VOL. 34, NO. 2

Pennsylvania GEOLOGY

COMMONWEALTH OF PENNSYLVANIA
Edward G. Rendell, Governor
DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES
Michael DiBerardinis, Secretary
OFFICE OF CONSERVATION AND ENGINEERING SERVICES
Richard G. Sprenkle, Deputy Secretary
BUREAU OF TOPOGRAPHIC AND GEOLOGIC SURVEY
Jay B. Parrish, Director

Bureau web site: www.dcnr.state.pa.us/topogeo
DCNR web site: www.dcnr.state.pa.us
Pennsylvania home page: www.state.pa.us

CONTENTS

ON THE COVER

A skull cast of the Cretaceous *Tyrannosaurus rex* ("tyrant lizard king"). The cast, which can be seen in the lobby of the Pennsylvania Geological Survey's Middletown office, is a generous donation by Michael and Barbara Sincak, owners of Treasures of the Earth, Ltd. *T. rex* probably never lived in what is now Pennsylvania, but, as evidenced by fossil footprints from various locations in Triassic rocks in the southeastern part of the state, other dinosaurs once roamed the area. Photograph by Stuart O. Reese.

PENNSYLVANIA GEOLOGY

PENNSYLVANIA GEOLOGY is published quarterly by the Bureau of Topographic and Geologic Survey, Pennsylvania Department of Conservation and Natural Resources, 3240 Schoolhouse Road, Middletown, PA 17057–3534.
Editor: Anne B. Lutz.
Contributed articles are welcome. Guidelines for manuscript preparation may be obtained at www.dcnr.state.pa.us/topogeo/pub/pageolmag/pageolguide.aspx or by contacting the editor at the address listed above.

VOL. 34, NO. 2 **SUMMER 2004**

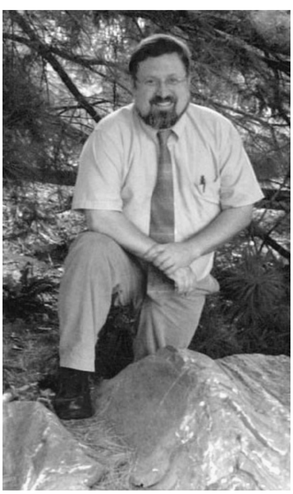
STATE GEOLOGIST'S EDITORIAL

Rock Boxes Are Back!

When I was about 10 years old, I wrote to the Pennsylvania Geological Survey, and in response, I received by mail my own rock collection in a white plastic box that had red text on it. It was one of about 20,000 that were sent out annually during the 1960s. This was a tremendous boon to me as a budding geologist because, living as I did in southeastern Pennsylvania, my rock collection until then consisted only of schist, gneiss, and some coal that fell off a truck. Suddenly, I had access to all sorts of rocks, positively identified by professional geologists.

I am pleased to announce that we have started offering rock boxes again. But, as you might imagine, costs have escalated. We have come up with a creative solution for providing both the interested public and schools with rock specimens from Pennsylvania. A box containing 12 samples of Pennsylvania rocks and spaces for six more of your own rocks will cost $15.00 ($19.95 if it is mailed). However, the proceeds will be reinvested so that, for each box sold, we can offer three boxes to teachers free of charge when they attend rock box workshops presented around the state. Our partners in the Department of Education and the Pennsylvania Aggregates and Concrete Association (PACA) have helped create the rock boxes.

On a Saturday in October, 75 teachers came to our office for a one-day workshop that included a field trip, hints on lesson plans, and the opportunity to put together their own rock boxes. This hard-working group did the latter at a rate of 500 per hour!



Keep an eye on our web site (see inside front cover) for ordering information or workshop information if you are a teacher.

And this holiday season, do what I do whenever someone asks about gift suggestions for others. Say, "Everyone appreciates getting rocks."

Jay B. Parrish
State Geologist

Practical Uses for Air Pollution—Carbon Dioxide

by John A. Harper
Bureau of Topographic and Geologic Survey

JUST THE FACTS, MA'AM. When you hear the word "air," you probably think of oxygen, the element we need to breathe and carry on with our lives. But air is actually a mixture of many elements and chemical compounds, the principal ones being nitrogen (78.1 percent), oxygen (20.9 percent), argon (0.93 percent), carbon dioxide (0.037 percent), and water vapor (between 0 and 4 percent, depending on humidity). Trace amounts of ammonia, carbon monoxide, helium, hydrogen, krypton, methane, neon, nitrous oxides, ozone, sulfur dioxide, and xenon also occur in the air we breathe. In certain concentrations, many of these components can have deleterious effects on human life. One of these, carbon dioxide (CO_2), is a good example.

CO_2 is a nonflammable, colorless, and odorless compound that can occur as a gas, liquid, or solid (dry ice). It is approximately 1½ times heavier than air. It occurs in the atmosphere naturally as a result of plant and animal respiration, volcanic activity, and forest fires. It also results from human activities such as manufacturing, transportation, and the burning of fossil fuels.

CO_2 occurs naturally underground as well. It forms in shallow soils as the result of respiration by plants and microbes, and within landfills, some coal seams, and oil and gas reservoirs as a result of the bacterial and thermal decomposition of organic matter. CO_2 also occurs deep within the planet—it is especially abundant in the earth's mantle; the amount of CO_2 there dwarfs the amount in the atmosphere.

CO_2 is essential to life on Earth. Plants take in CO_2 during the day, converting the carbon to organic materials required for them to live and grow and giving off oxygen that animals need. CO_2 also controls respiration in animals, including humans. But, for humans and other animals, too much of a good thing is dangerous. Too much CO_2 in the air we breathe can be suffocating. According to safety standards developed by the American Conference of Governmental Industrial Hygienists (1998), people working a normal 40-hour workweek should not be exposed to a concentration of more than 0.5 percent CO_2 on a day-to-day basis. Increased concentrations of more than 2 percent will cause breathing problems, and concentrations of more than 10 percent could even be fatal.

CO_2 can adversely affect our lives in other ways as well. Too much in the atmosphere can enhance the greenhouse effect, raising global temperatures and melting ice caps, thus raising sea level and flooding many of the major population centers of the world.

SEQUESTRATION: THE JURY IS STILL OUT. CO_2 has many practical applications in our lives; it is used in the carbonation of beverages, as a propellant in place of the less desirable freon gas, in the production of synthetics, and as dry ice for refrigeration. But we are producing far more CO_2 by burning fossil fuels than we can use, so it behooves us to find a way to either reduce its production or somehow get rid of it.

The U.S. Department of Energy (DOE) estimates that the amount of CO_2 emitted by human activity, primarily from burning fossil fuels, has expanded from 0.028 percent of air before the industrial revolution to 0.037 percent today (U.S. Department of Energy, Office of Science, 2003). They estimate that the amount will continue to grow as global energy use expands in the future, unless we change the way we produce and use energy. Their solution involves a series of steps that fall under the term *carbon sequestration.*

Sequestration is a fancy term for capturing, separating, and storing or reusing something—in this case, carbon; locking it away in places called "sinks," where it won't readily escape to the atmosphere, and where it might provide some potential benefit. DOE is currently funding research in which the possibilities of sequestering carbon in numerous types of sinks that fall into four broad categories—terrestrial, oceanic, geological, and chemical/biological—are being investigated.

