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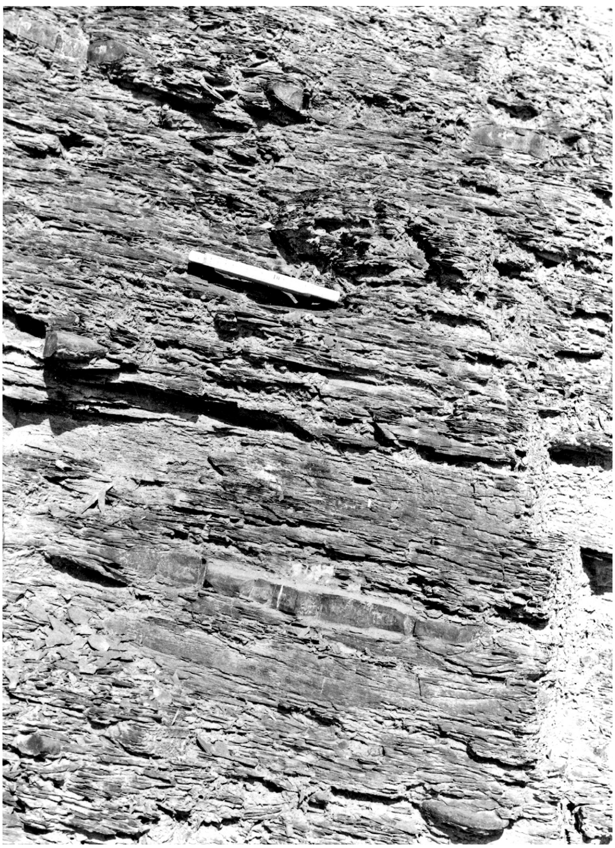
Pennsylvania GEOLOGY



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ON THE COVER

An outcrop of the Marcellus shale (see article on page 2), located about 1.8 miles southeast of Milton, Pa. The scale is about 6 inches long. Photograph by Jon D. Inners (Inners, J. D., 1997, Geology and Mineral Resources of the Allenwood and Milton Quadrangles, Union and Northumberland Counties, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Atlas 144cd, p. 37).

PENNSYLVANIA GEOLOGY

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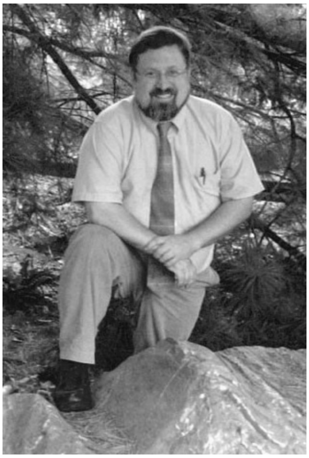
ERRATUM: On page 7 of the previous issue (*Pennsylvania Geology,* v. 37, no. 3/4), in the first entry of the explanation for Figure 3, the contour interval should be 6 inches.

STATE GEOLOGIST'S EDITORIAL

Shale We Look For Gas?

Recently, you may have noticed articles in the popular press about the abundant riches of gas beneath our feet in Pennsylvania, thanks to the Marcellus shale. Although the Marcellus will probably not be quite as productive as the hype suggests, there is not enough available information to fully evaluate its potential. We often are told that the United States has plenty of oil and gas if only pesky environmental restrictions could be removed and we could drill in Alaska. But peak petroleum production for the United States is past. We can find and produce more, but we are on the downward curve. Even coal, which we have always been taught could keep us warm for hundreds of years, is in shorter supply than we previously thought. The easy stuff (thick beds of Pittsburgh coal) is quickly being mined. In addition, international demand is increasing.

Pennsylvania is, however, faced with another, different kind of opportunity. Rather than producing fossil fuels, we might be able to dispose of waste CO_2 (the process of carbon sequestration), because we have even more capacity for storing waste gases than we do for providing the coal that produces the waste gases. The topic of carbon sequestration was addressed in a previous issue of this magazine (*Pennsylvania Geology,* v. 34, no. 2, p. 2–9). Here at the Survey we hope to focus much of our energy in the next few years mapping the carbon sequestration potential of the eastern portion of the state, as well as looking at those all-important water resources. All in all, it should be a busy time for us. And with oil at more than $100 per barrel and gold at around $1,000 per ounce, it is an exciting time to be a geologist.



Jay B. Parrish
State Geologist

The Marcellus Shale—An Old "New" Gas Reservoir in Pennsylvania

by John A. Harper
Bureau of Topographic and Geologic Survey

WHAT'S ALL THE FUSS? Black, organic-rich shales are common constituents of sedimentary deposits formed throughout geologic time. In Pennsylvania, black, organic-rich shales can be found in almost all of the Paleozoic systems, as well as in the Triassic rocks of the Newark and Gettysburg basins in the southeast. Some of these shales are the sources of the crude oil and natural gas found in Pennsylvania's sandstone and carbonate reservoirs. One shale unit in particular, the Middle Devonian Marcellus Formation (see front cover), has recently become a hot item with the nation's oil and gas industry, as well as with the news media. One would think, from all the fuss about the Marcellus, that it was a newly discovered gas reservoir containing enough gas to sustain America's needs for decades. In reality, the Marcellus has been a known gas reservoir for more than 75 years. What has made it newsworthy, besides much hyperbole, is that the oil and gas industry has both new technology and price incentives that make this otherwise difficult gas play economical.

FIRST, SOME HISTORY. Natural gas has been part of our heritage for more than 200 years. Gas, along with crude oil, was found in numerous wells dug or drilled for salt water in colonial times. The first well drilled specifically to produce natural gas in North America was completed in Devonian shales. Citizens of Fredonia, N. Y., noticed gas bubbling up through the bed of Canadaway Creek, and someone had the foresight to sink a well to collect the gas and use it to light the town in 1821, 38 years before Drake drilled his famous oil well at Titusville, Pa. The Fredonia well was only 27 feet deep, but it produced enough gas to provide the light equivalent of "two good candles." In 1850, the well was deepened to 70 feet and produced enough gas to light 200 burners. In 1858, a second well was drilled to more than 200 feet, and the gas lasted another 30 to 35 years.

