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Pennsylvania Geology

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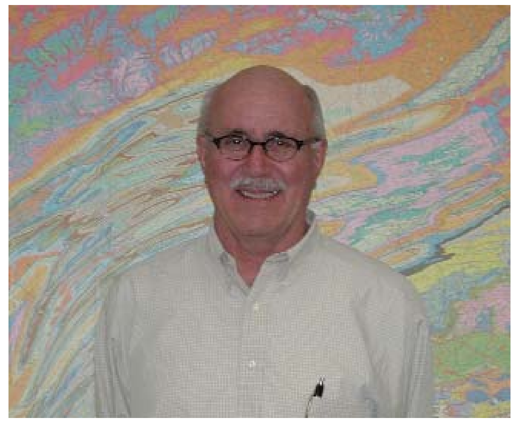
GeoFORCE students from Houston, Tex., and southwest Texas take a photo break while learning about Pennsylvanian stratigraphy and sedimentology, and water power, at McConnells Mill State Park (see article on page 13).

—Photograph by Gary M. Fleeger

EDITORIAL

From Conyngham to Japan

George E. W. Love, State Geologist
Pennsylvania Geological Survey



A wide variety of subjects, with interesting perspectives from the Marcellus to human interest, await you in this edition of *Pennsylvania Geology.* Some might feel that there is too little focus on geology, but I disagree. The excellent and informative article on the Marcellus gas play and its related water issues informs us in an understandable manner devoid of rants and conjecture. The articles by our interns share how teachers are being exposed to facts and issues related to the Marcellus, how we communicate with scientists from other countries, and how an education on Pennsylvania's hydrocarbon history can be gained through a fun visit to Titusville and the Drake Well Museum. Finally, Gary Fleeger's short but interesting article on the GeoFORCE program buoys my faith that we will have a future generation of thoughtful geological scientists. The profession has suffered decreases in enrollment in post-high-school institutions, according to studies by the American Geosciences Institute. That trend needs to be corrected to sustain our way of life, from both the "find resources" and "be environmentally responsible" sides of the science.

The articles written by two of our interns on pages 14, 15, and 16 make me proud, not because they are technical, but because they are representative of a component of the training in the next wave of geologists. The science aspects of the career are important, but the communications aspects are equally important. As an "old guy," I cannot count the number of presentations I have had to sit through—yes, "had to"—because the presenter was well meaning but frankly incapable of making a coherent presentation. As speakers, we owe a great deal to the audience; they are taking their valuable time to listen. Thank you to the interns and to those institutions of higher learning who see communication skills as a critical component of a scientific education.

And a nod to the publication of the Conyngham quadrangle! This effort has been 33 years in the making. The Survey is known for its high-quality, well-reviewed publications. Previous publication methods required much "hands on" preparation of maps, plates, and figures. Newer technologies now allow us to prepare information more quickly. Of course, the amount of time required to thoughtfully and accurately research the facts, assemble the interpretations, and subject our efforts to the peer review process may still be substantial. Additionally, and sometimes more importantly, changes in priorities have an impact on how quickly we produce publications. This is not an excuse, just a fact.

Finally, please read the announcement on page 19 about this year's Field Conference of Pennsylvania Geologists. Not only will the geology be worth viewing, the mid-October schedule will show off the autumn colors of our state (as well as those nearby Pennsylvania wannabes, New York and New Jersey). I look forward to this annual event where we can share information, interpretations, and camaraderie. What could be better?

The Marcellus Shale Gas Play—Geology and Production and Water Management, Oh My!

Katherine W. Schmid
Pennsylvania Geological Survey

Introduction

The Middle Devonian Marcellus shale underlies much of Pennsylvania, and many gas wells are being completed to produce from it. Some wells produce lots of natural gas (millions to billions of cubic feet or MMcf to Bcf), but others don't produce as much (thousands of cubic feet or Mcf). How much gas is produced from each well depends on geologic, engineering, and anthropogenic factors and constraints. Thousands to millions of gallons of water are used to drill these wells. Although some of this water does not return to the surface, a certain amount does "flow back" and requires safe disposal. In addition, all of the well drilling, completion, and stimulation techniques are constantly evolving. This paper contains information about where Marcellus shale gas wells are being drilled, what affects their production, how water is utilized in these wells, and the fate of that water.

Some of the information has been obtained from the Pennsylvania Internet Record Imaging System (PA*IRIS) (a database of oil and gas records reported to the commonwealth). PA*IRIS combines scanned images of oil and gas documents with the Survey's Wells Information System (WIS), a comprehensive database in which details associated with drilled oil and gas wells, as well as details for undrilled, canceled, void, or expired drilling permits, are stored and organized. More information about PA*IRIS can be found at www.dcnr.state.pa.us/topogeo/econresource/oilandgas/pa_iris_home/index.htm.

Marcellus Drilling Activity and Production

The Marcellus shale is a very productive shale gas reservoir, and many wells have been drilled in it during the past decade. In June 2002, Range Resources Appalachia LLC (Range) drilled the Renz No. 1 well down to the Lower Silurian Rochester Shale in Washington County (Pennsylvania Geological Survey, 2012). They originally hydraulically fractured (or "fraced") the well in three deeper formations in 2003: the Lower Devonian Oriskany Sandstone, dolostone beds in the Upper Silurian Salina Group, and the Lower Silurian Lockport Dolomite. The Marcellus interval was then fraced in 2004 using a method found to be effective in the Mississippian Barnett Shale in Texas. After completing the Marcellus, the well produced an average of 81 Mcf/day over 1,856 days (Pennsylvania Department of Environmental Protection, 2011). Other operators saw these results and began testing the Marcellus themselves. Growth was slow at first, and only a couple of vertical wells were drilled per year in the Marcellus in various counties until 2006. Range drilled a horizontal Marcellus well in 2007 (Pennsylvania Geological Survey, 2012), which produced an average of 513 Mcf/day for 791 days (Pennsylvania Department of Environmental Protection, 2011). After that, drilling Marcellus wells took off (Figure 1). Fifteen percent of the Marcellus wells completed in 2007 were horizontal. By 2011, 96 percent of the Marcellus wells were horizontal. As of the end of 2011, 1,034 Marcellus wells had been completed in 27 Pennsylvania counties by a total of 54 operators (Pennsylvania Geological Survey, 2012). In this context, a well is not considered completed until it has been prepared for production (i.e., it has been perforated or fraced) or has reported natural production.

Marcellus production is not uniform across the state. Even though Washington County is home to the discovery well of the Marcellus play and, according to our database (Pennsylvania Geological Sur-

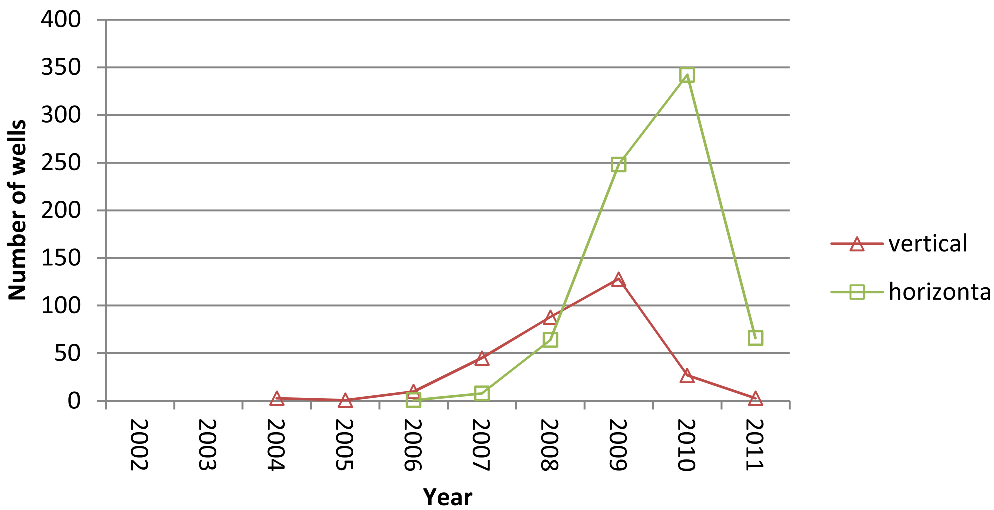


Figure 1. Annual Marcellus well completions through the end of 2011 (Pennsylvania Geological Survey, 2012).

vey, 2012), has the most Marcellus wells of any county in the commonwealth, Bradford and Susquehanna Counties have produced more gas from this organic-rich shale. The first Marcellus wells in Bradford and Susquehanna Counties were drilled in 2006 (Pennsylvania Geological Survey, 2012), but most of the wells completed there were drilled in 2009 or later.