Terrestrial sequestration involves emplacing CO_2 in woodlands, farmlands, deserts, and wetlands, where it can contribute to the growth of healthy forests, crops, and other vegetation. ***Oceanic sequestration*** involves two separate processes: (1) adding nutrients to ocean surface waters to stimulate the growth of phytoplankton that will then draw CO_2 directly from the atmosphere as they continue to grow and reproduce; and (2) injecting CO_2 into the deep ocean. This latter process is being studied to determine if there would be any negative effects to the biogeochemical cycles of the ocean, such as an increase in ocean acidity. ***Geological sequestration*** includes injecting CO_2 into underground rock formations (see below). ***Chemical sequestration*** would convert CO_2 into inert, long-lived commercial products or stable solid compounds such as magnesium carbonate. As an example of how this latter process would be helpful, DOE stated that if all of the carbon emitted in the world in 1990 was sequestered as magnesium carbonate, it could be stored in a space 10 kilometers by 10 kilometers by 150 meters (6 miles by 6 miles by 500 feet) (U.S. Department of Energy, Office of Fossil Energy, 2004b).

ROCK ON. The Pennsylvania Geological Survey recently teamed with seven other states in the study of geological sinks as part of a DOE-funded study of carbon sequestration in the Appalachian, Illinois, and Michigan basins. Several avenues of approach to storing carbon in subsurface rock formations are being considered (Figure 1), including pumping CO_2 into oil and gas reservoirs, deep unminable coal seams, abandoned underground coal mines, and saline (brine) aquifers.

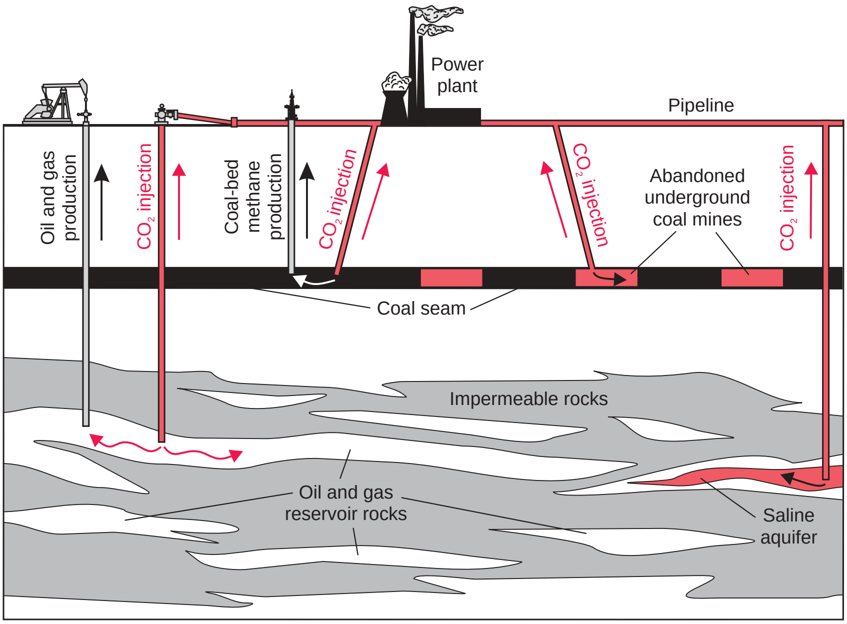


Figure 1. Methods of geological sequestration of carbon dioxide.

Although the estimated storage capacity of rock formations serving as brine aquifers is quite large, sequestration in deep saline aquifers does not have a practical value other than eliminating CO_2 from atmospheric emissions. That alone, however, can be quite impressive. For example, Statoil, a Norwegian oil company, is injecting the equivalent of the entire CO_2 output of a 150-megawatt coal-fired power plant into a saline reservoir in the North Sea (U.S. Department of Energy, Office of Fossil Energy, 2004a). Pennsylvania has many brine aquifers, including the Pennsylvanian Pottsville sandstones, Upper Devonian Murrysville sandstone, Lower Devonian Oriskany Sandstone, dolostones of the Lower Silurian Lockport Dolomite, and sandstones of the Upper Cambrian Gatesburg Formation. Many of these formations were mapped for their depths, thicknesses, brine occurrences, and brine chemistries as part of the project.

Similar to brine aquifers, abandoned coal mines offer a place to store CO_2 but with limited practical value. More importantly, CO_2 can provide practical value in geological sequestration by acting as a displacement fluid during enhanced oil (and natural gas) recovery from both conventional and unconventional reservoirs.

PUMP UP THE VOLUME. Back in the late 1800s, John Carll, the geologist with the Second Geological Survey of Pennsylvania assigned to the oil regions of northwestern Pennsylvania, noticed that oil production increased in certain areas after it rained. He surmised that rainwater flowed into unplugged, abandoned wells and displaced the oil in the producing reservoirs, thereby forcing the oil into the well bores of the producing wells (Carll, 1880).

Reservoirs, of course, are solid rock, not open cavities and caves, as many people think. In the Appalachians, most reservoir rocks are sandstones, which consist of sand-sized rock and mineral particles cemented together with silica, calcium, clay, or some other mineral agent (Figure 2). These rocks are rarely completely cemented, however. In many cases there are tiny spaces (pores) between the grains, or between and within the cemented areas, that allow oil, gas, and/or water to exist in a highly pressurized miscible state, meaning that the materials mix and act as a single fluid. As Carll (1880) noted, there cannot be empty pores in the reservoir rock. Below the groundwater table, something has to occupy those pores, whether it is oil, gas, water, or some other fluid. When runoff flowed into some wells during and after a heavy rain, the water moved into the sandstone and occupied the pore spaces, thus forcing the oil out of the pores and through the rock from pore to pore until it reached a well bore, where the well operators gladly found that their production had increased. Since about 1920, intentional flooding of oil reservoirs with water has become standard industry practice in areas where the more easily obtainable oil has already been depleted.

Crude oil is a viscous fluid. In the early stages of a reservoir in production, oil typically is miscible with natural gas and possibly some water. This miscible fluid is less viscous than oil alone, so it flows more readily than the oil would if it were the sole compound occupying the pore spaces. When a well is drilled, the pressure differential

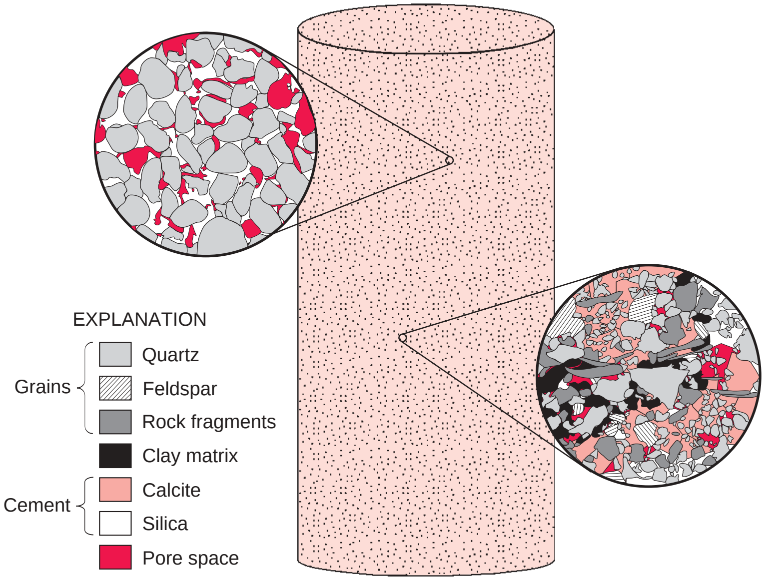


Figure 2. A segment of cored sandstone from an oil reservoir. At full scale, the sandstone appears to be homogeneous. But greatly magnified views of two small, separate areas show major differences in size, roundness, and composition of grains, different types of cements and matrix, and the resulting porosities that can occur. The upper magnified view shows a quartz arenite, a sandstone composed of rounded, equal-sized quartz grains cemented by silica. The lower magnified view is of a lithic graywacke, a sandstone composed of a variety of rock and mineral grains of different sizes and shapes, cements, and clay matrix.

