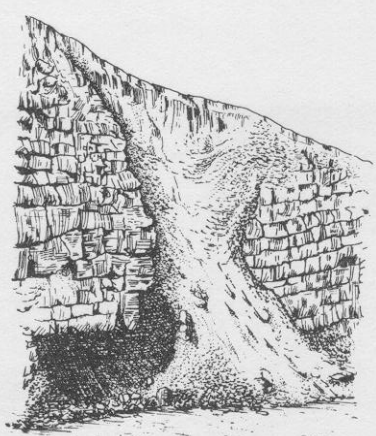
ENVIRONMENTAL GEOLOGY FOR LAND-USE PLANNING

"The Bureau of Topographic and Geologic Survey is actively concerned with the effect of geology on man's activities, whether it be geologic features as hazards or as resources. We recognize that it is not enough to map and name the rocks of Pennsylvania — we must go one step beyond and define their impact on man's use of the land and his environment. Geology is thus a valuable tool for planning, for conservation, and for efficient and wise expansion of man's many activities."

A.A.S.

RESOURCE



HAZARD

Illustrations

by

Albert Van Olden

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ENVIRONMENTAL GEOLOGY FOR LAND-USE PLANNING

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DEPARTMENT OF ENVIRONMENTAL RESOURCES
OFFICE OF RESOURCES MANAGEMENT
BUREAU OF
TOPOGRAPHIC AND GEOLOGIC SURVEY
Arthur A. Socolow. State Geologist

FRANK LLOYD WRIGHT'S "FALLING WATER,"
MILL RUN, FAYETTE COUNTY.

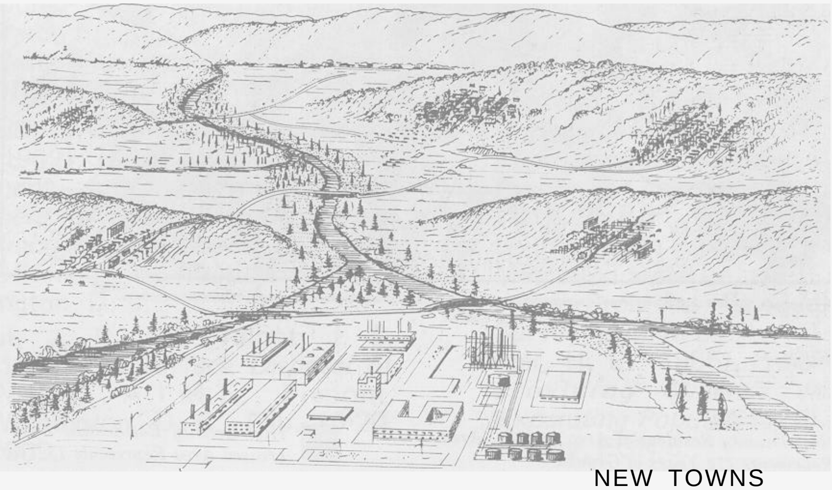
BUILDING ADAPTED TO THE LAND NOT LAND TO THE BUILDING

Environmental Geology is the adaptation of geologic conditions and principles to wise use of the land while safeguarding the quality of the environment.

The term "urban geology" became popular in the early 1960's for describing or using geologic principles to solve engineering problems in urban areas. In this setting, the geologist took a new approach to the study of available construction materials, water resources, landforms, and the characteristics of rocks which affect engineering activities. The geologist's primary concern at that time was the utilization of these mineral resources in building the community and the development of future planning, designing, and construction.

During the late 1960's the interrelationship of *topography, soil, rock, water resources,* and *mineral resources* was considered in evaluating any portion of our natural environment. The application of all geologic principles to the wise use as well as improvement of the environment became known as "Environmental Geology."

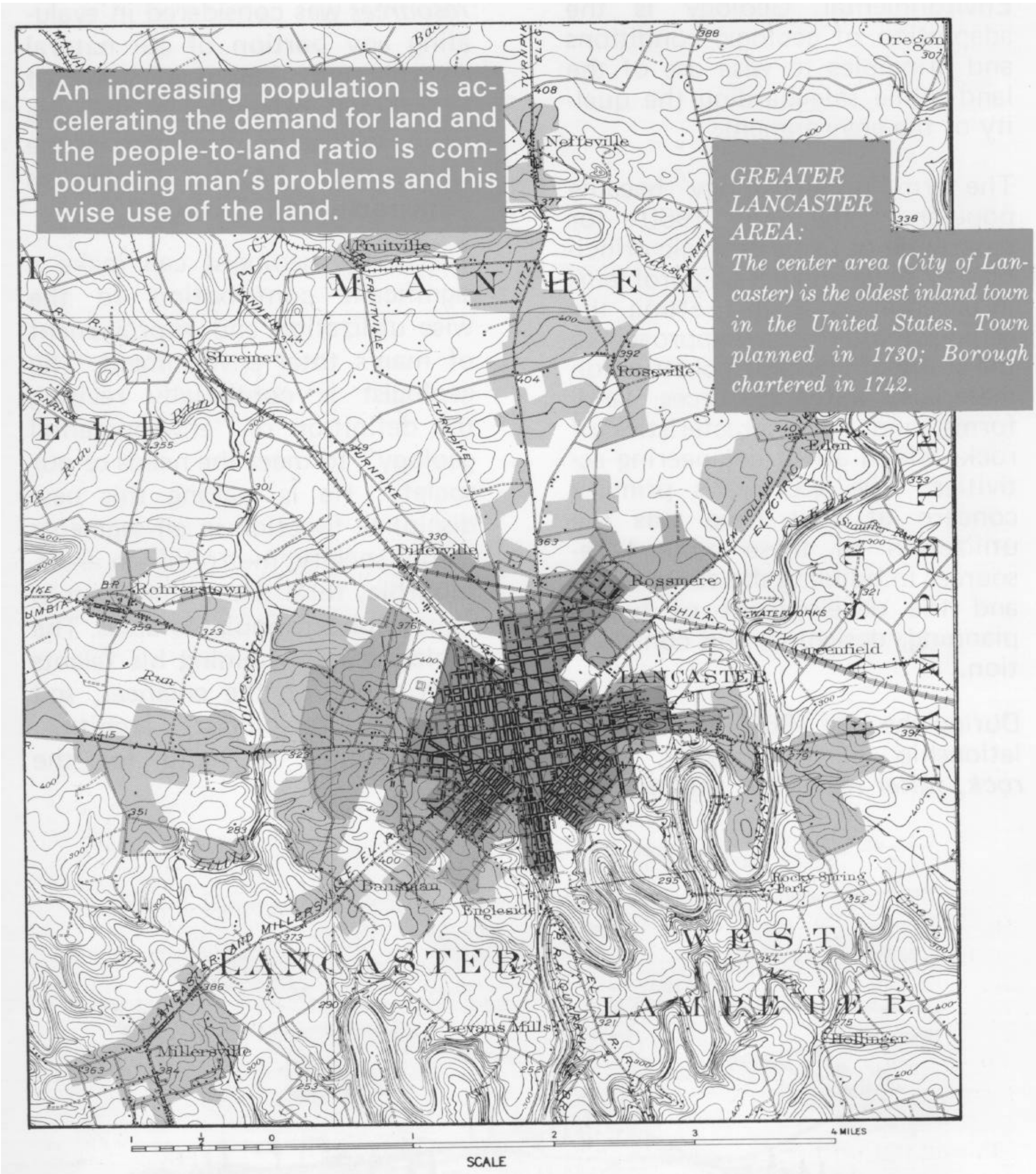
Today the geologist can make a significant contribution to the wise utilization and improvement of man's total environment. The geologist is continually revising the definition of "environmental geology" to meet the needs of our society. He is making this new discipline function in all segments of our society; metropolitan areas, suburbia, rural areas, and even in remote underpopulated areas. The geologist is combining his talents with those of the engineer, soil scientist, sociologist, architect, and planner to build for the future.



NEW TOWNS

WHY IS ENVIRONMENTAL GEOLOGY IMPORTANT?

- - - TO MEET THE NEEDS OF A GROWNG POPULATION



High-Density Residential Area in 1902; Area Represents 172 Years of Growth.

High-Density Residential Area in 1956; Increased Area Represents 54 Years of Growth.

High-Density Residential Area in 1969; Increased Area Represents 13 Years of' Growth.

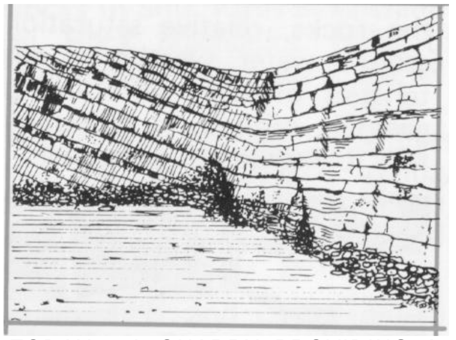
In the last 13 years the greater Lancaster area grew more than it had in the first 172 years

- - - TO MEET THE INCREASING TREND FOR MINERAL RESOURCES
- - - TO PRESERVE THE QUALITY OF THE ENVIROMENT
- - - TO MEET THE NEEDS FOR RECREATION
- - - TO MEET GROWING TRANSPORTATION NEEDS

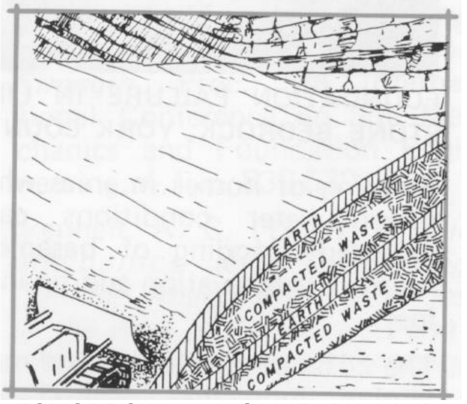
Even as the demand for mineral resources is increasing, the mineral producer must compete for land in Pennsylvania where many acres per year are being converted to home sites, commercial developments, highways, and industrial complexes. The answer in part to this land shortage is multiple use. Mineral construction materials and metal ores can be harvested, and then the land can be made available for home or industrial sites, recreational areas, greenspace, and many other uses.

In urban areas, particularly those with heavy industrial effluent discharge rates, there will be a growing interest in the use of subsurface reservoirs for liquid waste disposal. The geologist with his knowledge of this subsurface environment will play a vital role in determining the feasibility of each proposal while dedicated to preserving the quality of the natural environment.

Topography is important to planning because landforms and slope conditions exert influence on planning alternatives. Certain landforms are favorable for urban development highway right-of-ways and industrialization, while others are undesirable.



TODAY - A QUARRY PROVIDING A BASIC MINERAL PRODUCT; JOBS; AND INCOME TO COMMUNITY.



