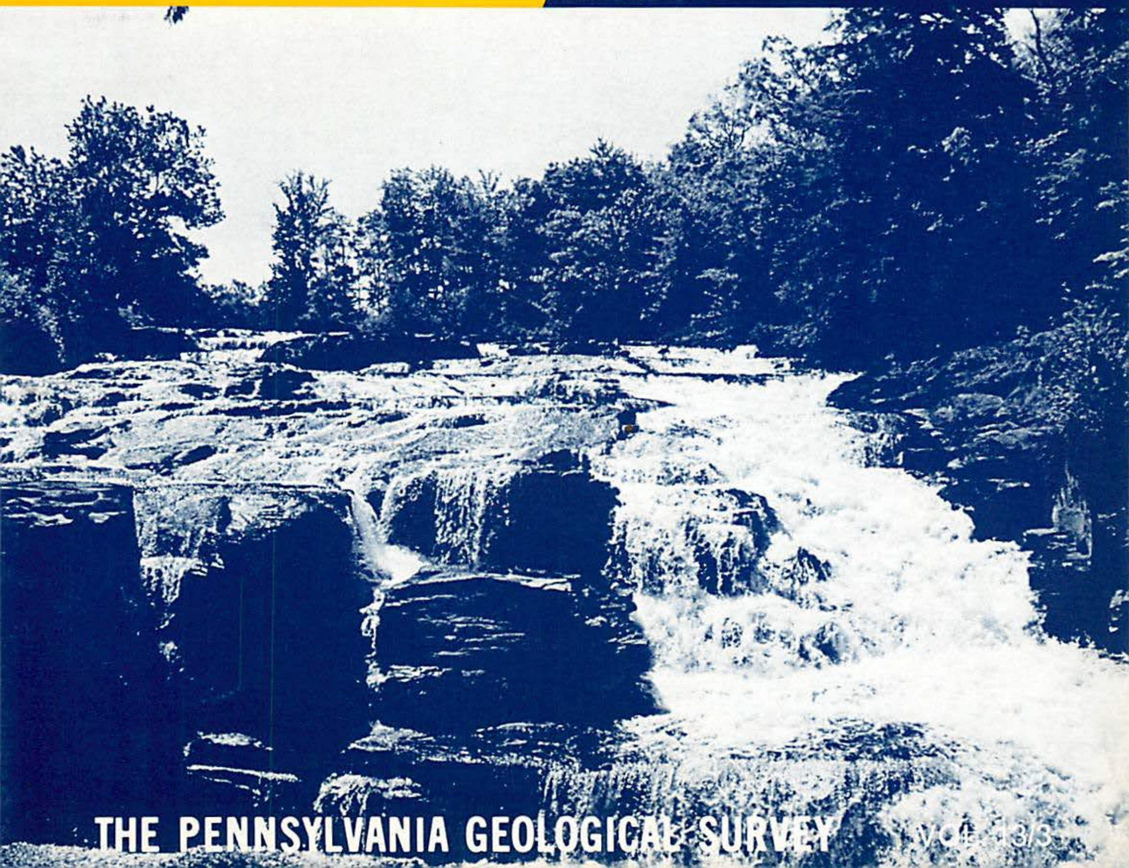
PENNSYLVANIA GEOLOGY



THE PENNSYLVANIA GEOLOGICAL SURVEY VOL. 13/3

COMMONWEALTH OF PENNSYLVANIA
Richard L. Thornburgh, Governor

DEPARTMENT OF ENVIRONMENTAL RESOURCES
Peter S. Duncan, Secretary

OFFICE OF RESOURCES MANAGEMENT
R. Timothy Weston, Associate Deputy Secretary

TOPOGRAPHIC AND GEOLOGICAL SURVEY
Arthur A. Socolow, State Geologist

CONTENTS

ON THE COVER: Shohola Falls, Pike County. Shohola Creek descends 200 feet in a half mile of falls and rapids over shales and sandstones of the Catskill Formation of Devonian Age. State Game Land 180 surrounds and includes the falls.

PENNSYLVANIA GEOLOGY is published bimonthly by the Topographic and Geologic Survey, Pennsylvania Dept. of Environmental Resources, Harrisburg, Pennsylvania, 17120.

Editor, Arthur A. Socolow; Associate Editor, Donald M. Hoskins.

Articles may be reprinted from this magazine if credit is given to the Topographic and Geologic Survey.

June 1982

FROM THE DESK

OF THE

STATE GEOLOGIST . . .

