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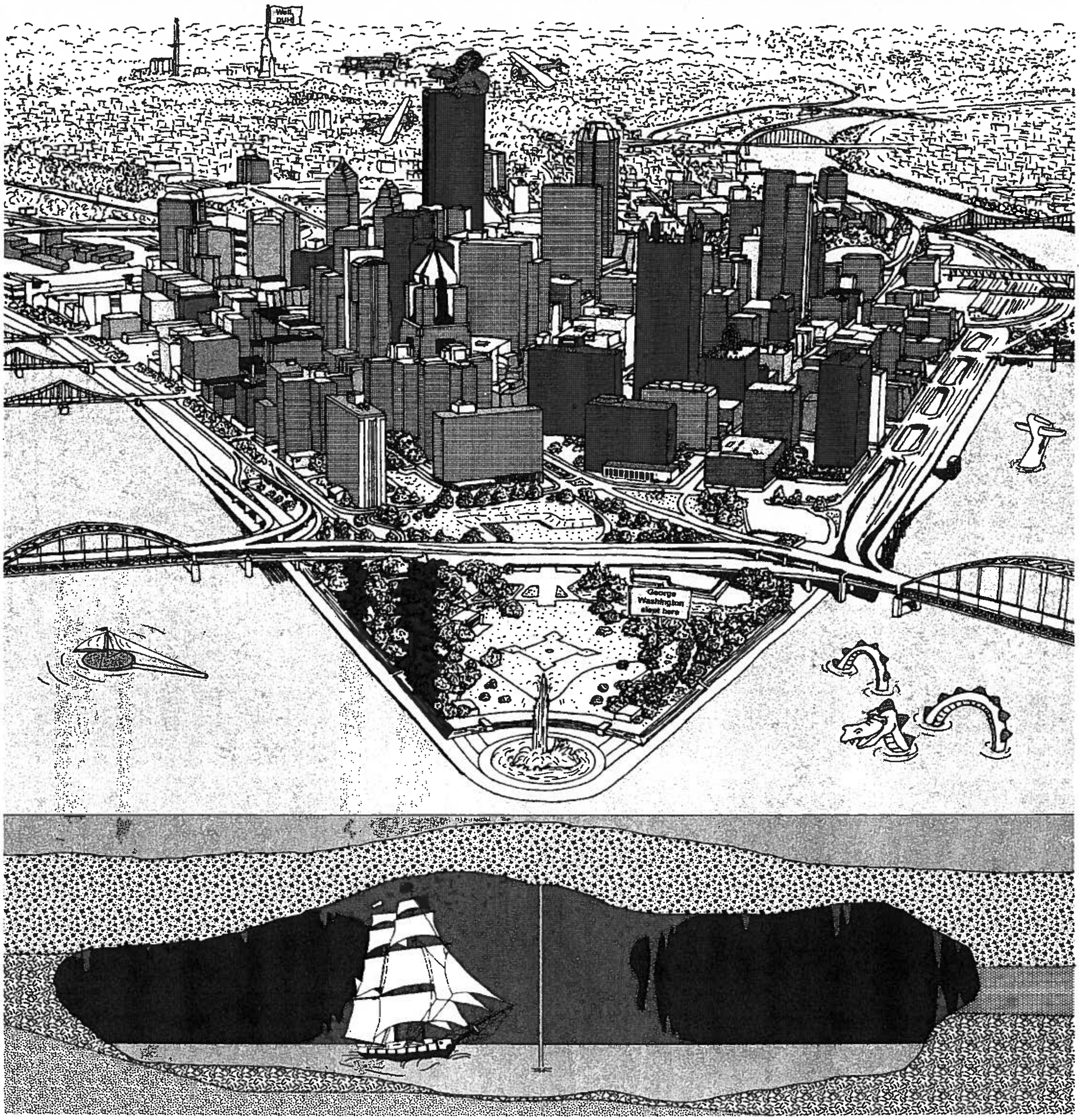
65th Annual Field Conference of Pennsylvania Geologists

PITTSBURGH AT THE MILLENNIUM: THE IMPACT OF GEOSCIENCE ON A CHANGING METROPOLITAN AREA



Hosts: Pittsburgh Geological Society
Slippery Rock University
Pennsylvania Geological Survey

October 5-7, 2000
Pittsburgh, PA

Guidebook for the
65TH ANNUAL FIELD CONFERENCE OF PENNSYLVANIA GEOLOGISTS

PITTSBURGH AT THE MILLENNIUM: THE IMPACT OF GEOSCIENCE ON A CHANGING METROPOLITAN AREA

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October 5-7, 2000

Hosts: Pittsburgh Geological Society
Slippery Rock University of Pennsylvania
Pennsylvania Geological Survey

Headquarters: Best Western Parkway Center Inn, Pittsburgh, PA

Cover: Strange happenings in the big city. Can you find: Pittsburgh's version of the Empire State Building (where's Faye Wray when you need her?); the University of Pittsburgh's Height of Ignorance; Pittsburgh's "Fourth River;" an early colonial bedroom; Darth Vader's Castle; the US Brig Niagara (following a wrong turn on Lake Erie!); a Monongahela monster; a very large Phillips screwdriver; the Good Ship Lollipop; and the super-secret A-bomb carrying plane that crashed in the Monongahela one night and was supposedly spirited away by the CIA while everyone was sleeping.

Cover and cartoons by: John A. Harper

UPDATE ON ENGINEERING GEOLOGY IN THE PITTSBURGH AREA

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INTRODUCTION

The last Field Conference of Pennsylvania Geologists in Pittsburgh twenty years ago placed heavy emphasis on Engineering Geology in its Guidebook entitled "Land Use and Abuse - The Allegheny County Problem" (Figure 11; Adams and others, 1980). Historically, Engineering Geology has been one of the main thrusts of applied geology in the Pittsburgh area (e.g., Philbrick and Nesbitt, 1941; Philbrick, 1953, 1959, 1960; Ackenheil, 1954; Ferguson, 1967). This results directly from our geology, topography, climate, and land use history (Gardner, 1980).