TOMORROW - A SANITARY LANDFILL PROVIDING THE COMMUNITY WITH AN ECONOMICAL MEANS OF WASTE DISPOSAL.

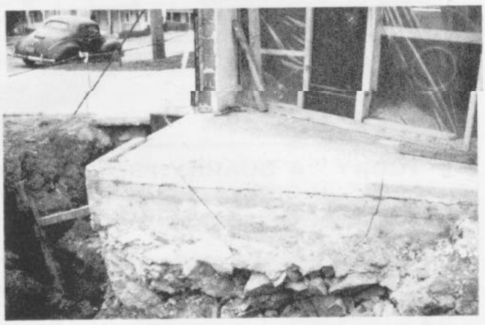
FINALLY - GREENSPACE A COMMUNITY PARK.

WHY IS ENVIRONMENTAL GEOLOGY IMPORTANT?

- - - TO AVOID COSTLY MISTAKES

- - - FOR SAFETY AND HEALTH

The costs of foundation construction for buildings and roads are directly related to the strength of the rocks, relative saturation by ground water, weathering characteristics of the rocks and other geologic criteria. If a foundation fails, construction costs soar.



FOUNDATION FAILURE IN LIMESTONE BEDROCK, YORK COUNTY.

Building of homes in areas where ground-water conditions cause repeated flooding of basements results in aggravation and financial loss.

The costs of developing and maintaining municipal ground-water production and solid waste disposal sites depend heavily on accurate initial geological interpretations.

The stability of slopes cut into rocks for highways and other engineering structures is a very important element in considering the feasibility and economics of the project. If a rock cut-slope is not designed to be stable, hazardous conditions may prevail and maintenance costs over the years may be considerable.

ROAD COLLAPSE, SANDSTONE, SILTSTONE AND SHALE BEDROCK, WARREN COUNTY.

It has been estimated that Pennsylvania's 12 million residents produce and discard 60,000 tons of solid waste a day. The safe disposal of this trash is a problem for every community. The community that understands its geologic environment is better equipped to develop proper solid waste management.

Tunnels through mountains or under rivers, soaring bridges or towering dams all require knowledge of geology in determining their safe location, design, and construction.

Safety consciousness is particularly important in communities where pressure and competition for land has resulted in construction on unstable slopes, in known landslide areas, over active faults, and in flood plains. These difficult conditions are all geological in nature; coping with them requires geological knowledge and planning.

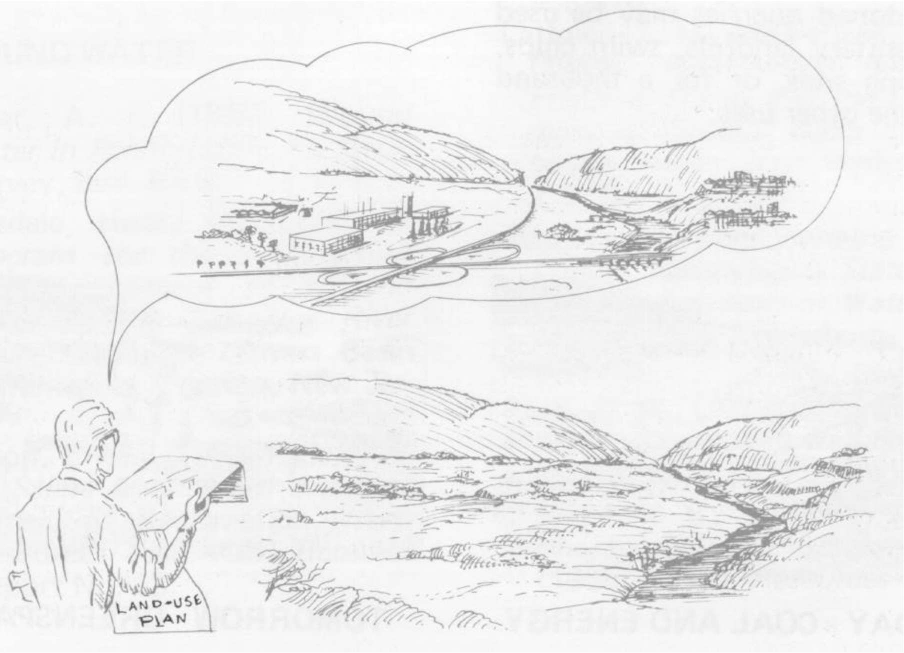
- - - IN LAND-USE PLANNING

Land-use planning based on environmental geology is recommended locally, regionally and nationally. Geologic factors affecting the natural environment should be considered before building in, on, or over rock.

A thorough understanding of the topography allows a high, scenic vista overlooking an urban area to be used for an aesthetically pleasing purpose and not for a junk yard or sanitary landfill. A detailed flood-plain map and report help to delineate the danger of locating a housing subdivision on a flood-prone site and properly indicates its more appropriate use for agriculture or recreation.

The wise management of our water resources is essential. Pennsylvania is faced with an ever-increasing need for water in the same areas where the water is being polluted, natural recharge is being destroyed, and natural runoff patterns are being altered. The geologist can help provide the answers for this increased need for large quantities and high-quality water. He can recommend deep bedrock wells, shallow wells in alluvium along a river, or surface reservoirs where the geologic conditions are favorable.

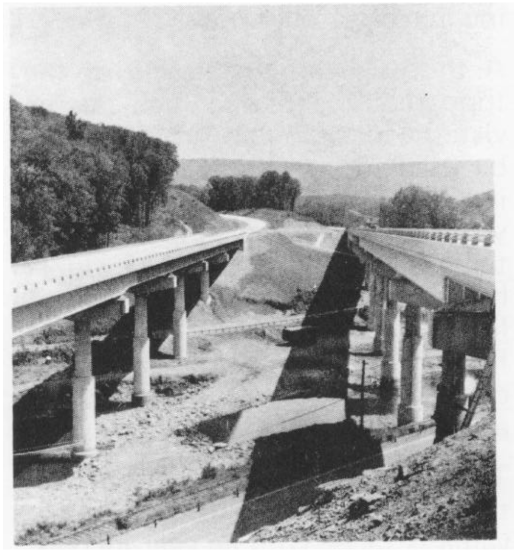
Certain rock units exposed in Pennsylvania are very susceptible to landslides and rock falls. Before and during the excavation for highways, schools, and other large buildings, geological studies are needed. The conclusions and recommendations developed by the geologist should be utilized by the engineer in the design of the road or building.



HOW IS ENVIRONMENTAL GEOLOGY USED?

- - - TO SOLVE PROBLEMS

In many urban areas in Pennsylvania it is important that the locations and depth of subsurface coal mine workings be accurately known to insure that precautions are taken prior to building or site selection. Construction with proper modifications may then be made in these potentially hazardous subsidence areas.



Environmental geology can be utilized to solve problems involving man-made features and natural features or to rehabilitate land that is presently unsuitable. This may involve the restoration of abandoned quarries and strip mines, thereby renovating wasteland for recreational or other uses, as well as abating water pollution.

Abandoned quarries may be used for sanitary landfills, swim clubs, building sites, or for a thousand and one other uses.

TODAY - COAL AND ENERGY

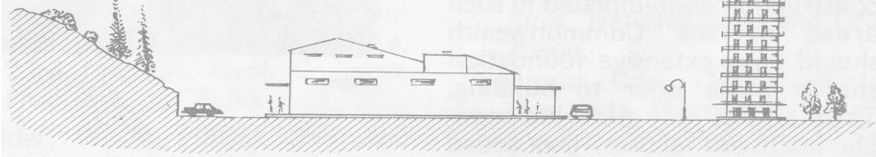
TOMORROW - GREENSPACE

- - - TO IMPROVE THE ECONOMIC HEALTH OF A COMMUNITY

SAND AND GRAVEL FOR CONSTRUCTION

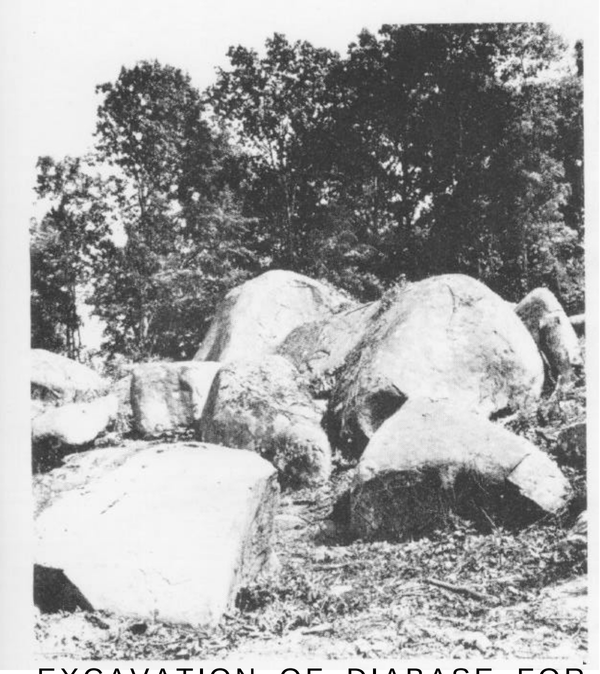
The quantity, quality, and immediate availability of industrial mineral deposits should be considered by each community. The extraction of nearby construction minerals can be beneficial to the community's future growth and economy of building programs, yet the excavation must be planned to become an asset rather than an eyesore.

Many communities have effectively arranged to bring mineral deposits into their plans for the future. Geologists should evaluate them, select those that should be zoned to mine, and design the sites for restoration and use after quarrying.



HOUSING DEVELOPMENT IN RESTORED SAND AND GRAVEL PIT

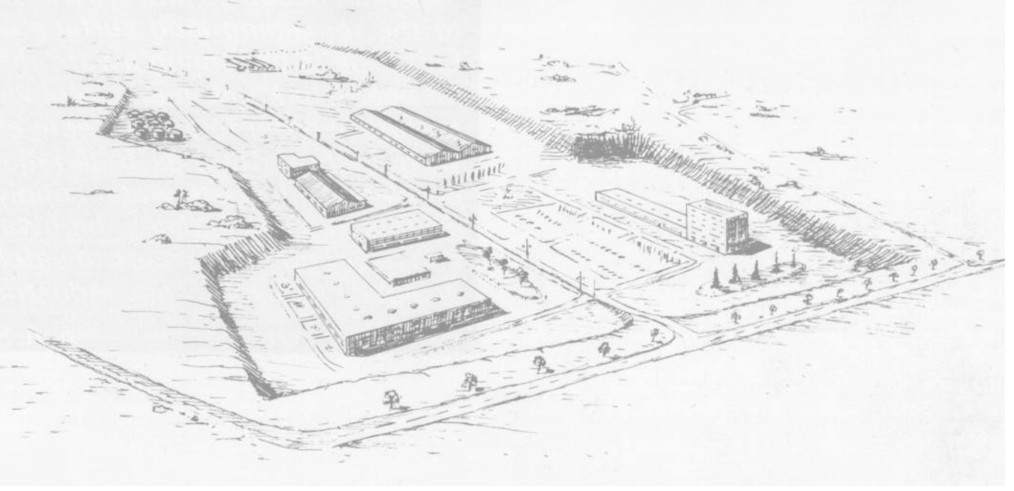
- - - TO IMPROVE THE ECONOMIC HEALTH OF A COMMUNITY



EXCAVATION OF DIABASE FOR SHOPPING CENTER, LANCASTER COUNTY.