FROM ACROSS THE NATION, THE STATE GEOLOGISTS

We are very privileged to be serving as host to the 74th Annual Meeting of the Association of American State Geologists this year at Hershey on June 6 to 10. This group, whose membership consists of the 50 State Geologists across the country, meets each year in a different state to discuss new developments and procedures of common interest and benefit to all. Federal programs and cooperative activities are regularly reviewed, particularly appropriate in light of the changes now taking place.

What is a State Geologist? He (and now we welcome the first "she" State Geologist from Utah) is commonly the Director of the State Geologic Survey of the respective state — although the title of the unit varies somewhat from state to state. Basically the State Geologist is responsible for heading up a complex program which identifies and evaluates the geologic conditions and geologic resources of the state, with emphasis on serving the geologic needs of the citizens of the state. In some states this may also involve regulatory responsibilities over activities such as oil and gas drilling, water wells, and mining.

The State Geologist, thus, serves at the interface between scientific investigation of geologic matters and the public need to cope with geologic issues. The issues may include geologic hazards (landslides, earthquakes), mineral resources needs to keep industry operating (coal, limestone, iron ore, clay), or identifying the local geology in order to plan and construct highways, dams, sewage systems, or recreation facilities. State Geologists, therefore, do not enjoy the luxury of "ivory tower" positions, but rather must be accessible and attuned to respond promptly to a multitude of needs, be they from fellow government agencies, industry, schools, or the general public.

The ever-growing awareness of the role of geology in our society, including the lessons of energy and mineral shortages which have been thrust upon us, as well as the environmental impacts of natural geologic hazards and man-made engineering problems, all serve to provide for State Geologists a claim that each can share: there is never a dull moment.

So we welcome to Pennsylvania the State Geologists from across the nation and trust that their meeting and their sampling of Pennsylvania geology and hospitality will be productive, pleasant, and memorable.

Arthur A. Socolow

$ 8 Billion lost yearly from geologic and hydrologic hazards

Geologic and hydrologic hazards, such as earthquakes, floods, ground failures and volcanic eruptions, now cause an estimated $8 billion in losses annually in the United States. However, these losses can be greatly reduced, according to a new report by the U.S. Geological Survey. "Facing Geologic and Hydrologic Hazards—Earth-Science Considerations," describes the physical characteristics of geologic and hydrologic hazards, identifies the locations in the United States where these hazards tend to happen, specifies their impact on the nation's people, buildings, structures, and economy, and discusses actions that can reduce losses in lives and property.

The report is designed to provide basic earth science information that can be used by planners and decisionmakers in taking actions to reduce losses from geologic and hydrologic hazards.

The USGS report suggests a variety of possible actions designed to reduce losses from geologic and hydrologic hazards including:

* Avoiding the hazard by selecting other appropriate areas in which to live or reducing the hazard by building where the probability of the hazard's occurrence is lowest.
* Zoning or planning within an area characterized by a relatively high probability of occurrence of the hazard to reduce building density or prohibit certain types of structures susceptible to a particular type of hazard.
* Allowing all types of structures within a potentially hazardous area, but requiring site-specific engineering design and construction to increase the capability of the site or structure to withstand the hazard.
* Distributing the potential losses through insurance and other financial methods.

The report says that both average annual losses and the potential for sudden great losses have increased and will continue to do so fairly rapidly for several reasons, including:

* More and more people are living in flood-prone areas, areas of high seismic risk, exposed coastal locations, landslide prone areas and near potentially active volcanoes;

* Urban centers are growing annually through construction of homes, schools, hospitals, high-rise buildings, factories, utility systems, dams, oil refineries, airports, and other facilities. This growth causes additional high-value property to be exposed to geologic and hydrologic hazards every year.

The report points out that making decisions and taking actions designed to reduce losses is especially difficult because of the technical nature of the earth-science information that must be considered and because of the uncertain times and places where these hazards may occur and the great variation in the magnitude and probability of occurrence.

