directly adjacent to a man-made object, the result can be very costly and dangerous. In rural areas where homeowners have no access to municipal water supplies, subsidence can disrupt ground water supplies, leaving homes with no water source.

Subsidence caused by the collapse of caves (**sinkholes)**, although not unknown in western Pennsylvania, is not considered a major problem here. It is more prevalent in central and eastern Pennsylvania where sinkholes have been a big problem since colonial days. More important to western Pennsylvanians are the many mine subsidence and foundation subsidence problems that occur in this region.

MINING WESTERN PENNSYLVANIA

Pennsylvania, which generated 68 million tons of coal in 1996 alone, ranks fourth in the nation in coal mining, with Greene County being the third leading county in the US. Coal generates billions of dollars, employs thousands of people, supports local economies, and provides most of the fuel for electric generation. Although coal has been mined in this area for more than 200 years, mining operations were largely restricted to rural areas until the onset of suburban sprawl after World War II. Many mining companies purchased the mineral rights to coal in the 1800s and are still exercising those rights today in one of two ways: 1) strip mining, where the rock and soil layers are stripped off to expose the coal; and 2) deep mining, where a shaft is sunk to the coal seam and tunnels are dug horizontally through the coal. Unlike strip mine laws that require mining companies to be responsible for environmental degradation, deep mining has no such restrictions. In fact, deep mining currently is considered to e desirable since its environmental and structural impacts are perceived as immediate, rather than long-term problems. Now, rapidly expanding suburbs and decentralization of industry are faced with land subsidence problems wherever minable coal exists or was mined (Figure 1).

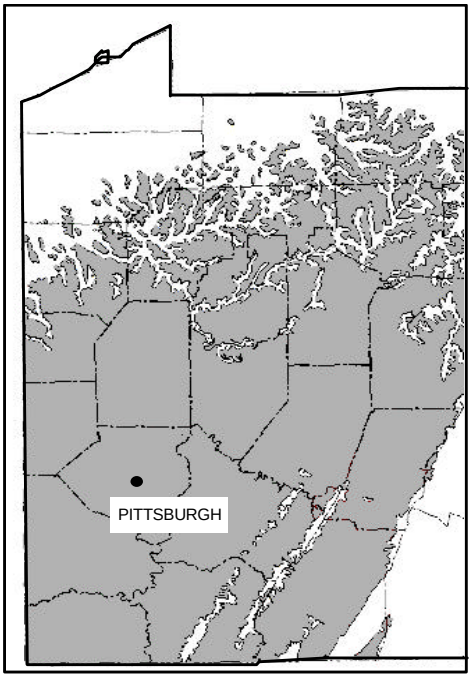

Figure 1. Map of western Pennsylvania showing the area (shaded) where coal exists or has been mined.

Deep coal mining methods have under-gone many changes since the first western Pennsylvania mines were open in the 1700s. The method used primarily up until the 1960s, and is still used in many areas, is **room-and-pillar** mining (Figure 2A). The miners open a system of entries to the farthest reaches of the property to provide access and ventilation before extensive mining begins. Mining then proceeds by driving rooms off these access ways at intervals so as to leave pillars of coal between rooms. This method leaves 50% or more of the coal still in place as pillars that hold up the mine roof. Collapse can occur within rooms, but this generally takes a long time and affects only small areas. Larger areas can be affected where failure occurs in several adjacent pillars.

Retreat mining involves removing the pillars that were left during room-and-pillar mining. Mining starts at the distant end of the mine and retreats toward the entries. Most of the pillars are removed, resulting in nearly complete extraction of coal (75-85%). Without support, however, the roof will collapse where the pillars have been removed. As a result, the rock and soil overlying the mine, called **overburden,** will collapse as well, causing subsidence at the surface. Overburden often contains rock layers that act as reservoirs for ground water (aquifers). When the mine roof collapses and the overburden sinks, these rocks break apart and water drains out of the reservoir. This typically results in water loss from wells in the affected area.

The third type of underground mining method, and the one that guarantees surface subsidence, is **longwall** mining (Figure 2B). This method uses a machine capable of removing 100% of the coal in enormous swaths. Mine safety is supplied by a set of **chocks**, sheltering steel braces that hold up the mine roof during coal removal, but which are constantly being moved as mining proceeds. As the chocks are moved, the mine roof is allowed to collapse behind them, resulting in almost immediate and guaranteed surface subsidence. Mining companies are required by law to repair, replace, or compensate for any structural damage caused by longwall mining, and actually anticipate subsidence damage when planning their mines.