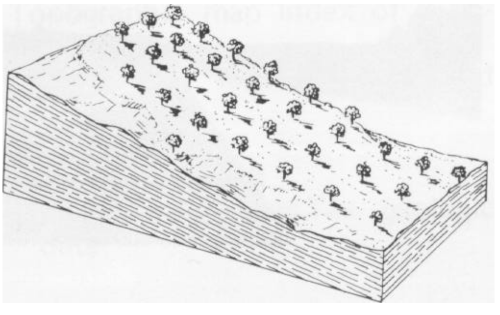
When a contractor bids blindly on an excavation or foundation project, he often bids high to cover unforeseen problems such as excessive ground water, particularly hard rock, or thick soil cover. If the geologist can advise in advance that there will be a specific quantity of a particular kind of rock, that the ground water will be at a certain depth, and that the soil and rippable rock are so thick, then the bids will be more realistic. The contractor can accurately calculate these costs. The dollar savings to the community can be very large over a period of Years.

Sinkholes may occur throughout Pennsylvania where limestone and dolomite are the bedrock. Sinkholes have been known to rob creeks of their water, destroy farm and commercial land, damage buildings, and endanger lives. Geologists can define where limestone and dolomite exist, and all construction contemplated in such areas of the Commonwealth should have extensive foundation studies made prior to building. These studies may eliminate possible fatalities, failures, and added maintenance costs.



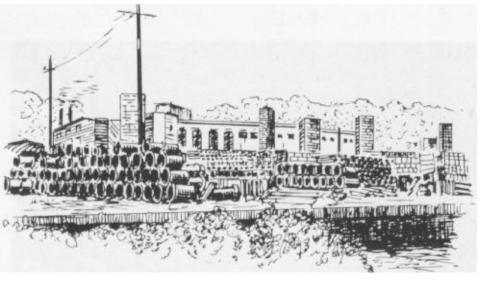
A knowledge of the occurrence of construction minerals can be a major factor in successful project planning. A savings of one million dollars was possible in a recently constructed highway interchange in eastern Pennsylvania because raw construction materials (sand, gravel, limestone, and shale) were available in the immediate area.

INDUSTRIAL PARK COMPLEX IN RESTORED SAND AND GRAVEL PITS



TODAY - HILLSIDE ORCHARD WITH SHALE BEDROCK..

What appears to be waste today may become profit tomorrow. Who knows, the shale formation underlying the hillside orchard may have a clay composition which permits its use for brick or ceramic material. A geologic report may point to new uses for a common rock or mineral.



TOMMORROW - CLAY TILE AND BRICK INDUSTRY.

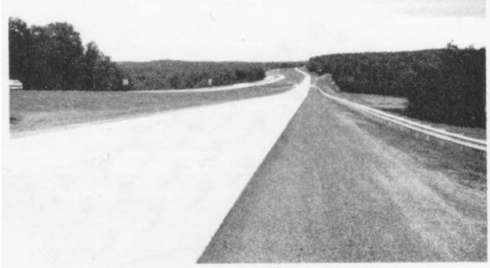
"As man occupies and crowds into the remaining land surface on Earth, he is becoming aware that he needs to know many geologic factors in order to deal effectively with such matters as foundation problems, adequate water supply, earthquakes, landslides, highway construction, and places to safely dispose sewage and industrial wastes."

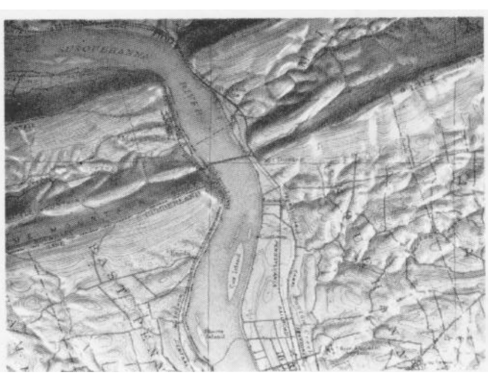
A.A.S.

MAJOR ENVIRONMENTAL GEOLOGY FACTORS

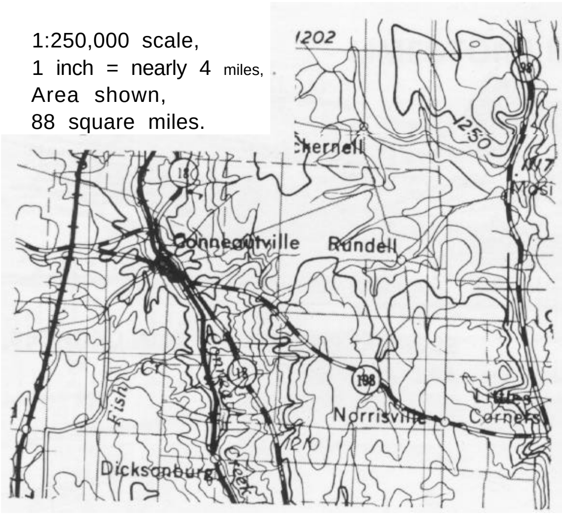
TOPOGRAPHY

Topography is the configuration of the earth's surface and is the outward and present-day expression of geological processes. Pennsylvania's topography, sometimes called her landscape, is the result of her varied rocks and climate. The more resistant the rock is to the weather, the greater the topographic relief, the higher it stands.

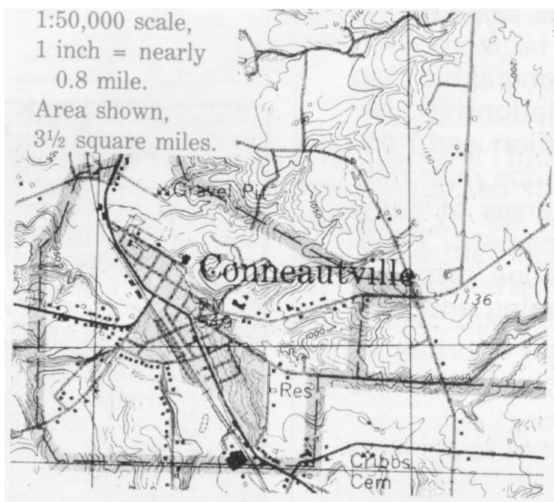


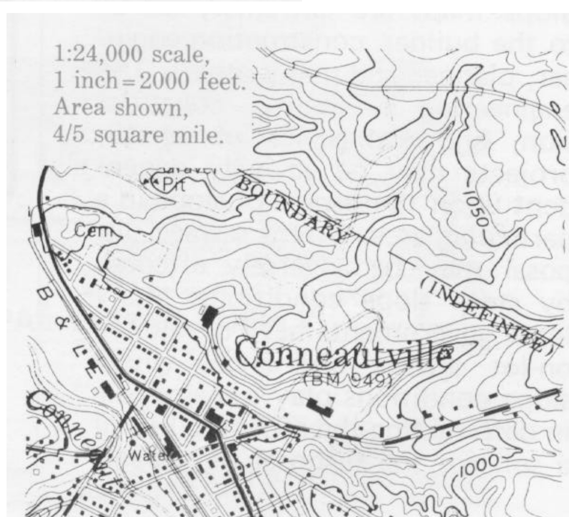


Natural features are probably the most stable part of man's total environment, since the social and economic aspects of it are changeable and subject to the moods and desires of society. Man can only hope to be a good manager of his own actions by living in harmony with his natural environment. To do so, he must understand the natural features which surround him.



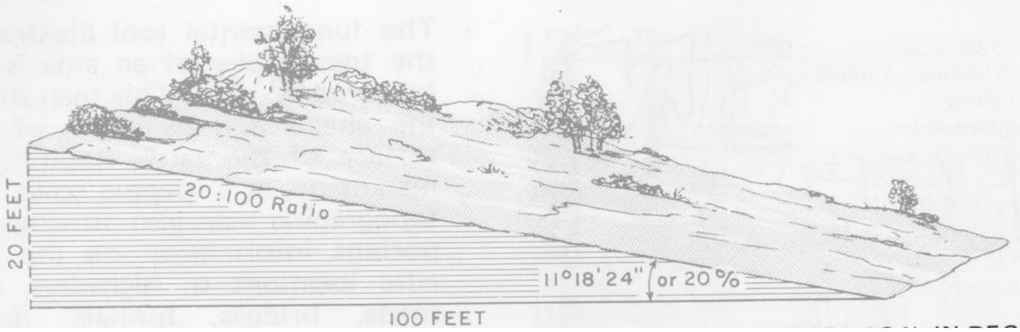
The fundamental tool illustrating the topography of an area is the *topographic map.* This map shows the shape and elevation of the surface of the earth, natural and man-made, at a specific scale. The topographic map also provides important information on the specific locations of highways, railroads, bridges, tunnels, dams, power transmission lines, pipe- quarries, mines, political boundaries, lakes, rivers, streams ponds, and other bodies of water:





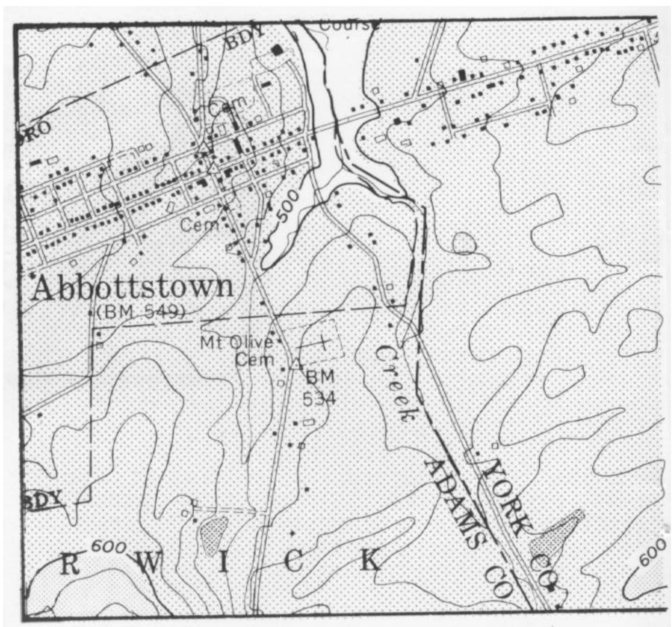
Topographic maps of Pennsylvania are prepared cooperatively by the U. S. Geological Survey and the Pennsylvania Geological Survey and are available in three scales. A current index to these maps and a map order form are available.