Some highlights from the report include:

* A repeat of the 1906 San Francisco, Calif., earthquake, which took 700 lives and destroyed buildings costing, in 1978 dollars, about $170 million, probably would cause $24 billion in damages now and, depending on the time of day, take about 5,000 lives and cause 700,000 injuries.
* If a similar large-magnitude earthquake occurred in the Los Angeles area, it would probably cause losses of about $45 billion and as many as 23,000 deaths.
* A repeat of the New Madrid, Mo., earthquakes of 1811-1812, estimated by many to have been the most violent series of earthquakes in the United States, could cause losses in the Midwest comparable with the "worst case" estimates for San Francisco or Los Angeles.
* The annual loss from floods in the United States has increased from $100,000 (in current dollars) at the beginning of the century to more than $3 billion today. More than 20,800 communities have flood problems and of those, about 6,100 have populations greater than 2,500.
* Direct and indirect damage from landslides in the United States totals more than $1 billion per year. An average of 25 lives are lost from landsliding each year.
* Expansive soils—soil and soft rock which tend to swell or shrink due to changes in moisture content—cause from $2 to $7 billion in damage annually. Of the more than 250,000 new homes built annually on expansive soils in the United States, 10 percent undergo significant damage and 60 percent undergo minor damage.
* Volcanic eruptions occur relatively infrequently, but they cannot be ignored. Eruptions have a significant short-term impact,

as the 1980 Mount St. Helens eruptions have shown. The total cost of these eruptions is expected to reach $2-3 billion.

Copies of the 110-page USGS Professional Paper 1240-B, "Facing Geologic and Hydrologic Hazards—Earth Science Considerations," illustrated with over 100 maps and color photographs, may be obtained for $7.50 each from the Branch of Distribution, U.S. Geological Survey, 1200 South Eads St., Arlington, VA 22202. Orders must specify the professional paper number and include check or money order payable to the U.S. Geological Survey.

"CULPRIT" MINERALS MAY HINDER GAS PRODUCTION IN BLACK SHALES

by John H. Barnes
Pa. Geological Survey

In recent years, the Pennsylvania Geological Survey has participated in studies of the potential of black shales as sources of natural gas (see Piotrowski, 1978 and Harper, 1980). While most shales in Pennsylvania have until recently been little-explored for natural gas, one that has been a proven producer since the very dawn of this industry is the Dunkirk shale facies of the Devonian "Canadaway Group" (Piotrowski and Harper, 1979). It was into this shale that the Nation's first gas well was drilled in 1821 at Fredonia, New York, only 30 miles outside of Pennsylvania. Numerous small wells still feed gas from the Dunkirk shale to individual homes and factories in Erie County.

Two of the wells recently drilled into this shale in Erie County (Fig. 1) provided illustration of a manner in which the mineralogy of the shale can affect production. The first of these wells, Welch Foods #3, was drilled to a depth of 900 feet near the borough of

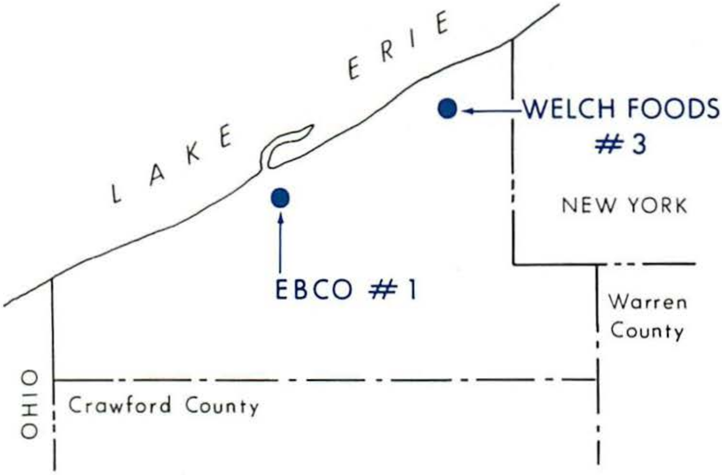


Figure 1. Map of Erie County showing locations of EBCO #1 and Welch Foods #3 wells. (after Piotrowski and Harper, 1979).

North East. A natural open-flow rate of 12,000 cubic feet/day was initially reported. In an attempt to increase flow, the well was "stimulated" by "foam-water fracturing", a process that basically involves pumping liquids into the well under high pressure to force open fractures in the rock and allow the gas to flow out more easily. After this was done, the flow increased to 150,000 cubic feet/day temporarily, but after a month it had decreased to 3,500 cubic feet/day. At this low level, the company did not consider it economically feasible to lay a pipeline to their plant, and the well is out of production (Piotrowski and Harper, 1979; Harper, 1980).

The second well, EBCO #1, was drilled to 901 feet in the city of Erie for the Erie Burial Case Company. This well encountered three significant shows of gas with a total initial potential in excess of 3,000,000 cubic feet/day; however, the flow rate later dropped to 975,000 cubic feet/day. As a result of this high flow rate, apparently caused by a natural system of fractures, stimulation was not necessary, and today the well is supplying the fuel needs of the EBCO plant. (Piotrowski and Harper, 1979; Harper and Piotrowski, 1978).