As a result of the Fredonia wells, a flurry of drilling activity commenced along the Lake Erie shoreline, eventually reaching at least as far as Sandusky, Ohio. The gas came from black, organic-rich shales and from fractured shales and siltstones above and interbedded with the black shales. Typically, the wells were 1,000 feet deep or less, and many were producing from as shallow as 25 or 30 feet. By the beginning of the twentieth century, just about every backyard and manufacturing plant within a mile of the Lake Erie shore in Pennsylvania had at least one gas well that kept the house or business reasonably well lighted and heated. The wells had unreliable pressures that varied with changes in the weather—when a cold front came through, it was time to break out the wood stove. However, the wells seemed to last forever. Many of the backyard wells drilled in the early part of the twentieth century are still providing gas to residents of Erie County.

In the 1930s, the oil and gas industry began finding large commercial quantities of natural gas in the Lower Devonian Oriskany Sandstone in New York and Pennsylvania. As companies were drilling to this target, their wells penetrated the black shales of the Marcellus Formation, situated a few tens to a few hundreds of feet above the Oriskany. Just about every well had a strong flow of gas that shut down drilling for several days. The Marcellus fascinated the industry until it became clear that the gas occurred in "pockets" and that the flows could not be sustained. These gas flows died down quickly, and the drillers soon began to ignore them when they encountered them. Everyone knew there was gas in the Marcellus, but the consensus was that there was not enough to make a well.

Following the energy crisis of 1973, the onset of energy shortages and the subsequent increase in natural gas prices spurred the U.S. Department of Energy to fund a multistate cooperative program called the Eastern Gas Shales Project (EGSP) that spanned the Appalachian, Illinois, and Michigan basins. The two purposes of the project were to determine the extent, thickness, structural complexity, and stratigraphic equivalence of all Devonian organic-rich shales throughout the basins; and to develop and implement new drilling, stimulation, and recovery technologies to increase production potential. Geological teams correlated and mapped the rocks; geophysical teams worked on new technologies to locate fracture systems and potential reservoirs; geochemical teams investigated ways to modify the shale matrix to increase gas flow; engineering teams derived and tested models of various fracturing techniques and directional drilling procedures; and oil and gas companies drilled and cored numerous test wells in each of the states involved in the project. Five wells were drilled in Pennsylvania (Figure 1), and cores were collected of

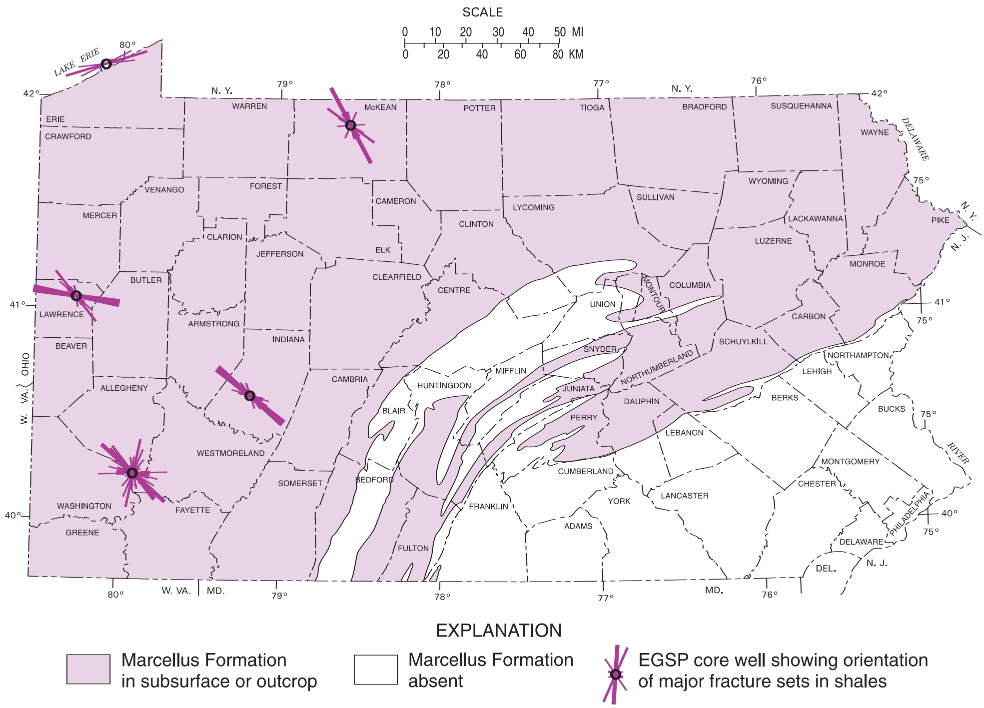


Figure 1. Map showing the general distribution of the Marcellus Formation in Pennsylvania. Also shown are the locations of five wells drilled and cored during the Eastern Gas Shales Project (EGSP) study of the 1970s and 1980s. Orientations of measured fractures are shown (fracture data from Evans, 1994).

the Devonian shales in each that provided a wealth of data about bedding, mineralogy, fracture systems, and so forth.

I was part of the Pennsylvania Geological Survey team that spent several years doing basic mapping and correlation. The end products included numerous cross sections, maps, and technical reports (e.g., Piotrowski and Harper, 1979) showing formation thickness, net feet of organic-rich shales, and net feet of clean sandstone throughout the entire Middle and Upper Devonian sequence in western and north-central Pennsylvania. We determined that the Devonian organic-rich shales could be important gas reservoirs, at least in northwestern Pennsylvania where they were both thick and close to the surface. These shales were thought to have excellent potential to fill the needs of users, especially if the expected development of better technology for inducing and enhancing fracture systems that is so important to sustain production in shale came about. The deeper shales, particularly the Marcellus Formation, were considered to be much less attractive targets and would remain so until gas prices increased and technology advanced enough to make drilling and completion competitive with more conventional targets. Neither occurred until recently.

The furor over the Devonian shales faded during the early 1980s due to low gas prices and lack of sufficiently useful technologies for extracting the gas. The complete EGSP library, which has remained relatively obscure because of the lack of interest, is quite extensive and includes a wealth of physical, chemical, geological, and engineering information. Much of it can be found in the National Energy Technology Laboratory's compendium of natural gas archives (National Energy Technology Laboratory, 2007), which is available at no cost from the U.S. Department of Energy. In addition, summaries have been published over the years, such as that by Roen and Kepferle (1993), which provide very useful information on the shales. Anyone interested in finding out more about Devonian shales as gas reservoirs should consult these publications.