TOPOGRAPHY



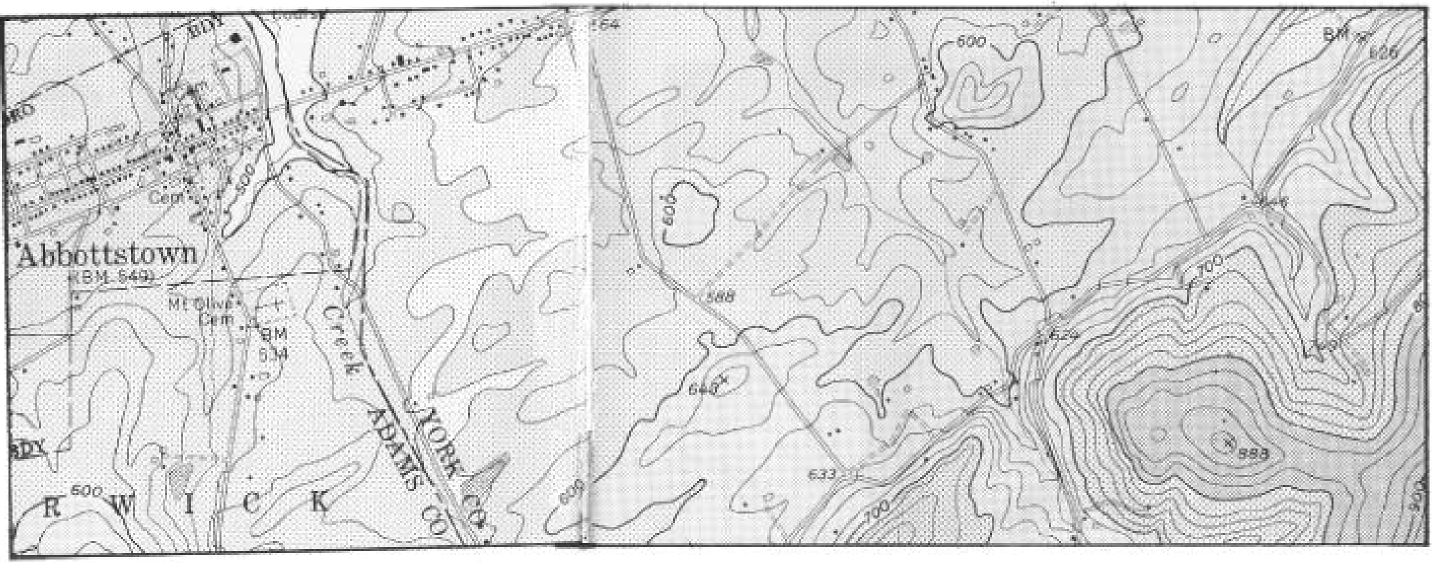
SLOPE EXPRESSED AS %, IN DEGREES, AND AS A RATIO.

A topographic map is used in the determination of the slope of the land. Slope may be computed directly from the topographic map by noting the relationship between vertical elevation and horizontal distance. A *slope map* may be drawn showing areas of equal ranges of slope in percent. Topographic maps and slope maps are basic tools for planning and zoning.



Slope maps are extremely useful to the builder, construction engineer planner and many others. The engineering feasibility, construction, and economics of certain projects may be strongly dependent upon the degree of slope in a particular area. On-lot sewage disposal may be adversely affected by steep slope conditions. Many local governments have developed on-lot sewage ordinances where slope conditions play a major role in determining the acceptability of a soil for the disposal of sewage.

L A Y E R



LAYER RELIEF MAP

0 - 500′

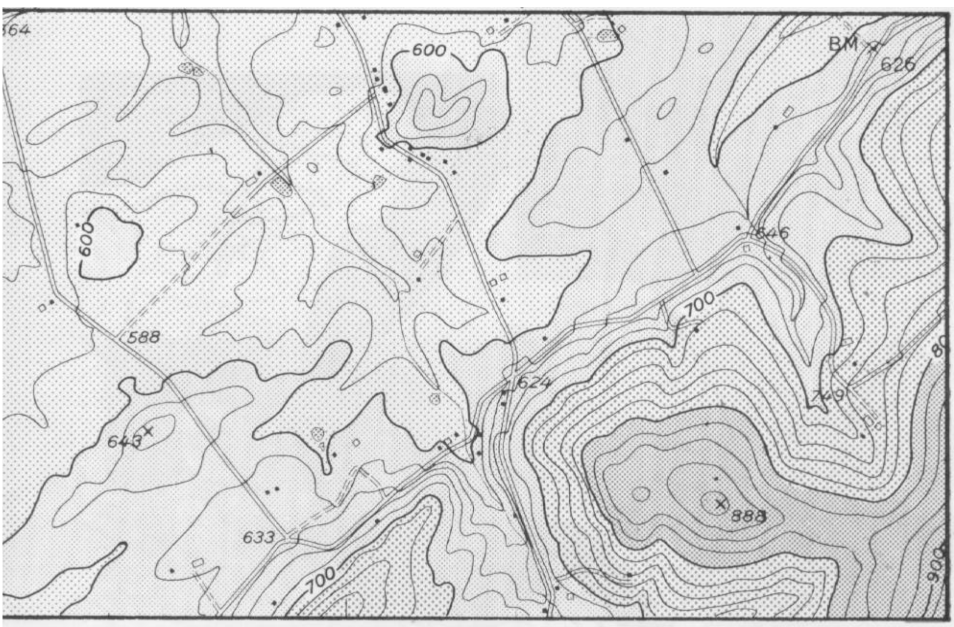
501-600′

601-700′

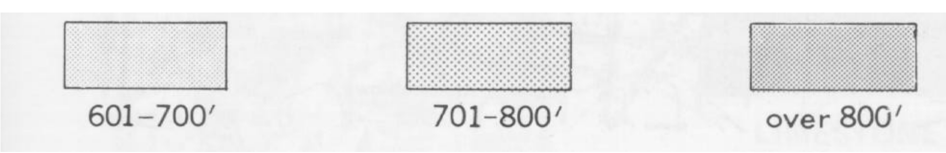
701-800′

over 800′

Another by-product of the topographic map is the *layer relief map.* This map also shows surface elevation, but only by category of relief. That is, the areas having a specified range in elevation within selected contour lines are noted by the use of a single color or pattern. This map is useful to the planner in the evaluation of land. From a layer relief map the high-elevation categories may easily be identified for a scenic overlook, park, residential, or some other use that will not be objectionable when viewed from lower elevations.

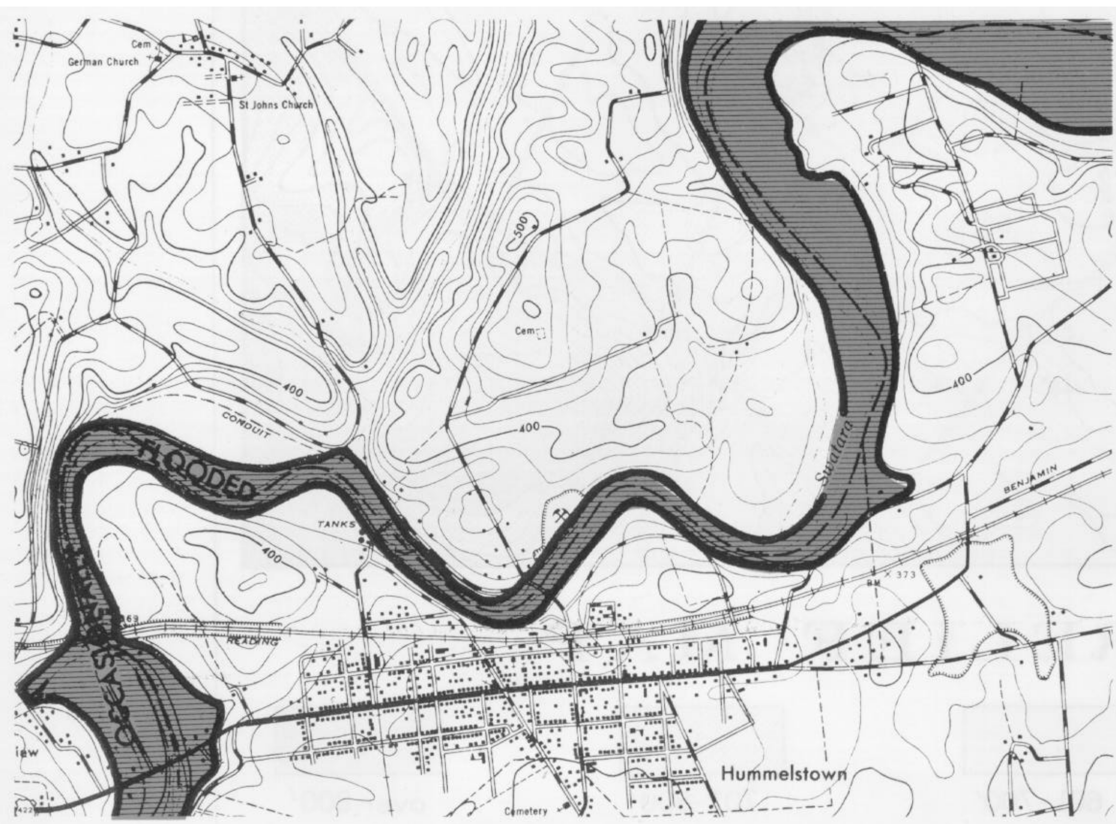


R E L I E F M A P



Flood plains, areas adjacent to streams which are subjected to periodic flooding by high water flowing in the stream bed, are important to the farmer, builder, and flood control engineer as well as the planner. Land use for a flood plain area is usually limited because of the public safety factor and the economics of property loss during flooding. If a flood plain area is to be utilized for construction, agriculture or recreation the hazards must be recognized and the land developed accordingly.

Flood plain topography may be obtained by inspection of a topographic map. A *flood plain map* may easily be constructed by outlining known flood areas on a topographic map and noting the high-water elevations and the frequency of flooding to these elevations.



FLOOD PLAIN MAP

"Based on its vital role to all life, as well as its importance to industry, water is Pennsylvania's most valuable resource. With a growing population and an increasing industrial demand, the Commonwealth faces a continuing need to develop its water resources. The study and inventory of ground water in Pennsylvania is a mandated responsibility of the Bureau of Topographic and Geologic Survey. In carrying out this charge, the Survey has been involved with ground-water studies for over 50 years and has an extensive list of resulting ground-water publications as well as a proud record of services to citizens and fellow government agencies.

With this growing need for water quantity, and growing concern for water quality, the Survey looks to maintaining a ground-water program responsive to the present and future needs of the Commonwealth."