The technical problems and challenges of Engineering Geology in the Pittsburgh area have not changed over the past twenty years. The problem zones (e.g., undermined areas, weak rock units, unstable slopes) and bad sites of twenty years ago are still problem zones and bad sites today. Now, however, they are increasingly being modified, developed, and built upon because of changing economic conditions, decreased land availability, expanding infrastructure (e.g., transportation) requirements, and new geotechnical construction procedures. It is therefore appropriate to present an update on

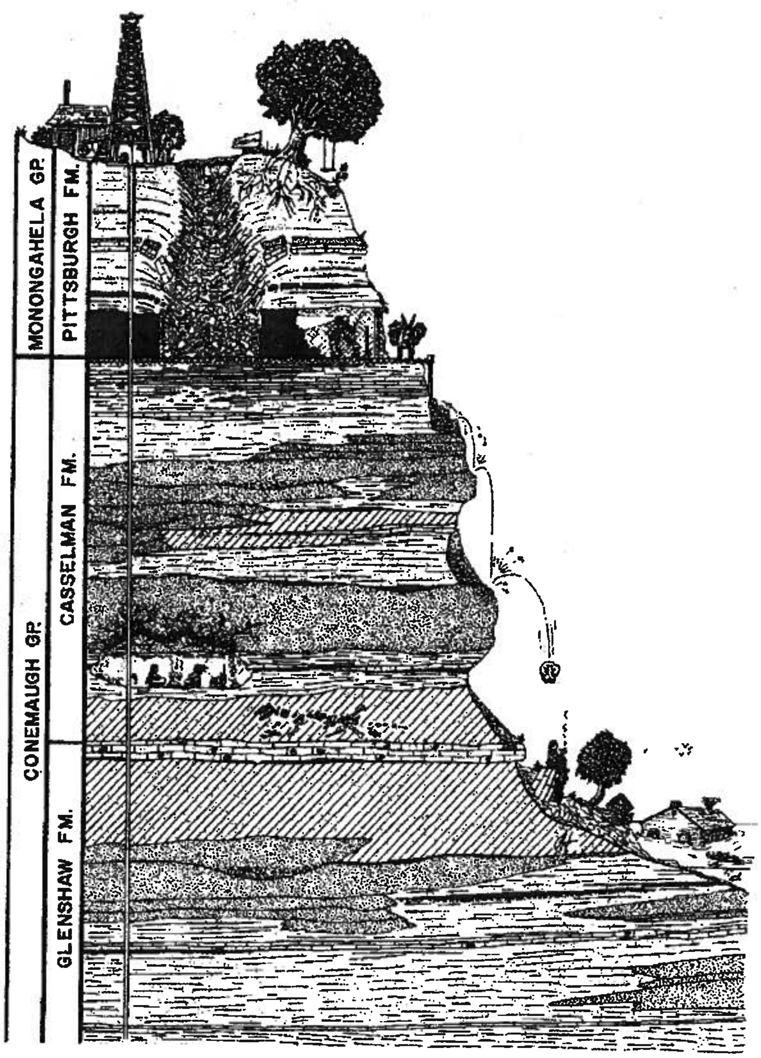

Figure 11. Geologic hazards of the Pittsburgh area (from Adams and others, 1980.)

Engineering Geology for the present Field Conference on "Pittsburgh at the Millennium: The Impact of Geoscience on a Changing Metropolitan Area."

Engineering Geology is broadly defined as "geologic work that is relevant to engineering, environmental concerns, and the public welfare" (Association of Engineering Geologists, 2000). As such, Engineering Geology is here considered to include Environmental Geology, Hydrogeology, and related portions of Geotechnical and Geoenviromnental Engineering. Emphasis in the following sections will be placed, however, on traditional aspects of Engineering Geology rather than on geotechnical and geoenvironmental construction and remediation.

After a brief review of Engineering Geology problems and challenges in the Pittsburgh area, we note some advances in local and regional Engineering Geology Practice that have occurred since 1980. Then we identify two major future challenges that we see for the region. Finally, we offer some suggestions for improvement of Engineering Geology Practice and repeat the oft-made pleas (e.g., Delano and Adams, 1999) for greater use of available information and existing knowledge in this regard.

ENGINEERING GEOLOGY PROBLEMS AND CHALLENGES

The most significant and widespread Engineering Geology problems and challenges in the Pittsburgh area are related to coal mining, slope instability, waste disposal, and flooding. Other, less significant and/or widespread problems and challenges involve clay and limestone mining, water supply, surface and subsurface drainage and erosion, and expansive materials.

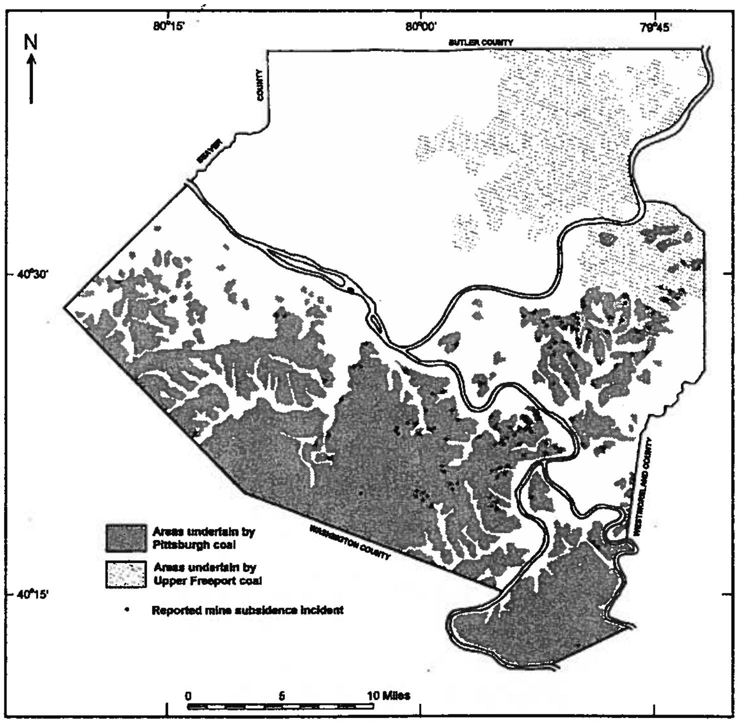

Figure 12. Areas of Allegheny County underlain by mineable coal. Each dot represents a reported incident of subsidence documented between 1960 and 1985 (modified from Bruhn, 1980).

Coal has been mined in the Pittsburgh area since about 1760 (Adams and others, 1980; Delano, 1985). The earliest mining was in the famous Pittsburgh coal (base of Pennsylvanian age Monongahela Group) which is exposed in many upland areas in and near Pittsburgh (Figure 12). Mining also has occurred in several other coal seams, especially the Upper Freeport (top of Pennsylvanian age Allegheny Group, typically about 650 ft [198 m] below Pittsburgh coal). Much of the near-surface, economically mineable coal has been removed over the past two hundred years. This has left a legacy of abandoned surface and underground mine workings and coal waste disposal areas.

