EGG-CRATE MINE SUBSIDENCE[1]

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Abstract: Steep-sided or near-vertical ground failures over shallow room-and-pillar works are well known and thoroughly covered in the literature. Variously termed pothole, sinkhole, cockpit, and chimney (or chimney cave) subsidences, these failures tend to occur without warning and sometimes many years after mining, usually as single or small clusters of events. Recently, during background work on a Pennsylvania bituminous AML fire, a regular pattern of light and dark areas on vintage aerial photographs was seen to closely match abandoned room-and-pillar works. On the ground, this pattern proved to be complete subsidence into the mine voids with only minor settling over the pillars and ribs. The differential subsidence has produced a topography closely resembling an egg crate – thus the term coined here, "egg-crate subsidence." Examination of additional historic aerial photographs of the region revealed the egg-crate patterns are common. Where egg-crate subsidence patterns exist, secondary mining seems to be rare owing to roof support problems during the initial mining. Unmined coal and old works are ideal sites for fire, water pollution, and land use development problems. Although remining has eliminated many egg-crate subsidence areas, enough remain, at least in western Pennsylvania, to pose long-term nuisances. Some of the conditions contributing to egg-crate subsidence (time, depth, mining height and method, etc.) will be presented as will the value of preserving and digitizing old aerial photography and mine maps. New data and remote sensing techniques are being studied which may be able to add these egg-crated areas to the AML inventory.

Additional Key Words: shallow underground mining, fire hazard, historic aerial photos, remote sensing

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[1]Paper was presented at the 2007, 30 Years of SMCRA and Beyond, June 2-7, 2007, Gillette WY R.I. Barnhisel (ed) published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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Introduction

In 2006, background work on a Pittsburgh coal mine fire required georeferencing a 1914 map of the Lynn Station Mine (Figure 1) to a 1938 aerial photograph (Figure 2). During the process, a striking geometric light/dark pattern in the photo was observed to clearly coincide with old workings in the affected section of the mine.

Figure 1 1914 Mine map.

Figure 2 1938 Aerial photograph.

The site's surface consists of 3- to 8-foot hummocks on about 20-foot centers and looks very much like a snow skier's mogul field or a foam "egg-crate" mattress pad. Trenches dug to access the fire revealed that mining was advance only and conducted under less than 15 feet of cover consisting of weathered shale, alluvium, and soil (Figure 3). Some entries were open but roof collapse had filled crosscuts.

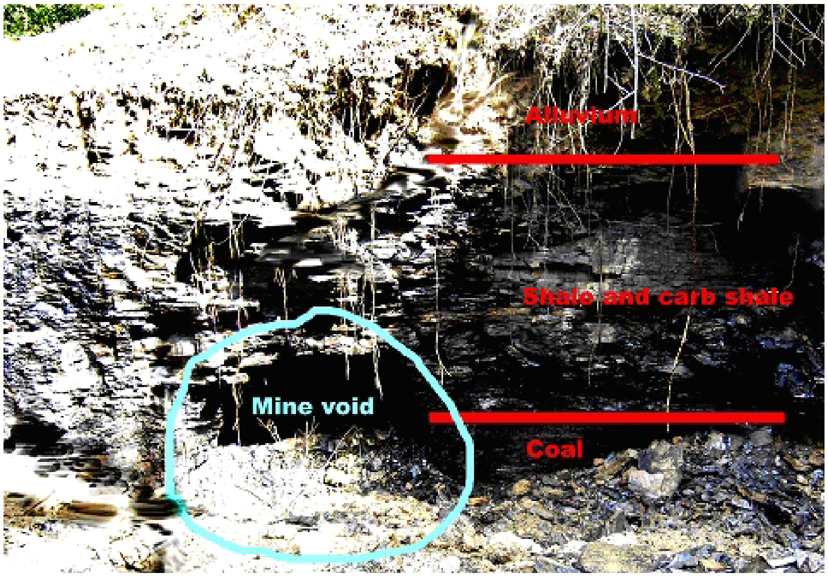

Figure 3 Exposed mine works and cover.