Looking at the county-specific average daily production numbers provides a better comparison than simply counting the numbers of wells. Figure 2 shows the average daily Marcellus production in each county and the range between the highest and lowest producers in each. Bradford and Susquehanna Counties both produce more than the statewide daily average, while Washington County produces a little less. All the counties with more than just a couple of wells drilled show a broad range in production. Susquehanna County wells exhibit the largest variation, ranging from 3 Mcf per day (Mcf/d) to 22,726 Mcf/d. Cambria County has the lowest average daily production, 33 Mcf/d, but this represents only a single well.

Reservoir Geology and Engineering Characteristics

What causes these variations in production? First, the subsurface geology associated with a well site affects how much gas can be produced. This includes numerous physical and chemical factors that have affected the rock since it first formed, internal changes that occurred over time, and structural deformation. Second, how that well is drilled and completed also influences gas production.

The first geologic factor that affects natural gas production is the geochemistry of the rock. Hydrocarbons cannot be generated if the total organic content (TOC) of the rock is less than 1 percent of its mass (Laughrey, 2009). TOC measurements in the Marcellus range from 0.3 percent to 7.2 percent in Pennsylvania (Laughrey and others, 2011). Higher TOC concentrations generally mean that more hydrocarbons can be generated. Although we don’t know what the TOC values of the Marcellus were at the time most of the state’s oil and gas was generated about 300 million years ago, they had to be significantly higher than they are today.

A second important geologic factor is the depth and thickness of the shale. Heat and pressure increase with increasing depth, and these work together to generate hydrocarbons in the source rock. This generation and expulsion of fluids then raises the rock pressure even higher (Lash and Blood, 2007). Because of these increasing pressures in the shale, seals are necessary to prevent the gas from

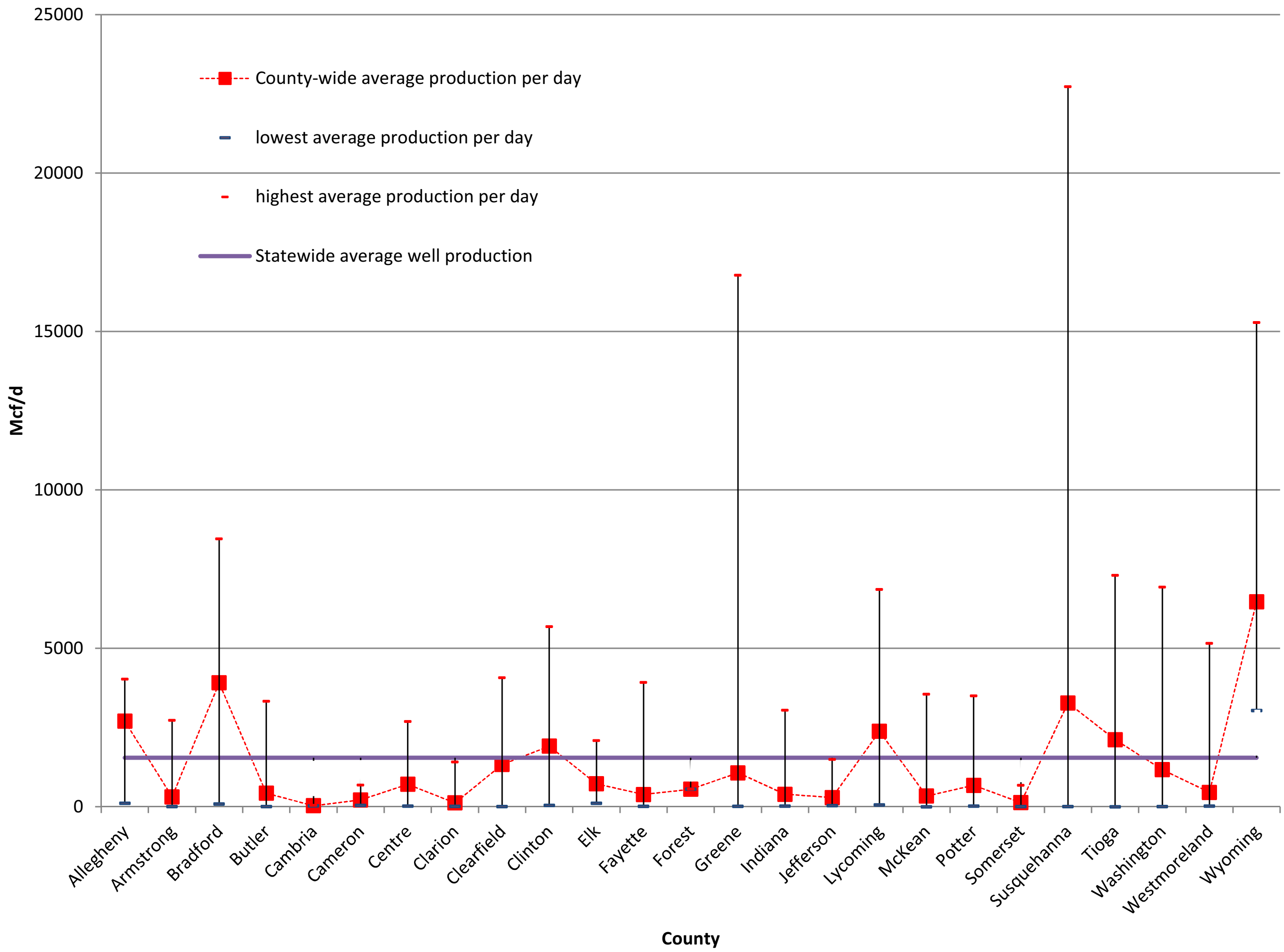


Figure 2. Average daily Marcellus gas production per well in Pennsylvania counties through June 2011. The highest and lowest daily values for each county are also shown.

escaping (Lash, 2006). Organic shales can act both as a source of the natural gas and a seal that traps it (Engelder, 2008). Thicker shales make better seals and have the potential to generate more hydrocarbons. The thickness of the organic-rich portion of the Marcellus shale varies across the state (Figure 3), as does its depth (Figure 4).

Geologic structure also affects natural gas production. Joints and fractures are important for enhancing gas production in low-permeability shales (Engelder and others, 2009). They provide space to store the gas and flow paths for the gas to travel along. On the other hand, the existence of faults may compromise the integrity of the reservoir's seal or otherwise cause adverse effects on production. Faulting in the Marcellus has led to low production in some wells (Jonathon Brady, personal communication, 2007). Faults have been mapped in the Marcellus or underlying Onondaga Limestone over much of the western and northeastern part of the state (Figure 4).

