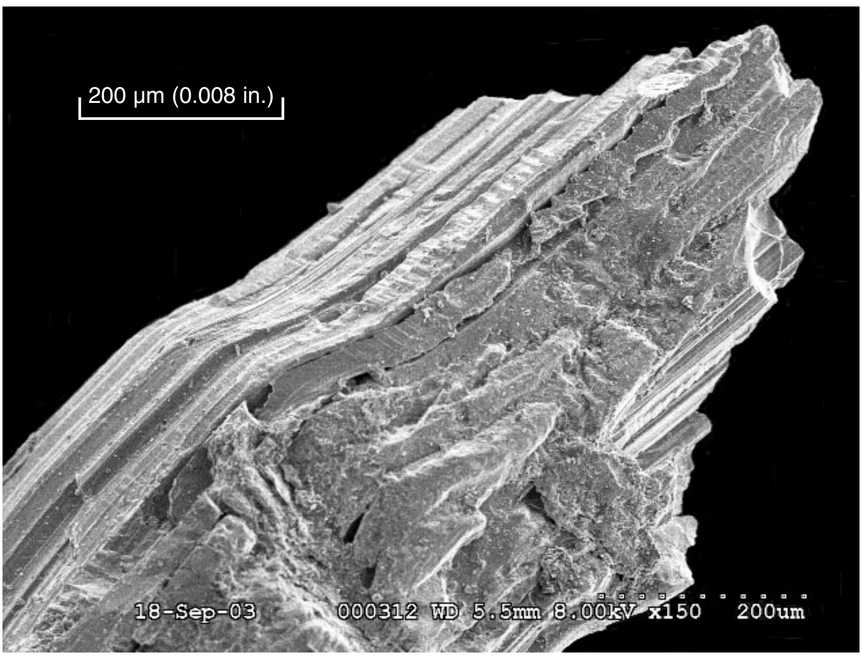
VOL. 33, NO. 3

Pennsylvania GEOLOGY



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ON THE COVER

Photomicrograph of celestine ($SrSO_4$) taken with the Survey's newly acquired scanning electron microscope (see article on page 2). The celestine sample is from Bellwood, Blair County, the first locality in the world where this mineral was documented to exist. A proposal was submitted to the Pennsylvania House of Representatives to name celestine the state mineral of Pennsylvania (Charles, Edwin, 2003, Celestine, the proposed state mineral: Pennsylvania Geology, v. 33, no. 1, p. 14–16).

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.
Editors: Anne B. Lutz, Caron E. O'Neil, and Jay B. Parrish.
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 editors at the address listed above.

VOL. 33, NO. 3 **FALL 2003**

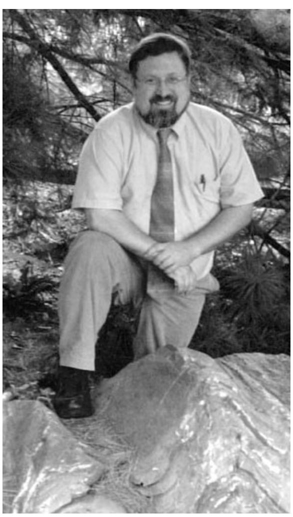
STATE GEOLOGIST'S EDITORIAL

Time Travel Through Aerial Imagery

You have probably seen a movie where an old map is unrolled and treasure hunters eagerly examine it for clues as to where something long lost may be found. As geologists, we also make use of old maps to find features on the landscape that have been lost for many years. Today it is possible to digitally scan and rectify a map, so that it fits on top of our current electronic maps. When one does this, there are a multitude of discoveries to be made. Small family burial plots might show up in a suburban development, or houses might appear in what is today an empty field.

And still, one can wish that someone back in 1830 had had the foresight to make just one more map, one which would have captured a picture of what the world looked like on that particular day. Environmental geologists often make use of old aerial photography in our library to travel back in time and determine what activities were occurring on a particular piece of ground. And they sometimes wish for photographs between the ones we have to capture a moment of change. To aid such researchers, we are scanning aerial photography taken from 1938 through 1940 (currently kept in the State Archives), so that, one day, images of Pennsylvania before much of today's development will be availabe on the web.

There's nothing we can do about getting more data from the past, but we can leave a legacy for our children by capturing a picture of our world as often as possible and leaving it for them. We are doing this with PAMAP. This year, we had about 20 percent of the state flown. If all goes well, the state will be covered every four years, providing a historical record for some future researcher who wants to see exactly what was happening in Pennsylvania way back in 2003.



Jay B. Parrish
State Geologist

Replacement of Equipment in Survey Lab Means New Capabilities

by John H. Barnes
Bureau of Topographic and Geologic Survey

Early in 2003, the Survey's laboratory facilities were enhanced by the acquisition of a scanning electron microscope (SEM) equipped with an energy-dispersive X-ray spectrometer (EDS) (Figure 1). This equipment replaced the Survey's 34-year-old X-ray fluorescence spectrograph. In addition to having become unreliable, the X-ray spectrograph no longer filled our needs. It was designed for determining the chemistry of bulk samples, information that, today, can be obtained from commercial laboratories. The SEM/EDS system provides a nondestructive method of obtaining semiquantitative analyses of tiny grains and detecting compositional variations within a sample.