Site investigators and workers noted several unique aspects of the area. The fire growth was an order of magnitude faster than "typical" shallow mine fires. Efforts to form a pool of quenching water were unsuccessful because the water drained away rapidly and was less effective than it should have been. The shallow, soft cover, however, made for easy digging and the fire was soon outflanked and extinguished.

Mine and site conditions, coupled with the appearance of the egg-crate pattern so soon after mining, suggest that the pattern reflects not only topographic changes but also vegetative stresses possibly because of lack of moisture due to rapid, near-complete shallow subsidence.

Similar patterns were noted during background work on another AML project (a mine pool discharge in Fayette County, Pennsylvania). The mining period and site conditions were comparable to the Lynn Station Mine fire and suggest that similar patterns might be widespread, useful for AML emergency triage and design, and perhaps suitable for inclusion in the AML inventory.

Shallow Subsidence

Shallow subsidence usually presents itself as scattered individual pits resulting from cylindrical or conical collapse of overburden into the mine void. Shallow subsidence depressions can also occur when unconsolidated granular overburden pipes or flows into the mine void through subsidence cracks. After second mining, trenches or swales may develop first and followed later by pit development. Several terms, among them sinkhole, cockpit, pothole, and chimney – are descriptive and appropriate. Many decades may pass between mining and individual events that are typically singular and sporadic (Figure 4).

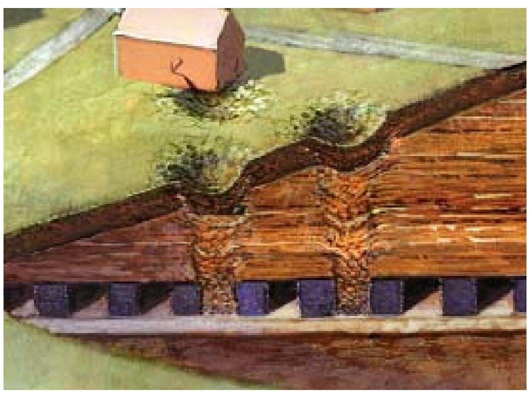

Figure 4 Sinkhole subsidence (excerpt from www.pamsi.org poster).

Multiple sinkholes develop following chain reaction pillar collapse, surface loading, and floor punching. These sinkhole swarms are more likely in the less indurated strata of the younger coal basins (see Figure 5, Sean Carroll, WY and Figure 6. Scranton, ND).

Figure 5 Sean Carroll subsidence field, WY.

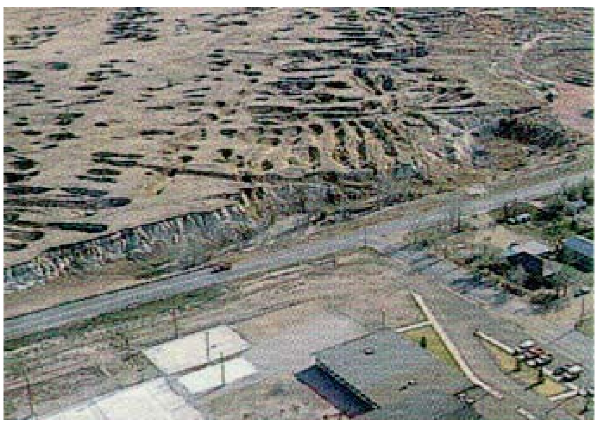

Figure 6 Scranton, ND

Similar fields are rare in the Appalachian coalfields and most sinkholes are isolated events which AML workers deal with individually. As background to her research, Dyne (1998) provides an excellent treatment of several workers' findings pertinent to chimney caves and similar shallow subsidences. She addresses type of collapse, time since mining, depth of overburden, and other factors responsible for the formation of these subsidence effects. Dyne found that many decades can pass between mining and the actual subsidence event. The "egg-crate" type of subsidence introduced here formed under much shallower cover during a mining era that is long gone. Unlike the better-known shallow subsidences, egg-crate formation is widespread over the shallow works and may have been penecontemporaneous with first mining and certainly formed within a few years after mining. Because subsidence is essentially total and the land surface is stable, egg-crated areas have not been included in the AML inventory.