Because of the problems encountered with the Welch Foods #3 well and other wells in Devonian black shales in which foam-water fracturing was used, samples of cuttings from the successful EBCO well were submitted to the Survey's Mineral Resources Division for study. As part of our routine procedure for study of rock, the samples were scanned by X-ray diffraction, a technique which helps to identify the minerals that are present in the rock. Among the minerals typically found in shale, evidence was found to suggest the presence of minerals that belong to the smectite group (sometimes called the montmorillonite group).

Smectite is a clay mineral and, like other clay minerals, is composed of flat layers of molecules. The familiar minerals mica and vermiculite also have this structure, which gives them their characteristic platy habit. In clays, including smectite, however, the plates are too small to be seen without the great magnification of an electron microscope.

The unique feature of the smectites that sets them apart from other clay minerals is that the layers of molecules are only very loosely bound together. Because of this, smaller molecules, such as water molecules, can enter the space between the smectite layers and push them apart (Fig. 2) (Grim, 1968). This effect can be tested and observed via a standard procedure with the X-ray diffraction equipment, which measures the distance between layers of molecules. A sample from the EBCO well was divided into three sub-samples: one was heated to a high temperature to drive off any water, a second contained water between the smectite layers, a third was placed in an atmosphere of ethylene glycol, which pushes the layers even farther apart than water. When the three sub-samples were X-rayed (Fig. 3), the one which contained interlayer water and the glycol-treated one showed a lower peak height (A) and a higher background (B) than the dehydrated sub-sample, characteristic of samples containing smectite. These sub-samples also

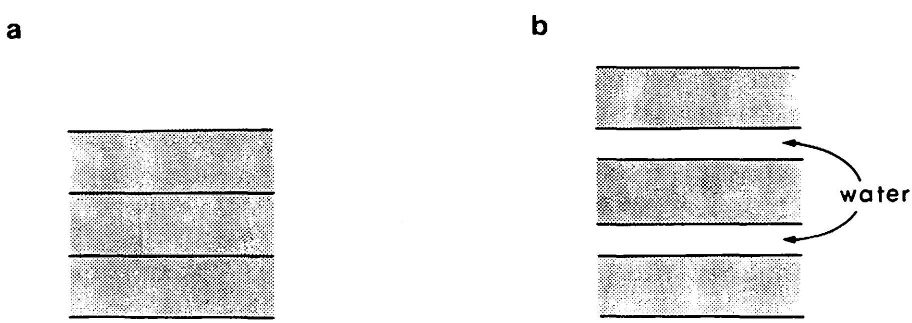


Figure 2. Simplified diagram of the structure of smectite (a) unexpanded, in its dehydrated form, and (b) expanded by interlayer water.