Subsidence of the ground surface above abandoned underground workings (where some or all of the coal was removed, generally by

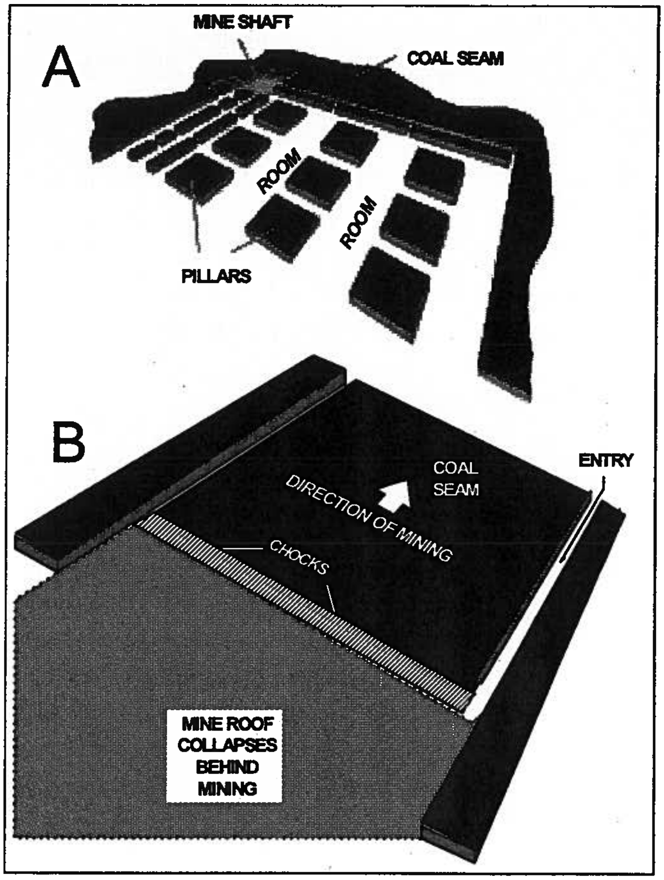

Figure 13. Diagrams of coal mining methods (from Pittsburgh Geological Society, 1999b). A. Room-and-pillar mining. Pillars of coal are left in place to prevent the mine roof from collapsing during mining. These are removed during retreat mining. B. Longwall mining, sowing collapse of the mine roof as mining advances and the chocks are moved forward.

room and pillar methods, Figure 13A) and acid drainage from abandoned surface and underground workings and coal waste areas have been long-term problems. Occasionally, underground mine fires and fires in surface mines and coal waste areas also occur. In addition, the extent of problems caused by disposal of sewage and residual and hazardous wastes in surface and underground coal mines is only now becoming known.

Most of the presently active coal mining in the region is south and southwest of Pittsburgh where the Pittsburgh coal is relatively deep underground and longwall mining methods are employed. These methods (Figure 13B) extract most of the coal in large panels with corresponding subsidence of the ground surface (Figure 14) over the panels and adjacent areas. This subsidence almost always has detrimental effects on watersheds, streams, and surface and subsurface water supplies as well as surface structures and facilities. For example, sections of Interstate Route 70 east of Washington, Pennsylvania (south of Pittsburgh) subsided as much as 5 ft (1.5 m) as a result of longwall mining earlier this year.

Act 54 of 1994 amended the Bituminous Mine Subsidence and Land Conservation Act of 1966 to facilitate longwall mining by allowing previously prohibited mining beneath certain structures (e.g., public buildings, dwellings) in place on April 27, 1966. Act 54 requires coal mine operators to repair structures damaged by subsidence and to replace water supplies affected by mining. Unfortunately, property owners are often forced to prove, at their own expense, that coal mining has caused their property damage and/or water loss. This has lead to increased concerns about irreversible environmental effects at and near the ground surface, e.g., surface water and groundwater gradients and flows, changes in stream habitats, damage to historic and other structures (Figure 15). Longwall mining of coal will provide significant future problems and challenges in Engineering Geology, both underground and at the ground surface.

Given the legacy of coal mining in the Pittsburgh area, reclamation of abandoned mine lands, i.e., surface and underground mines and coal waste disposal areas, will continue for the foreseeable future. Some of this reclamation is done for environmental enhancement, mainly with government funding. Other reclamation is done on a project-specific basis with government

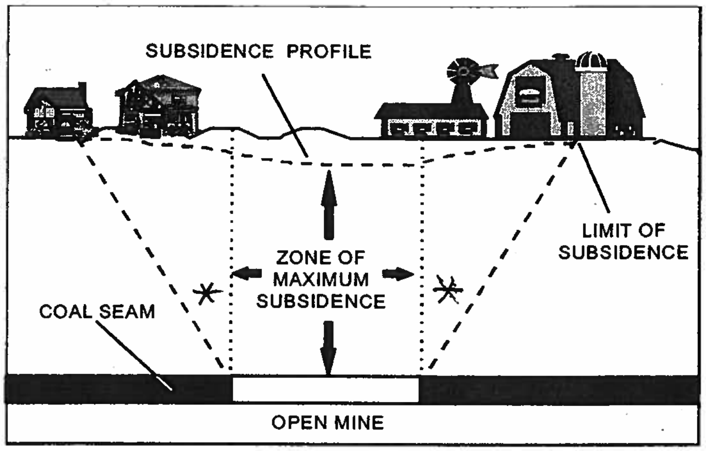

Figure 14. When a mine opening collapses, more surface area is affected than just the land directly above the collapsed void (modified from Pittsburgh Geological Society, 1999b). *Angle of Influence – under much discussion and dispute, particularly for longwall mining.

and/or private funding. Some of this latter reclamation involves surface mining of coal remnants, including pillars, and placement of engineered fill for various site improvements. More of these reclamation activities resulting in site improvements for subsequent development are anticipated as land shortages in the Pittsburgh area require future infrastructure improvements and other developments to be done on sites previously considered marginal or unbuildable.

Despite reclamation activities, surface subsidence above abandoned underground coal mines (generally where coal was partially extracted by room and pillar methods many years ago) is an on-going concern, both in older residential and commercial areas and in areas of expanding suburban developments. Absent surface stabilization, e.g., by mine grouting (Figure 16), insurance provides the best and most affordable protection against subsidence damage in most such cases. We generally recommend that home and business owners purchase Mine Subsidence Insurance (available since 1961 under the Pennsylvania Mine Subsidence Insurance Fund) where the cover is less than about 300 ft (91 m) above abandoned underground coal mine workings. Where there is potential for total extraction of coal in the future, e.g., by longwall mining or retreat mining with room and pillar methods, we recommend Mine Subsidence Insurance for all overburden thicknesses.

The Pittsburgh area has long been known for slope instability (Figure 17; Scharff, 1920; Ackenheil, 1954; Gray and others, 1979; Adams and others, 1980, Adams, 1986; Hamel, 1980; Hamel and Hamel, 1985; Pomeroy, 1982). Key aspects were summarized by Hamel and Ferguson (1999). Briefly, soil slope instability usually involves landslides that are common in collu-

Figure 15. That reminds me, your deed includes the mineral rights - the Coal Company sold them back after they mined all the coal from under this area! (From Freedman, 1977).