A.A.S.

WATER RESOURCES

At the present time in the United States, about 300 billion gallons of water per day are used. This represents about 27% of present available stream flows. It is estimated that by the year 2000, withdrawal of surface water will total 900 billion gallons per day or about 80% of available stream flow. In order to meet this demand, storage facilities will have to increase and be located in strategic places. In addition, the use of ground water will increase and artificial recharge of our subsurface aquifers will be common practice.

SURFACE WATER

Fresh surface water flows in rivers, streams, lakes, ponds, and the thousands of unnamed, small tributaries found in Pennsylvania. Surface water has served us well by providing a seemingly inexhaustible supply of domestic and industrial water. Yet everyone knows that this supply is exhaustible and means to manage it are imperative.

Pennsylvania's surface water resource must be considered by the concerned individual on the basis of transportation, regional availability of potable water, recreation, sewage disposal, and pollu tion from all sources. Our supply of surface water may seem relatively constant over a long period of time, but this supply is subject to sharp curtailment, yearly by draught or for extended periods of time by pollution.

The first key to good water management is the collection of specific data on the surface water. A continuing program of surface water data collection throughout the Commonwealth is conducted by the U. S. Geological Survey in cooperation with the Pennsylvania Department of Environmental Resources. The information gathered in these studies is published annually in two volumes: Water Resources Data for Pennsylvania Part 1. Surface Water Records, and Part 2. Water Quality Records.

The information contained in these volumes may be used in three principle ways: 1) the calculation of discharge or total volume of surface water available in a specific area, 2) determination of water quality in reference to use of water and potential health hazards of water, and 3) in the determination of flood frequency and flooding potential of a stream.

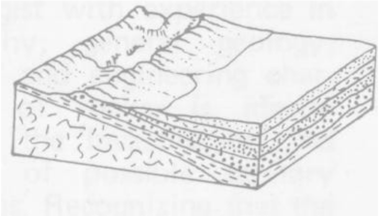
GROUND WATER

Ground water is the water contained in rocks below the earth's surface. This water moves through the rocks in cracks, crevices, and small interconnected pore spaces between the mineral grains of the rock. Ground water has the advantages of relatively constant supply, quality, temperature, and relatively low-cost production.

The reserves and quality of ground water present in the rocks of Pennsylvania are important. This vast, relatively untapped water supply is a valuable asset to a community that anticipates population and industrial growth.

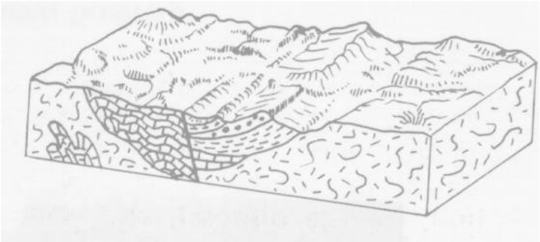
The Pennsylvania Topographic and Geologic Survey conducts studies of ground water in each of the widely different physiographic and geologic provinces of the

Commonwealth. Detailed ground-water reports resulting from these studies are concerned with the occurrence and movement of ground water in each of these geologic regions. Every region and each rock formation within the region have special characteristics that must be defined. These data ultimately provide clues to the quantity and quality of ground water available.



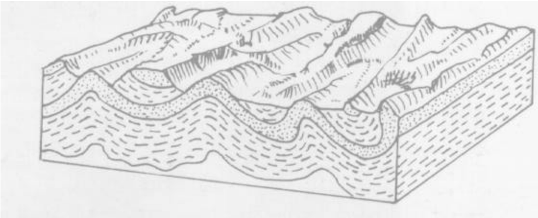
COASTAL PLAIN

The principal objectives in the Survey reports are the determination of total well yield, well depth, depth of water-bearing zones, depth of weathering, and the chemical quality of the water. Each of these factors relates to geologic structure, rock type, and the topographic position of the well.



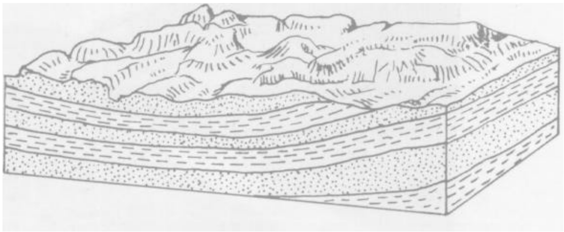
PIEDMONT

Each report includes a *ground water availability map.* A full-color arrangement that is based on the water-bearing ability of the rock units is used on this type of map. The water-supply potential of each zone is color coded and easily discernible on the map.



VALLEY AND RIDGE

Expanded programs of ground-water investigations are currently underway. In addition to these programs, the data being collected from Pennsylvania's water well drillers are being computerized so that ground-water data can be easily used as a basic element in regional planning.

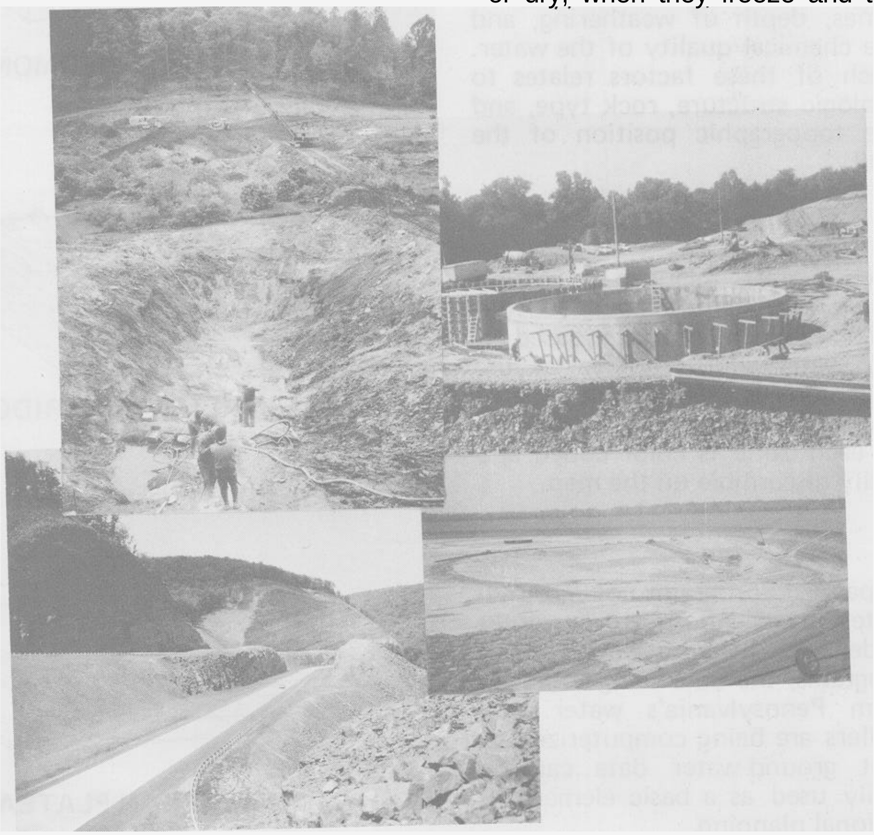


APPALACHIAN PLATEAU

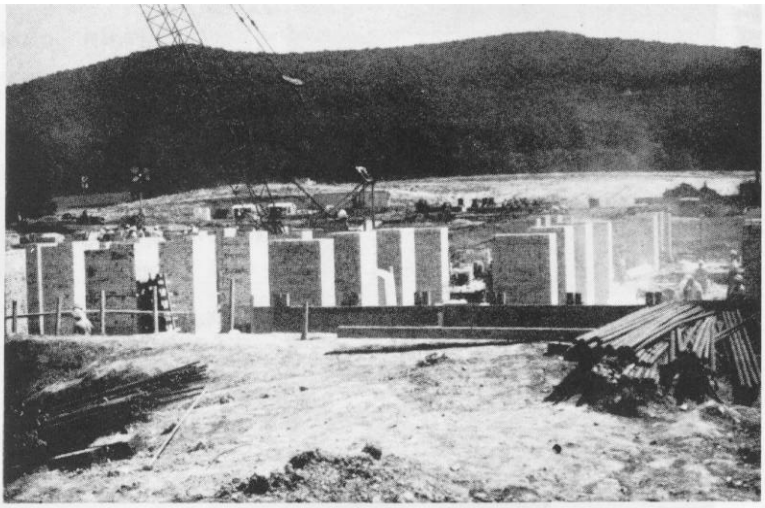
ENGINEERING CHARACTERISTICS OF ROCKS

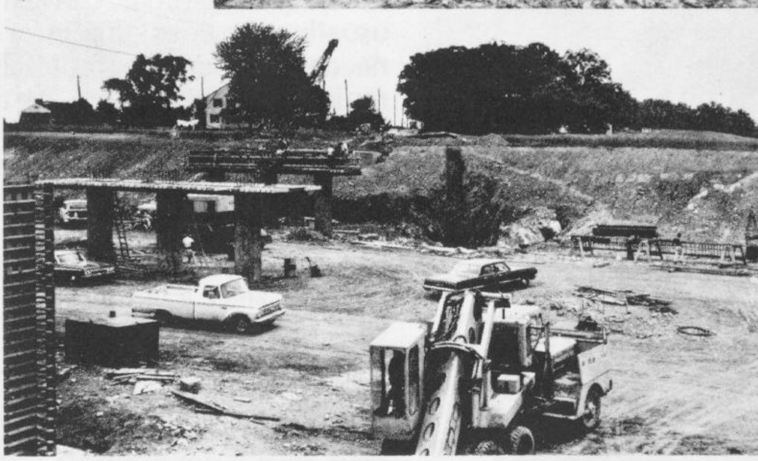
Most construction takes place on or into rock. Where structures are placed and how they are designed, built, and maintained should depend in part on the engineering characteristics of the underlying rocks.

Anyone anticipating piling great weights on top of rock, anchoring bridges or dams to rock, drilling holes and digging tunnels in rock, laying concrete slabs on top of rock, or disposing wastes in rock, must know how these same rocks are going to react under a variety of conditions. How will the rocks involved react when they are wet or dry, when they freeze and then



PPG PLANT, CUMBERLAND COUNTY.





U.S. 222, LANCASTER COUNTY.

thaw, when the dip of the rocks is flat, gentle or steep, or when they are subjected to earthquakes or large-scale subsidence? Answers to these questions often determine where certain structures may safely be built.

Few people who travel through the white-tiled tunnels along the Pennsylvania Turnpike and on soaring bridges over the Allegheny and Delaware Rivers realize how the details of geology affected the location, design, and construction of these engineering works.

JOINT-BLOCK SEPARATION

VERTICAL BEDDING

JOINTING

EXCAVATION OF ROCKS

Certain characteristics of rocks govern their ease of excavation. The degree of weathering, the mineral composition of the rock, the structure of the rock mass, and the porosity-permeability of the rock all contribute to the degree of difficulty involved in excavating it.