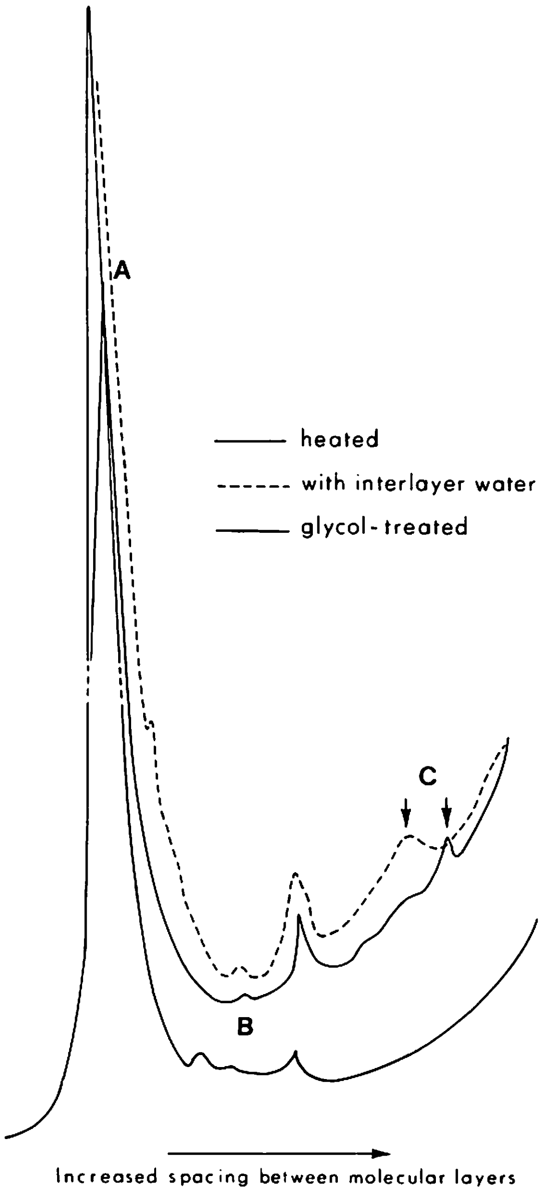


Figure 3. X-ray diffraction patterns of sample from EBCO #1. Water-bearing and glycol-treated show asymetry on right side of peak and lower peak height (A), and high background to the right (B), suggestive of smectite-bearing material. Note the characteristic shift in the position of one high-spacing peak (arrows) (C), typical of smectite when glycol-treated.

showed a peak (C) that was missing in the heated sub-sample and that was displaced to a larger spacing in the glycol-treated sub-sample (see arrows in Figure 3). This confirms the presence of material that includes an expandable smectite.

One explanation, then, as to the cause of the drastic reduction in flow of the Welch Foods #3 well is that the fluids that were injected into the ground to open up the rock and allow greater flow actually expanded the smectite, which closed up the fractures and pores in the rock tighter than before, shutting off most flow. Prior to this rather routine X-ray text at the Pennsylvania Survey, the presence of smectite in the Devonian black shales of Pennsylvania was unreported. Later tests by the U.S. Geological Survey have shown this mineral to be a common constituent of black shales (Hosterman and Whitlow, 1981), and have shown the need for some different method of stimulation of gas wells in these formations (Harper, 1980).

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Out of print geologic reports available

The Pennsylvania Survey has accumulated various surplus publications. We are making them available to college libraries and earth science departments, and to interested individuals as supplies permit. If you are interested, contact Arthur Socolow, State Geologist, Pennsylvania Geologic Survey, P.O. Box 2357, Harrisburg, PA 17120.

USGS Bulletins		Date
969A	Dillsburg magnetite deposit, York County, Pa.	1950
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995D	Boyertown magnetite deposits in Pa.	1953
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Subsurface faulting in McKean County – a "textbook" example

by Christopher D. Laughrey
Pa. Geological Survey

An unusually good example of subsurface faulting is demonstrated on the geophysical log of the Amoco Production Company's #1 Mars Company gas well in McKean County. The well is located on the Hazel Hurst 7-½ minute quadrangle in Sergeant Township. The well was completed on July 31, 1974, as a shallow extension of the Hazel Hurst field. Total depth is 6,160 feet. The deep formations were found to be dry, but the Upper Devonian Bradford Group sandstones were evaluated as potentially productive and pipe was set at 2,608 feet.

The fault zone is recognizable on the geophysical log between 5,920 and 5,926 feet (Figure 1). The Middle Devonian Onondaga Group occurs from 5,875 to 5,920 feet. This stratigraphic interval is then repeated between 5,926 and 5,976 feet. This repetition can be seen in the signatures of the gamma-ray and neutron porosity logs.

The gamma-ray log is an indicator of the shaliness of the formation and is used for subsurface correlation. Shales, siltstones and clays have a relatively high concentration of natural radioactivity whereas sandstones and limestones are usually low in radioactivity. The gamma-rays emitted from the formation are detected using a Geiger-Mueller or a scintillation instrument. When the gamma-ray log passes through sandstone or limestone, the line shifts to the left. When the log encounters shale, clay or siltstone, the line shifts to the right. The gamma-ray log illustrated in figure 1 exhibits a nearly perfect repetition of the four Onondaga Group members across the indicated fault zone.

The neutron log is basically considered a porosity tool. The neutron device emits high energy neutrons from a radioactive source. When the neutrons encounter hydrogen nuclei in the formation in the form of water or oil, the neutrons are absorbed. The detector will