between the rock and the well bore causes the fluid to migrate from the higher pressure rock toward the lower pressure well bore where it can flow, or be pumped, to the surface. As the miscible fluid flows into the well bore, it begins to separate into its individual components. The gas bubbles out of the liquid and moves readily to the surface. The water and oil collect in a tank where they separate, so that the oil can be skimmed off and sold, and the water can be trucked to a treatment plant. It is inevitable that after some time the natural gas will be bled out of the reservoir, and the oil will revert to its viscous state; it then has to be sucked or forced out of the reservoir. When some other fluid (water, gas, or chemicals) is introduced into the oil reservoir, it becomes miscible with the oil and again reduces the viscosity, thereby helping the oil move through the reservoir and enhancing production—thus the term enhanced oil recovery, or EOR.

Water flooding is the most common form of EOR in the Appalachians, but operators have also used natural gas, CO_2, steam, and a variety of chemicals at one time or another. The oil reservoirs of the

Bradford field in McKean County flooded very nicely with water, but well operators found through trial and error that injecting natural gas or air actually worked better than water at flushing oil out of reservoir rocks in Venango County. Both of these methods have been tried-and-true for generations in Pennsylvania, whereas the “newfangled” methods such as using CO_2, steam, and complex organic chemicals never quite achieved the success hoped for (Lytle, 1960, 1966; Ondrusek and Paynter, 1982). Part of the problem stems from unsuccessful attempts to focus the mobility of the EOR fluids through the reservoir. These fluids tend to take the easiest path through the rock, rather than going precisely where the operator wants them to go. If you are that well operator, you don’t want to spend a lot of money on advanced technologies that provide a minimum of improvement in production.

More recent successes with the newer technologies in other areas of the world have lent hope that they might become useful in the Appalachians as well. CO_2, for example, has been an effective method of EOR (including conventional oil and gas as well as gas from shales and coal seams) in other states and nations for many years (Morris, 2004). Its use has even increased in recent years, particularly in the western United States, and research on the development of additives that control CO_2 mobility within the reservoir during CO_2 flooding has gained importance (Martin and others, 1996).

HOW IT WORKS. CO_2 will mix with oil, but it mixes more quickly with water. Water, on the other hand, doesn’t absorb as much CO_2 as does an equal amount of oil. Therefore, using CO_2 for effective EOR is a two-step process. When liquefied CO_2 is first injected into a reservoir, it preferentially mixes with and displaces the water near the well bore, leaving the more viscous oil remaining in the pore spaces. It also helps repressurize the reservoir. After some time, when most of the water has been displaced, the CO_2 begins mixing with the oil as well. This might take some time—up to four weeks, according to Boomer and others (1999), a period when the well is shut in to allow the CO_2 to “soak” into the other fluids. Eventually, the CO_2 becomes miscible with the oil, reducing its viscosity and allowing it to flow from the higher pressure reservoir to the lower pressure well bore (Figure 3). The CO_2 can then be captured and reused.

The biggest drawback, as mentioned above, is finding a way to control CO_2 mobility through the reservoir. CO_2, as with any fluid, will follow the path of least resistance. It is less viscous than either water or oil, so it has a tendency to move irregularly through a reservoir, especially one that is heterogeneous—rock that consists of a variety of grain sizes and shapes, mineral layers, pore spaces, intercon-

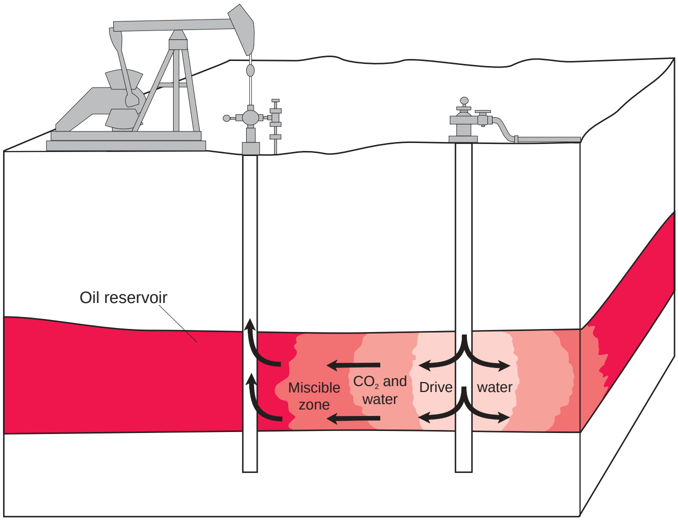


Figure 3. Generalized diagram of an oil reservoir showing how carbon dioxide flooding helps increase oil production.

nected pore spaces (its permeability), and other characteristics (Figure 2). Porosity variations are the biggest problem. CO_2 preferentially flows through large pore spaces rather than small ones. If the oil resides in the small pores, it will be only minimally affected by the CO_2 injection. If one cannot control where the injected fluid goes, one cannot count on it to remove the oil.

The oil and gas industry has been experimenting with different chemical additives, resulting in varied success. Creating a foam by mixing CO_2 with a chemical surfactant reduces the mobility of CO_2 by generating films of bubbles in pore spaces (Martin and others, 1996). This allows somewhat better control over the EOR process. Another method involves injecting CO_2 with water-soluble calcium salts, such as calcium chloride, that will precipitate as solids within the larger pores during injection. Ameri and others (1991) tested this method on the Upper Devonian Berea Sandstone in West Virginia and determined that it was an effective method of controlling CO_2 mobility and production efficiency.

SO, WHAT'S THE BENEFIT? There are several benefits to EOR using CO_2. First of all, it has been shown to successfully aid in the production of residual oil that would have remained in the reservoir. It is also capable of increasing natural gas production in both conventional (sandstone) and unconventional (coal seam and gas shale) reservoirs. These are important benefits in a country where fossil fuels remain our primary source of energy. The increased hydrocarbon production would also benefit the economy by stimulating commerce within Pennsylvania. But perhaps the biggest long-term benefit is in decreasing the amount of CO_2 expelled into the atmosphere.

Generally, it takes about 5,000 to 10,000 cubic feet of CO_2 to replace one barrel of oil in a reservoir (Millennium Energy, Inc., 2004). As the CO_2 flushes oil out of the rock, it fills the pores. So, for every barrel of oil produced by this method, 5,000 to 10,000 cubic feet of CO_2 will remain in the reservoir. As an example, suppose that an operator using a CO_2 flood in an oil field in Venango County produces an average of 1,000 barrels of oil per day from his wells. This means that as much as 10 million cubic feet of CO_2 will be stored in the reservoir every day. If CO_2 becomes a viable EOR method in the oil fields of Pennsylvania, the oil industry will be removing a lot of waste CO_2 from power plants and manufacturing companies that otherwise would be released to the atmosphere.

Kind of makes you breathe a little easier, doesn't it?