Within the last three to four years, as a result of a combination of higher prices, recent technological advances, and the development of large gas resources from black shales in other parts of the country, the interest in Pennsylvania's organic-rich shales has risen once again to a fever pitch within the state's oil and gas industry. This is particularly true for the Marcellus Formation, which lies beneath much of Pennsylvania (Figure 1). Some companies are paying incredible fees for leases, while others are spending enormous amounts of money to drill Marcellus gas wells across the state, from Greene County in the southwest to Wayne County in the northeast. All of this activity has been exciting the press, landowners, and state and municipal authorities, who look upon the Marcellus as a major economic boon for Pennsylvania.

RADIOACTIVITY = ORGANIC RICHNESS = GAS. The oil and gas industry uses a number of geophysical logging tools to characterize the subsurface rocks. The most commonly run logging tool in the Appalachian basin, the gamma-ray log, is a very sensitive Geiger counter that measures the natural low-level radioactivity inherent in almost all sedimentary rocks. Most of the radiation emitted by these rocks is due to the radioactive potassium isotope (potassium-40) found in feldspars, micas, clay minerals, and other common and abundant silicate minerals. On gamma-ray logs, shales can be differentiated from other rocks such as clean sandstones and limestones because shales have higher concentrations of potassium-40-bearing minerals.

Organic-rich shales have higher radioactivity responses than typical shales because the organic matter tends to concentrate uranium ions that otherwise would be scattered throughout the sediment (Adams and Weaver, 1958; Schmoker, 1981). As a result, many organic-rich shales have uranium and thorium contents that are greater than 10 parts per million and that may approach 100 parts per million, which will show up on a gamma-ray log as higher-than-normal gamma-ray responses (Figure 2). Comparisons of gamma-ray logs with drill cuttings show a fairly strong correlation between higher-than-normal radioactivity and black color in shales, derived from the organic content. To put it simply, black coloration generally correlates with organic richness, which correlates with high gamma-ray response.

The icing on the cake, so to speak, was the number of studies done during and after EGSP that indicated an empirical relationship between high gamma-ray response and both gas production and total gas content in organic-rich shales. In other words, higher-than-normal gamma-ray response also equates to gas-production potential. The correlation might not be 100 percent, but it is very high. This is a very important concept for those looking to produce shale gas. Many companies would look for places where the entire formation is thick, but they should actually be looking for where it is most rich in organic matter. When we mapped the Devonian formations during EGSP, we created maps showing the net feet of shale having higher-than-normal radioactive signatures on gamma-ray logs (equivalent to net feet of organic-rich shale) (e.g., see back cover). It is my belief that these maps are far more accurate for finding good sources of natural gas than just mapping formation thickness.

THE MEEK SHALE INHERIT THE EARTH. The Devonian shales in Pennsylvania occur at and near the base of a thick sequence of intercalated marine, transitional, and continental rocks known as the Catskill clastic wedge. This sequence is more than 10,000 feet thick in eastern Pennsylvania but thins to about 2,000 feet along the Lake Erie shoreline (Colton, 1970). Pennsylvania's thick sequence of Devonian shales can be divided into organic-rich black shale facies and not-so-organic-rich gray shale and siltstone facies (Figure 2). This sequence is capped by the sandstone-rich portion of the Upper Devonian that has been the "bread and butter" of the oil and gas industry in this state for 150 years.

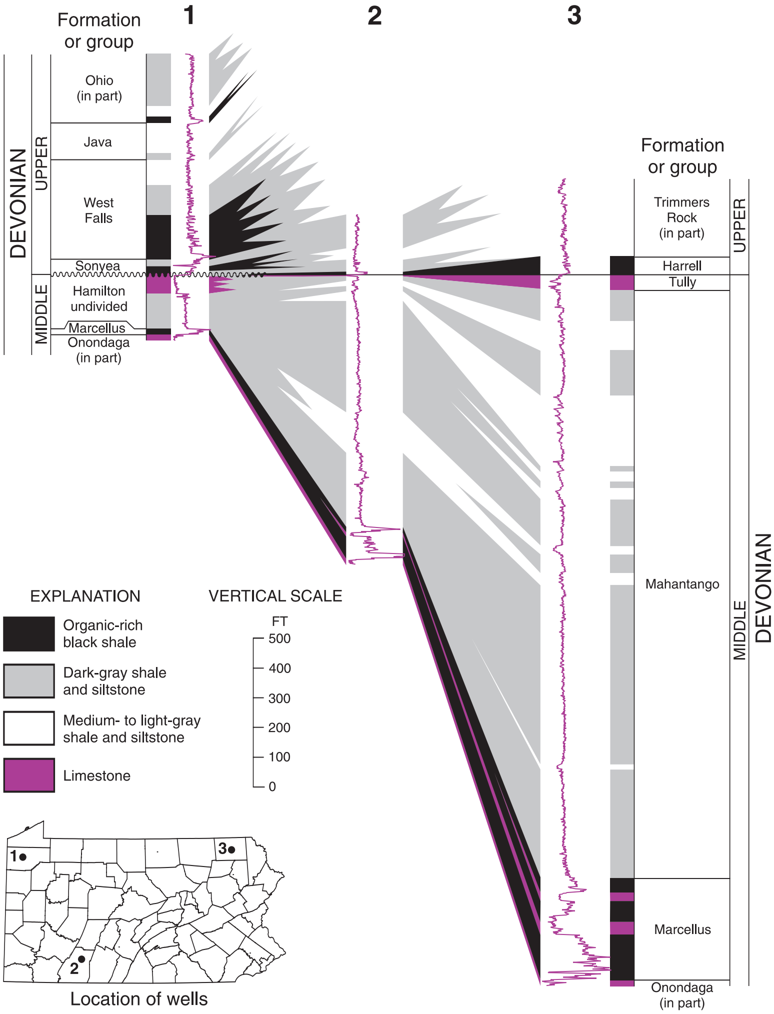


Figure 2. Correlation of Middle and Upper Devonian organic-rich shale facies and interbedded strata in three wells in Pennsylvania, based on gamma-ray log signatures (the jagged purple lines) and descriptions of well cuttings. Note that the black shales correspond in large part to higher-than-normal gamma-ray readings (radioactivity increases to the right in all log signatures).