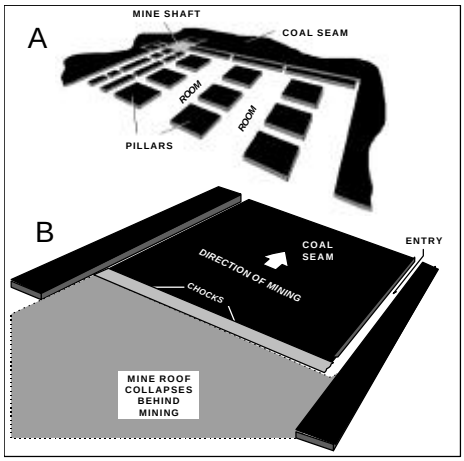

Figure 2. Coal mining methods. A -- Room-and-pillar mining. Pillars of coal are left in place to prevent the mine roof from collapsing during mining. These are removed during retreat mining. B --Longwall mining, showing collapse of the mine roof as mining advances.

SUBSIDENCE POTENTIAL

Underground cavities that collapse can have a profound effect on the ground surface, on any structures built there, and on any intervening features such as ground water reservoirs. The size of the cavity, its depth beneath the surface, and the nature of the rocks in the intervening layers are important influences in the extent of surface subsidence. The most destructive subsidence events tend to occur where the cavity is only a few feet or a few tens of feet below the surface, regardless of the other factors. Figure 3 shows the relationship of a coal mine void to a potential subsidence event. The zone of maximum subsidence occurs directly above a collapsed mine opening. The damage does not stop there, however, but extends outward to encompass a much larger area at the surface, as shown by the potential subsidence profile in Figure 3.

In areas situated above abandoned room-and-pillar mines, structures and ground water tables more than 200 feet above the mine generally do not suffer major damage from subsidence. Cases of subsidence where the coal was as much as 800 feet deep have been recorded, but these are unusual and probably involved multiple pillar failure.

Changes in conditions within old room-and-pillar mines sometimes cause local surface subsidence even where pillars have been left. Unstable rock beneath one or more pillars can lead

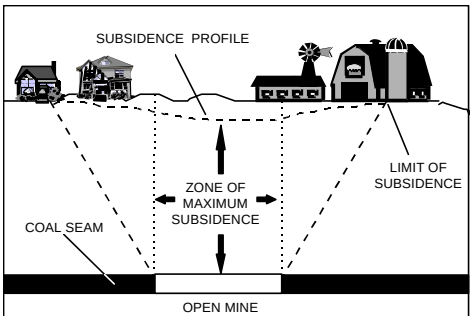

Figure 3. When a mine opening collapses, more surface area is affected than just the land directly above the collapsed void.

to pillar failure, causing collapse of the mine roof and subsequent surface subsidence. Mine fires can also result in surface subsidence by destroying pillars.

At the time it was made into law, the Bituminous Mine Subsidence and Land Conservation Act of 1966 required mining companies to leave coal pillars for support of all homes present at the time of mining. Retreat and longwall mining were only allowed in rural areas where few or no buildings existed. For new homes the law required that the deed indicate the existence of, or lack of, subsurface support. Originally, coal companies had to contact property owners and assign a price for leaving coal pillars as support. Although such a purchase could be a financial burden to landowners, it was the only practical means of substantially lessening the probability of subsidence damage in areas of active mining. Later amendments to this law allow mining companies to use longwall methods without regard to the existence of surface structures. These amendments also require the companies to make restitution for any damage caused at the surface as a result of mine collapse, including the loss of ground water supplies.

PREVENTION AND REMEDIATION

The only way to prevent mine subsidence is to stop mining and backfill all existing mines. This is not a realistic option, however, as our economy is dependent on coal, and filling all mines would be too expensive. Subsidence will occur with retreat and longwall mining, but where the timing and amount of subsidence can be estimated, provisions can be made to minimize the damage. Even where timing and extent of damage are uncertain, a number of prevention and remediation techniques is available.

In situations where a structure is underlain by abandoned room-and-pillar mines, but pillar support is insufficient, there are several methods of support available. These include filling the mine, adding roof supports, and constructing grout columns.