REFERENCES

Ameri, Samuel, Aminian, Khashayar, Wasson, J. A., and Durham, D. L., 1991, Improved CO_2 enhanced oil recovery—mobility control by in-situ chemical precipitation: U.S. Department of Energy, Bartlesville Project Office, DOE/MC/22044–15, 120 p.

American Conference of Governmental Industrial Hygienists, 1998, Industrial ventilation—A manual of recommended practice (23rd ed.): Cincinnati, Ohio, ACGIH, no. 2092, 512 p.

Boomer, R. J., Cole, Roger, Kovar, Mark, and others, 1999, CO_2 huff-n-puff process in a light oil shallow shelf carbonate reservoir: U.S. Department of Energy, Bartlesville Project Office, DOE/BC/14986–14, 82 p.

Carll, J. F., 1880, The geology of the oil regions of Warren, Venango, Clarion, and Butler Counties: Pennsylvania Geological Survey, 2nd ser., Report III, 482 p.

Lytle, W. S., 1960, History, present status and future possibilities of secondary recovery operations in Pennsylvania: Pennsylvania Geological Survey, 4th ser., Mineral Resource Report 41, 23 p.

________ 1966, Steam injection operations in Pennsylvania: Producers Monthly, v. 30, no. 12, p. 2–5.

Martin, F. D., Heller, J. P., Weiss, W. W., and others, 1996, Field verification of CO_2 foam: U.S. Department of Energy, Bartlesville Project Office, DOE/MC/26031–32, 71 p.

Millennium Energy, Inc., 2004, Enhanced oil recovery (EOR): http://www.millenniumenergyinc.com/eor.shtml (accessed September 2004).

Morris, Guntis, 2004, EOR continues to unlock oil resources: Oil and Gas Journal, v. 102, no. 14, p. 45–65.

Ondrusek, P. S., and Paynter, W. T., 1982, Penn Grade Micellar Displacement Project: Morgantown, W. Va., U.S. Department of Energy, DOE/ET/08002–26, 246 p.

U.S. Department of Energy, Office of Fossil Energy, 2004a, Geologic sequestration research: http://www.fossil.energy.gov/programs/sequestration/geologic/index.html (accessed September 2004).

________ 2004b, Novel carbon sequestration concepts: http://www.fossil.energy.gov/programs/sequestration/novelconcepts/index.html (accessed September 2004).

U.S. Department of Energy, Office of Science, 2003, Carbon sequestration: http://cdiac2.esd.ornl.gov/ (accessed September 2004).

PA*IRIS Continues to Grow in Partners and Products

by Cheryl L. Cozart
Bureau of Topographic and Geologic Survey

The Pennsylvania Internet Record Imaging System (PA*IRIS) partnership is a public/private partnership between the Pennsylvania Geological Survey (Department of Conservation and Natural Resources [DCNR]) and a growing list of clients. It consists of a system of images of oil and gas documents that are viewable over the Internet, plus several new features that are described below. The partnership began conceptually in August 1998 with 28 companies, primarily from the oil and gas industry, that had an immediate need for remote data access.

BACKGROUND. The actual documents are on file in the Pittsburgh office of the Survey, and, before PA*IRIS, people came into the office regularly to examine this information and determine where or how to drill their next well. Traveling to Pittsburgh to research and copy oil and gas documents was a time-consuming, costly task, however. Additionally, doing business this way was not cost-effective for the Survey, we were out of file space, and the paper documents were wearing out or being lost. We wanted to find a way to furnish our information to the user community and provide those users with better service.

We began by hiring a contractor and brainstorming a solution. We then put the solution into effect by purchasing and configuring hardware and software, electronically scanning more than 500,000 pages of completion reports, location plats (detailed well-location maps), and plugging certificates (required before abandoning a well) and going live over the Internet as promised one year later in August 1999. Today, what began as a simple concept of providing images over the Internet has blossomed into a full-service oil and gas information system that is available on the web 24 hours a day, 7 days a week to our official partners and free of charge in-house during normal office hours.

WHAT DOES PA*IRIS OFFER? PA*IRIS combines scanned images of oil and gas documents with the Survey's Wells Information System (WIS), a database application of permitted and non-permitted wells. From WIS, oil and gas base maps are created. These digital maps are interactive, enabling the user to click on a permit to obtain well properties. Wells are displayed on a 7.5-minute topographic map base. In addition to WIS and the base maps, since inception, a number of new products have been added to the imaging system. They include production and geophysical-log databases, a custom report-writing area, and geophysical-log images in Tagged Image File Format (TIFF).

IMAGES. Clicking on the icon for the imaging system on the opening screen leads to a document-retrieval window (Figure 1). This is the home page for accessing images of completion reports, location plats, historical records (for wells never permitted), quadrangle sec-

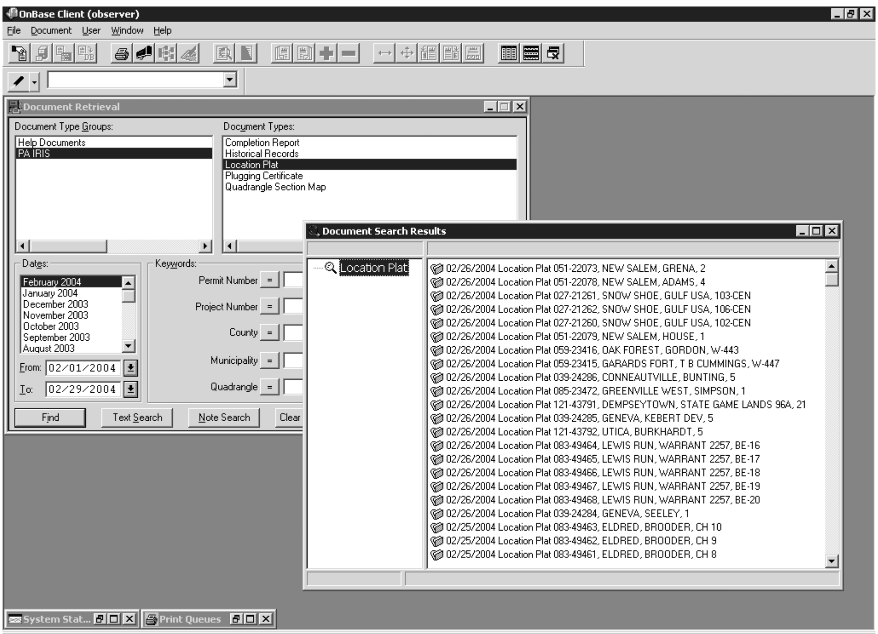


Figure 1. The document-retrieval window, which is the home page for opening images related to completion reports, location plats, historical records, quadrangle section maps, and plugging certificates. The above example shows a search of new location plats entered into the system during February 2004. A list of all new plats is displayed in a separate window. Double-clicking on any item in the list opens the image.

tion maps (oil and gas base maps divided into nine sections for easy page-sized printouts), and plugging certificates. Each document type has a number of search fields that can be used either individually or in combination. The completion report, for example, has more than 19 searchable fields. Most search fields are straightforward, such as permit number, operator name, or farm name. The system also allows for more in-depth searches, such as finding the wells that penetrate the Trenton and deeper formations. Figure 2 shows an example of the imaging interface and the type of document that can be retrieved.