In addition to these and other geologic factors, reservoir engineering methods also impact gas production. These include, among other things, the type or orientation of the well (whether it is vertical, slanted, or horizontal), what drilling fluid is used to drill the well, the fracing method used, the number of stages (sections of the well that have been isolated for fracing) stimulated, and the length of each stage. Horizontal wells produce more gas than vertical wells because more of the wellbore (the

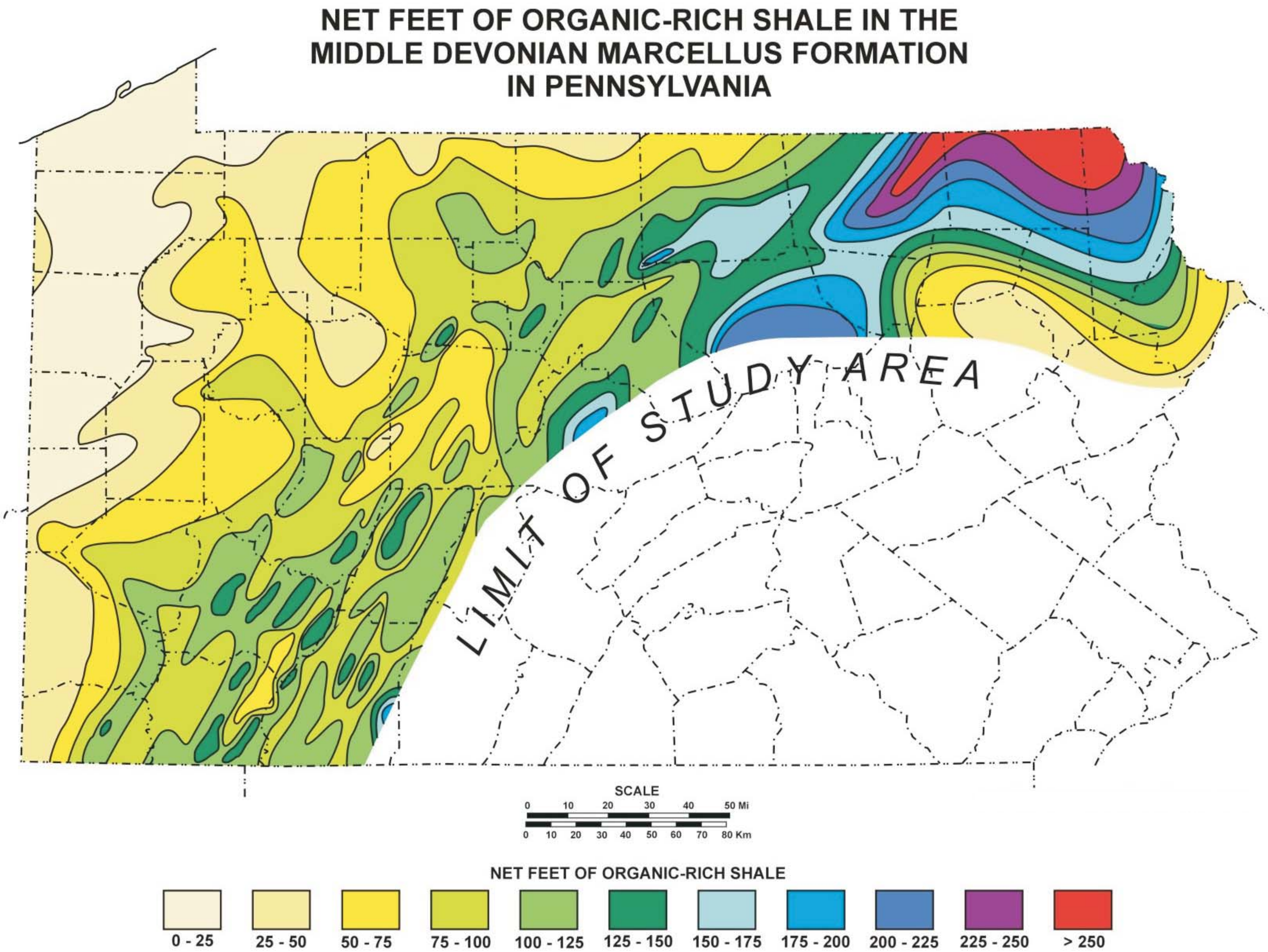


Figure 3. Net thickness of the organic-rich facies of the Middle Devonian Marcellus shale (modified from Piotrowski and Harper, 1979).

horizontal part, or lateral) is in contact with the source rock. The equipment and fluid used during drilling are also important considerations. Wells can be drilled with various rigs, drill bits, and fluids. As an example, although wells can typically be drilled faster using air as the drilling fluid, these wells tend to have more hole-stability problems than wells drilled with muds. Conversely, drilling a well using a drilling mud that is too thick may inhibit fracture creation when that well is completed. So ultimately, the choice of drilling fluids and techniques may vary regionally. Finally, the number and length of the well stages fraced depends on the length of the wellbore and/or lateral as well as engineering considerations.

Water Usage and Natural Gas Production

Drilling and completing Marcellus wells typically uses millions of gallons of water. As of 2010, obtaining this water had not been a barrier for gas companies in the Marcellus region (Veil, 2010). The amount of water used while drilling the well depends on how the well is drilled and the total depth of the well. Veil (2010) estimated that an average of 80,000 gallons of water is used per Marcellus well during the drilling process.

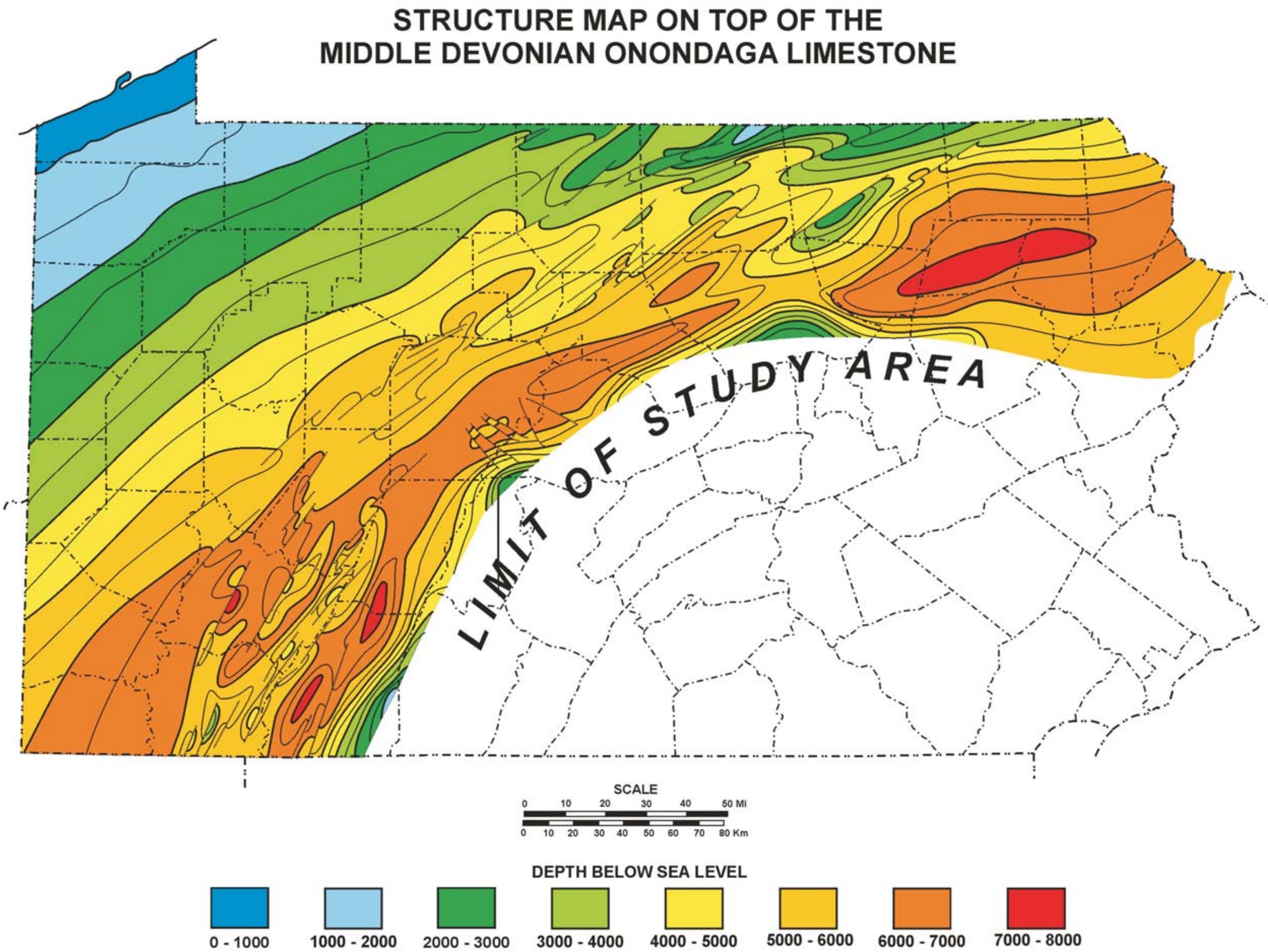


Figure 4. Structure map on the top of the Middle Devonian Onondaga Limestone. This map shows the elevation below sea level of the base of the Marcellus shale (modified from Piotrowski and Harper, 1979).

