PENNSYLVANIA GEOLOGY

THE PENNSYLVANIA GEOLOGICAL SURVEY

COMMONWEALTH OF PENNSYLVANIA
Richard L. Thornburgh, Governor

DEPARTMENT OF ENVIRONMENTAL RESOURCES
Clifford L. Jones, Secretary

TOPOGRAPHIC AND GEOLOGICAL SURVEY
Arthur A. Socolow, State Geologist

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ON THE COVER: Anticline and syncline fold structures in the northern limb of the western Middle Anthracite Field. Commonly referred to as the Ashland Anticline, this feature is located 0.8 mile south of Pa. Route 61 and 54 in the Borough of Centralia, northeast of Ashland Borough.

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

OCTOBER 1979

FROM THE DESK
OF THE
STATE GEOLOGIST . . .

OUR COAL: PROBLEMS AND HOPE

Recent news reports of the lethargic production record currently being manifested in the coal fields of Pennsylvania (actually, all of Appalachia) point up a basic truism for any mineral resource: Regardless of the availability of reserves, the utilization and economic success of a mineral resource depends upon the market demand. The anticipated and much desired increased demand for Pennsylvania and Appalachia coal has not materialized, despite the heralded objective to become less dependent upon foreign oil.

For purposes of corrective action and as a lesson in mineral economics, it is worth a look at the causes of the coal market and production malaise. The reasons are many and the ones being cited here are not necessarily in order of importance: (1) The demand for electricity has been lower than expected and thus the demand for our coal, providing 75% of Pennsylvania's electric generation, is lower than expected. (2) There has not developed either the economic incentive or government requirement to cause oil-burning power plants to convert to coal use. (3) Federal air quality standards greatly limit the use of our coal (because of its sulfur content) in the populous areas of our state where the potential use for coal is greatest to supply industry and electric generating needs. To date, the techniques for dealing with the coal-sulfur problem have proved to be both extremely costly and mechanically unreliable. (4) The cost of mining coal has increased significantly due to the procedures and technology required by governmental environment protection laws and regulations. Higher cost coal in the face of a weak market does not make for impressive production records. (5) The cost of opening new mines or expanding the capacity of existing ones, is astronomical. Underground mines, which are needed to get at the large deep reserves of coal available in Pennsylvania, could cost well over $100 million each, to cover the price of equipment and mine development even before any coal would be produced. At current high interest rates, coupled with an uncertain market demand for coal, plus a federal energy policy that is neither clear nor final, plus environmental constraints upon production, all combine to discourage the necessary large financial investments needed to expand or modernize coal production capability. (6) Lag time should be mentioned here because it impacts upon the ability of coal production facilities to respond to expansion, modernization, or installation of environmental protection equipment. From the time planning begins for

(Continued on page 13)

Arthur A. Socolow

MINERALS

IN PENNSYLVANIA COAL

R. B. Finkelman, F. T. Dulong, R. W. Stanton, and C. B. Cecil
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Coal, a combustible sedimentary rock, is commonly believed to consist primarily of degraded organic matter but may, in fact, contain substantial amounts of minerals. Minerals constitute the bulk of the ash or residue left upon combustion of the coal. By convention, in the United States, low-ash coal contains less than 8 percent ash, medium-ash coal, 8 to 15 percent, and high-ash coal, more than 15 percent. Material containing more than 33 percent ash is classified as coaly or carbonaceous shale, silt, etc. (personal commun. G. H. Wood, Jr.)

Samples of coal from Pennsylvania are currently being studied in an attempt to determine the mode of occurrence of elements of environmental interest (Cecil et al., 1979). These studies have revealed that the coal contains a diverse and interesting assemblage of minerals. Except for cleat fillings and rare nodules of marcasite, pyrite, or carbonates, most mineral grains in coal are quite small, far less than 1 mm in size.

X-ray diffraction analysis of coal ash after low-temperature oxidation (<150°C) of the whole coal indicates variable concentrations of kaolinite, illite, pyrite, and quartz in all the nearly 100 samples studied to date. Calcite, dolomite, siderite, marcasite, rutile, anatase, gypsum, coquimbite, mixed-layer clays, montmorillonite, and plagioclase feldspars have been detected in quantities ranging from rare to abundant in some of these samples.

The coal also contains an abundant suite of other less common or accessory minerals. Some of these accessory minerals have been extracted for mineralogic examination by grinding and handpicking or by density or magnetic separations. However, the most effective method of examination is by scanning electron microscopy of polished blocks of coal (Finkelman and Stanton, 1978). Table 1 is a list of the accessory minerals; several minerals are illustrated in Figures 1-3.