GEOPHYSICAL LOGS. Two areas of PA*IRIS are dedicated to geophysical logs: (1) an index database; and (2) TIFF images of geophysical logs. The geophysical-log index is a database that has a list of wells that have logs on file in the Pittsburgh office. There are several menu options from which to choose within the database. Selecting new incoming logs, for example, will result in a list of all logs that arrived in the Pittsburgh office during the previous month. The user

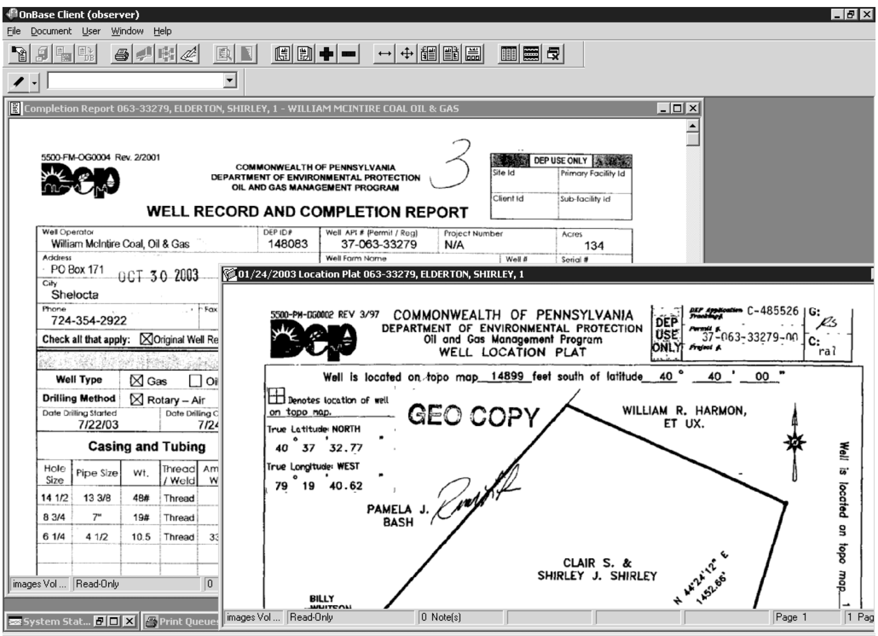


Figure 2. An example of completion report and location plat documents that can be displayed for review. The permit number relates all documents. For example, opening a completion report and double-clicking on the image opens the associated location plat or plugging certificate image.

can also obtain lists of logs by permit number, quadrangle, or type of log (such as compensated density logs or gamma-ray neutron logs).

Geophysical-log TIFFs are the newest product added to PA*IRIS. They may be viewed or downloaded over the Internet to a local computer. We scan both new incoming logs and older logs already on file on a daily basis. Eventually, all logs on file will be available through PA*IRIS. Approximately 14,000 logs have been scanned as of October 2004. An example of the geophysical-log database and a portion of a TIFF image are shown in Figure 3.

PRODUCTION TABLE. The production table is a database that contains information about wells for which annual production has been reported, starting in 1980 (Figure 4). The latest year for which data is displayed is five years before the current year, because, in Pennsylvania, by law, the last five years of production are confidential. Each March, data for a new year are released. Companies are currently reporting production data for the year 2003, which will be released in 2008. Figure 4 also shows the variety of queries that may be run from the production database (the six buttons at the bottom of the screen). For example, click-

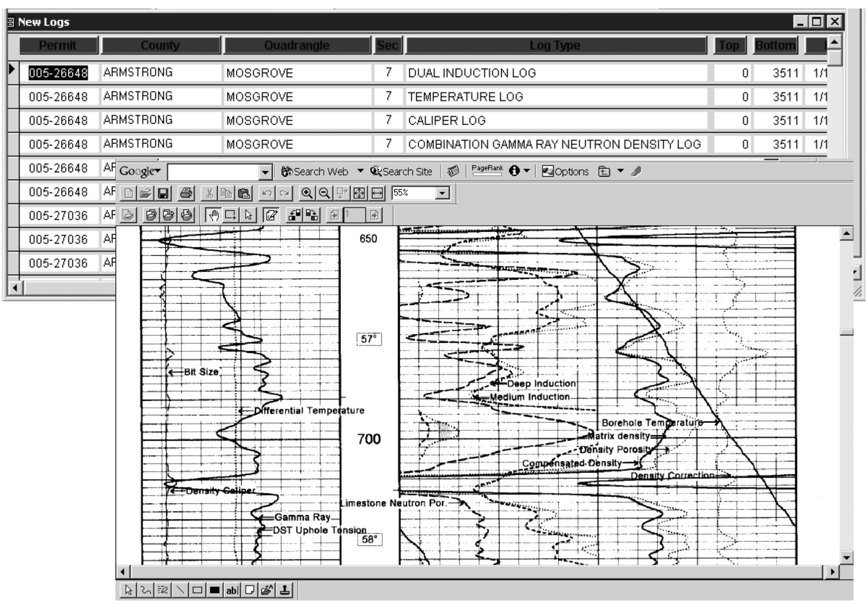


Figure 3. An example of the geophysical-log database, showing a list of new incoming logs (top) and a portion of a geophysical-log TIFF image. Logs shown are gamma ray, neutron, density, temperature, and induction.

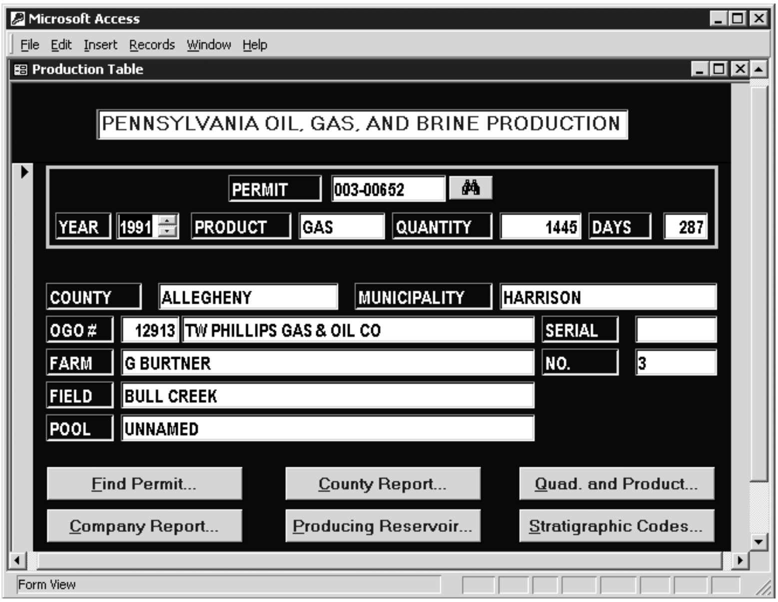


Figure 4. Part of a database of reported oil, gas, and brine production. Clicking on the labeled buttons at the bottom of the screen returns topical reports in spreadsheet format.

ing on the "Company Report" button results in a display of all wells having reported annual production by company and producing year.

WELLS INFORMATION SYSTEM DATABASE. The Wells Information System (WIS) is directly connected to the PA*IRIS imaging system but in database format rather than in imaging format (Figure 5). WIS is 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. The database resides in Oracle, a commercial software package. This relational database package allows for the entry, storage, access, and analysis of data through any number of linked data fields. The data connect through some common factor, usually the state-assigned permit number. The WIS database is augmented on a daily basis as staff members enter, revise, and interpret data reported by oil and gas companies via completion reports, location plats, geophysical well logs, and other reporting forms. It is important to note that information is entered into WIS prior to the receipt of the physical document for scanning into PA*IRIS.