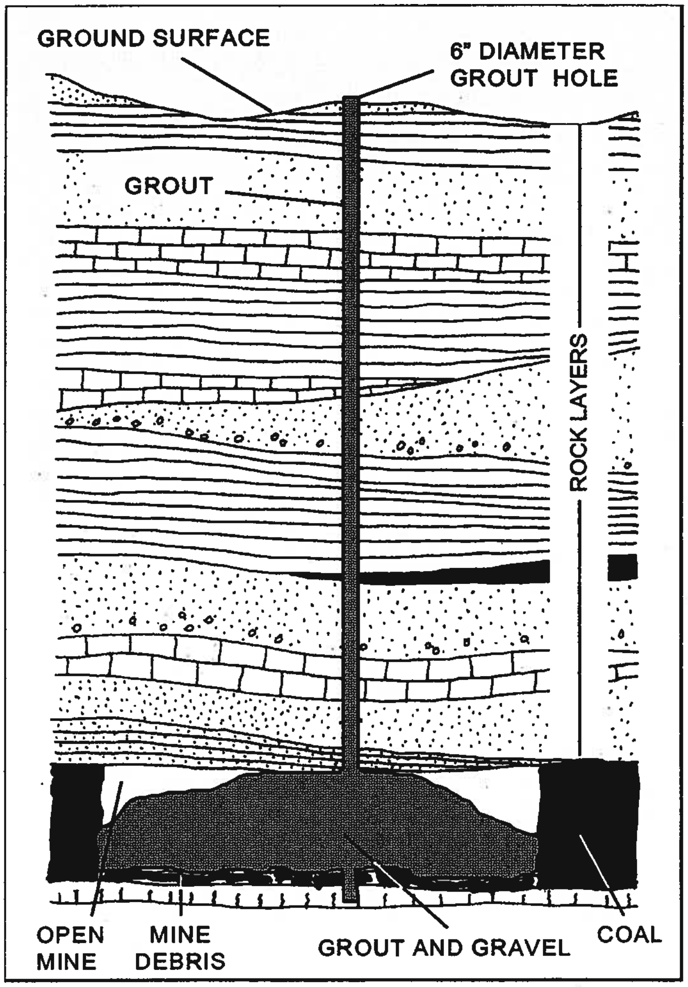

Figure 16. Using a grout column to fill a mine void (from Pittsburgh Geological Society 1999b).

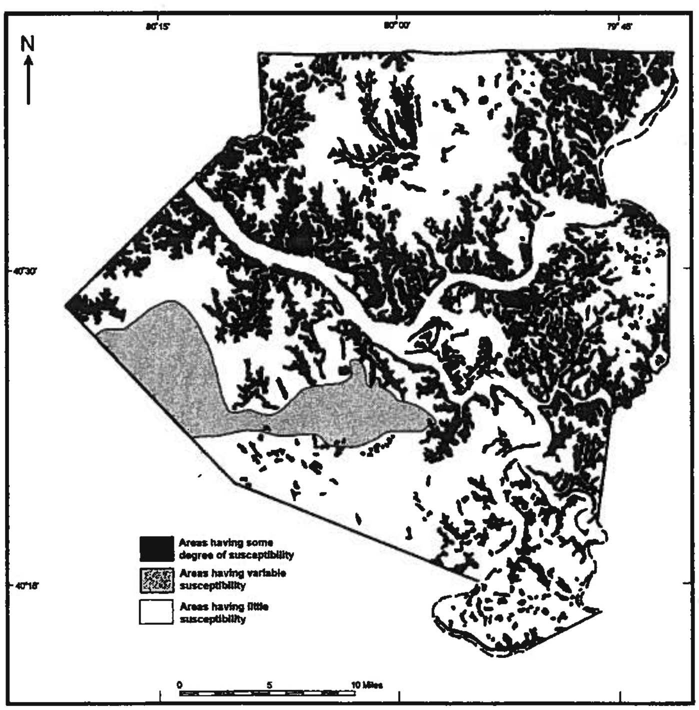

Figure 17. Generalized map of susceptibility to landsliding in Allegheny County. Modified from Briggs, 1977.

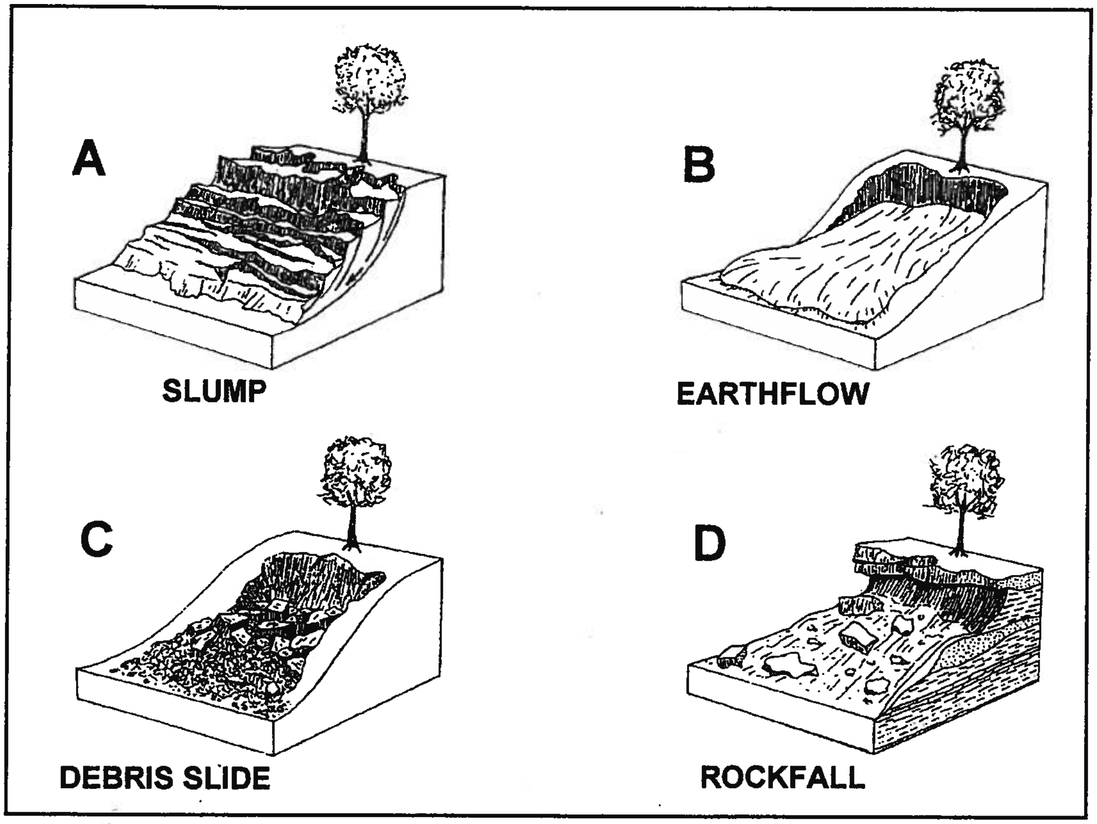

Figure 18. The most common kinds of landslides in the Pittsburgh area (from Pittsburgh Geological Society, 1999a).

vium (old landslide and/or creep debris) and man-placed fill, particularly non-engineered fill (Figure 18A-C). Rock slope instability generally involves rock falls (Figure 18D) and/or shallow rock slides in natural slopes as well as excavated slopes. Instability in portions of excavated rock slopes is prevalent along certain transportation corridors, particularly where the slopes were excavated many years ago with earlier design and construction methodologies; see Stop 6.