Although all these minerals are minor constituents in coal their relative abundances vary considerably. Some, such as the submicron gold particles, were observed in only one or two samples, whereas

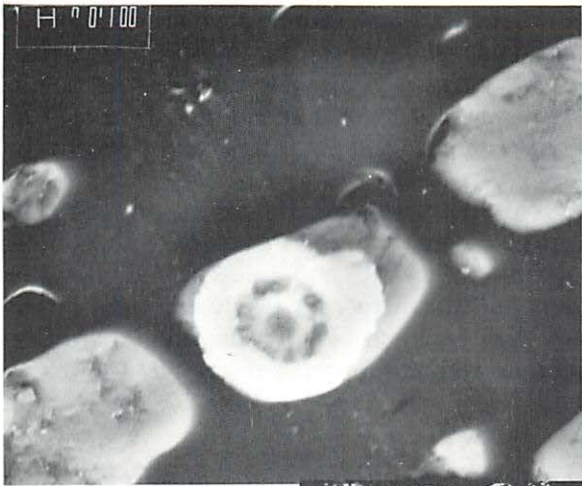

Fig. 1. Reflected light optical photomicrograph of birefringent marcasite in pyrite. Scale bar is 10 μm.

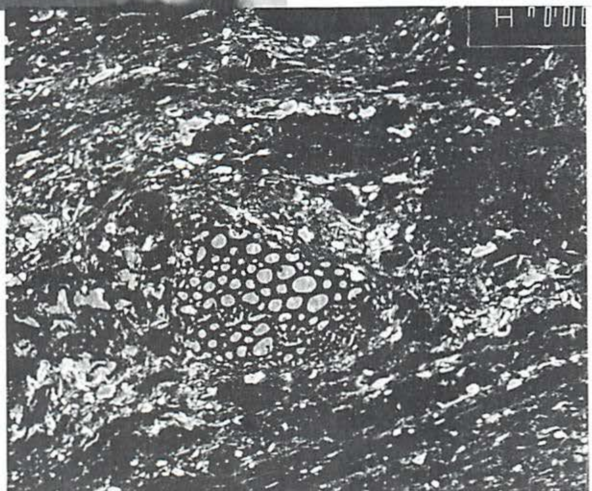

Fig. 2. Scanning electron photomicrograph of minerals (clays and quartz) in a polished block of coal. Scale bar is 10 micrometers.

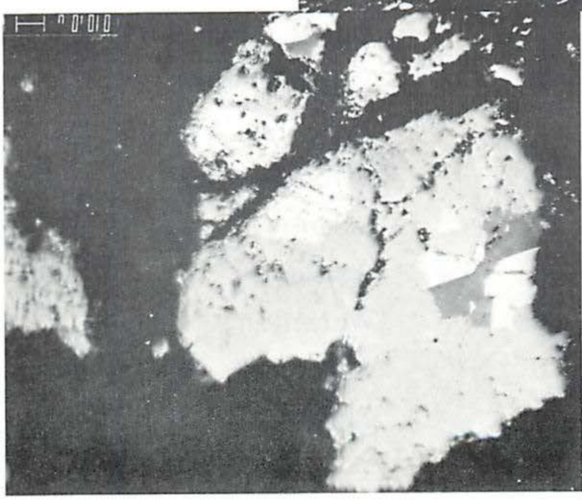

Fig. 3. Scanning electron photomicrograph of crandallite in kaolinite filled pores (plant cell lumen). Scale bar is 1 micrometer.

others were encountered in almost every sample studied. In Table 1 we have indicated the probable abundances for most of the accessory minerals. Several of the accessory minerals were not sought in every sample because they required special techniques to locate or to identify. No attempt was made to suggest relative abundances for these minerals.

The minerals listed were identified as the result primarily of examining samples of Upper Freeport medium volatile bituminous coal collected from the Homer City #1 and Lucerne #6 mines in Indiana County, PA.; samples from other Pennsylvania bituminous and anthracite coal beds were studied less intensively. Therefore, this list is not comprehensive, and undoubtedly many other minerals exist in Pennsylvania coal.

Table 1 *Accessory Minerals in Pennsylvania Bituminous Coals*

[Quotation marks indicate that the identifications have been based primarily on major element data and should be considered as tentative; *, also found in Pennsylvania anthracite; +, new to Pennsylvania; A, common; B, rare; C, very rare.]

"Ankerite"	B	Halite	
* Apatite	A	Hematite	
"Argentite"	C	Ilmenite	B
"Barite"	A	*+"Linnaeite group"	C
* Chalcopyrite	A	Magnetite	B
"Chromite" (?)	C	*"Monazite"	A
"Clausthalite"	A	Opal	
Chlorite	A	"Potash feldspars"	A
Corundum		Pyrrhotite	
Crandallite	A	"Pyroxene group"	B
* Diaspore	B	+ Siderotil	
"Elemental gold"	C	* Sphalerite	A
*"Galena"	C	* "Witherite"	C
"Gorceixite"	B	"Xenotime"	A
		* Zircon	A

A knowledge of minerals in coal is useful in predicting the behavior of trace elements during combustion, gasification, and liquefaction and is a primary aid in deducing geological history of a coal. A study of minerals in coal such as this, not only adds substantially to information about Pennsylvania's most important mineral resource but also adds important data to the rich mineralogical lore of Pennsylvania.