Complete filling of the mined area can be done during mining by backfilling with rock or mine waste or, after mining, by pumping cement grout, crushed slag, fly ash, sand or other material into the mined-out areas until the void spaces are filled as completely as possible. This is very expensive, and very rarely used for single family homes. It is used more frequently for larger buildings such as schools where the tax base will cover the cost of remediation.

Construction of roof supports within old mines is undertaken only in areas that are accessible, dry (that is, above the local ground water table), and where the roof rock is relatively strong. Concrete supports can be used where the mine generally is less than 50 feet deep. This process involves inserting concrete-filled steel casing in the mine, either through an entry or through large-diameter holes drilled into the mine.

The most commonly used technique for providing support for structures located 50 to 150 feet above old mines in the Pittsburgh area is subsurface stabilization. This technique involves the use of columns of grout and gravel (Figure 4) at selected spacing in the mine and the overburden. Grout is a slurry of water-rich cement injected into mine openings through drilled holes. It is a common form of remediation in the Pittsburgh area. These columns reduce the span length of unsupported openings in the mine and strengthen prevention and remediation techniques is available.

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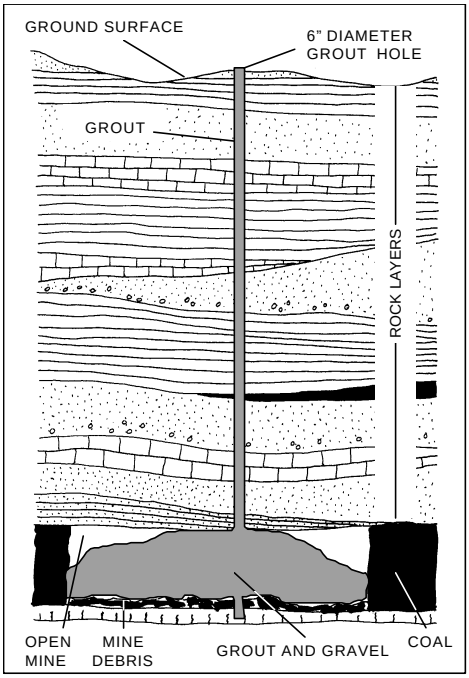

Figure 4. Filling a mine void with a grout column.

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FOUNDATION DAMAGE

Foundation damage from localized soil subsidence, heave, or basement wall collapse constitutes a major geologic problem in western Pennsylvania. It can cause extensive damage but typically is not the headline maker that mine subsidence has been. The foundation of any structure is its most important feature – it provides support for the walls and columns. If foundation problems occur, the damage commonly propagates upward into the main part of the structure. Common foundation problems in western Pennsylvania include: 1) settling or subsidence due to compaction or erosion of the soil; 2) uplift (heave) due to expanding bedrock or fill; and 3) basement wall failures due to poor drainage of the adjacent ground.

WHAT CAN YOU DO?

Western Pennsylvania residents should be aware of the danger of land subsidence and other geologic hazards before buying new homes or building on undeveloped land. Because of the 200-year history of mining in this area, it is imperative that new building sites be investigated thoroughly before construction. In addition, each new home purchase should be investigated prior to sale to determine the potential effect of either past or future mining operations on the area. Homeowners, especially, should be aware of the dangers of building or buying a house in a subsidence-prone area.

The Mine Subsidence Insurance program of the Pennsylvania Department of Environmental Protection (DEP) is located in McMurray, Washington County, Pennsylvania. If you want to know if your property sits above an open mine, you should contact the program at (724) 941-7100 and apply for insurance. DEP will investigate to see if insurance is warranted, and will issue an inexpensive policy if they find there is potential for damage. If a building has been damaged, DEP will conduct an inspection to determine the extent and nature of the damage. The old saw, “An ounce of prevention is worth a pound of cure”, is certainly relevant in this case. Insurance is available and affordable, but even the best policy will fail if it is not implemented.

A good guide to the hazards of owning a home or office in western Pennsylvania is *"Lots" of Danger! Property Buyer's Guide to Land Hazards of Southwestern Pennsylvania* which is available for $4.00 + $1.50 for shipping and handling from the Pittsburgh Geological Society, PO Box 58172, Pittsburgh, PA 15209; telephone (412) 928-2255.

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