Our experience indicates that most landslides affecting people and their property in the Pittsburgh area result from (1) human activity, and (2) failure to apply existing knowledge. Expanded land use controls, e.g., building codes and grading ordinances, and stricter enforcement of these regulations offers great potential for reducing landslide hazards associated with new construction. A landslide insurance program (analogous to the above-mentioned Mine Subsidence Insurance) offers great potential for protecting homeowners and businesses from financial losses associated with landslides in areas of existing facilities unaffected by new construction. Several landslide insurance bills have been introduced in the Pennsylvania Legislature over the past twenty years but none has received the support necessary for passage. Much of the problem with developing support for these bills stems from the inability to devise a stable and long-term method of financing.

Given the mining and industrial history of the Pittsburgh area, along with its topography and Appalachian heritage of disposing of materials on hillsides and/or in holes in the ground (e.g., abandoned surface and underground coal mines, subsidence sinkholes), waste disposal has provided and will continue to provide Engineering Geology problems and challenges. These

Correct Fig. 19 included at end of this paper

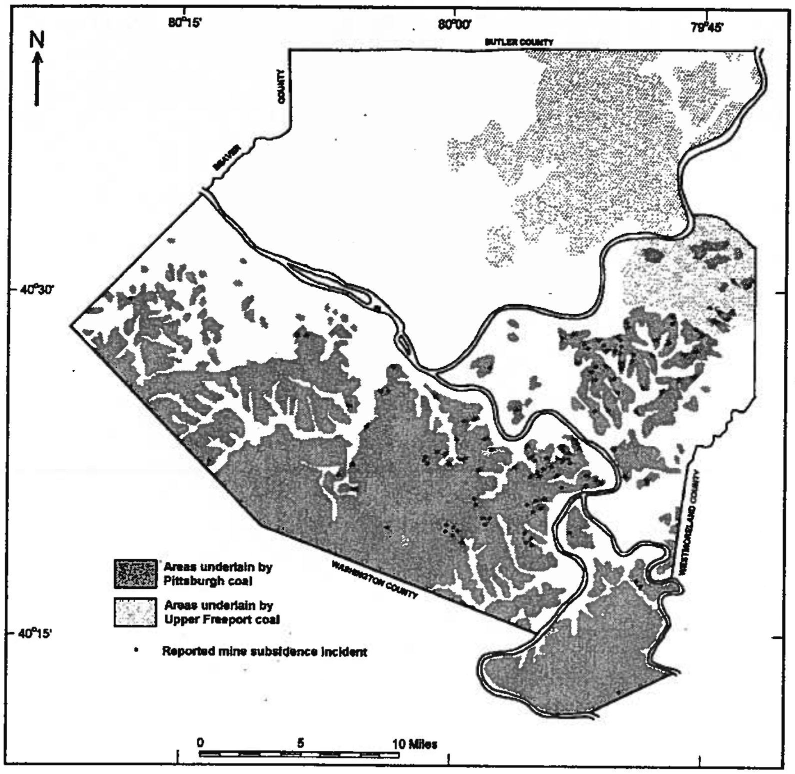

Figure 19. Generalized map of the flood-prone areas in Allegheny County. Modified from Briggs, 1977.

include cleanup of contaminated sites (e.g., toxic waste dumps, brownfields) and contaminated groundwater; dealing with mining and industrial wastes encountered during various construction activities; and provision of new and expanded sites for disposal and/or recycling of mining, industrial, and power generation wastes (see Stops 9 and 10). Side effects of waste disposal, e.g., methane generation and migration from municipal waste landfills (often in or near abandoned surface and underground coal mines), provide additional challenges.

The topography (including streams and rivers) and climatic conditions of the Pittsburgh area are such that it has long been prone to both local and widespread flooding (Figures 19 and 20). Floods on the major rivers have, to a considerable extent, been reduced by dams constructed on the main tributaries or in the headwaters of these rivers by the U. S. Army Corps of Engineers since 1936 (Johnson, 1979). These dams, originally constructed for flood control, are now multipurpose. They are much different in purpose, features, and operation from the navigation dams we will see during the barge trip of the present Field Conference.

Local flash floods from heavy precipitation events, e.g., severe thunderstorms, will occur forever in the Pittsburgh area. A thunderstorm on July 1, 1997, with 4 inches of rain in 1.5 hours, caused more than $11 million in damage and loss of one life in Pitcairn and Monroeville, eastern suburbs of Pittsburgh. More recently, 3 to 5 inches of rain on August 6-7, 2000, caused flash flooding with extensive damage at numerous locations in Southwestern Pennsylvania *(Pittsburgh Post-Gazette,* August 8, 2000, p. A-1, A-8). Ever increasing land development, which often includes removal of natural flood retarding features (including wetlands) along streams, exacerbates local flooding problems.

With increased development pressures on remaining open land in the Pittsburgh area, we anticipate more local flooding problems in the future, despite various storm water control regulations and ordinances. Storm water detention facilities are designed to retain extra runoff resulting from development for a storm of a certain recurrence interval, e.g., a 50-year storm which has a probability of occurrence of 2% in any given year, not an occurrence of once every 50 years. When a storm exceeds the design level, as happens from time to time, the extra runoff from a developed area (in excess of pre-development runoff) bypasses the detention facility to cause additional downstream flooding. Failure to consider soils and geologic conditions in design

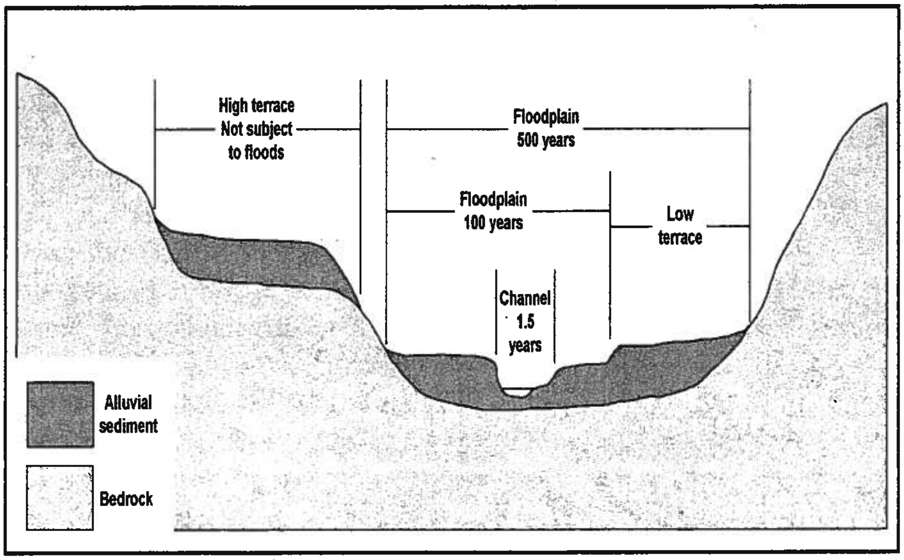

Figure 20. Cross section of a typical western Pennsylvania river valley showing the extent of flooding from periodic (1.5-year), 100-year, and 500-year floods. High terraces, formed before and during the Pleistocene, commonly occur between 150 and 250 feet above current river levels (from Pittsburgh Geological Society, 1999c).

and construction of storm water detention ponds has resulted in numerous slope failures in these facilities.