The three most important organic-rich shales include the black shale facies of the Middle Devonian Marcellus Formation and of the Upper Devonian West Falls Formation and Ohio Shale (the Rhinestreet and Huron facies, respectively) (Figures 2 and 3). All have been explored at one time or another as natural gas reservoirs. Three less

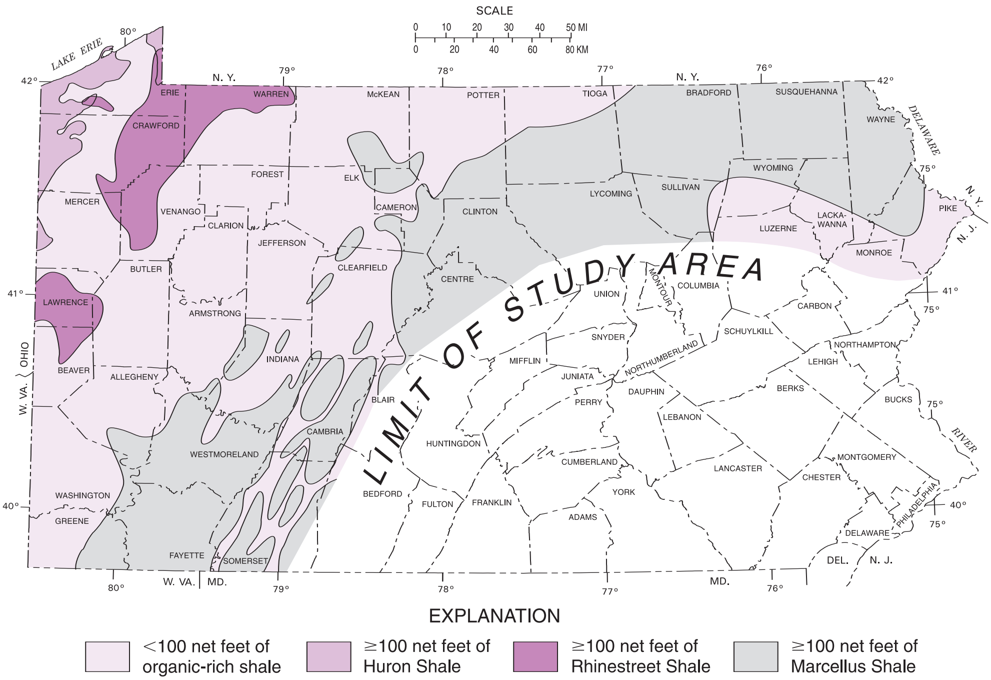


Figure 3. Distribution of the thickest sequences of organic-rich shale in the Ohio Shale, West Falls Formation, and Hamilton Group (Huron, Rhinestreet, and Marcellus facies, respectively) (based on Piotrowski and Harper, 1979, and Harper and Abel, 1980).

important units include the Upper Devonian Harrell (and partially equivalent Genesee), Sonyea, and Java Formations (Figure 2). All of the organic-rich shales, plus the associated gray shales and siltstones that overlie and intercalate with them, participate as the reservoir for the shale-gas production along the margin of Lake Erie. A system of fractures in these shales constitutes the most important part of the reservoir by providing porosity and permeability that allows the gas to leak slowly from the rock.

QUO VADIS, MARCELLUS? The Marcellus Formation underlies most of Pennsylvania (Figure 1), but the organic-rich portion reaches its maximum development in the northeastern part of the state (see back cover). Despite the long history of gas shows in the Marcellus, it took until recently for its potential as a commercial gas target to attract attention.

By standard definition for mapping purposes, the Marcellus Formation in Pennsylvania typically is defined as the black shales at the base of the Middle Devonian Hamilton Group; the upper part of the group is occupied by gray and dark-gray shales, siltstones, and (to the east) sandstones of the Mahantango Formation (Figure 2). The organic richness (i.e., the black coloration) within the Hamilton Group in the subsurface varies from place to place so that the Marcellus/Mahantango boundary fluctuates. Piotrowski and Harper (1979, Plate 3) showed that the Hamilton Group as a whole thickens fairly regularly from northwest to southeast. However, the net feet of higher-than-normal radioactive shale in the Hamilton Group—the Marcellus facies—has an interesting configuration (Piotrowski and Harper, 1979, Plate 4). The Marcellus generally thickens to the east, as expected, but throughout the eastern half of the Appalachian Plateaus physiographic province as far north as Tioga County, it also develops into a series of linear thick areas situated on the crests of anticlines (see back cover). Some of this thickening can be explained by repetition of the section through faulting, but close correlation of logs along and across the anticlines also indicates that, for some reason, more of the Hamilton Group rock section becomes organic rich over these structures.

Pennsylvania's Marcellus shale play began in 2003, when Range Resources–Appalachia, LLC (formerly Great Lakes Energy Partners, LLC) drilled a well to the Lower Silurian Rochester Shale in Washington County. The deep formations (such as the Oriskany Sandstone and the Lockport Dolomite) did not look favorable, but the Marcellus shale had some promise. Range drilled some additional wells, and through experimentation with drilling and hydraulic fracturing techniques borrowed and revised from those used on the Mississippian Barnett Shale gas play in Texas, began producing Marcellus gas in 2005. Since then, the company has permitted more than 150 Marcellus wells in Washington County alone. Other companies have joined the fray with permitting and drilling in many areas of the Appalachian Plateaus in Pennsylvania. As of the end of 2007, more than 375 suspected Marcellus wells had been permitted in Pennsylvania. An additional 78 had been permitted as of this writing (end of February, 2008). Therefore, it appears that the Marcellus gas play will continue until and unless gas prices fall dramatically.

IT'S ALL ABOUT THE FRACTURES. Conventional gas reservoirs, such as the Lower Devonian Oriskany Sandstone, contain gas in pore spaces between the sand grains. The gas migrated into the rock from one or more source rocks during the Alleghanian orogeny about 250 million years ago. Organic-rich shales, however, are their own source rocks, and gas molecules generated from the organic matter adsorb onto the organic matrix of the rock. Over time, with the development of fractures of all sizes and orientations (Figure 1) due to a variety of tectonic and hydraulic stresses, some of the gas desorbed from the matrix and migrated into these fractures. It was these pockets of gas that the early drillers tapped. Because desorption takes place relatively slowly, the fractures could not be refilled quickly enough to maintain a constant flow, so drilling continued past this potential reservoir and commercial quantities were found in deeper conventional reservoirs. The natural fractures are neither numerous nor extensive enough to maintain production except in certain areas of Kentucky, West Virginia, Ohio, and along the Lake Erie shore.