Acknowledgements

We thank our colleague Jean Minkin for reviewing this note and for contributing data from her study of minerals in Pennsylvania coals. Gordon H. Wood, Jr., also of the U.S. Geological Survey, substantially improved the note with his comments.

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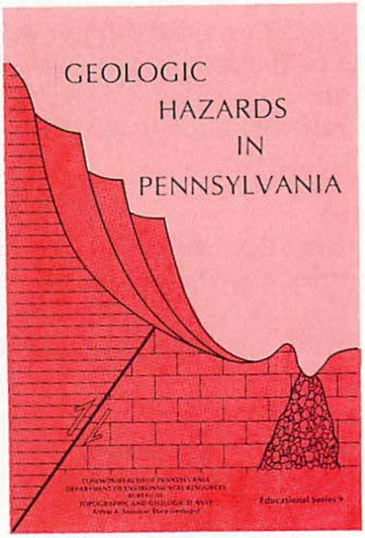
WESTERN CRAWFORD COUNTY GEOLOGY AND GROUNDWATER REPORT

The character of the rock formations and the nature of their contained water have a definite impact on utilization of land. As a developing area where industry and recreation are expanding, it is most appropriate that the geology and groundwater resources of western Crawford County be recorded and available to the public, local officials, planners, and environmentalists. To that purpose the Pennsylvania Geological Survey has published "Geology and Groundwater Resources of Western Crawford County, Pennsylvania," by George Schiner and John Gallaher. This project was carried out in cooperation with the U.S. Geological Survey.

The new report is complete with a 103-page text, plus large, detailed maps showing bedrock geology, unconsolidated glacial deposits, and groundwater availability. The report is designed to be easily usable and intelligible by those who need to deal with the geologic and hydrologic conditions of the area.

Bulletin W46, "Geology and Groundwater Resources of Western Crawford, Pennsylvania" is available from the State Book Store, P.O. Box 1365, Harrisburg, Pennsylvania 17125. The price is $12.50 (plus 75¢ for Pa. residents).

Geologic Hazards In Pennsylvania



Continuing its efforts to identify both favorable and problematical geological conditions as they affect the citizens of Pennsylvania, the Bureau of Topographic and Geologic Survey in the Department of Environmental Resources has published a new booklet entitled "Geologic Hazards in Pennsylvania" authored by J. Peter Wilshusen.

Geologic hazards of various kinds are common to almost every area of the world. Natural geologic hazards that most commonly receive attention in different parts of the world are earthquakes, volcanic eruptions, landslides, and sinkholes. Since Pennsylvania is fortunately spared the disastrous effect of volcanos and earthquakes, the Commonwealth is not widely recognized as having any serious problems with geologic hazards. Yet, Pennsylvania annually suffers millions of dollars of damage and untold personal disruptions as a result of frequent and widespread occurrences of landslide phenomena and sinkhole collapses.

The purpose of "Geologic Hazards in Pennsylvania" is to enable citizens, local government officials, developers, architects, and engineers to recognize the various geologic hazards in time to take preventive and corrective measures that will prevent physical and bodily harm, and save vast sums of money. The book includes photographs and diagrams which will enable the reader to identify the various types of geologic hazards. Accompanying index maps then show where in Pennsylvania each type of problem commonly occurs.

"Geologic Hazards in Pennsylvania," also identified as Educational Series No. 9, is a 56-page, illustrated booklet carefully designed so that readers without a technical background can readily comprehend the message. Copies are available at no cost from the Bureau of Topographic and Geologic Survey, P.O. Box 2357, Harrisburg, Pennsylvania 17120.

Ladder - Back Ripples In The Catskill Formation

by Jon D. Inners and Philip J. Daly*

Ripple marks –i.e., subparallel ridges and hollows formed by waves or currents in sandy sediments—are probably the most common and easiest understood of the myriad depositional structures that occur in shallow water sedimentary rocks. Simple ripple marks are of two basic types: (1) symmetrical, or oscillation, formed by the back and forth motion of waves; and (2) asymmetrical, or current, formed by flow in one direction only. In addition, many complex variations of these common ripples have been described in the geologic literature (Kindle, 1917; Pettijohn and Potter, 1964). Not only are ripple marks valuable clues to deciphering the depositional environment of a particular rock sequence, but they also provide insight into the hydraulic regime of ancient streams–including current direction, water depth, flow velocity, etc.—and the wave dynamics along ancient shorelines. Complex ripple marks can also pose tantalizing questions as to their origin. Such a set of puzzling ripples has recently been found in the course of geologic mapping in the Bloomsburg-Mifflinville-Catawissa area.