The hydraulic fracturing of wells uses even more water. Just under 1 million gallons of water were used to frac the Marcellus discovery well in 2004, and the first horizontal Marcellus well in Pennsylvania was fraced with 3.7 million gallons of water (Pennsylvania Geological Survey, 2012). Based on data obtained from PA*IRIS/WIS through the end of 2010, the amount of water used in frac jobs definitely varies depending on the type of completion. For vertical Marcellus wells, water usage has ranged from less than 40,000 gallons to as much as 8.2 million gallons, with an average of 1.0 million gallons of water per frac job. Horizontal Marcellus wells used an average of 3.8 million gallons of water per frac job, with numbers ranging from about 60,000 gallons to 12.4 million gallons (Pennsylvania Geological Survey, 2012).

Why is so much water being used to complete Marcellus wells? One of the main reasons is fractures. Injecting water increases the complexity of fracture networks (Warpinski, 2006), which are the key components in the production of natural gas from shales. Marcellus wells typically produce more gas when more water is used in the frac job (Figure 5). As several factors impact gas production (above and beyond the volume of water used), a statistical correlation between production and water usage has not been attempted here.

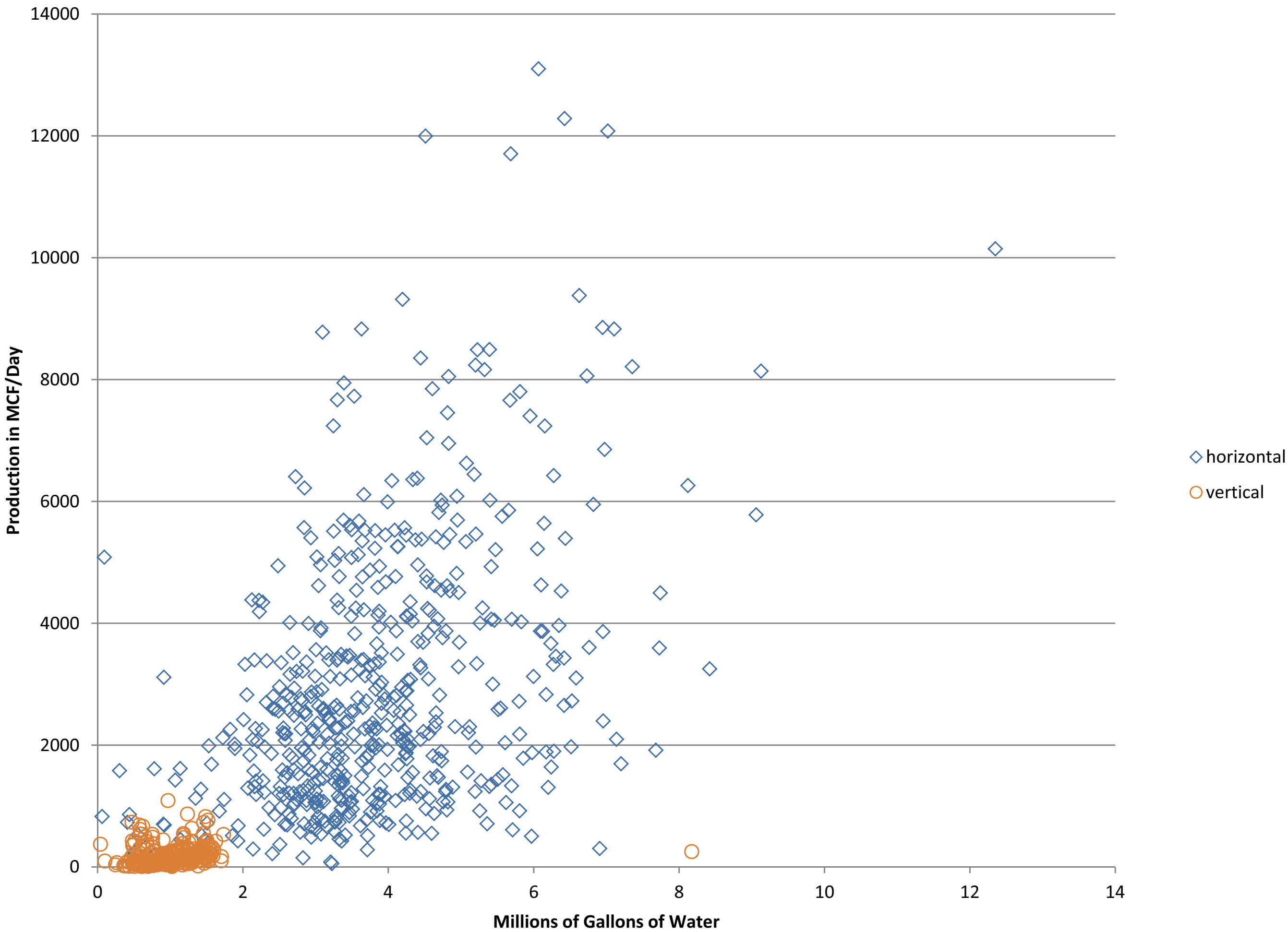


Figure 5. Average Marcellus gas production per million gallons of water used for horizontal (blue diamonds) and vertical (orange circles) well stimulations.

Ground Water Protection Council and ALL Consulting (2009) predicted that as technology and methods improve, less water will be needed per foot of completed wellbore. So far, we have not observed this trend in the Marcellus in Pennsylvania. The amount of water used per foot of wellbore to complete vertical wells is gradually increasing. In contrast, the amount of water used per foot of wellbore in horizontal completions has more than tripled since 2007 (Pennsylvania Geological Survey, 2012). Also, the average total measured depth of both horizontal and vertical wells is increasing (Pennsylvania Geological Survey, 2012) (Figure 6). With this combination of higher average water use per foot and deeper (longer) wells, one can see water usage increasing in the Marcellus shale gas play.

Wastewaters

After drilling and during gas production, Marcellus wells produce water. Initially, some of the frac water flows back to the surface. This flowback water produces high discharge rates (greater than 1,575 gallons per day) for a short period of time (Schramm, 2011). Total dissolved solids (TDS) in flowback water ranges from 30 grams per liter (g/L) to 200 g/L (Vidic, 2010). Not all of the frac water flows back, however. Some remains in the rock formation at depth. Recovery estimates for flowback water range from 9 percent to 70 percent (Ground Water Protection Council and ALL Consulting, 2009; Carter, 2010; Hoffman, 2010; and Jiang and others, 2011).