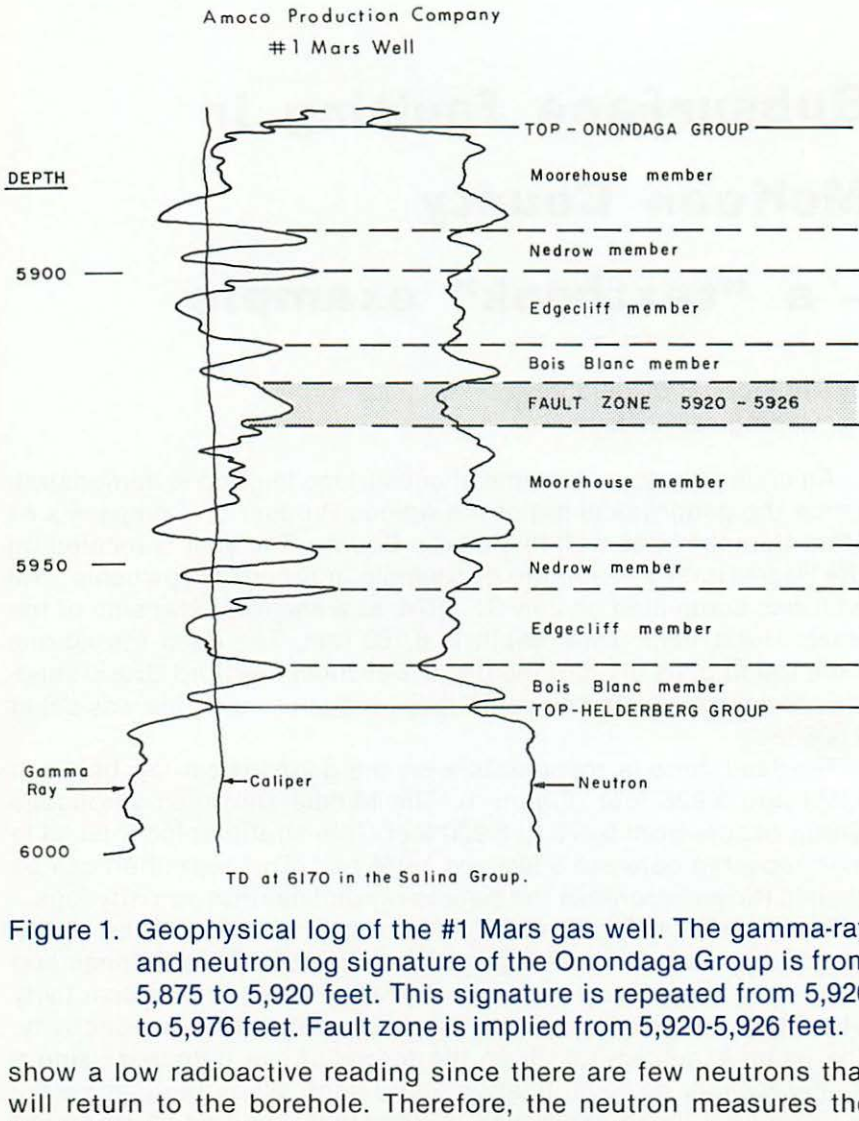


Figure 1. Geophysical log of the #1 Mars gas well. The gamma-ray and neutron log signature of the Onondaga Group is from 5,875 to 5,920 feet. This signature is repeated from 5,926 to 5,976 feet. Fault zone is implied from 5,920-5,926 feet.

show a low radioactive reading since there are few neutrons that will return to the borehole. Therefore, the neutron measures the liquid filled porosity of a formation. In figure 1, the neutron log shift is to the right (low hydrogen) when the log encounters limestone members of the Onondaga Group (gamma-ray shifts to the left). This indicates that the Moorehouse, Nedrow, Edgecliff and Bois Blanc members are dense, non-porous limestones. The same neutron log pattern is repeated across the fault zone.

Figure 1 also shows the caliper log. The caliper measures hole diameter and it can indicate wash-out sections in the formations. The caliper log in figure 1 indicates a rather constant, undisturbed hole

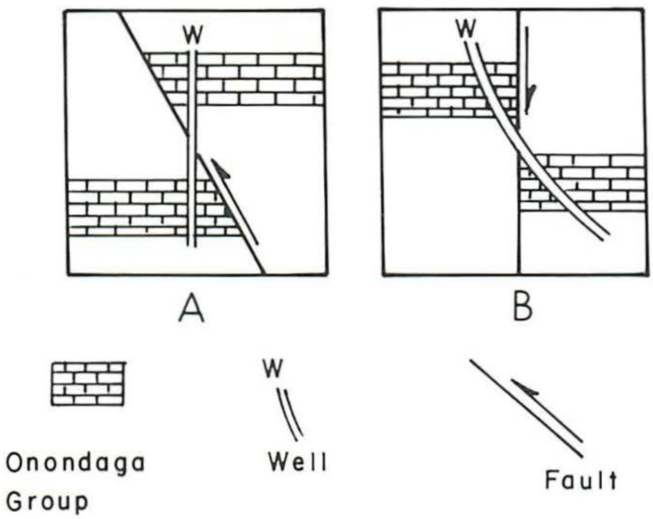


Figure 2. Two possible geologic conditions that could account for the repetition of beds illustrated in Figure 1.