The ripples occur near the top of an easily accessible rock outcropping on the east side of L.R. 415, just north of its intersection with L.R. 19014, about 1.25 km northwest of Mainville, Main Township, Columbia Co. (Figure 1) (Lat. 40°58′56″N, Long. 76°23′20″W, Catawissa quad.). Even though traffic on L.R. 415 is relatively light, visitors should be wary because of the narrow shoulder on the road adjacent to the outcrop. Parking for several vehicles is available on the opposite side of the road.

Rock exposed at the site consists of approximately 85 m of interbedded gray and red sandstone, siltstone and claystone provisionally assigned to the upper part of the Irish Valley Member of the Catskill Formation. The rock types are arranged in fining-upward cycles, with sandstone at the base and claystone or silt-clay laminite at the top (Figure 2). Such cycles are typically developed by meandering river systems: the basal sandstones are channel and point bar deposits; the medial fine sandstones and siltstones represent levee deposits; and the claystones and siltstones at the top are overbank, flood-basin deposits.

The complex ripple marks of interest (Figure 3) are found on a

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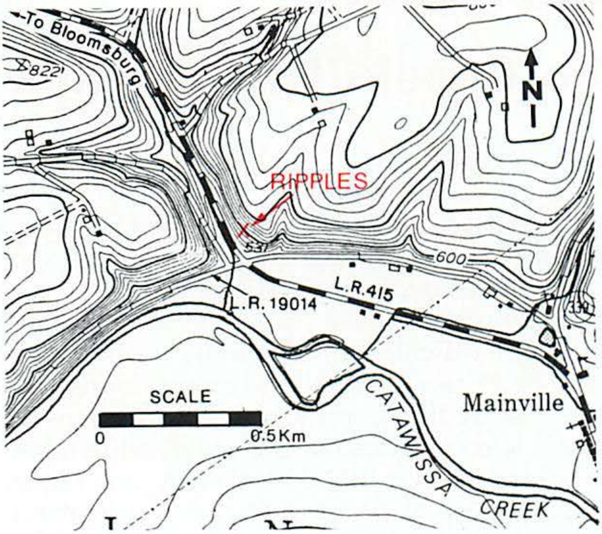

Figure 1. Location map.

single bedding plane in thin bedded, light grayish red, sandy, silt-clay laminite at the top of the upper cycle. They consist of an early formed set of asymmetrical ripples (steep face to the northwest) on which a later formed set of nearly orthogonal, small-scale symmetrical ripples has been superimposed. The symmetrical ripples are distinct in the troughs of the asymmetrical ripples but appear only as faint lines on the crests. Compound ripples of this general type have been referred to as "ladder-back" ripples (Anan and others, 1969). Several other nearby bedding planes contain only small-scale symmetrical ripples that trend roughly parallel to the small ripples of the complex set.

Important attributes of ripple marks bearing on paleogeographic interpretation include the wave length, wave height, trend, and asymmetry. For the two sets of ripples in question, these measurements are as follows:

	Wave Length	Wave Height	Trend (Fig.4)	Asymmetry
Asymmetrical	50 - 55 mm	4 - 5 mm	N54E	To NW
Symmetrical	7 - 8 mm	1 - 2	N41W	None

The current that formed the asymmetrical ripples flowed at right angles to the ripple trend in the direction of the steep ripple-face, i.e. toward N36W (Figure 4).

In recent sediments, ladder-back ripples are particularly characteristic of the intertidal zone; several types of diverse origin have been described from coastal areas in New England (Anan and others, 1969). Such ripples may form from shifts in current direction during