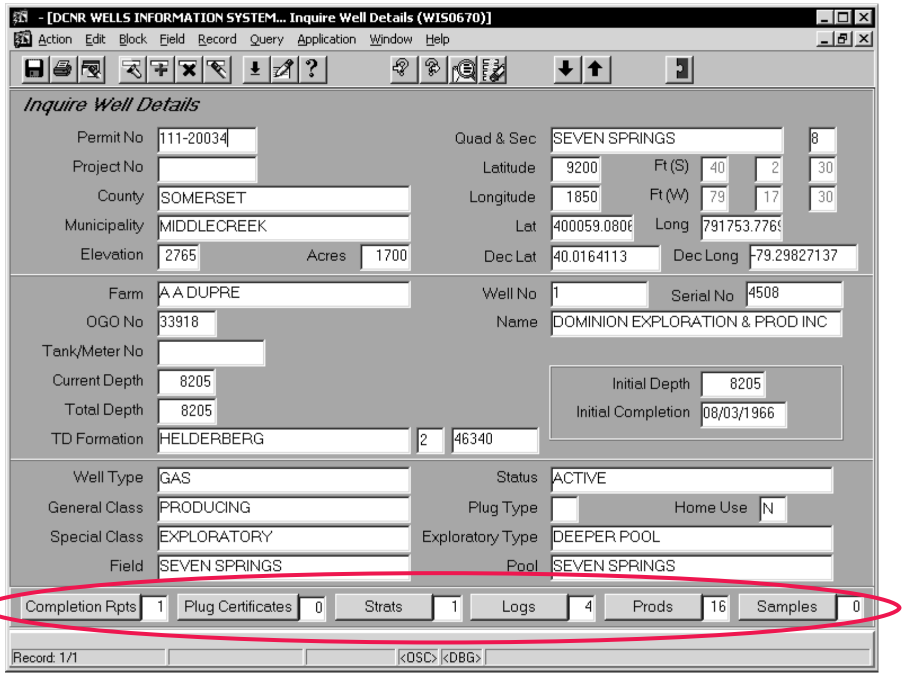


Figure 5. The basic query screen for finding information on oil and gas wells in Pennsylvania. Clicking on any of the summary topics circled at the bottom of the screen opens other database tables that show other well details.

Custom reports may be run by clicking on the WIS_REPORTS icon in the PA*IRIS application. Standard reports already exist, yet a specific parameter such as county, quadrangle, municipality, or total depth of a formation can be entered. One report in particular displays information about every permit that has been issued, including whether that permit has resulted in a drilled well or whether it became an expired, cancelled, or void permit. WIS reports can display decimal latitude and longitude (Figure 6), making it easy to plot wells in most GIS applications.

OIL AND GAS BASE MAPS. Oil and gas base maps have traditionally been produced by the Survey's Pittsburgh office in paper format. Today, digital maps are also available upon request, as well as online through the PA*IRIS application. Users have the ability to completely interact with these maps without having to install any special GIS software. In the case of the PA*IRIS partnership, an ArcReader viewer program installed on the server enables partners to interact

Well Header Report by County
County: FAYETTE

Page Items:

	Permit	Farm Name	Operator	Quadrangle	Map Section	Decimal Latitude	Decimal Longitude	Well Typ
730	051-20810	S & E BUNCIC	BURKLAND WILLIAM S	SMITHFIELD	7	39.77299342	-79.8692641	GAS
731	051-20811	USX	VIKING RESOURCES CORP	SMITHFIELD	3	39.84836893	-79.7742175	GAS
732	051-20812	DOPPELHEUER	DOPPELHEUER GREGORY	UNIONTOWN	3	39.99389974	-79.6624025	GAS
733	051-20814	STASH	MID PENN ENERGY CORP	UNIONTOWN	3	39.99016507	-79.6661476	DRY
734	051-20816	MYERS/ BALABAN	VIKING RESOURCES CORP	UNIONTOWN	2	39.98630123	-79.6773009	GAS
735	051-20818	USX 1402	VIKING RESOURCES CORP	UNIONTOWN	2	39.99264240	-79.6785153	GAS
736	051-20820	USX 1402	VIKING RESOURCES CORP	UNIONTOWN	2	39.99341138	-79.6745897	GAS
737	051-20821	USX 1402	VIKING RESOURCES CORP	UNIONTOWN	2	39.99533316	-79.6712350	GAS
738	051-20822	SHIROCKY	GREAT LAKES ENERGY PA...	DAWSON	5	40.05862704	-79.6751688	GAS
739	051-20824	COLDREN	VIKING RESOURCES CORP	UNIONTOWN	2	39.99028190	-79.6748034	GAS
740	051-20826	GERALD GRAHAM	PETRO DEV CORP	BRANDONVILLE	2	39.72707420	-79.5671748	GAS
741	051-20827	USX 1402	VIKING RESOURCES CORP	UNIONTOWN	2	39.99588185	-79.6766600	GAS
742	051-20828	USX 1402	VIKING RESOURCES CORP	UNIONTOWN	2	39.99154381	-79.6829048	GAS
743	051-20829	SHIROCKY	GREAT LAKES ENERGY PA...	DAWSON	5	40.06352735	-79.6690246	GAS
744	051-20830	ELIAS	GREAT LAKES ENERGY PA...	DAWSON	5	40.06955029	-79.6912481	GAS
745	051-20831	JAMES JOSHOWITZ	REJISS ASSOC	DAWSON	9	40.02450439	-79.6598127	GAS
746	051-20833	LUKE J KNAPP	GREAT LAKES ENERGY PA...	DAWSON	5	40.06686134	-79.6843518	GAS
747	051-20834	HAYES	RANGE OPR CO	DAWSON	5	40.05563516	-79.6682741	DRY
748	051-20837	MAHAROWSKI	VIKING RESOURCES CORP	UNIONTOWN	2	39.98761923	-79.6726976	GAS
749	051-20839	WARD	DOUGLAS OIL & GAS INC	DAWSON	5	40.04674095	-79.6695240	GAS
750	051-20842	GUYNN	AMER REF & EXPLORATION...	UNIONTOWN	3	39.99670118	-79.6578356	GAS
751	051-20843	ROSENSTEEL	DOUGLAS OIL & GAS INC	DAWSON	6	40.04242401	-79.6656433	GAS

Sheet 1

Figure 6. An example of a customized report, which may be obtained by clicking on the WIS_REPORTS icon in the PA*IRIS application.

with each map. The user can click on a well and identify the database details behind it, find a well on a map, or measure the distance between wells (Figure 7).

STILL GROWING. . . PA*IRIS has grown from 28 charter members to 92 companies, including DCNR, throughout the United States and Canada (see back cover). The majority of companies are based in Pennsylvania. Since each company has many employees, the total number of people we are supporting is greater than 250. The affiliations of our partners are as follows: 87 companies in the oil and gas industry, Pennsylvania Department of Environmental Protection, Pennsylvania Game Commission, U.S. Department of Energy, and U.S. Geological Survey.