Since the early 1960s, Pennsylvania's oil and gas industry has used hydraulic fracturing (fracing, pronounced "fracking") to enhance the recovery of oil and natural gas. This involves pumping a fluid such as water or kerosene and, usually, sand or some other granular material into the producing formation under high pressure until the rock cracks. The process enhances the porosity and permeability of the rock, and the granular material (the propant) serves to prop open the newly created fractures. As a result, the surface area of the rock increases, allowing gas to travel more readily from the pores to the well bore.

Shales are different than conventional hydrocarbon reservoirs. They have extremely low permeabilities and do not accept frac jobs as readily. During EGSP, petroleum engineers modeled many types of frac jobs trying to find the right combination of fluids, propants, and pressures to maximize production in shales. But it was not until development of the Barnett Shale play in the 1990s that a technique suitable for fracing shales was developed. This technique is called a "slick-water frac" and consists of sand and very large volumes of freshwater that has been treated with a friction reducer such as a gel. Slick-water fracs maximize the length of the fractures horizontally while minimizing the vertical fracture height, resulting in greater gas mobility and more efficient recovery of a larger volume of the gas.

Another technique that has become useful in producing Marcellus gas is horizontal drilling. The first horizontal well was drilled in Texas in 1929, but it took until the 1980s for the technology to be improved enough to become a standard industry practice. The technology involves drilling a vertical hole to several hundred feet above the target reservoir, then directing the drill bit through an arc until it is literally drilling sideways instead of downward (Figure 4). This has several advantages: (1) it increases the amount of reservoir penetrated

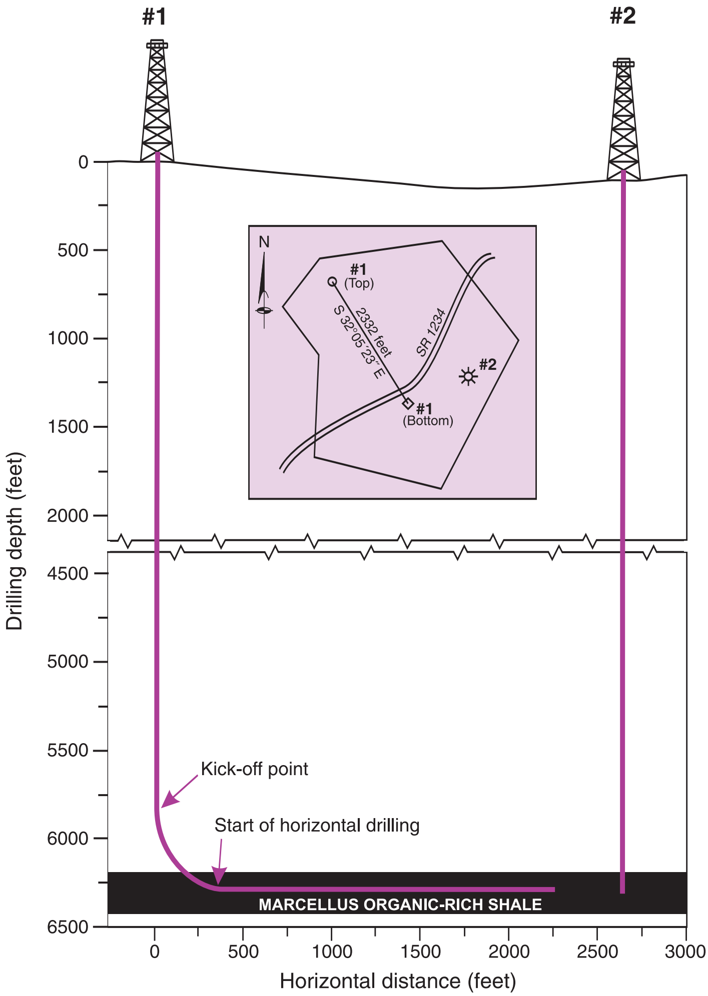


Figure 4. A comparison between a horizontal well and a typical vertical well drilled to the Marcellus organic-rich shales. The horizontal well has the advantages of turning a relatively thin reservoir into a very thick one, and of being certain to intersect a larger number of fractures. The inset map shows a hypothetical lease and the two wells. Note that this map shows the locations of both the top and bottom of the horizontal well and the course and distance between them.

from perhaps a few tens of feet to as much as 3,000 or 4,000 feet; (2) it increases the number of fractures penetrated; and (3) it can be used to develop hydrocarbon resources beneath sensitive areas such as wetlands and cities where a drilling rig cannot be set up. A slick-water frac in a vertical Marcellus well uses from 500,000 to more than 1,000,000 gallons of water (a typical sandstone frac job uses only about

5,000 to 50,000 gallons). A slick-water frac in a horizontal Marcellus well will probably use several million gallons of water. Based on information from the Barnett Shale play, a horizontal well completion might use more than 3 million gallons (so far, I have not seen a well record involving a horizontal shale completion in Pennsylvania).

BUT IS IT REALLY WORTH IT? During EGSP, the U.S. Geological Survey estimated that the Marcellus contains about 295 trillion cubic feet (Tcf) of gas-in-place in the Appalachian basin (Charpentier and others, 1993). Figuring a recovery of 3 to 5 percent, that means 9 to 15 Tcf is recoverable throughout the basin. Briggs and Tatlock (1999) assessed Pennsylvania's natural gas resources and estimated that the Devonian shales could potentially produce 8.4 Tcf within the state, which is in line with the lower estimate of Charpentier and others (1993). A more recent assessment of the Devonian shales in the Appalachian basin (Milici and Swezey, 2006) determined that these shales contain 31.4 Tcf of recoverable gas. Of course, none of these estimates took into consideration today's prices and technologies. One very recent estimate indicates that the Marcellus has more than 500 Tcf of gas in place with about 50 Tcf recoverable (Smeltz, 2008). Whether any of these estimates is reasonable remains to be seen.

The true value of the Marcellus organic-rich shale as a gas reservoir has yet to be determined. Cabot Oil and Gas Corporation, which is leasing and drilling in northeastern Pennsylvania, has been quoted as saying its wells are testing between 800,000 and 1,000,000 cubic feet per day (IHS, 2008, p. 1). Based on the limited production information that has been received by the state so far, the average daily production from a Marcellus well in Pennsylvania is about 45 thousand cubic feet of gas per day, which is considered marginal at best. It should be noted that this average is based on only two years' data from relatively few vertical wells. We still do not have any details from horizontal shale wells. Only time (and more data) will determine just how productive and lucrative the Marcellus play is. It is possible that the Marcellus will ultimately turn out to be the great gas reservoir everyone is fussing about.