Insurance against flood damage is available through the National Flood Insurance Program. We generally recommend that home and business owners in flood-prone areas obtain this insurance where it is available.

Clay and limestone mining are much less widespread than coal mining in the Pittsburgh area, though some clay mining has occurred in conjunction with coal mining. The environmental effects of clay and limestone mines are not usually as deleterious as those of coal mines, though some subsidence damage has occurred over abandoned underground clay mines. One adverse effect of limestone mining in the ridges east of Pittsburgh has been the loss of caves with unique geologic features as well as bat habitats.

Much of the water supply in urban and suburban areas around Pittsburgh is from surface sources, especially the major rivers, either directly or through well fields. However, local and individual home water supplies are from wells and/or springs in most rural areas. Water supply problems, both large scale and local, are likely to provide more Engineering Geology challenges in the future.

Surface and subsurface drainage and erosion problems are generally local and/or site-specific. With increasing development in the Pittsburgh area, and particularly with increased development of marginal or previously unbuildable sites, we anticipate significant future drainage and erosion challenges, both surface and subsurface. An example of severe localized erosion from surface drainage can be seen along the most recent portion of Interstate Route 279, constructed approximately 11 years ago in northern Allegheny County. Surface runoff has eroded channels up to 3 ft (0.9 m) deep in highway fills. In places, these channels have exposed the full depth of the concrete shoulders of the road.

Expansive materials in the Pittsburgh area are both natural and man-made. Natural expansive materials are mainly sulfide minerals, e.g., pyrite, associated with coals and carbonaceous shales (Dougherty and Barsotti, 1972; Fasiska and others, 1974; Nixon, 1978). Manmade expansive materials are certain steel slags (Crawford and Burn, 1969, plus Discussions).

Problems with expansive materials, which are generally treated on a site-specific or project-specific basis, have in the past generally been few and far between. However, an elementary school approximately 30 mi (48 km) south of Pittsburgh in Washington County was recently constructed on pyritic soils and shale. This school heaved with considerable structural damage. Remediation has been slowed by continuing litigation.

We expect both the number and frequency of these problems to increase in the future with the increased (1) use of marginal or previously unbuildable sites, (2) use of excavated on-site but questionable materials in fills on these sites, (3) attempts to recycle old industrial wastes, and (4) tendency to forget lessons of the past. In this regard, we note that the use of any and all slag as fill under the roadway and shoulder areas is currently prohibited by District 11-0 of the Pennsylvania Department of Transportation, which includes much of the Pittsburgh area.

ADVANCES IN LOCAL AND REGIONAL PRACTICE

There have, of course, been many developments world-wide in Engineering Geology over the past twenty years. These include various computer applications and software; surveying and mapping systems, geographic information systems (GIS), and global positioning systems (GPS); techniques of geophysical investigation, in situ testing, field instrumentation, and laboratory testing; geosynthetics applications; and various environmental applications. All of these have been and continue to be used to some extent in the Pittsburgh area, but none is unique here.

The Pennsylvania Geologist Licensing Law, Act 151 of 1992, was a major advance for geology throughout the Commonwealth and certainly for Engineering Geology in the Pittsburgh area. The June 2000 letter from the State Registration Board for Professional Engineers, Land Surveyors and Geologists to all registrants in these professions regarding penalties for unlawful representation and/or practice in these professions is also significant regarding Engineering Geology Practice throughout Pennsylvania.

Progress in Engineering Geology Practice, here and elsewhere, is slow and incremental. Our short list of advances and developments of significance in the Pittsburgh area over the past twenty years is:

- Common use of wireline drilling with split inner barrels for improved recovery of soft and/or fractured rocks, e.g., claystones, common to the region
- Increased emphasis on Engineering Geology along with testing requirements for drilling inspectors and improved procedures for investigation, analysis, and reporting (e.g., "Supplemental Guidelines for Subsurface Exploration, Sampling and Testing in District 11-O," 1999) in District 11-0 of the Pennsylvania Department of Transportation, one of the largest users of Engineering Geology services in the Pittsburgh area
- Correlation and age dating of Pleistocene terrace remnants along the Upper Ohio and Monongahela Rivers in West Virginia, Pennsylvania, and Ohio (Jacobson and others, 1988), with geoarchaeological (Hamel and Jacobson, 1988) as well as engineering applications (Jacobson and others, 1988, fig. 4 shows slackwater and alluvial terrace correlations and elevations for more than 125 mi [200 km] of the Monongahela Valley upriver from Pittsburgh and for more than 188 m [300 km] of the Ohio Valley downriver from Pittsburgh). (Also, see Marine and Donahue on p. 28 of this guidebook..)
- Mineralogical and geochemical study of slag at Nine Mile Run site in Pittsburgh (Prellwitz, 1998; Stop 4)
- Documentation of widespread existence of deep-seated Pleistocene age rock slides and

clarification of their mechanism of occurrence as well as their geologic and engineering implications (Hamel, 1998; Stop 6)

- Publication in 1999 of the monumental and long-awaited book *The Geology of Pennsylvania* (Shultz, 1999) with its Part IX "Environmental and Engineering Applications" treating many items significant in the Pittsburgh area (most of the chapters in Part IX were prepared 10 to 15 years ago but their information is still very relevant.)

MAJOR FUTURE CHALLENGES

In addition to the previously mentioned problems and challenges, there are two broad future challenges that transcend technical areas:

- Decreasing availability of land
- Declining quality, expertise, and standards of geotechnical practice

Most of the Pittsburgh area has been developed in some manner in the past. Flat lands along the rivers, streams, and ridge tops were developed first. Then development extended into steeper land along the edges of these areas. All of the good sites and many of the marginal sites have already been developed. Much of the past development was built into the hillsides by hand or with limited mechanical equipment. Access to these areas consists of winding streets, which followed the original topography. These older residential and commercial areas now have deteriorated infrastructure, e.g., leaking water and sewer lines.

Virtually all presently undeveloped sites in the Pittsburgh area were passed over or left alone in the past because they have deficiencies, e.g., small size, difficult or limited access, and/or significant geological, geotechnical, and environmental problems, e.g., subsidence - prone shallow underground coal mines, coal mine drainage, slope instability, past waste disposal, flooding. Future development in the Pittsburgh area is thus severely constrained by geology, topography, climate, and previous land use. We are now facing a shortage of land suitable for development, particularly large areas for major developments. The significant issue of preservation of open space for aesthetic, social, and environmental reasons will not be addressed here.