As Mark Stephenson, Stephenson Group Natural Gas Company (a PA*IRIS charter member) stated (personal communication, 2004), “PA*IRIS is a no-brainer for the larger companies. It is convenient and saves them time and money and makes research very simple. More importantly, it is a must for smaller companies, like mine. We have fewer staff and must wear many hats. Traveling to Pittsburgh to do research is important, but sometimes we must forego that step due to lack of time and staff. Having PA*IRIS is like having four more

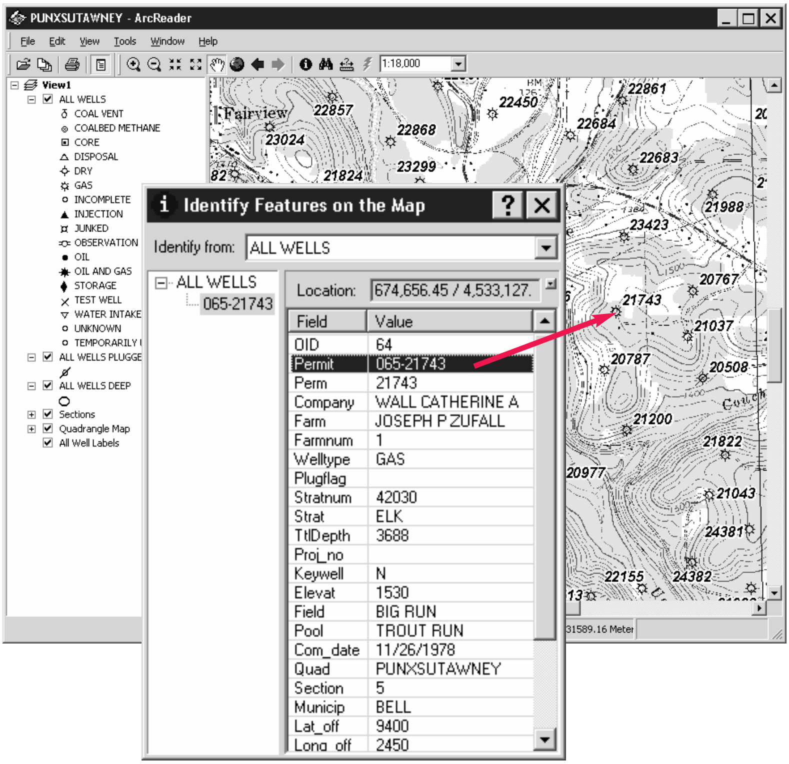


Figure 7. An example of a digital oil and gas base map. An interactive published map is opened by clicking on the ArcReader icon in the PA*IRIS application and selecting a quadrangle listed in the directory. Using a tool on the toolbar and clicking on the well symbol on the map reveals database details.

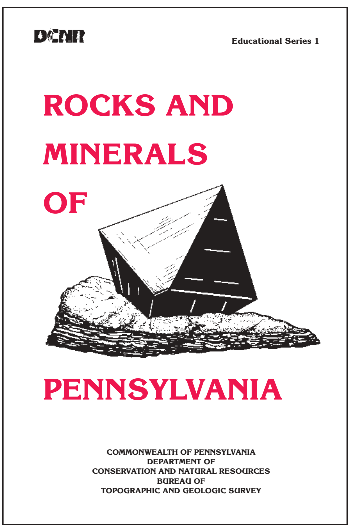
people on our staff: two clerical people for pulling and filing documents, one geologist for determining geological formation tops and producing horizons, and a GIS person for mapping the wells. We can't afford not to have this system! It has been a true ROI (return on investment) factor!"

PA*IRIS is available to all people visiting the Pittsburgh office of the Pennsylvania Geological Survey during normal office hours (8:00 a.m. to 4:00 p.m., Monday through Friday) at no charge. Remote access requires joining an official partnership with DCNR to obtain the necessary licenses. For pricing or other information about the PA*IRIS system, please contact the Pittsburgh office at 412–442–4235 or e-mail us at ccozart@state.pa.us.

EARTH SCIENCE TEACHERS' CORNER

New Edition of *Rocks and Minerals of Pennsylvania*

What do pencils and diamond rings have in common? How is southeastern Pennsylvania similar to a supermarket checkout? What minerals were found in Pennsylvania first? These are among the questions that can be answered by reading the Bureau of Topographic and Geologic Survey's **Educational Series 1** booklet, **Rocks and Minerals of Pennsylvania,** by staff geologist John H. Barnes.



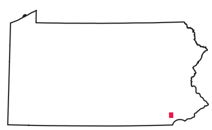
First published in 1962, ES 1 was revised and reissued in 2004. Features of the new fourth edition of this popular 30-page booklet include an expanded list of common and interesting minerals found in Pennsylvania and new and revised illustrations. In this edition, a greater emphasis is placed on the rocks and minerals of Pennsylvania than in the previous editions.

ES 1 is aimed at a middle-school audience, but it is appropriate for anyone who has no formal training in geology and who is interested in obtaining some basic information about the rocks and minerals of Pennsylvania. After a brief introduction touching upon the ways in which rocks affect our daily lives, the subject of minerals, the building blocks of rocks, is explored. The nature and classification of minerals are presented, as well as simple procedures that anyone can use to identify minerals. "New" minerals that were found in Pennsylvania before they were found anywhere else in the world are listed. The formation and distribution of igneous, sedimentary, and metamorphic rocks are examined in the second part of the booklet, again focusing on what rocks are found in Pennsylvania, why they are found here, and how to recognize them. A centerfold geologic map of the state indicates the various ages of the rock units. The last part of the booklet contains a descriptive list of 35 common or especially interesting minerals that are found in Pennsylvania.

Rocks and Minerals of Pennsylvania and other booklets in the Educational Series are free publications. They can be obtained from the Pennsylvania Geological Survey, 3240 Schoolhouse Road, Middletown, PA 17057–3534, telephone 717–702–2017. This publication can also be viewed on-line at http://www.dcnr.state.pa.us/topogeo/education/rocksminerals/es1.pdf.

NEW RELEASE

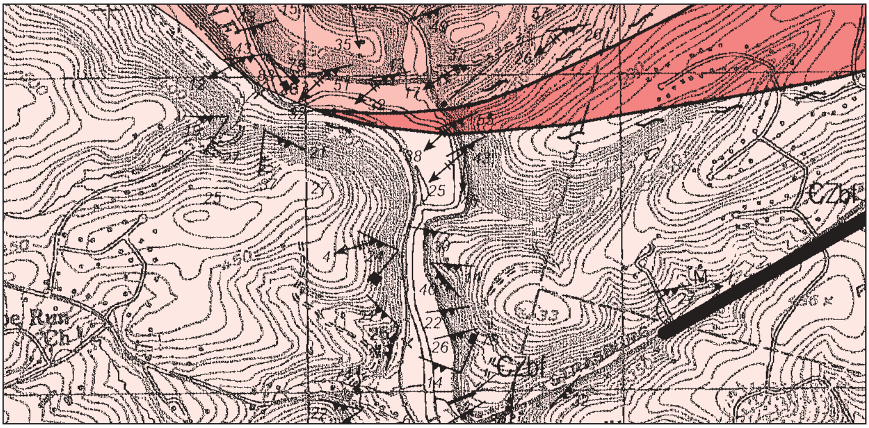
Bedrock Geology of the Coatesville Quadrangle



The Bureau of Topographic and Geologic Survey recently released **Atlas 189b, Bedrock Geology of the Coatesville Quadrangle, Chester County, Pennsylvania,** by staff geologist Gale C. Blackmer. This CD–ROM publication covers an area where modern geologic mapping had been lacking and is part of a long-term initiative to provide an updated geologic framework for the Piedmont province. It includes a 16-page text in portable document format (PDF), two plates also presented as PDF files, 122 images of rock exposures, and vector and raster datasets.