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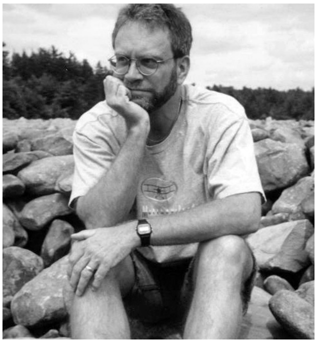
Meet the Staff—Part 6

In Part 6 of "Meet the Staff," we learn about the GIS Services area of the Survey. One of the staff members, John Barnes, also works in Laboratory and Geochemical Services and was previously introduced in Part 4 of this series (see *Pennsylvania Geology*, v. 37, no. 2, p. 16–18). The other staff are introduced below.

GIS SERVICES. The GIS Services section was created in 2001 to integrate the expanding capabilities of geographic information systems (GIS) and companion digital technologies, such as global positioning systems (GPS), into the daily operations of the agency. In addition to providing cartographic support to other geologic staff, the GIS Services staff also use the analytical capabilities of GIS technology to present complex geologic relationships more clearly. Studies within the state have included such topics as the occurrence of acid-producing minerals, density of karst features, and delineation of physiographic units.

Looking to the future, the statewide imagery and lidar-derived elevation data being generated by the PAMAP program will be used in GIS projects to better define the topography and geology of Pennsylvania. Initially, the level of detail in these data will require that GIS Services staff redefine many fundamental datasets, such as watershed boundaries and stream reaches across the state.

Michael E. Moore. After receiving his B.S. degree in geological sciences in 1975, Mike spent most of the next 11 years working as a consultant for the bituminous coal industry and as a staff geologist for coal-mining companies.



Mike Moore

In June of 1986, he began his tenure at the Survey as a hydrogeologist, working on water-resource investigations. In 1989, Mike was promoted to Chief of the Groundwater Geology Section (now Groundwater Services) and thereby assumed responsibility for supervising water research and policy programs. Eventually, he also administered the Survey's water-well drillers licensing and records programs. Under Mike's watch, the web applications for the collection of data for new wells and access to data for existing wells were created.

As a consequence of a bureau reorganization in 2001, Mike accepted the challenge of supervising the newly created GIS Services section, where he was provided with the opportunity to implement his career-long interest in the application of digital technology in the earth sciences. Since then, Mike and his staff have provided cartographic, spatial analysis, and database services to individuals both inside and outside the Department of Conservation and Natural Resources (DCNR).

Victoria V. Neboga. Victoria Neboga is a native of Kiev, Ukraine, where she earned a master's degree in hydrogeology and engineering geology in 1985. Her first job was as a geologist in the Institute for Projecting Enterprises, Bureau of Geologic Investigations, assisting the Ukrainian sugar industry. Victoria's career with the commonwealth

Victoria Neboga

started in December 2002 in the Department of Labor and Industry, Center for Workforce Information and Analysis, where she produced statistical reports.

Victoria joined the Survey in May 2005, and her first task was to learn GIS software and principles. Now, as a Geologic Scientist, she creates both digital and hard-copy cartographic products that characterize the natural resources of Pennsylvania. Her assignments include working in cooperation with other staff geologists to produce geologic maps and related GIS datasets that are released as Survey open-file reports. Most of these projects are part of the STATEMAP component of the U.S. Geological Survey's National Cooperative Geologic Mapping Program.

As time permits, Victoria also works on a GIS database that will define more than 500 landforms within Pennsylvania. This project benefits from high-resolution imagery as well as lidar-derived elevation data from the PAMAP program. Most recently, Victoria used her GIS skills to create a sophisticated interactive index map that helps DCNR employees identify which of more than 13,000 PAMAP tiles are relevant to their project areas.

Stuart O. Reese. Stuart, a Senior Geologic Scientist, arrived at the Survey in March 2002. Prior to that and after receiving his M.S. degree in geology in 1986, he spent several years working as a hydrogeologist, first at Wright-Patterson Air Force Base in Dayton, Ohio, and then at a Camp Hill, Pa., consulting firm. He went on to serve 10 years with the Pennsylvania Department of Environmental Protection (DEP) in their groundwater protection program. While at DEP, Stuart acquired a strong interest in a newly emerging tool—GIS. When a position opened at the Survey, he applied and was hired to work in the GIS Services area.

As part of his bureau duties, Stuart utilizes GIS software not only to make digital maps (such as the STATEMAP products), but also to analyze data associated with concerns ranging from envi-

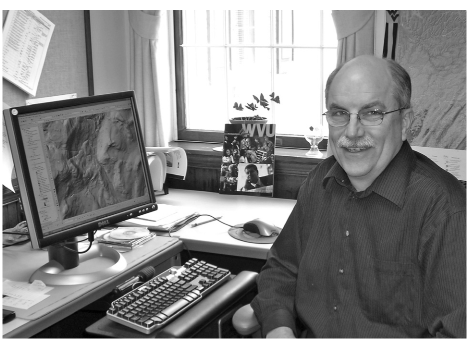
Stuart Reese

ronmental hazards to the DCNR TreeVitalize programs. Some of his work on environmental hazards resulted in the online reports Map 68 and Map 70, which he coauthored with fellow staff geologist Bill Kochanov. These maps use gradational colors to show the concentration of karst features (mostly sinkholes and closed depressions).

Part of Stuart's time is spent on work outside of GIS Services. He was responsible for the Survey's web site for a few years and still maintains several web pages. And although he is not formally assigned to Groundwater Services, Stuart often assists in that area.

Thomas G. Whitfield. Tom has a B.S. in geology and did graduate work in mining technology and borehole geophysics. He started his career as a well-log analyst and completion consultant for two geophysical well-logging companies in the oil and gas fields of western Pennsylvania. He then worked for U.S. Steel Corporation as comanager of their midwestern field office, doing coal-exploration projects for nearly 6 years. In 1986, Tom joined the DEP Bureau of Oil and Gas Management, where he helped implement the program to plug orphaned and abandoned wells.