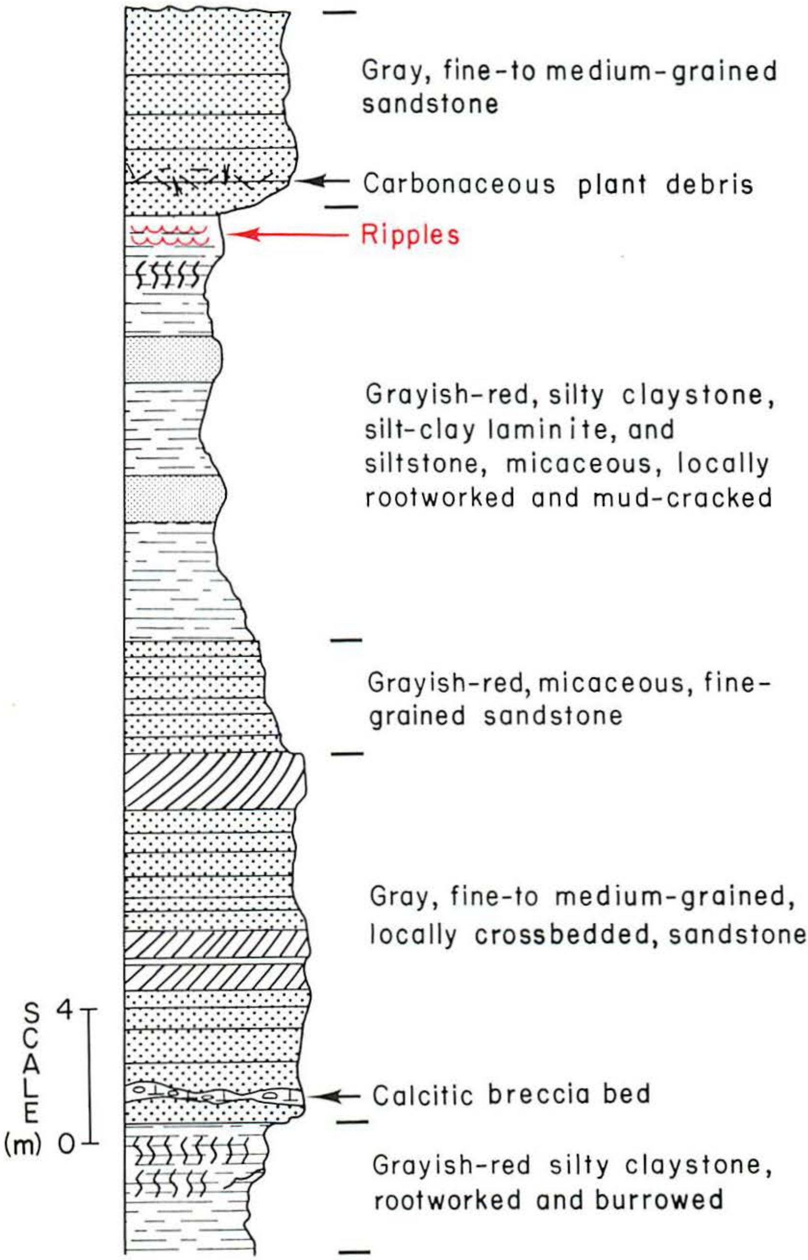

Figure 2. Fluvial fining-upward cycle with rippled silt-clay laminite at top, upper half (south end) of Mainville site. Another cycle similar to this is exposed immediately below at the north end of the cut.

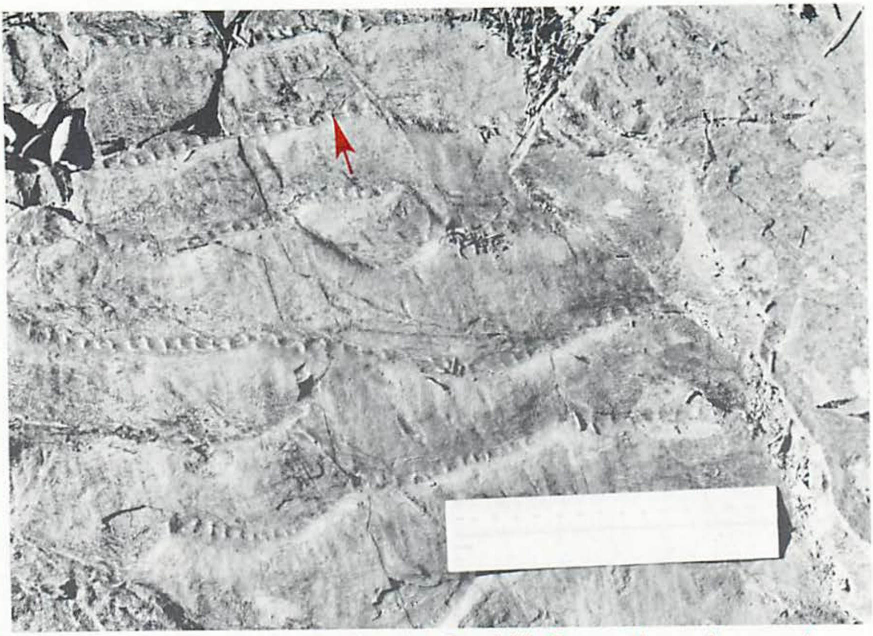

Figure 3. Ladder-back ripples in Catskill Formation. Arrow shows main current direction. Scale is 15 cm long.

of the sediments in which the ripples occur, it is perhaps entirely large ripples as the tide ebbs, or by the interaction of tidal currents and waves. Generally, however, these features are on a scale several times larger than the ripples in the Catskill Formation.

Compound ripple marks very similar to those illustrated here have also been described from ephemeral streams in Utah (Picard and High, 1970). In this case, asymmetrical ripples form first when flood water in the channel is deep enough to flow over marginal and channel sand bars. As the water level falls, downstream currents are refracted shoreward over the bars, and small-scale, nearly symmetrical ripples are formed at right-angles to the asymmetrical ripples.