A. Reverse faulting.

B. Vertical Fault — repetition of beds due to deflection of the borehole.

diameter across the fault zone. This indicates that any fractures formed during the faulting episode were subsequently filled with mineral cement. Together, the three logs shown in figure 1 represent an uneconomical zone in this particular well.

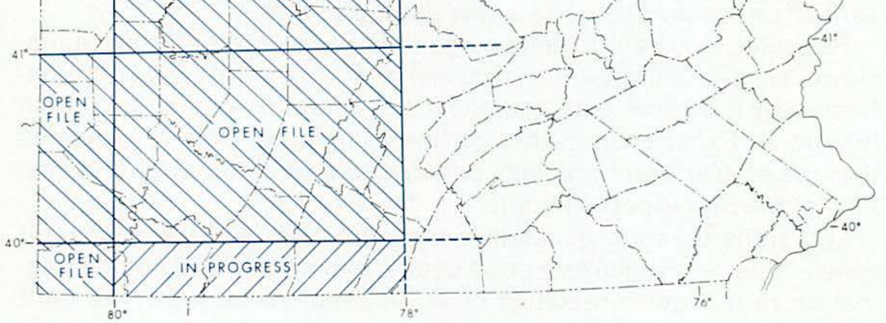
Repeated beds are usually diagnostic of reverse or thrust faults. However, it is important to consider that a borehole might be deflected by a vertical fault and show an apparently repeated section (Figure 2). Experience in this portion of McKean County indicates that the #1 Mars well probably penetrated a thrust fault on the east limb of the Smethport anticline.

Log signatures are generally somewhat ambiguous across fault zones. It usually requires a good deal of experience and some imagination to recognize repeated beds on geophysical logs. The fault shown on the #1 Mars well log is undoubtedly a "textbook" example.

LANDSLIDES IN WESTERN PENNSYLVANIA

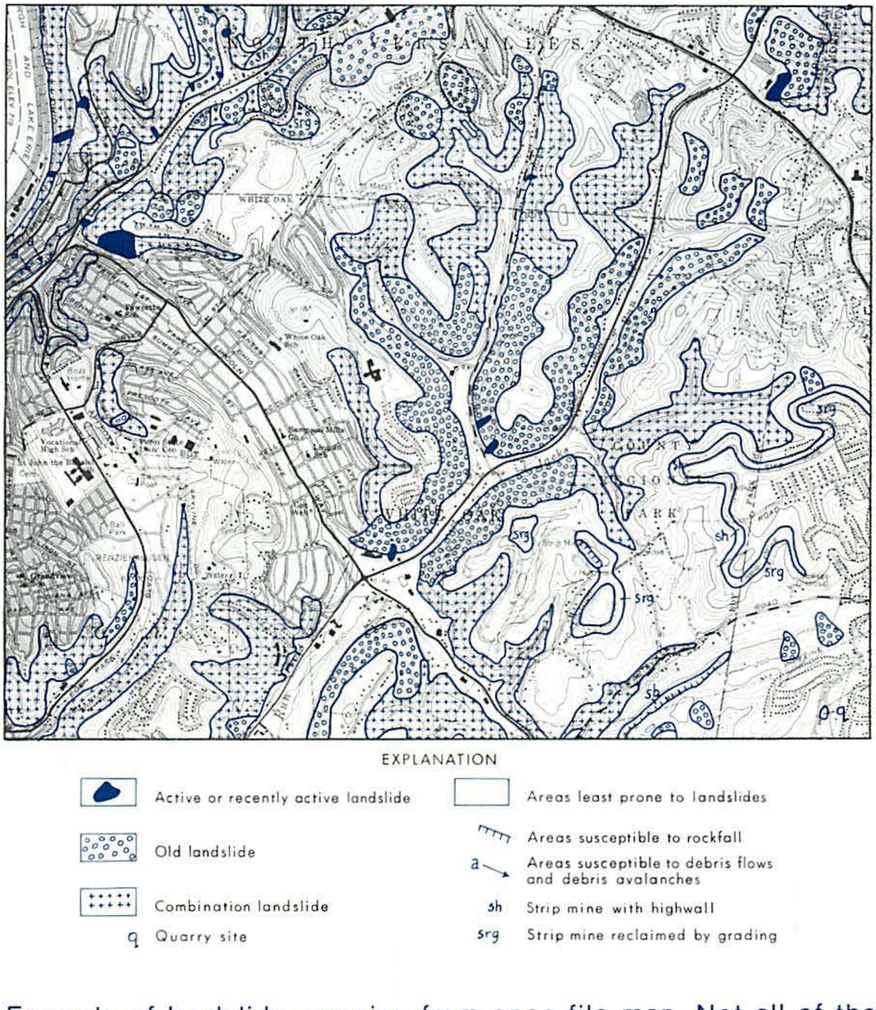
A set of maps showing landslides and related features for most of western Pennsylvania has been prepared by the U.S. Geological Survey and released on open file. Areas covered by these maps are shown on the accompanying index map. The maps are on 7½-minute quadrangle bases (1:24,000 scale) and show active or recently active landslides, old landslides, several categories of slopes susceptible to sliding, areas susceptible to rockfall, and a number of man-made features such as strip mines and coal refuse banks. Information shown on the maps was gathered primarily by air photo interpretation and supplemented by field checking and reference to historical records.