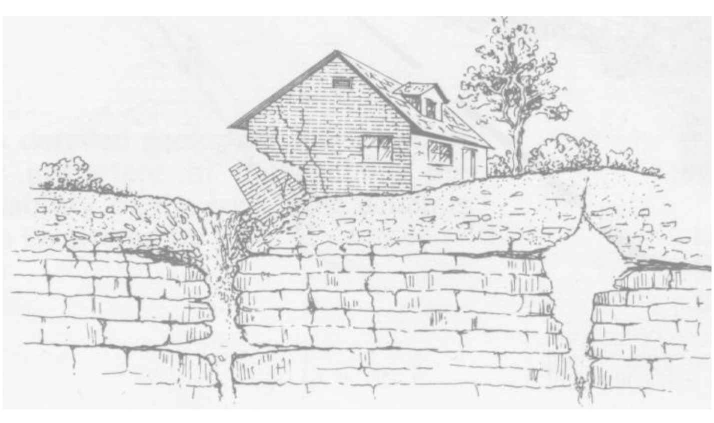
A simple geologic investigation usually provides the information needed to permit predictable and rapid rock excavation. As a result of this investigation, the geologist will be able to advise officials letting bids on excavation jobs that there will be so many cubic yards of a particular rock type, or he may alert a community's highway department that one route is more feasible than another, based on the amount and costs of rock excavation. Thus, the geologist may save a community thousands of dollars yearly.

Based on these same rock characteristics (degree of weathering, mineral composition, structure, porosity-permeability), the geologist is able to predict the relative drillability of a rock unit. This information will allow others to accurately estimate time and costs of drilling operations.

CARNEGIE INTERCHANGE, I-79, ALLEGHENY COUNTY

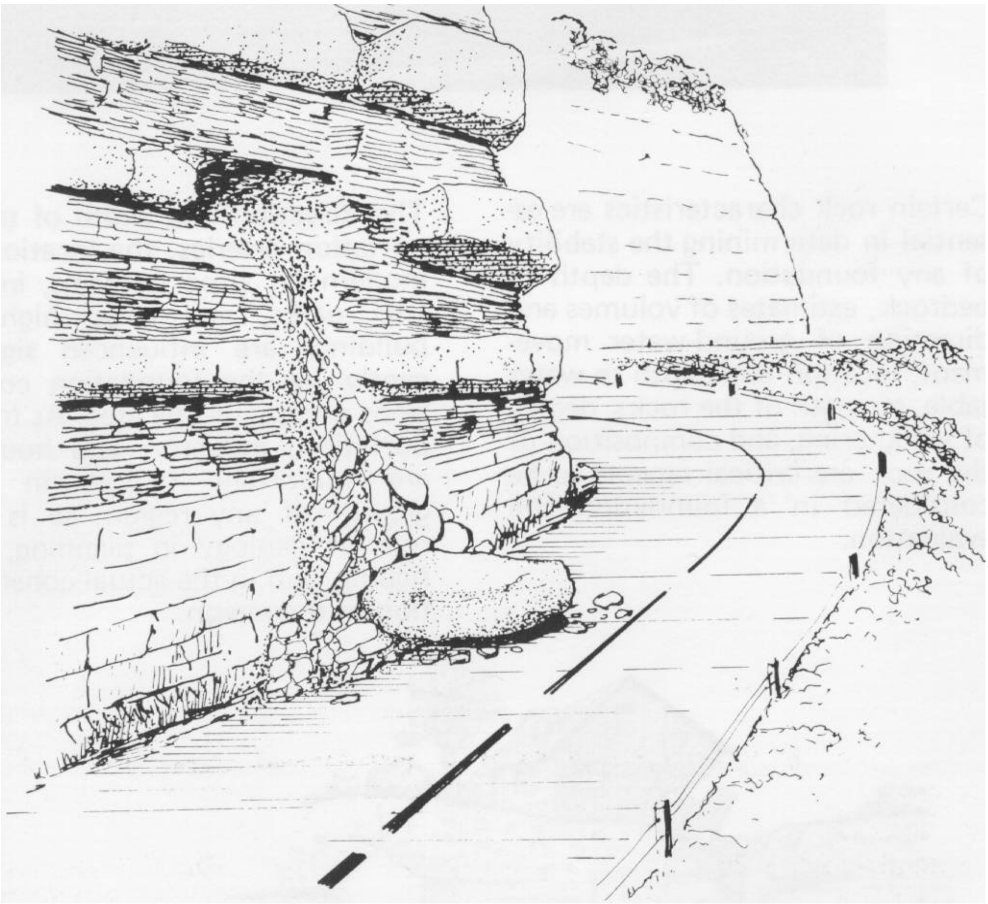
Certain rock characteristics are essential in determining the stability of any foundation. The depth to bedrock, estimates of volumes and direction of ground-water movement, location and depth to water table, strength of the rocks, degree of weathering, and composition of the rock are critical aspects to be considered in a foundation site evaluation.

The direction and width of transportation arteries, the location of modern jet airports, dams, industrial parks, and large, high-rise buildings are influenced significantly by the foundation conditions present in the area. As transportation, industry, and housing are important factors in the growth of any region, so is the role of geology in planning, designing, and in the actual construction of the region.



Rock lithology, structure, and geometry of the rock mass (description and orientation of bedding, joints, and faults), quantity and direction of ground-water flow, plus other minor geological factors contribute to the development of a stable or unstable rock mass on any man-made slope. As our population grows, there is increasing pressure to develop land with steeper slopes.

CUT-SLOPE STABILITY



SLOPE FAILURES IN WESTERN PENNSYLVANIA

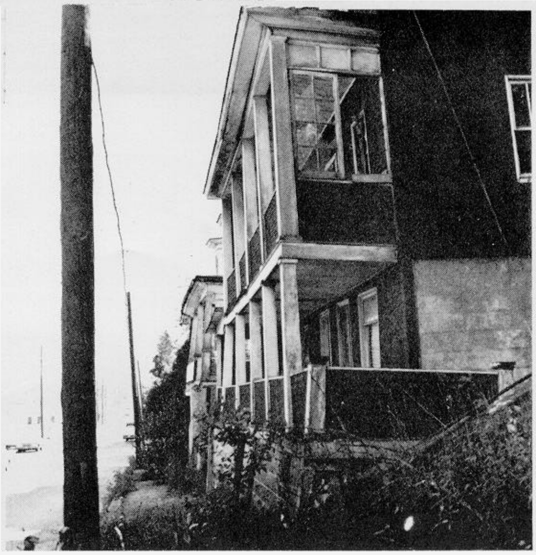
A detailed geological investigation is important in determining the stability of the rock mass which is to be altered by man.

LANDSLIDE NEAR MILLVALE, ALLEGHENY COUNTY

The location of deep and surface, inactive and active mines is important to those concerned with the subsidence potential of surface construction, water pollution abatement, and a continuing supply of fresh water in areas of Pennsylvania where mining has or is prone to take place.

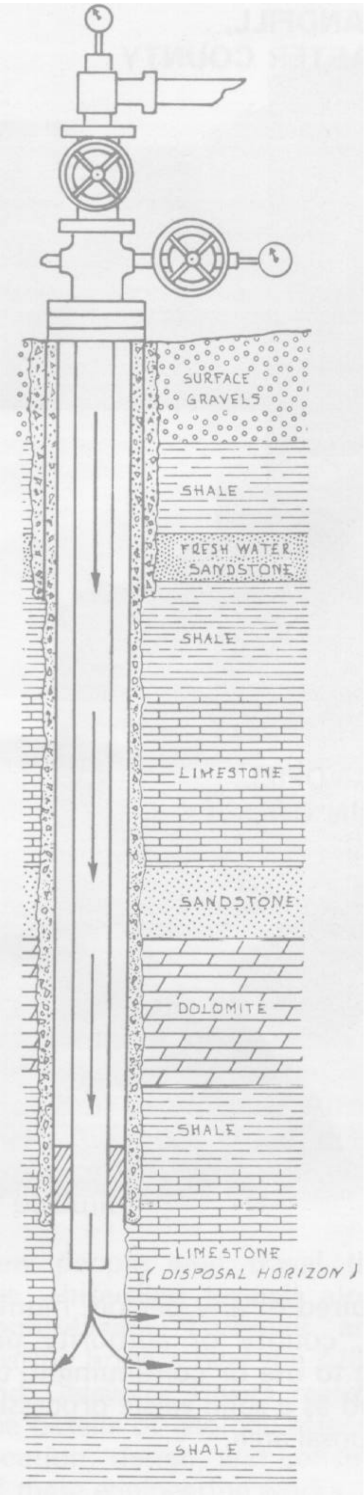
HOMES DAMAGED BY MINE SUBSIDENCE, SCHUYLKILL COUNTY

SUBSIDENCE



It is particularly vital to know the types of mined minerals, the composition of the spoil rock stored at mined sites, the quality of the water in strip pits, the possibility of strip pit leakage to surface and ground-water reservoirs, and the roof thickness over the mined-out areas.

Engineers may be able to cope with difficult construction conditions due to mining under the construction sites, but only by knowing in advance the geology and geometry of the conditions they face.



SUBSURFACE, NON-RADIOACTIVE LIQUID WASTE DISPOSAL

The need for subsurface waste disposal of toxic, liquid industrial wastes will become more pressing as the volume of industrial waste effluent increases dramatically and the public demand for abatement of water pollution grows.

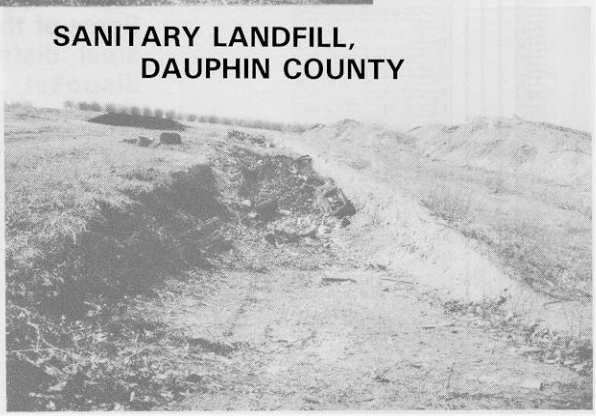
The technology of subsurface waste disposal is presently in its infancy and many public and private organizations are attempting to develop feasible, safe, and economically sound techniques. Many factors must be considered in determining the geologic feasibility of a disposal system. Some of the more notable are the areal distribution of the waste disposal zone in the rocks, thickness of the zone, presence of thick, impermeable upper and lower confining rocks, adequate vertical separation from fresh water horizons, and the chemical compatibility of waste fluids and rock fluids.