But what of the paleogeographic implications of the ladder-back ripples in the Catskill Formation? The fining-upward cycles in the upper Irish Valley are probably non-marine fluvial cycles that formed upstream of a prograding shoreline on a muddy, coastal plain only a little above sea level. Although it is possible that there may have been some tidal influence in the deposition of these beds, particularly in the sandy channels, no presumptive evidence for tidal deposition (e.g. marine fossils) was observed at the Mainville site. The writers incline toward the view that the ripples formed in an extremely shallow, ephemeral rivulet in the flood basin adjacent to a large, low-gradient stream. Judging by the small scale and fine grain size different stages of the tidal cycle, by water flowing in the troughs of fortuitous that current direction defined by the asymmetrical ripples (i.e. N36W) lies almost exactly down the Late Devonian paleoslope. The symmetrical ripples may have formed either by refraction of very shallow currents or by wind agitation acting on small pools of water as the rivulet gradually dried up. The abundance of mudcracks in the red claystones and siltstones immediately adjacent to the rippled beds indicates that periodic desiccation was a characteristic feature of the depositional environment in which the ripples formed.

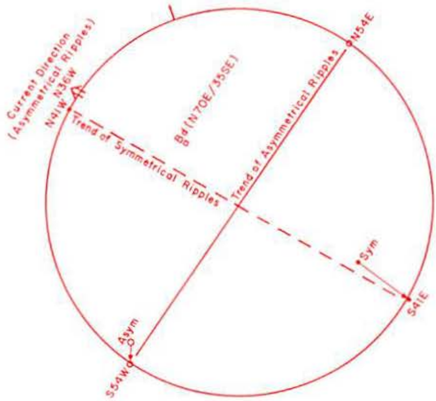

Figure 4. Stereographic projection of ripple lineations and pole to bedding. Bedding has been rotated to horizontal about bedding strike to arrive at original depositional trends of ripples.

Fining-upward cycles in the upper part of the Irish Valley and lower part of the overlying Sherman Creek Member of the Catskill Formation have long been the target of intense uranium exploration (McCauley, 1961; Sevon and others, 1978). The uranium minerals commonly occur in association with concentrations of carbonaceous plant fragments, similar to that at the base of the gray sandstone capping the Mainville exposures (Figure 2). In fact, several small adits, presumably dug out during the uranium boom of the late 50's, can be found in gray sandstone at the north end of the cut described here and at exposures a short distance to the west. The presence of ladder-back ripples in a potentially uranium-bearing sequence appears to provide yet another clue to the environmental framework of Catskill uranium occurrences.

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SURVEY ANNOUNCEMENTS

REPORT ON GEOLOGY AND SAFER COAL MINING

In keeping with the dedication of the Pennsylvania Department of Environmental Resources to make mining in Pennsylvania as safe as possible, the Bureau of Topographic and Geologic Survey has issued a new publication entitled "Geologic Conditions Affecting Safe Bituminous Coal Mining in Pennsylvania: Selected Papers."

Assembled by former staff geologist, Samuel I. Root, the new, 202-page book contains seven outstanding papers which identify various geologic conditions that create safety problems in coal mining. By learning to recognize those hazardous geologic conditions, it is then possible to take appropriate actions to eliminate or minimize the chances for mine accidents.

Among the factors discussed are the relationship of roof instability to methane in the mines, how to best orient mine tunnels when certain types of fractures exist, and the design and location of pillars in the presence of various rock depositional features. The new publication is an example of how the Bureau of Topographic and Geologic Survey is focusing on the ways that geology can help solve problems and serve the needs of the citizens of Pennsylvania.

"Geologic Conditions Affecting Safe Bituminous Coal Mining in Pennsylvania" is available as Information Circular 84 from the Pennsylvania State Book Store, P.O. Box 1365, Harrisburg, Pennsylvania 17125. The price is $2.80 (plus 6% sales tax for Pennsylvania residents).

COAL STUDY TO HELP EXPLORATION

In order to explore, evaluate, and develop Pennsylvania's coal resources, it is necessary to understand exactly how each of the coal layers was formed and by what criteria favorable localities may be located today. The results of such an investigation are reported in the latest publication released by the Pennsylvania Geologic Survey. Mineral Resources Report 75, "The Economic Geology of the Upper Freeport Coal in the New Stanton Area of Westmoreland County, Pennsylvania: A Model for Coal Exploration" was co-authored by Mark Sholes, William Edmunds, and Viktoras Skema. This report is a case study of a discrete area in which modern stratigraphic and sedimentologic concepts have been applied to evaluate the physical and chemical properties of the Upper Freeport and associated rocks.

With the availability of a great amount of data in the study area, the authors were able to compile detailed cross sections, isopach maps and structure contour maps. Analyses of these data resulted in depositional and paleogeographic models. It is believed that the results of this study will assist geologists and the coal industry to more effectively pursue the development of this and other coal formations of Pennsylvania.