Given this shortage of land, development is moving in two directions:

- Re-use and recycling of previously developed sites and areas, e.g., brownfields developments on former steel mill sites along major rivers, upscale housing in former hillside neighborhoods of moderate to low income homes
- Development of sites previously considered marginal or unbuildable because of topographic, geologic, and geotechnical problems requiring expensive engineering and construction solutions including large excavations and fills; road, stream, and wetland relocations; and complex infrastructure, e.g., roads, bridges, culverts, storm water detention facilities, utility lines

These two development directions are not always separate. Some projects blend elements of both, e.g., upscale housing extending from an old neighborhood onto a previously undeveloped unstable slope where expensive stabilization measures are required.

It should be obvious that high quality work, high levels of expertise, and high standards of practice are necessary for successful project completion under these conditions.

Unfortunately, we have observed in the Pittsburgh area and elsewhere over the past twenty

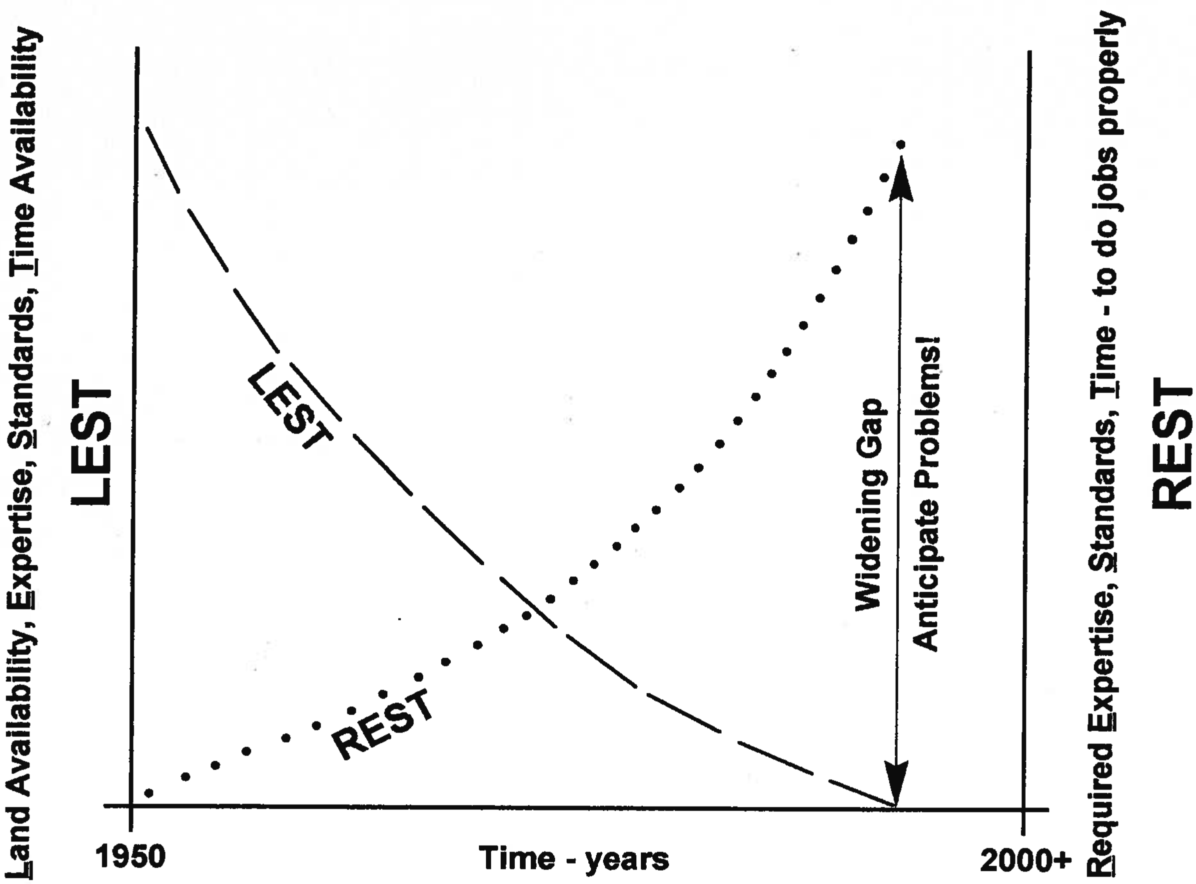

Figure 21. LEST-REST, the time dependent saga of geotechnical practice in the Pittsburgh area.

years a general decline in quality, expertise, and standards in Engineering Geology and Geotechnical and Civil Engineering, the technical fields with which we are most familiar.

Dealing with decreased land availability and the general decline in quality, expertise, and standards of practice presents major challenges to Engineering Geology (and Geotechnical and Civil Engineering) in the Pittsburgh area for the New Millennium (Figure 21). Considering only technical issues, we cannot envision a way to deal effectively with land shortages other than to improve Professional Practices in Engineering Geology and related fields. Our suggestions along these lines are presented below.

SUGGESTIONS FOR IMPROVEMENT OF GEOTECHNICAL PRACTICE

Most problems and difficulties in geotechnical practice result from failure to apply available information, existing knowledge, and well-established project development procedures. Many, if not most, of these problems and difficulties result from failure to apply in an organized manner basic concepts and techniques of Engineering Geology.

In order to improve this situation and reverse the previously mentioned decline in quality, expertise, and standards of practice, we (Hamel and Adams, 2000, in press) have recommended emphasis on fifteen Fundamentals which apply equally well to Practice in Engineering Geology and Geotechnical Engineering:

Geology	Construction/Constructabilty
Geometry	Communication
Soil and Rock Mechanics (Geomechanics)	Diplomacy
Observation	History
Imagination	Field Emphasis
Common Sense	Checking
Precedents/Experience	Redundancy
	Flexibility

Most of these Fundamentals are, in fact, applicable to Professional Practice in all areas of geology and engineering.

We have further recommended focusing these Fundamentals on an observational Engineering Geology approach to developing the geotechnical framework (key elements of geology, geometry, history) of each site or problem (Hamel and Adams, in press). This has a heavy Field Emphasis (as in above list and present Field Conference).

With regard to use of available information and existing knowledge, we again draw attention to the problems of slope instability in the Pittsburgh area. Information and knowledge for dealing more effectively with these problems was available some twenty years ago in terms of the series of landslide inventory and susceptibility maps prepared by the U. S. Geological Survey (e.g., Pomeroy and Davies, 1975) and various technical publications (e.g., Hamel and Flint, 1969, 1972; Gray and others, 1979; Hamel, 1980; Hamel and Adams, 1981; Briggs and others, 1975; Pomeroy, 1982; Schuster and Krizek, 1978). Unfortunately most of this available information and previous knowledge on geologic conditions and geotechnical procedures does not regularly find its way into contemporary Practice in Engineering Geology and Geotechnical Engineering in the Pittsburgh area.

Considerable information is also available on the occurrence of and potential for coal mine subsidence in the region (e.g., Ackenheil and Associates, 1968; Cortis and others, 1975; Bruhn, 1980; Bushnell, 1975). Even so, it is not uncommon for Engineering Geology and Geotechnical Engineering reports to omit mention of coal seams, mining history, and subsidence potential.