Tom started with the Geologic Mapping Division of the Survey in March 1991. After about a year, he volunteered to try a new technology called "GIS." In the fall of 1992, Tom became the first full-time GIS person in the Survey and soon after set to work as a key member of the team digitizing the 1:250,000-scale *Geologic Map of Pennsylvania* and compiling the *Bedrock Geology of Pennsylvania* dataset. As a Senior Geologic Scientist in GIS Services, Tom works on various GIS projects, including the previously mentioned STATEMAP products. He also works with the technical aspects of PAMAP imagery and lidar-derived digital elevation models. He recently developed a raster-seam conflation tool that repairs seam lines in raster mosaics.

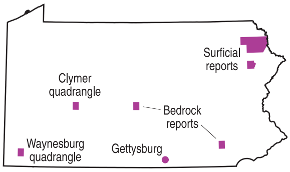


Tom Whitfield

Tom also has an unusual hobby. He is a certified emergency medical technician (EMT) with 28 years of experience, and he volunteers with a local ambulance service. The Survey benefits from Tom's expertise in this area, as he chairs our "Fire and Panic Committee" and educates the staff on how best to handle life-threatening emergencies.

NEW RELEASES

Sixteen New Open-File Reports Now Online



The Bureau of Topographic and Geologic Survey recently released sixteen online open-file reports, all of which are available on the Survey's web site at www.dcnr.state.pa.us/topogeo/openfile/ofloc.aspx. A list of these reports and their authors is shown in the table on the next page.

Two of the reports are in the bedrock map series and eleven are in the surficial map series. These 13 studies were funded by the STATEMAP component of the U.S. Geological Survey's National Cooperative Geologic Mapping Program. Each report includes one 1:24,000-scale, full-color geologic map, text, and data tables. The maps are presented in portable document format (PDF). Relevant geographic-information-system (GIS) data and ArcMap documents are also provided as separate downloads.

Another guide to the geology of the Gettysburg Battlefield has been made available in the general geology series. This report is a 16-page field-guide article that was condensed from the 105-page guidebook used at the 2006 annual meeting of the Geological Society of America and also published by the Survey as **OF 06–02.** The article was written especially to be used by a solitary geologist driving around the battlefield, although it can be used by anyone visiting Gettysburg.

Two new coal availability studies are now available online as mineral resource reports. These reports are the fourth and fifth in a series of coal availability studies for the Main Bituminous coal field of Pennsylvania to be published in recent months (see *Pennsylvania Geology,* v. 35, no. 3/4, p. 13, and v. 36, no. 1, p. 20). Coal available for extraction is that which is accessible within various regulatory, land-use, and technologic constraints. As in the earlier reports, the authors used GIS technology to compare areas of original coal to areas where coal had been mined and where mining is restricted. The Clymer study indicates that about 208 million short tons is available for mining, or about 42 percent of the total original resources. The Waynesburg study shows that about 897 million short tons of coal is available for mining, which is about 77 percent of the original resources.

BEDROCK GEOLOGY REPORTS

OFBM 08–01.0 *Bedrock geologic map of the New Holland quadrangle, Lancaster County, Pennsylvania,* by Carolyn H. Brown, STATEMAP cooperator, Pennsylvania Geological Survey.

OFBM 08–02.0 *Bedrock geologic map of the McAlevys Fort quadrangle, Huntingdon, Centre, and Mifflin Counties, Pennsylvania,* by Arnold G. Doden and David P. Gold, GMRE, Inc., State College, Pa.

GENERAL GEOLOGY REPORT

OFGG 08–01.0 *Geology of the Gettysburg Battlefield—How Mesozoic Events and Processes Impacted American History,* by Roger J. Cuffey, Pennsylvania State University; Jon D.Inners and Gary M. Fleeger, Pennsylvania Geological Survey; and others.

MINERAL RESOURCE REPORTS

OFMR 08–01.0 *A Study of Coal Availability in the Clymer 7.5-Minute Quadrangle, Indiana County, Pennsylvania,* by Viktoras W. Skema, Leonard J. Lentz, John C. Neubaum, and Rose-Anna Behr, Pennsylvania Geological Survey.

OFMR 08–02.0 *A Study of Coal Availability in the Waynesburg 7.5-minute Quadrangle, Greene and Washington Counties, Pennsylvania,* by Viktoras W. Skema, James R. Shaulis, and Rose-Anna Behr, Pennsylvania Geological Survey, and others.

SURFICIAL GEOLOGY REPORTS

by Duane D. Braun, Bloomsburg University

OFSM 08–01.0 *Surficial geology of the Waymart 7.5-minute quadrangle, Wayne and Lackawanna Counties, Pennsylvania.*

OFSM 08–02.0 *Surficial geology of the Forest City 7.5-minute quadrangle, Wayne, Susquehanna, and Lackawanna Counties, Pennsylvania.*

OFSM 08–03.0 *Surficial geology of the Clifford 7.5-minute quadrangle, Susquehanna and Lackawanna Counties, Pennsylvania*.

OFSM 08–04.0 *Surficial geology of the Honesdale 7.5-minute quadrangle, Wayne County, Pennsylvania.*

OFSM 08–05.0 *Surficial geology of the Wayne County portion of the White Mills 7.5-minute quadrangle, Wayne County, Pennsylvania.*

OFSM 08–06.0 *Surficial geology of the Wayne County portion of the Narrowsburg 7.5-minute quadrangle, Wayne County, Pennsylvania.*

OFSM 08–07.0 *Surficial geology of the Sterling 7.5-minute quadrangle, Wayne and Lackawanna Counties, Pennsylvania.*

OFSM 08–08.0 *Surficial geology of the Wayne County portion of the Newfoundland 7.5-minute quadrangle, Wayne County, Pennsylvania.*

OFSM 08–09.0 *Surficial geology of the Aldenville 7.5-minute quadrangle, Wayne County, Pennsylvania.*

OFSM 08–10.0 *Surficial geology of the Galilee 7.5-minute quadrangle, Wayne County, Pennsylvania.*

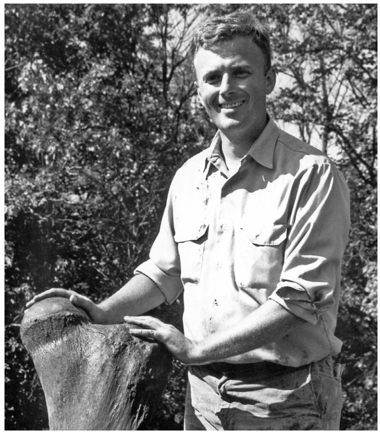
OFSM 08–15.0 *Surficial geology of the Damascus 7.5-minute quadrangle, Wayne County, Pennsylvania.*

IN MEMORIAM

Donald T. Hoff

Mineralogist, Earth Scientist, Curator, and Friend

1930–2007



Don Hoff and mastodon femur in 1968. Photograph courtesy of The State Museum of Pennsylvania (Pennsylvania Historical and Museum Commission).