Bulletin M 75, "The Economic Geology of the Upper Freeport Coal in the New Stanton Area of Westmoreland County" is available from the State Book Store, P.O. Box 1365, Harrisburg, Pennsylvania 17125. The price is $2.80 (Pa. residents add $0.17 tax).

OUR COAL: (continued from page 1)

such change, through the periods of technical design and approval, financial arrangements, ordering and receiving delivery of necessary hardware, installation and construction on site, there may elapse anywhere from 2 to 8 years, depending on the size of the project. Such lag time in the face of uncertain markets and the high price of necessary money, all contribute to depressing coal expansion and modernization.

The above list is not complete; it does not include the decline in skilled and willing manpower who would have to work in the underground coal mines needed to get the large remaining reserves of Pennsylvania coal. Neither does the list include problems of deteriorating coal transportation facilities.

Despite all the above, as economic geologists, *we are optimistic over Pennsylvania's long-range coal production prospects.* We are blessed with coal reserves that could accommodate our needs for over 200 years. These reserves are in our own "back yard," unbeholden to foreign quirks and upheavals. The constraints to production and expansion cited above, be they technical, financial, or governmental policy, are not insurmountable. It is well that the Administration of Pennsylvania is dedicated to getting on with the job of encouraging and stimulating the development of our vast coal resources. Such a positive approach is well likely to expand beyond our state boundaries and improve the contribution of coal in our national energy situation.

URANIUM MINERALIZATION AT EASTON, PENNSYLVANIA

by Richard I. Grauch, U.S. Geological Survey
Kenneth R. Ludwig, U.S. Geological Survey

A reconnaissance study of several uranium localities in Pennsylvania was made during 1975 and 1976 (Grauch and Zarinski, 1976) as a part of a U.S. Geological Survey investigation of the distribution and origin of uranium in the Reading Prong-Jersey Highlands-Hudson Highlands region. At that time Robert C. Smith II of the Pennsylvania Geological Survey showed one of us (R.I.G.) a newly discovered uranium occurrence at Quarry L near Easton (Smith, 1975, 1977; fig. 1 of this paper). As at three other Easton area occurrences, the predominant uranium phase is thorian uraninite disseminated in a host of serpentinized dolomitic marble, which Montgomery (1957) correlated with the Precambrian Franklin Formation. The quarry exposes a layered sequence of serpentine, dolomitic marble, tremolite-rich layers, and phlogopite-rich layers; the layering apparently mimics original compositional layering but has been stretched and shows boudins. Uraninite occurs in the podiform phlogopite-rich layers, although it is not everywhere present in these layers. Smith and Grauch collected a 3 1/2 m long channel sample across one of the uraniferous layers in quarry L, and results of a gamma ray spectrometric analysis of that sample show 503 ppm RaeU, 390 ppm Th, and 1.5% K (C. M. Bunker, analyst, U.S.G.S.). Smith (1977) reported a chemical analysis of a separate sample from the same channel that shows 360 ppm U. The discrepency between the two analyses does not necessarily suggest radiometric disequilibrium (as inferred by Smith, 1977) as analyses were performed on separate samples. Cubic crystals of uraninite with small octahedral faces as much as 3 mm on an edge were collected from the sampled layer. The unit cell of one of those crystals is 5.527 A, which suggests that some thorium and/or other impurities may be present.

Uranium and thorium occurrences in the Easton area have been known since the 1930's when Gehman (1936) found what he first believed to be uraninite and later described as thorianite at two localities, the Williams quarry (formerly the Sherrer quarry) and near the College Hill reservoir (Fig. 1). Gehman (1936) also described a yellow uranium mineral from an abandoned quarry on the Bushkill Creek; (this is probably either the Quarry L of Smith (1975) or Schweyer's quarry (Peck, 1911). The occurrence of uranium minerals at three widely spaced localities spanning a strike belt about 1 1/2 km led Gehman to speculate that economic quantities of uranium and thorium might occur at depth. In 1933 Wells and others published a description of some of Gehman's samples which they called the first authenticated thorianites from the United States. Their samples were unusually rich in uranium (Th/U = 1.07) and Wells and others (1933) informally proposed designating a mineral with the structure of thorianite but with a thorium-uranium ratio near 1 as uranothorianite. In another portion of the paper, they asserted that the mineral should be called thorianite. Montgomery (1957) described additional samples from Williams quarry and College Hill reservoir, as well as, a thorian uraninite from the Royal Green quarry in New Jersey (Fig. 1). He concluded that the predominant uranium mineral at the three localities is thorian uraninite; thorium content of six samples varies from 15 to 35% ThO_2.