Some state governments, Pennsylvania included, are in the process of conducting studies and evaluating existing geologic and engineering data relative to the feasibility of waste disposal to the underground.

COMPLETED LANDFILL,
LANCASTER COUNTY

SOLID WASTE DISPOSAL

SANITARY LANDFILL,
DAUPHIN COUNTY



Solid waste disposal is one of the principal concerns facing the municipal official and the planner today. Under Pennsylvania's Solid Waste Management Act, a permit is required of any person, municipality, county or authority proposing to use or continuing to use its land as a solid waste processing or disposal area.

All sanitary landfill operations must conform to certain standards set by the Pennsylvania Department of Environmental Resources. Permit applications must contain a topographic map of the proposed fill and adjacent area. This map must show borrow areas, typical cross-sections of lifts, dimensions and elevations of the base lifts, grades required for proper drainage of lifts, and the location of all public and private water supplies, wells, springs, streams, swamps and other bodies of water within one-quarter mile of the proposed landfill site property lines. It also must show underground and surface mines, mining spoil piles, mine pool discharge points, elevation of mine pools, gas and oil wells, and areal extent of mine pools.

In addition to the topographic information, the operator of the landfill must append to his application a report of the soils, geology and ground-water characteristics of the proposed site. The depth of soil and rippable rock at the proposed landfill site must be known and must be suitable for cover and consistent with the design requirements of the sanitary landfill. The depth to bedrock, the extent of weathering of bedrock, the rock structure, the direction of ground-water movement, the depth to the ground-water table, and the type of occurrence of ground water in the bedrock are needed for review of the application by the Department of Environmental Resources.

The geologist with experience in physiography, general geology, hydrology, and engineering characteristics of rocks, is ideally suited for the investigation and evaluation of possible sanitary landfill sites. Recognizing that the safe disposal of this solid waste is a problem for every community, the geologist and the community working together to better understand the natural environment will assure a wise solid waste management program.

"Man's fast growing population and continually increasing standard of living throughout the world is consuming and demanding ever increasing amounts of mineral resources even as those resources are everywhere becoming more difficult to find. The need for more energy is taxing the combined resources of coal, oil, gas, and atomic energy — all of which constitute materials coming out of the ground.

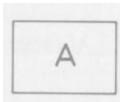
Thus, Pennsylvania faces a real challenge: to continue to produce minerals to serve our requirements, while also conserving our landscape and our waters. The two are reconcilable but only by serious and sincere efforts by all concerned."

A.A.S.

In earlier years the most valuable mineral resources extracted in Pennsylvania were metals. But, in recent time it is industrial (nonmetallic) minerals which have become of prime importance. The current gross value of all industrial mineral products annually far exceeds that of metallic ores.

These industrial mineral resources consist of solids such as coal, limestone, sandstone, and shale; liquids such as oil; and gases as in the case of natural gas. Most of these deposits are abundantly distributed in Pennsylvania but their value often depends on the ability to use the raw material near its source.

The full utilization of all mineral resources should be considered in developing a community's economy; promoting this utilization is mutually beneficial to the economy of the community as well as the economic benefit through local construction costs.



Sandstone

Sandstone, fine-grained, grayish-red, cross-stratified, massive bedded; contains layers of shale and conglomerate in places; used locally as building stone; quarried and crushed rock makes fairly durable fill, base course and ballast.

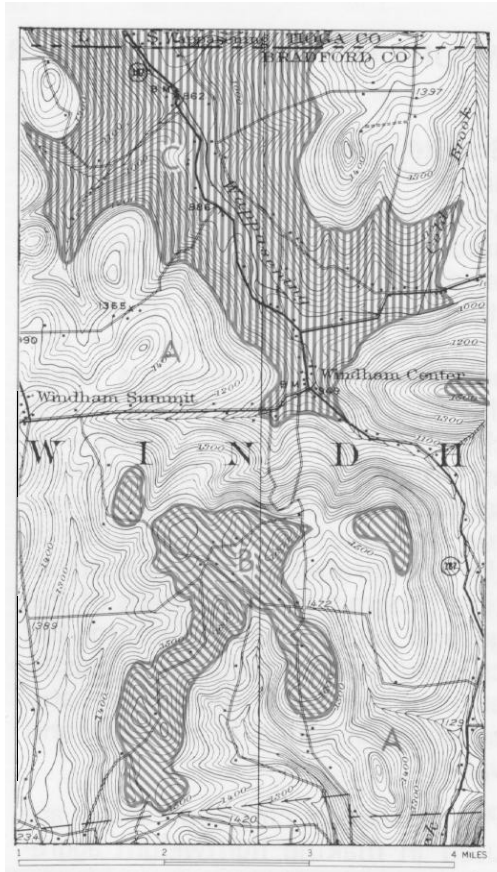
Mixed Sandstone and Shale

Sandstone, fine-grained, moderately hard, laminated; .shale, lacks platy character, medium-gray color; thick sandstone beds suitable for building stone; moderately good for riprap and ballast; excellent for fill and base course and reasonably good for surfacing material.

Shale

Shale. mudstone, medium-to dark-gray color; plastic or slippery when wet, especially weathered part of rock; makes weak, poorly drained fill and very poor surfacing material; excellent material for common brick; maybe possible use for lightweight aggregate.

(Example only - not real properties of rocks in place.)



A *mineral resource map,* produced by a geologist, defines the exact limits of the mineral deposit and its exact location within a political area. This map with a descriptive legend describes the rock formations of the area in detail and points out those formations most likely to be of value to the community.

The Pennsylvania Geological Survey publishes mineral resource reports and maps that suggest the best areas to mine or quarry a particularly valuable rock or mineral. The quality of these resources are also indicated. In addition, a series of cross-sections that enable the reader to visualize the mineral deposit in three dimensions are presented when applicable.

IMPORTANT ROCKS AND MINERALS OF PENNSYLVANIA

Granite, sandstone, quartzite, dolomite, limestone, diabase and other rocks of Pennsylvania are used for building or ornamental purposes in addition to crushed stone for construction purposes. The crushed stone industry depends upon local markets since the cost of transportation is the chief limiting factor. Conversely, an urban area should have nearby sources of low-cost rock materials for its building program. Due to the accelerated highway construction program plus the needs of the general building construction, the crushed stone market now vastly exceeds that of dimension and ornamental stone in tonnage and value.

Pennsylvania's clays and shales are used in making lightweight aggregate, brick, and ceramic products. Sandstone and sand and gravel are valuable mineral resources used for making glass and concrete.

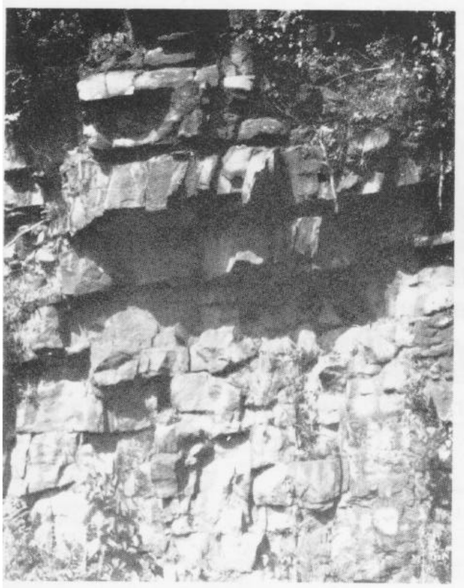
Coal, oil and natural gas are three most important mineral fuels found in the Commonwealth. Of these, coal out-ranks all others. As the thickest and best quality coal seams are mined-out, the industry turns to less attractive coal deposits. The geologist is called upon to identify, outline and compute reserves of these lower-grade coals.

The increasing nationwide natural gas shortage has renewed exploration interest in the existing shallow gas fields of western Pennsylvania and the deeply-buried rocks over a large portion of the state. Well-head gas prices have risen about 25% in the past three years. New developments in the oil and gas industry of Pennsylvania are reviewed annually and in special reports by the Pennsylvania Geological Survey.

ORISKANY SANDSTONE QUARRY, HUNTINGDON COUNTY

LIMESTONE MINE

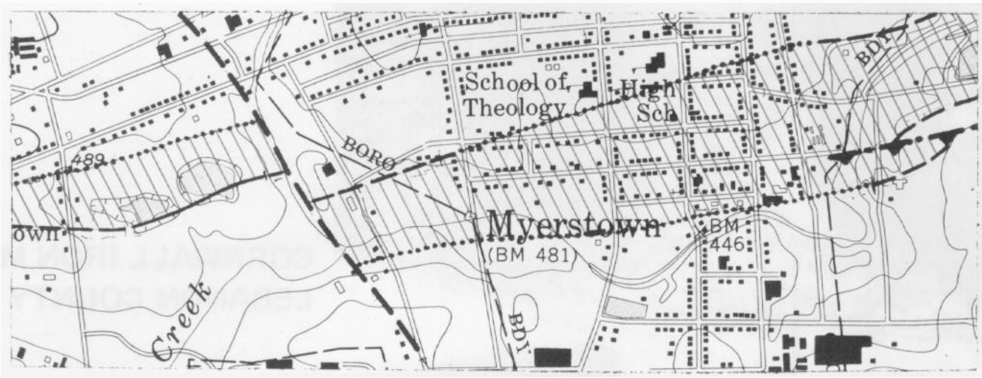
CORNWALL IRON MINE, LEBANON COUNTY



SANDSTONE

LIMESTONE QUARRY

MINERAL EXTRACTION AND URBANIZATION



HIGH-CALCIUM LIMESTONE BENEATH A BOROUGH

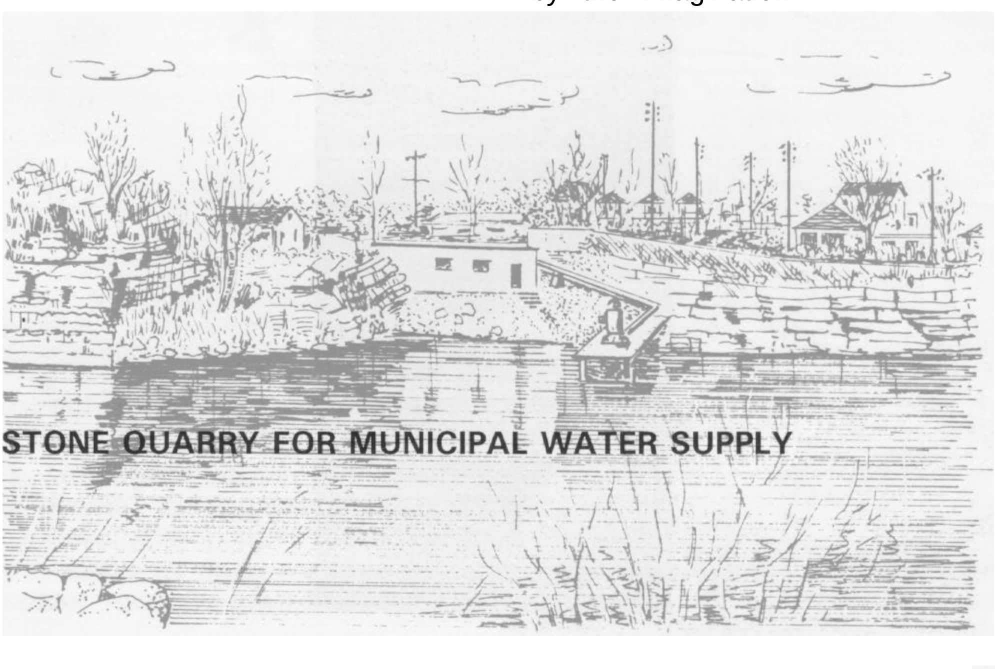
It is important to know the reserves of any given mineral deposit. If these reserves are not known, urban and suburban developments may be allowed to expand to the very limits of active quarrying and before the community realizes it, the operation must close. Closing a mineral producing operation not only means the loss of valuable minerals, but also a loss of construction materials to the community, possible loss of jobs and revenue to the area, and higher costs for the same materials from distant sources.