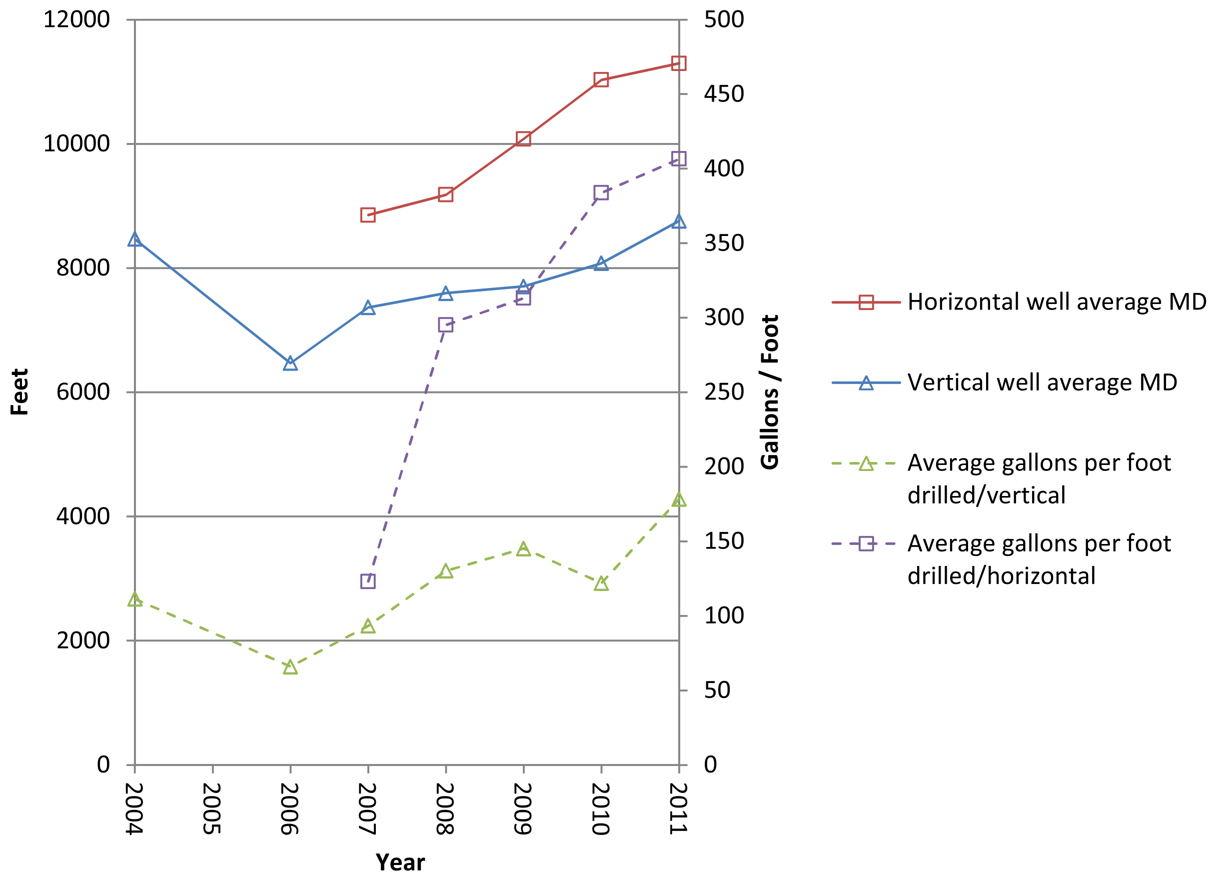


Figure 6. The average water volume used per foot drilled (dashed line) compared with the average measured Marcellus well depth by year (solid line). Measured Depth (MD) is the total depth/length of the drilled well. Horizontal wells are shown using boxes and vertical wells are illustrated with triangles.

Eventually, flowback water discharge is replaced by that of produced water, also known as formation brines. Brines are naturally present in the pore spaces of subsurface rocks and as moisture adsorbed onto grains of the rock (Poth, 1962). Produced water flow rates tend to be lower than those of flowback water (i.e., 63 to 945 gallons per day), and tend to discharge for the life of the well (Vidic, 2010). TDS ranges are much higher in produced waters (100 to 300 g/L) (Vidic, 2010).

All returned waters from gas-well sites are considered to be industrial wastewaters and need to be disposed of accordingly (Pennsylvania Department of Environmental Protection, 2012). To understand the potential fate of these waters, wastewater reports for Marcellus wells completed between June 2009 and June 2011 were obtained from the Department of Environmental Protection (DEP) (Pennsylvania Department of Environmental Protection, 2011). Figure 7 shows the total amount of wastewater reported for each county. The totals include fluids reported as drilling fluids, frac flowback water, and produced water. These have not been differentiated because the criteria used by the companies to report their data are unknown.

After flowback water and brines are recovered, they need to be properly disposed of in some way. Six disposal methods have been reported to the state to date: industrial waste treatment plants, reuse other than road spreading, injection disposal wells, municipal sewage treatment, landfills, and road spreading (Pennsylvania Department of Environmental Protection, 2011). Figures 8 and 9 illustrate the relative extent to which these methods have been used by oil and gas operators during the periods June

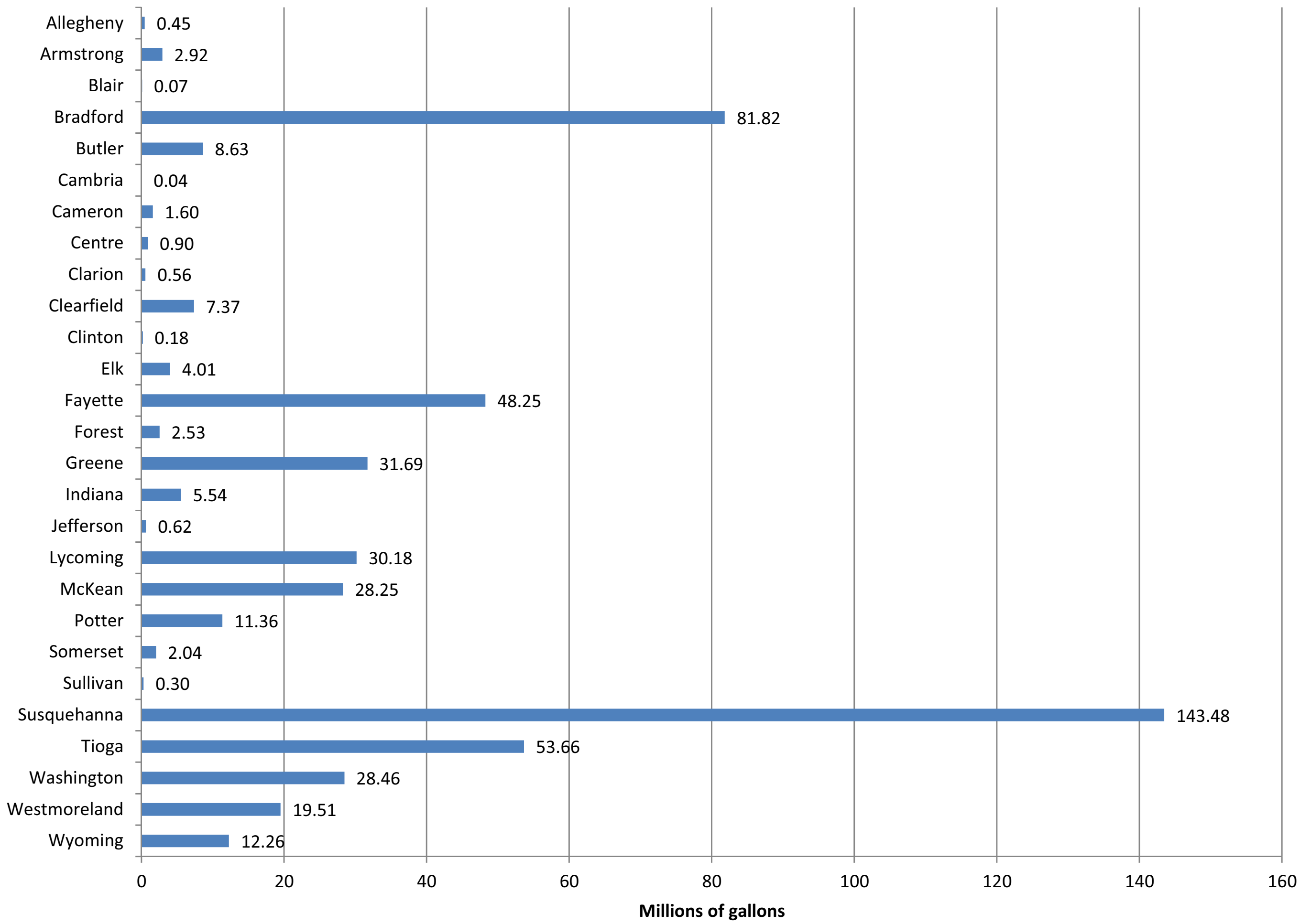


Figure 7. Total amount of wastewater reported from Marcellus wells for Pennsylvania counties from June 2009 through June 2011 (Pennsylvania Department of Environmental Protection, 2011).