The bedrock units in the report area are an amalgamation of multiply deformed metamorphic terranes and range in age from Middle Proterozoic to early Paleozoic. The Coatesville quadrangle is traversed by two large thrust faults (the Martic thrust and Embreeville fault) and includes two mapped shear zones. Rocks north of the Martic thrust exhibit evidence of one deformation, and rocks south of the thrust show signs of three deformation events. The metamorphic grade in the nongneissic rocks decreases from south to north across the quadrangle.

The text includes sections on stratigraphy, structure, and metamorphism in the Coatesville quadrangle, as well as a discussion of their tectonic implications. Plate 1 has a bedrock geologic map, three cross sections, many structural symbols of selected field measurements, a correlation diagram, and



A portion of the geologic map (1:24,000 scale) from the Coatesville report, showing geologic units and structural symbols. The colors of the original map cannot be shown in this image.

geologic descriptions and an explanation of environmental characteristics for each of the map units. Plate 2 shows the locations of exposures observed in the field and data-collection stations. The maps on both plates are shown in full color at 1:24,000 scale.

The vector datasets (coverages) include polygon, line, and point features for the geologic units, structures, exposures, and data stations shown on the two plates. The raster datasets are a georeferenced image (GeoTIFF) for each map. The GeoTIFFs have been cropped to the map edges and do not include the explanatory and other information found on the plate margins. The vector and raster datasets, which were prepared using ESRI ArcGIS software, can be employed for spatial analysis and other geographic-information-systems (GIS) applications. Metadata are also provided.

Atlas 189b may be purchased for **$5.00** from the State Bookstore, Commonwealth Keystone Building, 400 North Street, Harrisburg, PA 17120–0053, telephone 717–787–5109. Payment may be made with VISA, MasterCard, or check or money order payable to *Commonwealth of Pennsylvania.* If the order is to be mailed, include **$4.00 postage** for one publication and **$0.50** for each additional publication. For over-the-counter orders and those mailed to a Pennsylvania address, add **6 percent sales tax** to the total cost of the order, including shipping. The report may also be purchased (by check or money order) over the counter at the Bureau's Middletown office (see address on back cover).

DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES
BUREAU OF TOPOGRAPHIC AND GEOLOGIC SURVEY

Main Headquarters
3240 Schoolhouse Road
Middletown, PA 17057–3534
717–702–2017
FAX: 717–702–2065

Pittsburgh Office
500 Waterfront Drive
Pittsburgh, PA 15222–4745
412–442–4235
FAX: 412–442–4298

BUREAU STAFF AND TELEPHONE NUMBERS

Director and State Geologist

Jay B. Parrish, P.G.	717–702–2053

Assistant Director

Samuel W. Berkheiser, Jr., P.G.	717–702–2055

Administrative Services

Lynn M. Goodling	717–702–2054
Elizabeth C. Lyon	717–702–2063

Library Services

Richard C. Keen	717–702–2020
Lewis L. Butts, Jr.	717–702–2018

Publication Services

Jody R. Zipperer (General Inquiries)	717–702–2073
Christine E. Miles, P.G.	717–702–2044
Caron E. O'Neil, P.G.	717–702–2042
Anne B. Lutz, P.G.	717–702–2043

Local Government Outreach Services

Kristen L. Hand (East)	717–702–2047
Jaime Kostelnik (West)	412–442–5828

Database Services

Cheryl L. Cozart	412–442–4234
Janice Hayden	412–442–4287
Joseph E. Kunz	412–442–4235
Lynn J. Levino	412–442–4299
Karen L. McCoy (Oil and Gas GIS Services)	412–442–5826

GIS Services

Michael E. Moore, P.G.	717–702–2024
John H. Barnes, P.G.	717–702–2025

GIS Services *(continued)*

Thomas G. Whitfield, P.G.	717–702–2023
Stuart O. Reese, P.G.	717–702–2028

Water Well Services

Sharon E. Fesus	717–702–2074
Jody R. Zipperer	717–702–2073

Groundwater Services

Gary M. Fleeger, P.G.	717–702–2045
Thomas A. McElroy, P.G.	717–702–2046

Geologic Mapping Services

Gale C. Blackmer, P.G.	717–702–2032
Helen L. Delano, P.G.	717–702–2031
Clifford H. Dodge, P.G.	717–702–2036
William E. Kochanov, P.G.	717–702–2033
James R. Shaulis, P.G.	717–702–2037
Viktoras W. Skema, P.G.	717–702–2035

Laboratory and Geochemical Services

Robert C. Smith, II, P.G.	717–702–2021

Coal-Bed Methane Services

Antonette K. Markowski, P.G.	717–702–2038

Coal Quality and Availability Services

Rodger T. Faill, P.G.	717–702–2041
Leonard J. Lentz, P.G.	717–702–2040
John C. Neubaum	717–702–2039

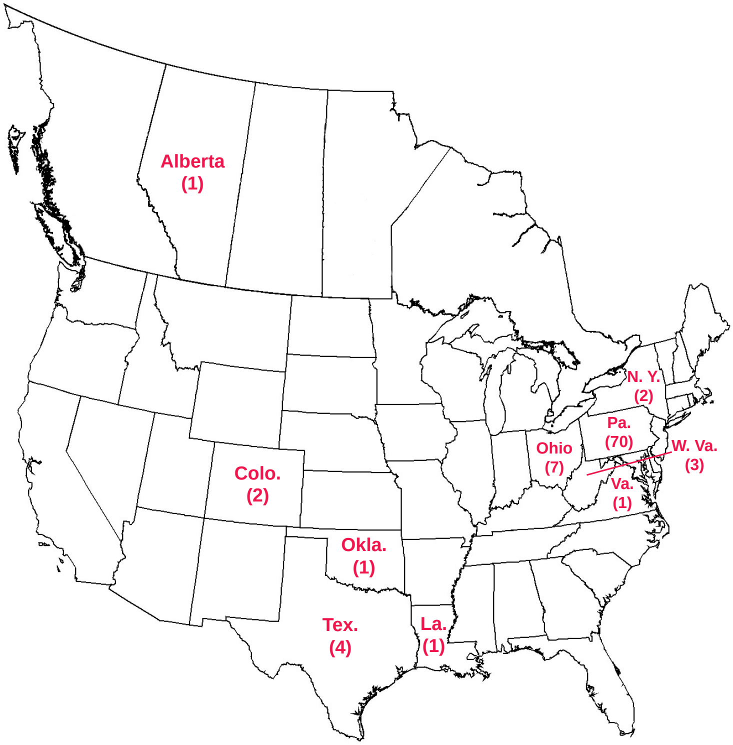
Oil, Gas, and Subsurface Geological Services

John A. Harper, P.G.	412–442–4230
Christopher D. Laughrey	412–442–4232
Joseph R. Tedeski	412–442–4295
Kristin M. Carter, P.G.	412–442–4233

IN COOPERATION WITH THE U.S. GEOLOGICAL SURVEY
TOPOGRAPHIC MAPPING
GROUNDWATER-RESOURCE MAPPING

LOCATION OF PA*IRIS PARTNERS

PA*IRIS partners are located in the labeled states and Canadian province. The number of partners is shown in parentheses. (See article on page 10.)



Bureau of Topographic and Geologic Survey
Department of Conservation and Natural Resources
3240 Schoolhouse Road
Middletown, PA 17057–3534

PRSRT STD
U.S. Postage
PAID
Harrisburg, PA
Permit No. 747

Address Service Requested