One answer to the growing shortage of land is multiple use wherever possible. Mineral deposits can be quarried; the land can then be rehabilitated and made available for industrial parks, housing developments, recreational sites, or greenspace.

Some communities have attempted to bring mineral deposits into their plans for the future. The city of Los Angeles has surveyed sand and gravel deposits in the San Fernando Valley, evaluated them by drilling, and zoned many as gravel-pit sites. After these deposits are quarried, the pits will first be used for solid waste disposal, and then restored for urban use. In Pennsylvania, along the Delaware River, this same sequence of events is taking place.

LIMESTONE MINE FOR MUSHROOM GROWING

The mineral industry especially has recognized this need for pre-planning of pit and quarry sites geared to their restoration and use of the land after quarrying. Uses for these quarries or mines are often without end, limited only by the imagination.



LIMESTONE QUARRY FOR MUNICIPAL WATER SUPPLY

The application of geology to planning provides primary and alternative selections and solutions. When a geologic study is applied to land-use planning, spatial limitations and priorities, engineering assistance, and financial savings can be realized.

The population and industrial capacity of Pennsylvania and the Nation are expected to soar. Together, the planner, engineer, government official, and geologist must answer the following questions:

Is our available water resource adequate for anticipated expansion?

What are the topographic limitations of the space available for expansion?

Are major engineering modifications necessary to prepare the available land for a specific use?

Are mineral resources for construction available nearby?

Can our mineral resources be extracted and be compatible with orderly zoning and construction?

Will our disposal systems for solid and liquid waste materials be adequate? Can they be expanded either by surface or subsurface means?

For More Details:

ON	WRITE
List of geological publications on Pennsylvania Topographic map index of Penn-Sylvania Oil and gas well locations and records Mine maps Water well records Miscellaneous open-file geologic data	State Geologist Bureau of Topographic & Geologic Survey Pennsylvania Department of Environmental Resources Harrisburg, Pennsylvania 17120
Annual surface water records Ground-water level records Flood maps, publications and records	District Chief Water Resources Division U. S. Geological Survey Federal Building, P. O. Box 1107 Harrisburg, Pennsylvania 17108

ON	WRITE
River basin reports State Water Plan Surface water records General flood records	Chief Engineer Pennsylvania Department of Environmental Resources P. O. Box 1467 Harrisburg, Pennsylvania 17120
State forest land mineral prospecting permits	Chief Geologist Division of Minerals Bureau of Forestry Department of Environmental Resources Harrisburg, Pennsylvania 17120
Status of topographic mapping in Pennsylvania Availability and costs of topographic map negatives and positives	Atlantic Region Engineer U.S. Geological Survey Topographic Division 1109 North Highland Street Arlington, Virginia 22210
Solid waste regulations, laws, guidelines, permits	Department of Environmental Resources Bureau of Land Protection and Reclamation Division of Solid Waste Management Harrisburg, Pennsylvania 17120
County soil surveys Miscellaneous soil studies	U.S. Department of Agriculture Soil Conservation Service Box 985, Federal Square Station Harrisburg, Pennsylvania 17108
List of Publications Mine safety procedures and regulations Physical and chemical testing of rocks Mineral reserve calculations Mine maps Mineral production statistics	U.S. Bureau of Mines 4800 Forbes Avenue Pittsburgh, Pennsylvania 15213
List of Publications Technical publications as they relate to road building	Highway Research Board National Academy of Sciences 2101 Constitution Avenue Washington, D. C. 20418
U.S. Corps of Engineer projects-Open-file geologic reports	Chief, Geology Section Philadelphia District Customs House, 2nd & Chestnut Sts. Philadelphia, Pennsylvania 19106 Baltimore District P. O. Box 1715 Baltimore, Maryland 21203 Pittsburgh District Federal Building Pittsburgh, Pennsylvania. 15122

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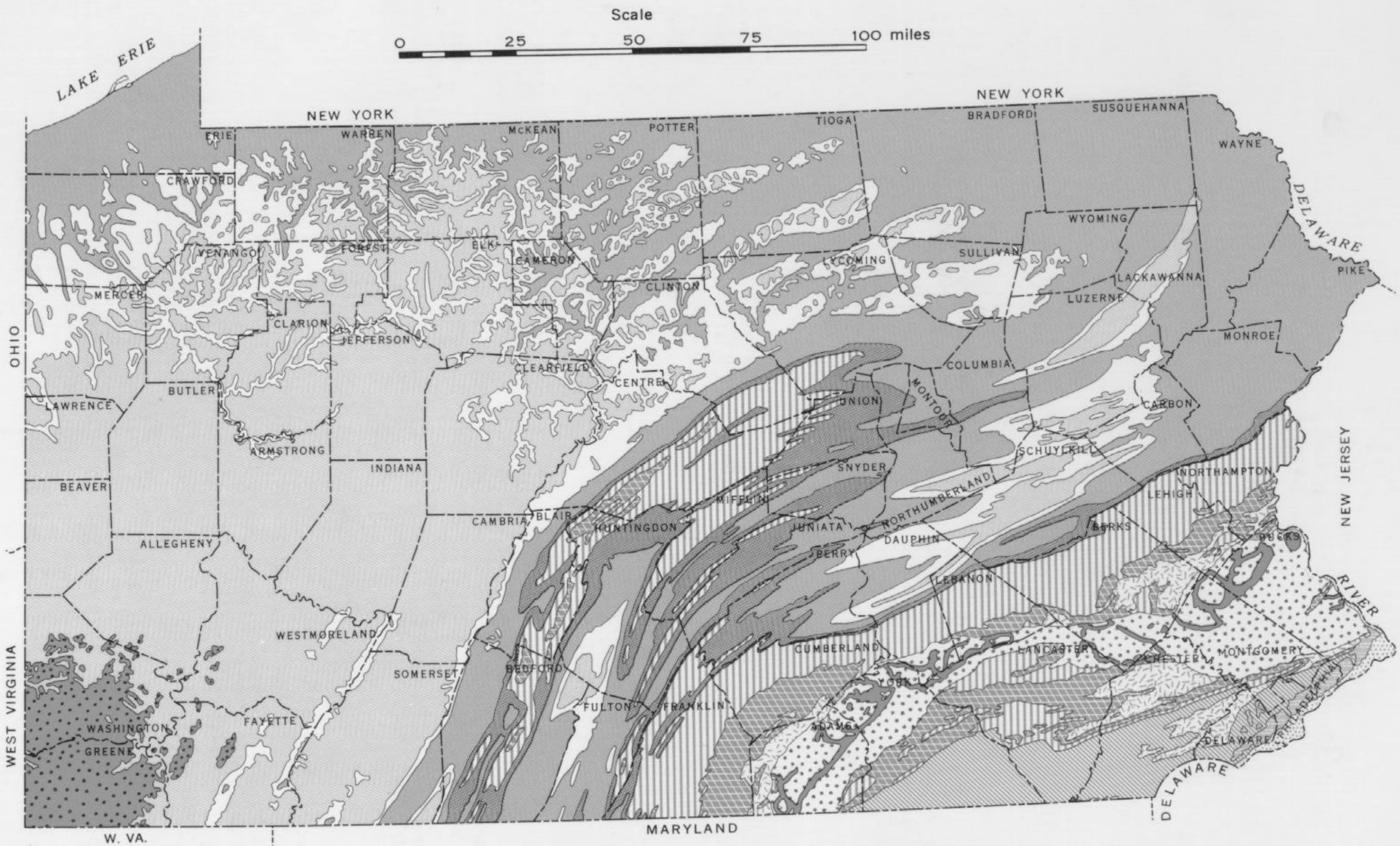
Photographs by Wm. Bolles (Dept. of Education) and authors

GEOLOGIC MAP OF PENNSYLVANIA



QUATERNARY
(0-2 mil. yrs.)
Sand, gravel, and silt.
Sand and gravel.

TERTIARY
(2-67 mil. yrs.)
Sand, gravel, silt, and clay.
Sand and gravel.

TRIASSIC
(195-240 mil. yrs.)
Red sandstone, shale, and conglomerate, intruded by diabase (red); includes small areas of Jurassic age rocks.
Building stone, iron.

PERMIAN
(240-285 mil. yrs.)
Cyclic sequences of shale, sandstone, limestone, and coal.
Lime, clay.

PENNSYLVANIAN
(285-325 mil. yrs.)
Cyclic sequences of sandstone, red and gray shale, conglomerate, clay, coal, and limestone.
Coal, clay, lime, building stone.

MISSISSIPPIAN
(325-365 mil. yrs.)
Red and gray sandstone, shale, and limestone.
Flagstone, limestone, clay.

DEVONIAN
(365-405 mil. yrs.)
Red sandstone, gray shale, black shale, limestone, and chert.
Flagstone, silica sand, clay, lime.

SILURIAN
(405-435 mil. yrs.)
Red and gray sandstone, conglomerate, shale, and limestone.
Lime, building stone.

ORDOVICIAN
(435-500 mil. yrs.)
Shale, limestone, dolomite, and sandstone.
Slate, limestone, zinc, clay.

CAMBRIAN
(500-570 mil. yrs.)
Limestone, dolomite, sandstone, shale, quartzite, and phyllite.
Lime, building stone.

LOWER PALEOZOIC
(probably Ordovician and Cambrian; 435-570 mil. yrs.)
Metamorphic rocks (meta-sedimentary and meta-igneous): schist, gneiss, quartzite, serpentine, slate, and marble.
Building stone, talc.

PRECAMBRIAN
(older than 570 mil. yrs.)
Gneiss, granite, anorthosite, metadiabase, metabasalt, metarhyolite, and marble.
Building stone, graphite, sericite.