2009 through December 2010 and January through June 2011, respectively. Note that landfills and road spreading are not shown in these pie charts because so little Marcellus wastewater had been disposed of using these methods during the 2009–2011 time frame. In addition, these figures are based specifically on data from Marcellus wells that included not only the volume of brine recovered but also the disposal method used.

Prior to 2011, a majority of brines were reported as being disposed of in industrial waste treatment plants. While most of these plants are situated in Pennsylvania, a few are located in West Virginia, Ohio, Maryland, New Jersey, and Texas. The Marcellus is the only major shale play in the United States that has utilized industrial wastewater treatment plants or municipal sewage plants to treat flowback and produced waters (Ground Water Protection Council and ALL Consulting, 2009). Because most treatment plants are not equipped to treat TDS, the Pennsylvania Governor's Marcellus Shale Advisory Commission called for operators to cease disposal at wastewater plants that do not remove high concentrations of TDS and constituents such as bromide (Governor's Marcellus Shale Advisory Commission, 2011). Now, much more water is being recycled and reused, and more water is being sent to injection wells. A smaller percentage of water is being sent to industrial waste treatment plants and almost none is being sent to municipal sewage treatment plants (Figure 9).

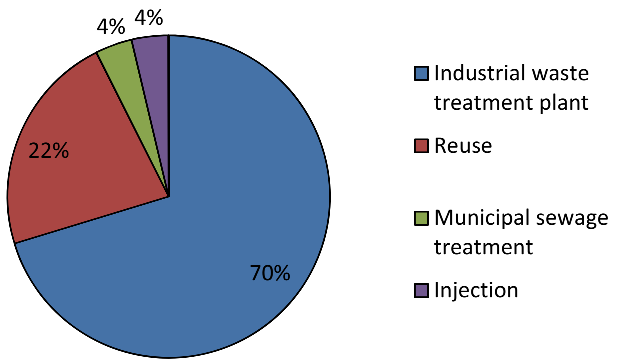


Figure 8. Ratio of brine disposal methods reported to the Pennsylvania Department of Environmental Protection from June 2009 through December 2010.

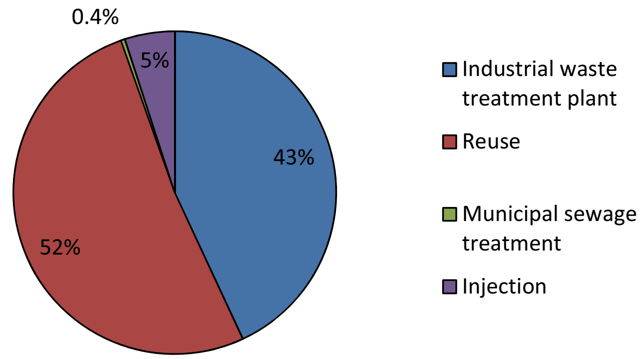


Figure 9. Ratio of brine disposal methods reported to the Pennsylvania Department of Environmental Protection from January 2011 through June 2011.

Based on well stimulation details provided by operators on official well completion reports, 12 percent of all the water used to complete Marcellus wells in Pennsylvania during the first half of 2011 was recycled from other wells (Pennsylvania Geological Survey, 2012). Recycling and reusing water has both advantages and disadvantages. Concentrations of several chemical constituents need to be brought to low levels or gas production will be inhibited. Even so, service providers are learning how to use waters with higher TDS concentrations (ProchemTech International, Inc., 2011). Reusing flowback water is a good way to cut back on freshwater usage and reduce water transportation costs and risks. Early results from using recycled waters in well completions look promising (Veil, 2010), and, in fact, at least three other United States shale plays also use recycled water (Ground Water Protection Council and ALL Consulting, 2009).

Conclusions

Marcellus shale gas wells are being drilled in a considerable number of Pennsylvania counties. As production ultimately depends on many geologic and human-influenced factors, some areas of the commonwealth are more productive than others. The drilling and completion of Marcellus wells uses thousands to millions of gallons of water. After a well is completed, some of that water flows back to the surface, only to be replaced, ultimately, by the discharge of formation brines. These wastewaters must be handled and disposed of appropriately. Of the six disposal methods oil and gas operators have reported to the DEP to date, a majority of Marcellus wastewaters are being disposed of in industrial wastewater treatment plants or are being recycled and reused at well sites. Recent data gathered for the period of January through June 2011 indicated that disposal in wastewater treatment plants is waning in popularity as more water is being reused in the drilling and fracing processes.

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EARTH SCIENCE TEACHERS' CORNER

GeoFORCE Texas Visits Pennsylvania

Gary M. Fleeger
Pennsylvania Geological Survey

Eighty high school students from Houston, Tex., and southwest Texas (southwest of San Antonio) visited Pennsylvania this summer as part of a week-long geology field trip across the Appalachians (see cover photograph).

GeoFORCE Texas (www.jsg.utexas.edu/geoforce/) is a selective outreach program of the Jackson School of Geosciences at the University of Texas at Austin. The goal is to target inner-city Houston and rural southwest Texas schools (specifically minority populations), to encourage more students to finish high school and go to college, and to spark their interest in science and math. Thus far, the program has succeeded admirably, with almost 300 graduates, a 100 percent high school graduation rate, and a 98 percent enrollment in college, mostly in science and math programs. Each year, about 40 students are selected from each of the two areas to participate in the program. Those students participate in a week-long field trip to a different part of the United States each summer during their four years of high school. The program culminates with the field trip across the Appalachians, where they can relate much of what they have learned in the trips of the previous three years to the complex geology of the Appalachians. GeoFORCE is provided at no cost to the students through generous donations of several dozen industry, foundation, government, and individual sponsors.

This year's trip, which took place from July 8 through July 15, 2012, started in Pittsburgh, and proceeded to five stops in Pennsylvania before moving on to Maryland, West Virginia, Virginia, and Washington, D.C. At the Pennsylvania stops, the students saw various aspects of the glaciation of northwestern Pennsylvania in the Moraine and McConnells Mill State Parks area, the bedrock and structure of the Appalachian Plateaus physiographic province, and various sources of energy. As they continued on to the Ridge and Valley province, they started with a spectacular view from the Ship Hotel overlook on U.S. Route 30 in Bedford County before traveling to Maryland to look at more details of the Ridge and Valley structures, as well as the geology of the Blue Ridge, Piedmont, and Atlantic Coastal Plain provinces. Tours of museums of the Smithsonian Institution and the U.S. Geological Survey headquarters were included in the trip.

This is the eighth year of the GeoFORCE Texas program, and the second visit to Pennsylvania. However, they are currently planning to return to Pennsylvania as part of their 12th Grade Summer Academy to the Appalachians each summer. GeoFORCE relies heavily on assistance from local geologists. The Pennsylvania Geological Survey, especially geologists Gary Fleeger and James Shaulis, worked with GeoFORCE to select sites and help develop the Appalachian trip, to write the guidebook, and to provide staff to serve as instructors.

The students are very appreciative of the effort put in by the staff, as evidenced by the thank-you card that Fleeger received. A comment on the card from one of the students sums it quite well: "Thank you for making even a boring rock cliff very interesting."