Donald T. Hoff, the curator for Earth Science at the State Museum of Pennsylvania (formerly the William Penn Memorial Museum) from 1963 until 1991, died on December 4, 2007. During his lengthy tenure, he organized outstanding geology displays as well as an extensive and well-referenced collection of minerals from Pennsylvania. Don was equally at home working in the field of paleontology and is well known for his excavation of a Pleistocene mastodon from a peat bog in Monroe County and giant amphibians from Triassic sediments in York County.

Don was a geology graduate of Waynesburg College, Pa., but his interest in geology began much earlier on mineral-collecting trips in Pennsylvania and Ontario with his family. He was especially interested in the native copper and piemontite occurrences in the South Mountain region of Adams County and in uranium minerals from throughout Pennsylvania. In 1984, he and Bob Smith (now retired from the Survey) coauthored *Geology and Mineralogy of Copper-Uranium Occurrences in the Picture Rocks and Sonestown Quadrangles, Lycoming and Sullivan Counties, Pennsylvania,* published by the Survey. In the report, Don was able to combine his interests by describing the fish and plant fossils that were found in the area, as well as the copper and uranium minerals that had replaced them. Don also wrote the chapter on minor mineral resources such as talc, serpentine, feldspar, graphite, mica, phyllite, beryl, phosphate, and metabasalt for the Survey's book, *The Geology of Pennsylvania.* Don probably most enjoyed writing his article about the Teeter quarry in Gettysburg, which was published by *Rocks and Minerals,* in which he was one of the first to recognize a small copper-rich zone akin to a Cornwall-type deposit complete with trace native gold-electrum. As far as is known, Don was the first person to have ever recognized such in bedrock in the Commonwealth, a fitting tribute to his powers of observation.

Don did everything he could to support the interests of rock, mineral, and fossil collectors in Pennsylvania. There are countless people who benefited from Don's assistance and tireless enthusiasm for all things geologic. An engaging conversationalist, his zeal in assisting the museum was contagious and typically resulted in remarkable cooperation. One landowner gave up a collection of dinosaur footprints from his home patio for the museum as a result of simply chatting with Don, who had stopped to make a purchase of cider at a roadside stand.

Don always seemed happy when discovering something new, but he would become happier still when sharing what he discovered with others. His enthusiasm and eagerness to share both stories and specimens will be missed.

—Robert C. Smith, II, and G. Robert Ganis

ANNOUNCEMENT

73rd Field Conference of Pennsylvania Geologists

The 73rd Field Conference of Pennsylvania Geologists will address the physiographic, stratigraphic, structural, and military geology of the Gettysburg area. It is being hosted by the Pennsylvania Geological Survey, The Pennsylvania State University, Gettysburg National Military Park, Pennsylvania Department of Environmental Protection, and Valley Quarries, Inc. The conference will be held September 25–27, 2008, and will be headquartered at the Wyndham Resort Hotel in Gettysburg, Pa. One day of the meeting will be devoted to stops related to the stratigraphy and structure of the Gettysburg basin (one of numerous Mesozoic rift basins in eastern North America), and the other day will be focused on the role geology played during the Gettysburg campaign. Two large quarries will be visited, each having peculiar geologic histories.

Current information can be found at **http://fcopg.org.** Future updates will include registration material. Registration forms may also be obtained in August and September from Field Conference of Pennsylvania Geologists, c/o Pennsylvania Geological Survey, 3240 Schoolhouse Road, Middletown, PA 17057–3534.

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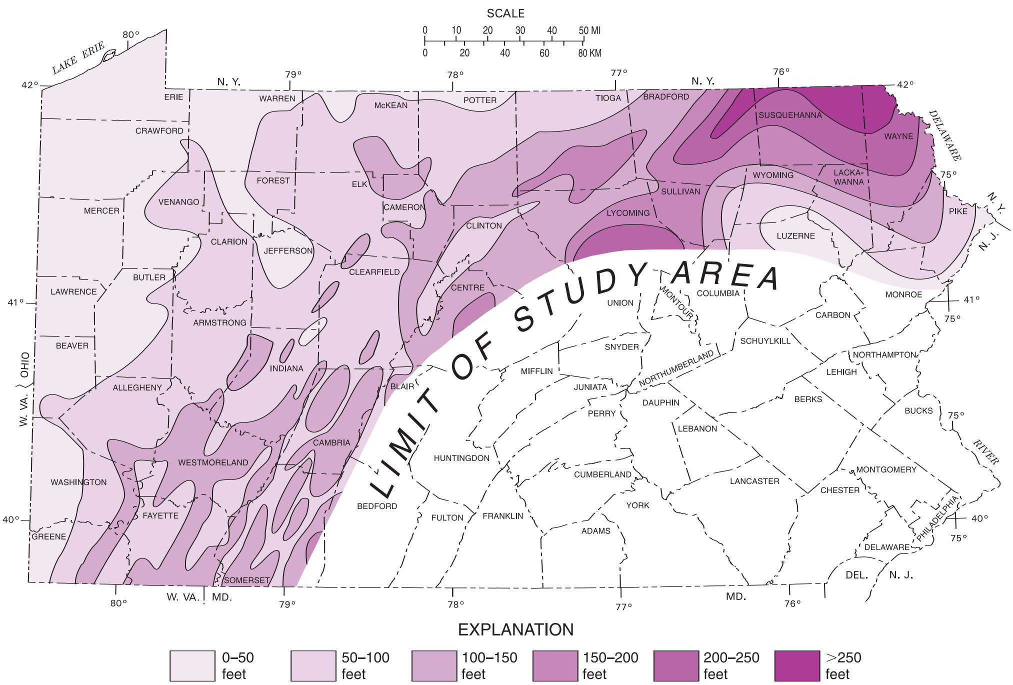
NET FEET OF ORGANIC-RICH SHALE IN THE MARCELLUS FORMATION

(Modified from Piotrowski and Harper, 1979, Plate 4)

(See article on page 2.)



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