This information is potentially useful to planners, developers and engineers as an aid in predicting slope stability conditions. The maps cannot substitute for detailed geologic and engineering investigations of a specific site, but can be used as a general guide to ground conditions for planning purposes and to indicate areas requiring more detailed investigations.



Location of open file maps

John S. Pomeroy, William E. Davies, Gregory C. Ohlmacher and Robert Hackman of the U.S.G.S prepared the maps, which are on file in the U.S.G.S. library in Reston, Virginia and at the Pennsylvania Bureau of Topographic and Geologic Survey offices in Harrisburg and Pittsburgh. The maps are available for examination and review at the bureau offices and may be copied from mylar originals at the user's expense.



Example of landslide mapping from open file map. Not all of the map symbols are shown in this example.

Richard F. Walther
25 years of service

Richard F. Walther, Geologist, Division of Oil and Gas Regulation, Bureau of Topographic & Geologic Survey, has celebrated his 25th anniversary of his employment with the Commonwealth of Pennsylvania.

Dick started his career with the Oil and Gas Division, Department of Mines and Mineral Industries, on February 27, 1957, as an Oil and Gas Inspector. In March 1957 he established the Pittsburgh Field Office of the Division under the direction of W. Roy Cunningham, Deputy Secretary of the Mines and Mineral Industries, which he maintained until the complete Oil and Gas Division moved to Pittsburgh in September 1963.

At various times during his tenure as Oil and Gas Inspector (1957-1979), he was the inspector for the following counties: Allegheny, Armstrong, Beaver, Butler, Cambria, Indiana, Lawrence, Mercer and Westmoreland. His duties included regulating drilling, plugging and underground gas storage reservoirs.

In September 1979, Dick was designated to work in the Natural Gas Policy Act Section. After working in that section for more than a year, he moved on to work in the Permit Section of Oil and Gas Regulation, reviewing all coal locations, well pillar applications and gas storage information.

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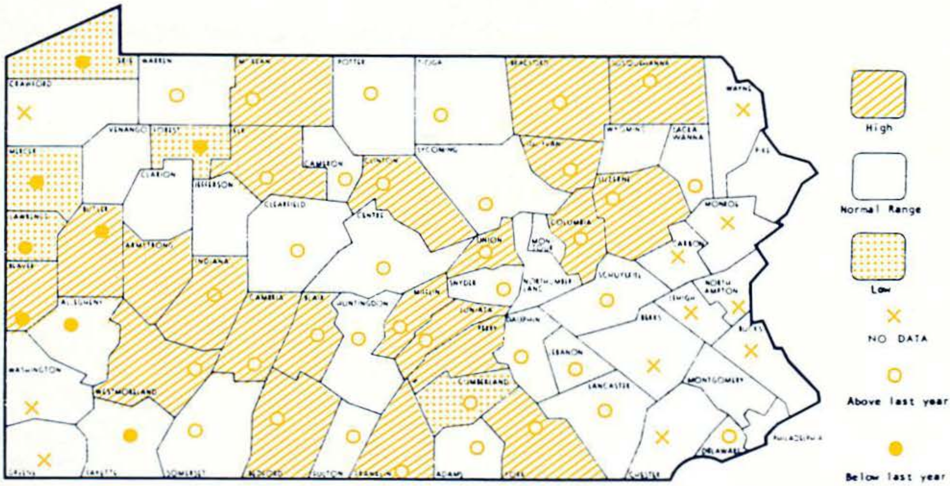

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