SUMMER AT THE SURVEY

Ah, summer! It's the time for picnics, swimming, and vacationing in far-off places. It's also the time when geologists go outdoors to look at rocks and make maps. It's true that some geologists prefer cooler days, but much work is accomplished in summer. In addition, our halls and offices are crammed with summer students, who provide support for our work at the bureau and who obtain valuable experience and knowledge. Below are summaries of three activities that took place at the Pittsburgh office this season.

Pennsylvania Geological Survey Hosts Teacher Workshop

Melissa R. Sullivan[1] and Kristin M. Carter
Pennsylvania Geological Survey

On July 11 and 12, 2012, the Pittsburgh Geological Society sponsored an outreach program for K–12 teachers at the Pittsburgh office of the Pennsylvania Geological Survey. The goal of the program was to inform teachers about current natural gas plays in Pennsylvania. Various professionals were brought in to talk to the teachers about the history, process, concerns, and benefits of natural gas drilling and hydraulic fracturing (abbreviated as "fracing" and pronounced "fracking"). John Harper and Kristin Carter, Survey staff geologists, gave presentations on oil and gas geology, the history of the petroleum industry in Pennsylvania, and water management during drilling and completion of shale gas wells. Albert Kollar and Raymond Follador, both members of the Pittsburgh Geological Society, spoke on how the future of energy is taking shape and details of the shale gas fracing process, respectively, presenting the teachers with both the pros and cons of domestic energy development. The last group of speakers included Jill Kriesky from the Center for Healthy Environments and Communities and Raina Rippel from the Southwest Pennsylvania Environmental Health Project. They focused on possible health concerns associated with Marcellus shale development, and the need for a long-term study of health near drilling sites. During the two-day workshop, much attention was focused on the media's view and treatment of the Marcellus shale play, some of which has misinformed the public. Teachers left with a better understanding of oil and gas drilling and hydraulic fracturing and with ideas on how to pass this knowledge on to their students.

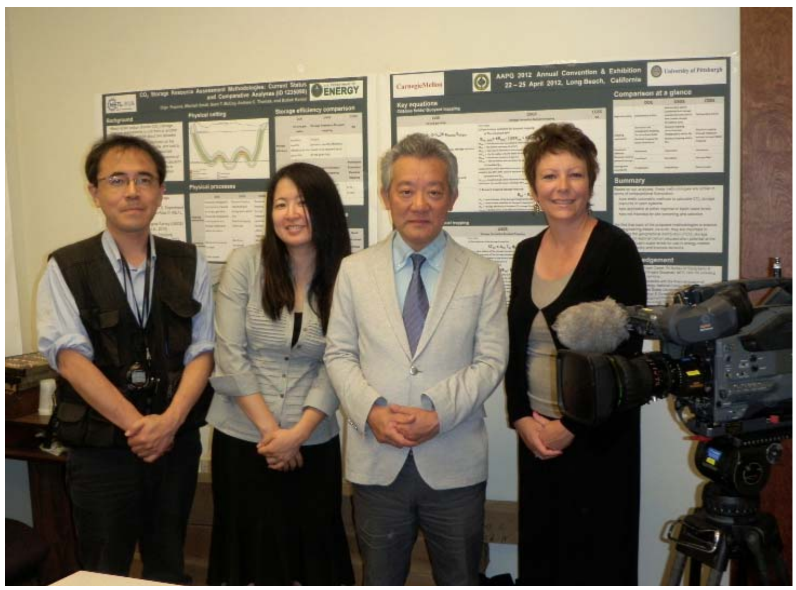
Teachers spent part of their summer learning about the oil and gas industry.

[1]Summer intern.

The Open University of Japan Visits the Pennsylvania Geological Survey

Michele L. Cooney[1]
Pennsylvania Geological Survey

Researchers from The Open University of Japan paid a visit to the Pittsburgh office of the Pennsylvania Geological Survey on July 5, 2012. The University of Japan, which has about 80,000 students nationwide, is preparing an educational film on drilling in the United States, shale gas, and how energy is being developed, which will be shown on Japan's national educational television channel. After visiting a drilling rig site in Greene County, Professor Kazuo Takahashi and his colleagues sat down with Kristin Carter, Chief of the Petroleum and Subsurface Geology Section, to discuss the production of oil and natural gas in the region. Even though the focal point of conversation was the emergence of the Marcellus shale gas play in the Appalachian basin, Carter briefed Takahashi on the rich history of oil and gas production in Pennsylvania so that he could understand the backdrop of the state's current activity relative to its decades of petroleum activity and experience. Takahashi was given insight into the Appalachian basin's favorable geologic resources and how technical advances and economic incentives have brought many oil and gas operators to the region. While many view gas production as a benefit to both the commonwealth and its residents, Carter explained that there are still opponents to natural gas drilling from an environmental perspective.



From left, the three visitors from Japan are Yuji Takeya, Tomoko Kawasumi, and Kazuo Takahashi. On the right is Kristin Carter.

Carter also discussed how the Survey focuses on outreach, working to educate the public about oil and gas geology, drilling, and industry activity. The Survey's website hosts organic-rich-shale data, maps, and presentations, as well as lesson plans for educators and a "Kid's Corner" for young students. In addition, the Survey's libraries are open to the public and feature maps, Survey publications, aerial photographs, and additional printed texts and journals. Professor Takahashi and his colleagues were both interested and excited to hear about oil and gas production in Pennsylvania, as well as the immense amount of outreach that the Survey offers to the public. In fact, Professor Takahashi's parting comment was that he was glad to see Pennsylvania's oil and gas industry "back on the map."

[1]Summer intern.

Survey Interns Visit Historic Titusville

Melissa R. Sullivan[1] and Kristin M. Carter
Pennsylvania Geological Survey

Figure 1. A replica of the Drake well.

On Friday the 13th (July 13, 2012), interns from the Survey's Pittsburgh office visited the Drake Well Museum and grounds in Titusville, Pa. (Figure 1). Much fun was had hunting for fossils from the "Drake Well Formation" outcrop near the railroad tracks opposite the parking lot. After having searched (with no success) for an elusive Pennsylvanian-age sponge *(Titusvillia)* and having seen many bivalves and trace fossils, the interns toured the museum, which has been undergoing major construction and remodeling in preparation for a grand reopening in August 2012. Although only a limited portion of the museum was accessible due to this construction, the interns were able to make silly putty (an oil-based creation), play with interactive exhibits, and learn about past and current uses of petroleum. They also explored the outdoor section of the museum, interacting with historical drilling equipment and nitroglycerin trucks, some of which were still working. Impressive attractions included working rigs, a barker, and a replica of Drake's oil well. A barker is an auditory device that attaches to an engine house to produce a distinctive noise, allowing rig operators to monitor their wells from far away.

The grand opening of the Drake Well's newest exhibit, called "There's a Drop of Oil and Gas in Your Life Every Day," occurred on August 26 (Figure 2). From the sneak peek the interns received, it is clear that there are many fun things for kids to do and parents to appreciate. Oil's integral role in our lives, as well as the history and evolution of the oil industry, can be learned from the exhibits. The museum is a must-see, and its newest exhibit will be a great addition.

Figure 2. "Save the Date" card for the grand opening of the new exhibit at the Drake Well Museum.

[1]Summer intern.