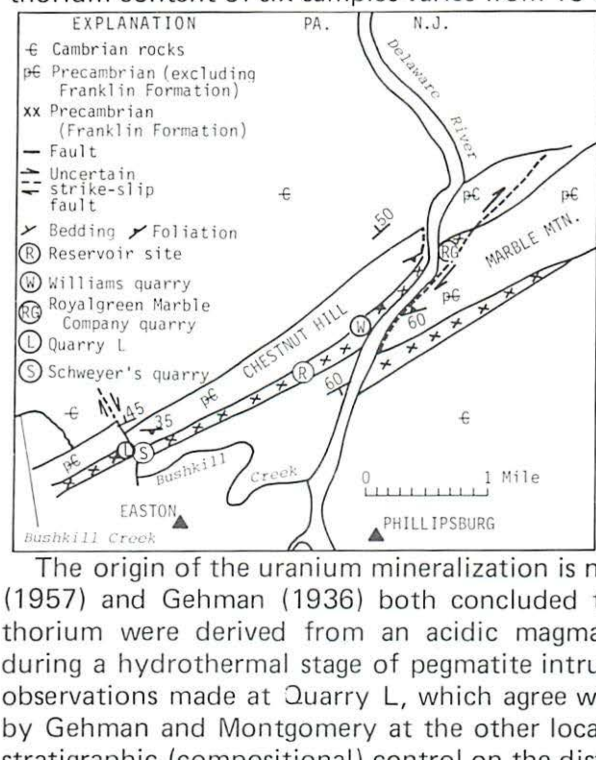

Figure 1. Sketch map of Easton area (modified from Montgomery, 1957).

The origin of the uranium mineralization is not clear. Montgomery (1957) and Gehman (1936) both concluded that the uranium and thorium were derived from an acidic magma and were emplaced during a hydrothermal stage of pegmatite intrusion. Our preliminary observations made at Quarry L, which agree with observations made by Gehman and Montgomery at the other localities, suggest a strong stratigraphic (compositional) control on the distribution of uraninite. This does not negate the hydrothermal hypothesis, but does suggest the possibility of a synsedimentary origin for the uranium and thorium with subsequent crystallization of uraninite during metamorphism.

A split of our channel sample gives a $^{207}Pb/^{206}Pb$ age of 948 ±

5 m.y. (Table 1). The data of Table 1 show that the age is almost concordant, but that the sample has probably lost approximately 3% of its radiogenic lead. If this loss occurred within approximately the last 200 m.y., the $^{207}Pb/^{206}Pb$ age is a good estimate of the age of uranium mineralization. Based on the ratio of chemically determined lead to uranium and thorium, Wells and others (1933) concluded that the age of the thorianite from Williams quarry is 790 m.y. Based on the lead-alpha age of a presumably cogenetic zircon, Montgomery (1957) concluded that the age of uranium mineralization at the Royal Green quarry is 850 m.y. Considering the techniques used by these earlier workers, their determinations of the age of mineralization are surprisingly close to ours which are based on measurement of isotope ratios, a more reliable dating technique. Our age of approximately 948 m.y. agrees with a generally accepted Grenville thermal event in other parts of the Precambrian in the northeastern United States. The near concordance of the U-Pb ages suggests that there has been no intense thermal disturbance of the rocks at Quarry L since about 948 m.y. ago.

Table 1.—*Uranium and thorium content and isotopic ages of Quarry L sample*

[Analysis of sample 675-72, a totally digested 1 g split of ground, 200 g rock sample]

U(ppm)	1050
Th(ppm)	547
U/Th	1.9
$^{206}Pb/^{238}U$	920 ± 10 m.y.
$^{207}Pb/^{235}U$	928 ± 10 m.y.
$^{207}Pb/^{206}Pb$	948 ± 5 m.y.

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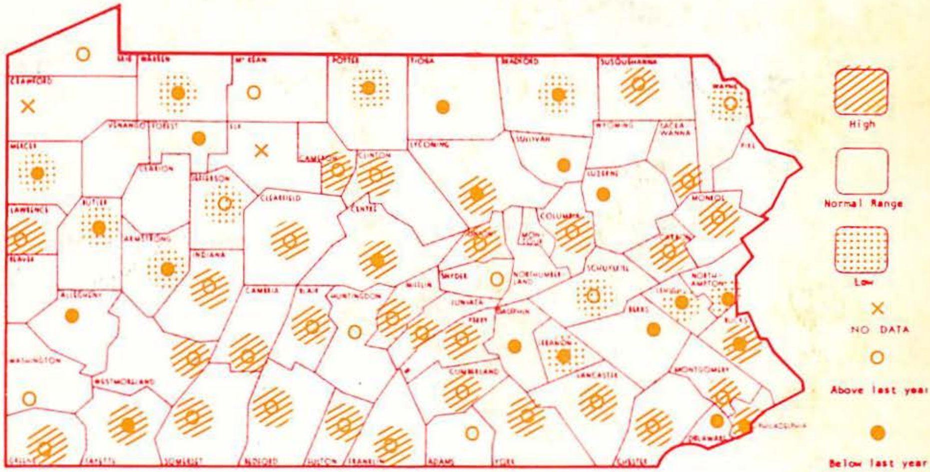

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