Egg-Crate Subsidence

Patterned Ground Example

The patterns seen on the old aerial photographs over the Lynn Station mine and near the deep mine discharge were so striking and so nearly mirrored the shallow mine works, they were considered a potential guide to similarly mined areas. These patterns were sought on other vintage aerial photographs taken of southwestern Pennsylvania. The photographs were taken in the late 1930's and early 1940's and 800 dot-per-inch scans of contact prints have been put online through PennPilot (2007). The search focused on upland areas where the Pittsburgh coal was shallow and mining likely. The egg-crate and similar patterns were soon found – and in abundance. Significant groupings occur near Uniontown, Fayette County; Delmont and Export, Westmoreland County; and Renton, Allegheny County. A typical grouping near Delmont is shown in Figure 7 (an enlarged 1939 photograph).

Figure 7 Shallow subsidence patterns near Delmont, PA (north to top).

Pattern variations in this photograph illustrate a wide range of shallow subsidence features. The spots on the photograph are evidence of subsidence that appear as: (1) sinkholes in the southwest and center, (2) probable egg-crate patterns, and (3) subtle linear troughs in the northeast center inside the cropline. Light colors adjacent the spots may be bare soil but are more likely water-stressed vegetation. The band's width varies with slope, narrow on steep slopes and wider on gentler slopes. Finally, the band is completely hidden by the canopy of the woodlot near the center.

Common Factors

All observed patterns share similar mining times and practices and all are under shallow cover. (None are seen in established woodlands; best examples appear in farming and other open areas – this a visibility issue.)

Time of Mining During the Depression, the Work Projects Administration (WPA) activities included a compilation of all known coal mining in western Pennsylvania. The WPA maps show, by seam, active and mined-out areas and often mine and company names. Published in 1934 and 1936, the maps indicate that, by that time, mining was complete for most of the observed areas exhibiting shallow subsidence patterns. Fortunately, OSM's National Mine Map Repository (NMMR) has microfilmed a few of the original mine maps used by WPA. These films provide mine level details including workings, roof problems, dates, and sometimes elevations. Mine maps show mining occurred between 1906 and 1920 for four of the observed patterned areas.

If near-modern production room-and-pillar mining is assumed to have started about 1910 and the PennPilot aerial photographs date from around 1939, then all observed patterns developed in less than 40 years; a period significantly less than indicated by the data compiled by Dyne (1998) for chimney caves.

Mining Practice and Cover The mines used room-and-pillar methods. Rooms were several times longer than wide and pillars tended to be narrower than the adjacent rooms; crosscuts were infrequent. The entries and rooms were driven from "crop-to-crop," literally into the "grassroots." Mines like Lynn Station had complete sections under less than 15 feet of cover and map notations often include terms such as: "caving roof," "bad ground," "mud," and "soft roof." Retreat mining was not evident and maybe rare. Roof control was likely difficult and immediate roof collapse almost a certainty.

As cover thickened, roof control became less of a problem and the subsidence type changed from immediate or short-term egg-crate failure to the more studied (and less predictable) chimney caves and pitholes.

Modern Transition

In Pennsylvania, production surface mining began with a rail-mounted steam shovel in 1928. By the late 1930's, the PennPilot aerial photographs reveal that both contour and area mining were becoming common. Economically, shallow underground mines could no longer compete and the final blows came from Health and Safety and environmental regulations that restrict mining to controllable roof conditions and minimum outcrop barriers. Egg-crate and similar short-term shallow subsidences are thus strictly artifacts of another era.