Available information, existing knowledge, and proven technology are all such that we can do much better than we have in the past in meeting the challenges of slope instability, mine subsidence, and other geological/geotechnical problems of the Pittsburgh area. This will require serious efforts, however, in (1) upgrading geological and geotechnical practice, and (2) training and mentoring the next generation of practitioners.

DEDICATION

This paper is dedicated to three pioneering Field Geologists and Engineering Geologists of the Pittsburgh area who passed away since the 1980 Field Conference:

- Shailer S. Philbrick - former Chief of Foundation and Materials Branch, Pittsburgh District, Corps of Engineers; Professor of Geology at Cornell University; Consultant; and Honorary

Member, Association of Engineering Geologists

- Norman K. Flint - long time Professor of Geology at University of Pittsburgh, outstanding teacher, and mentor to many students, including the writers
- Harry F. Ferguson - former Chief of Geotechnical Branch, Pittsburgh District, Corps of Engineers; Consultant; Colleague; and Honorary Member, Association of Engineering Geologists

ACKNOWLEDGEMENTS

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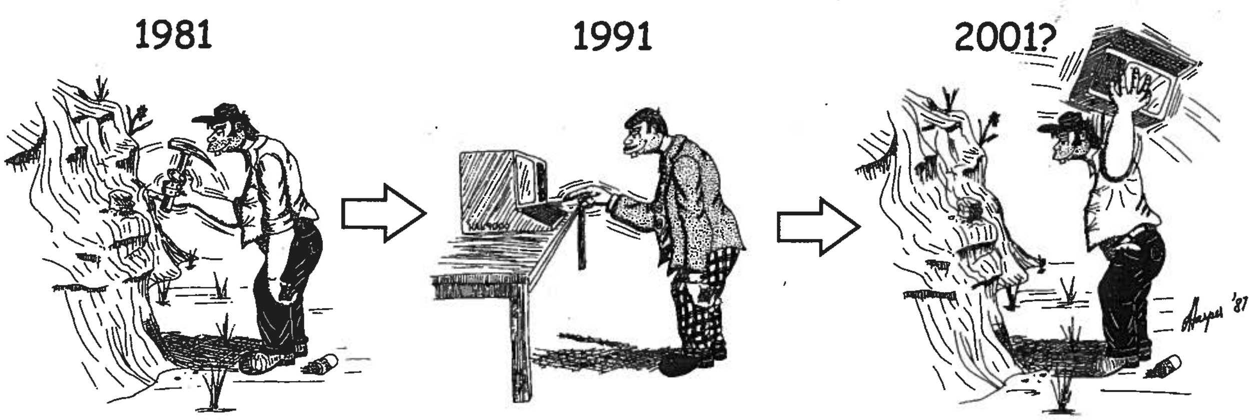

EVOLUTION OF GEOLOGY IN THE PITTSBURGH AREA

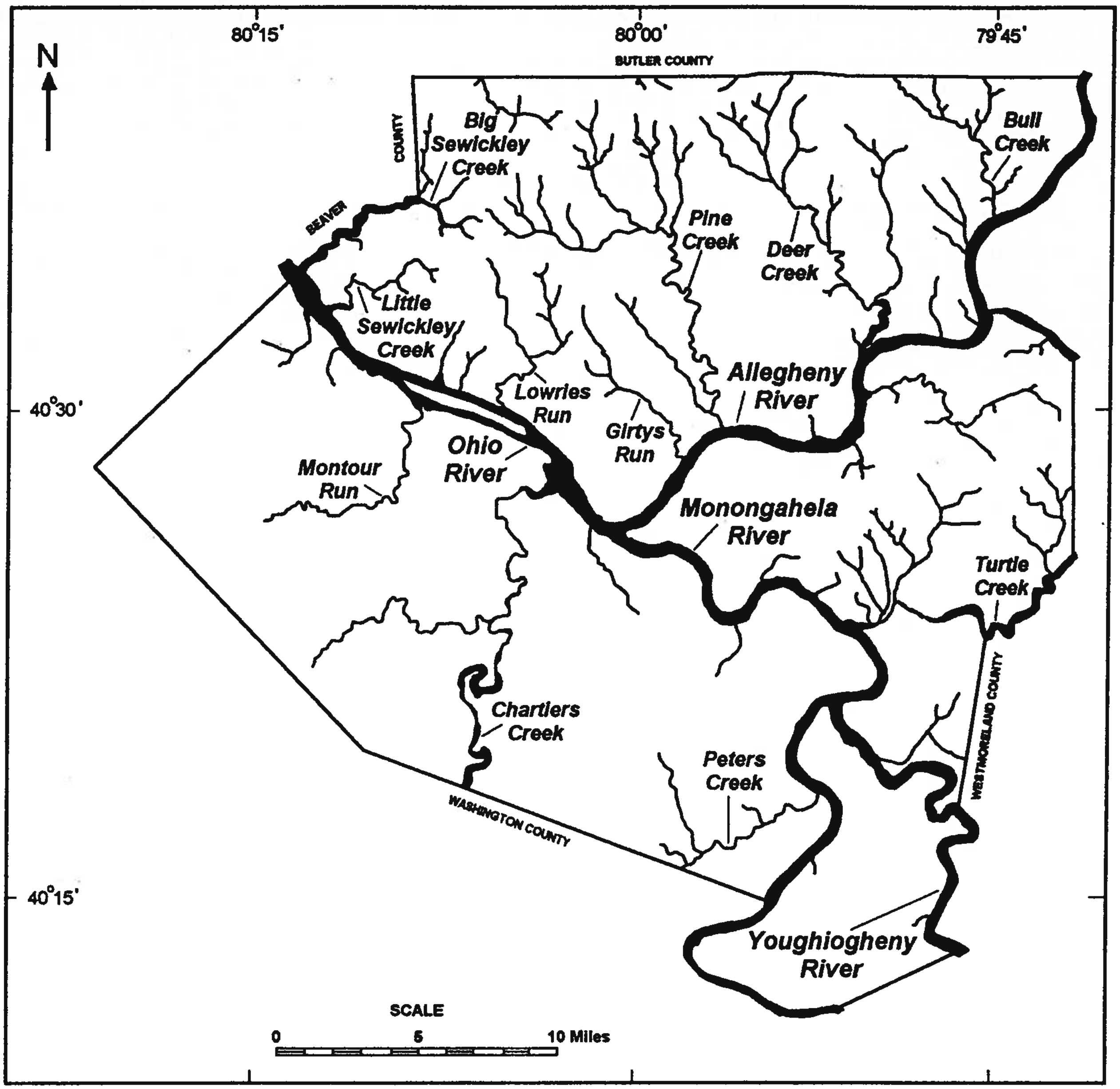

Figure __. Generalized map of the flood-prone areas in Allegheny County. Modified from Briggs, 1977.

Correct Figure 19

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Note:

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