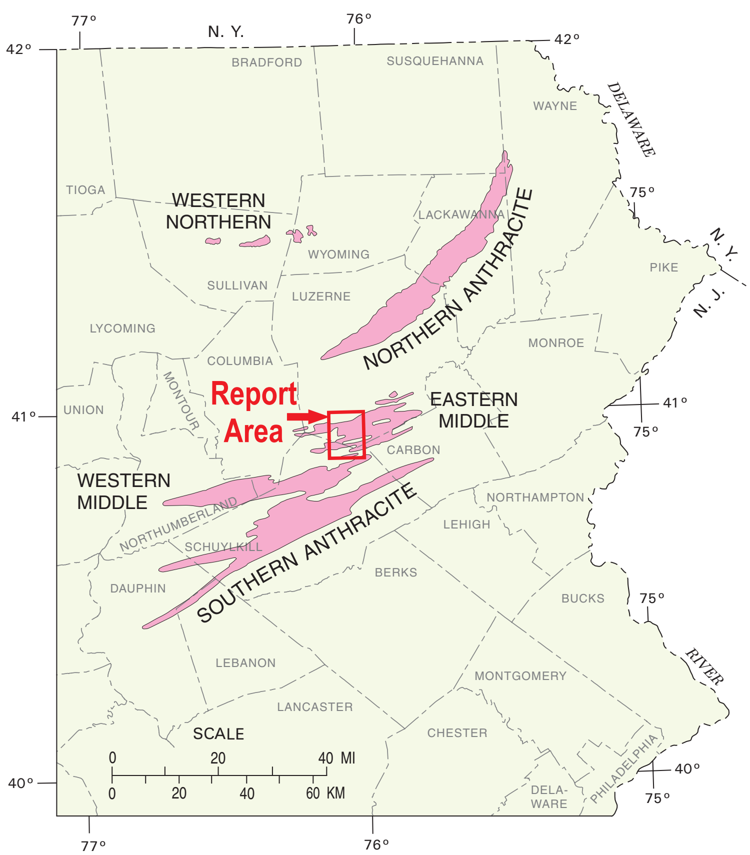
NEW RELEASE

Conyngham Maps, A Long-Awaited Arrival

Caron E. O'Neil and Jon D. Inners[1]
Pennsylvania Geological Survey

In 1979, Pennsylvania Geological Survey geologist Henry W. Schasse was given the assignment to map the geology of the Conyngham 7.5-minute quadrangle. He spent two seasons in the field before he left Pennsylvania and subsequently took a job at the Washington Geological Survey. Five years later, staff geologists David B. MacLachlan and Jon D. Inners continued the project, and in 1987, they submitted a bedrock geologic map (scale 1:24,000) and a coal resource map (scale 1:12,000) for review. Three years later, the Conyngham job was approved for formal publication.

The former Editing Section of the Survey then began preparing the maps for printed publication. A cartographer scribed coated mylars that would be used to produce the peelcoat negatives needed to create the map colors. An editor reviewed the maps for consistency and laid out the map plates, editing and setting type for the unit descriptions, tables, and explanation of symbols. As the job progressed, printing specifications were given to the commercial printer, who then supplied a cost estimate. It was to be one of the Survey's more expensive jobs.



Location of the Conyngham quadrangle in the Pennsylvania anthracite fields.

It was at this point that the job came to an indefinite halt. The state budget had become tight, and other jobs in the queue were given priority over Conyngham. The years passed, but the job was not forgotten. Occasionally, we would get requests from people aware of the work, and the third author (Inners) would remind those in authority of the importance of these maps.

In 1998, staff geologist Thomas G. Whitfield used GIS software in an effort to produce a no-cost digital version of the Conyngham job. The complexity of the geology and density of the linework on the compilation maps made this a time-consuming and difficult task, and once again the job was set aside.

This year, Conyngham was finally pushed back to the top of the list. With the benefit of a higher resolution scanner and improved GIS software, the maps were prepared as PDF files by staff geologist Caron E. O'Neil and released on the Survey's website as Atlas 175b, Bedrock Geology and Coal Resources of the

[1]Retired.

Conyngham Quadrangle, Luzerne and Schuylkill Counties, Pennsylvania. The GIS dataset that was used for this job is also available on the same site.

The Conyngham 7.5-minute quadrangle is located almost entirely in the medial part of the Eastern Middle Anthracite field, but it does include a small part of the Silver Brook basin at the extreme eastern end of the Western Middle field. The stratigraphic section extends from the Mississippian-Pennsylvanian Mauch Chunk Formation, through the Pennsylvanian Pottsville Formation, and up into the coal measures of the Pennsylvanian Llewellyn Formation. The largest coal basins are the Honeybrook and Cranberry in the eastern part of the quadrangle, the Green Mountain and Oneida in the western part, and the Tomhicken in the northern part. Minable coal beds range from the Alpha in the Pottsville Formation to the Orchard in the upper part of the exposed 750 feet of the Llewellyn Formation. The most important coal beds are the Buck Mountain, Gamma, Wharton, and Mammoth, all of which are in the Llewellyn Formation. When the map data was compiled, approximately 69 million short tons of anthracite was still in place, all of it within 1,000 feet of the surface. Since that time, there have been no large-scale mining operations in the Conyngham quadrangle, and it is unlikely that such operations will ever again be undertaken.

Along the eastern edge of the quadrangle, roadcuts on Interstate Route 81 provide a very instructive north-south cross section of the Conyngham area. The cuts extend from the south, where there is a spectacular cut through a thrust-faulted syncline in the Mauch Chunk-Pottsville Formations at Spring Mountain, west of McAdoo, to 6.5 miles away to the north, where there are several cuts (again in the Mauch Chunk-Pottsville Formations) through Butler Mountain at Interchange 145, northwest of West Hazleton. Between these two points are cuts through an anticline in the Mauch Chunk at Pismire Ridge (Interchange 141), a long cut through the Llewellyn Formation at Harwood, and cuts through two anticlines in the Pottsville conglomerate west of West Hazleton, the northern of which is particularly photogenic. The scenic "crown jewel" of the quadrangle, however, is the view from the *Top of the 80's* restaurant shown below.

Northwest-facing view of the Conyngham Valley from Top of the 80's *restaurant at the intersection of Interstate Routes 80 and 81. Sugarloaf Mountain is prominent in the back center part of the photograph, and Nescopeck Mountain forms the long ridge behind it.*

ANNOUNCEMENT

Field Conference of Pennsylvania Geologists, 2012

It's time to be thinking about this year's Field Conference of Pennsylvania Geologists, which will be held on October 19 and 20, 2012, and which will include four optional pre-conference field trips and activities. This year's topic is "Journey Along the Taconic Unconformity, Northeastern Pennsylvania, New Jersey, Southeastern New York."

The Field Conference has visited many sites along the Ordovician-Silurian boundary. The "transitional" contact between Silurian and Ordovician rocks in central Pennsylvania becomes unconformable in eastern Pennsylvania to southeastern New York as the hiatus widens. Following the northeastward decrease in intensity of deformation in the Ridge and Valley physiographic province through New Jersey, this trip will begin at the high-angle contact between the Tuscarora and Hamburg sequence at the Schuylkill River and proceed for 120 miles along the very low-angle unconformable contact between Lehigh Gap, Pa., and Ellenville, N.Y. Predominant Alleghanian deformation along the contact will be suggested, and, in New Jersey and New York, zones of increasing southeastward Taconic deformation away from the contact will be proposed. We will demonstrate the relative intensities and trends of Taconic and Alleghanian deformation in New York, and we will comment on the northeastward dying-out of Alleghanian structures in the Shawangunk Mountains. The perplexing story of events during the Taconic hiatus, lasting perhaps 10 to 20 million years, will be illuminated by an unusual diamictite in southeastern New York. For more information and registration materials, please consult the Field Conference's website at http://fcopg.org/.

RECENT PUBLICATIONS

Surficial geology open-file reports **(July 2012)**

- Surficial geology of the Benton 7.5-minute quadrangle, Columbia and Lycoming Counties, Pennsylvania
- Surficial geology of the Stillwater 7.5-minute quadrangle, Columbia and Luzerne Counties, Pennsylvania

Bedrock geology open-file report: **(June 2012)**

- Bedrock geologic map of the Blossburg quadrangle, Tioga County, Pennsylvania

Atlas Report 175b **(June 2012)**

- Bedrock geology and coal resources of the Conyngham quadrangle, Luzerne and Schuylkill Counties, Pennsylvania

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