AML Implications

Egg-crate subsidence is demonstrably a widespread feature in the western Pennsylvania coalfields that has long-term potential for AML problems. If egg-crate subsidence has occurred, conditions that support a fire worsen owning to increased air circulation and fuel proximity. Propagation of the fire is much faster underground than in open works. Once the fire is underground, the economic cost and increase in safety hazards climb dramatically. An associated hazard is when shallow mines are also connected to pools of underground mine water. Mine water in existing or developing mine pools will travel the path of least resistance and may discharge through a shallow mine catastrophically.

Conclusions and Proposed Research

Most AML mine fires start from surface burning at or near the coal outcrop. If egg-crate subsidence has occurred, conditions worsen owing to increased air circulation and fuel proximity and underground propagation is much faster than in open works. Once underground, hazards and control costs skyrocket.

Similarly, existing and developing mine pools will seek paths of least resistance. Shallow first mining is a clue that no barrier exists between old mine works and the surface. Without a barrier, mine pools will readily discharge, sometimes catastrophically.

Egg-crate subsidence is a readily-recognizable feature of past mining. Knowledge of where such features are common would help AML workers select best remediation methods for both emergencies and nuisances. As an artifact of last century's mining practices, egg-crate subsidences may be common elsewhere in the Nation's coalfields. Certainly where they are known to be widespread (as in Southwestern Pennsylvania), an inventory of these features appears warranted.

Except in arid or open areas such as farmland, the described features are seldom discernible in either old or current aerial photography or standard digital products. In October 2006, Office of Surface Mining and Reclamation Enforcement's (OSM) TIPS (Technical Innovations and Professional Services) group formed a Remote Sensing Team to investigate several remote sensing technologies for evaluating a range of coalfield issues including AML inventory of orphaned highwalls, acid mine drainage inventories, revegetation success in support of bond release, terrain change quantification, and special status species habitat analysis.

Two of the technologies have a lot of potential for a semi-automated inventory of egg-crated areas. One is based on pattern recognition and classification of photography and other imagery; the other uses high-density laser (LiDAR) and/or radar (IFSAR) reflections to generate elevation models. The reflection technology can penetrate very dense tree cover to produce ground-level data and reveal mining effects not visible in photographs. In the summer of 2007, data for these two techniques will become available for some of Appalachia. The prime focus will be on old highwalls in West Virginia with the goal of adding them to the AML inventory. Because proposed techniques for highwall identification appear to be well-suited for identifying egg-crate patterns, several "test plots" of shallow Pittsburgh coal mining will be included in the study.

The study will also include additional aerial photography dating from the 1940's to 1960's. The photography (as the original roll negatives) is in the US Geological Survey's EROS Data Center (http://edc.usgs.gov/products/aerial.html). Copies, paper or digital, are special orders and cannot be processed "online." OSM, through the TIPS program, is investigating more efficient acquisition. In the meantime, States and other programs may wish to "sample" the old photography for its value and provide TIPS feedback.

Lastly, old mine maps are even more important than aerial photography or “high-tech” methods. Most of these maps are in private or limited-access public collections and have never been copied, photographed, or digitized – once damaged or lost, they are gone forever. AML and other workers should encourage holders of mine maps to contact the Interstate Mining Compact Commission (http://www.imcc.isa.us/Do.htm) for guidance.

Literature Cited

Dyne, L.A. 1998. The prediction and occurrence of chimney subsidence in southwestern Pennsylvania. Thesis submitted to the Faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Mining and Minerals Engineering.

PennPilot. 2007. Website: http://www.pennpilot.psu.edu/
Penn Pilot is an online library of digital historical aerial photography for the Commonwealth of Pennsylvania. Using the interactive map provided on this website, you can browse, view, and download more than 40,000 photos covering the Commonwealth from 1937 to 1942. The photos were produced by the United States Department of Agriculture, Agricultural Adjustment Administration (now known as the Farm Service Agency).