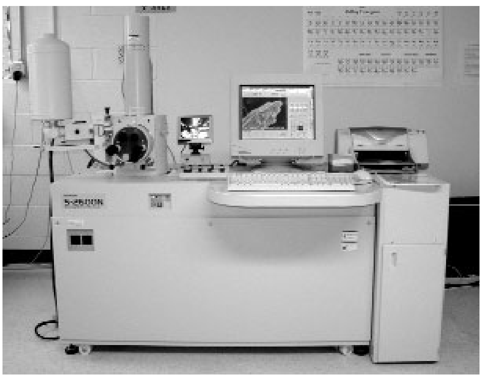


Figure 1. SEM acquired by the Survey early in 2003. The microscope is equipped to perform energy-dispersive X-ray microanalyses.

WHAT IT CAN DO. Most readers of *Pennsylvania Geology* are familiar with the capability of an SEM to take pictures of objects at high magnifications. In this article, we will illustrate some of the other ways an SEM can be used in examining geological specimens. We will use a very small specimen of celestine ($SrSO_4$) that was collected at the type locality at Bellwood, Blair County, as an example (Figure 2).

When a sample is examined in an SEM, it is exposed to a powerful beam of electrons, called the primary beam, that interacts with the sample in several different ways. Our SEM is equipped with three specialized detectors, each of which is designed to measure a specific reaction of the sample to the primary beam (Vaughan, 1989; Goldstein and others, 2003).

Secondary-Electron (SE) Detector. The photomicrograph on the front cover shows the upper fourth of the celestine sample shown in Figure 2. It was obtained using an SE detector. This is the type of detector that is used to obtain the highly detailed photographs for which the SEM is best known. One of the effects of the primary beam on the sample is to knock weakly bound electrons from the surface of the sample. The SE detector is sensitive to these so-called secondary electrons. Because they originate at the surface, the secondary electrons accurately portray the features on the surface of the sample.

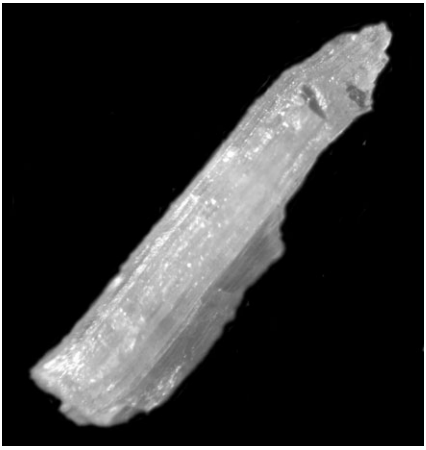


Figure 2. Optical photomicrograph of the celestine sample selected to illustrate the uses of the SEM. The sample is 3 mm long.

The cover photograph was taken at a magnification of 150× and is shown at a magnification of approximately 135×. Figure 3A shows the area near the tip of the sample at a much higher magnification. It reveals interesting structures that are not discernible at lower magnifications, such as details of cleavage surfaces. A stereoscopic view adds the third dimension to the image (Figure 3B).

Backscattered-Electron (BSE) Detector. When the primary electron beam strikes the sample, some of the electrons from the beam are reflected back out of the sample by the atoms in the sample. These are called backscattered electrons. They have much more energy than the secondary electrons and can originate from some depth below the surface of the sample. Because of that, they do not show the features of the surface as well as the secondary electrons do. They have a different advantage. A collision that reflects an electron back out of the sample is more likely to take place if the sample contains heavier elements, those that have a higher atomic number. So, on an image taken using the BSE detector, areas having heavier elements appear brighter than areas having lighter elements.

Figure 4 is a BSE image of the same area of the sample that is shown on the front cover. Some of the fine detail is missing, but other minerals on the sample that were not apparent in the SE image stand out dramatically as dark areas. (The two largest of those areas also

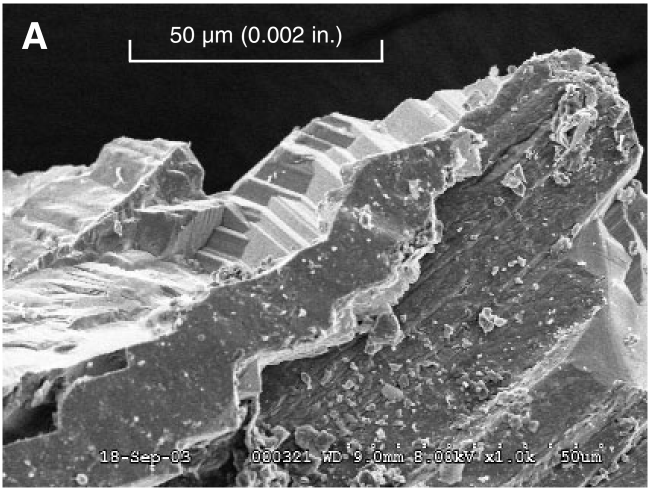
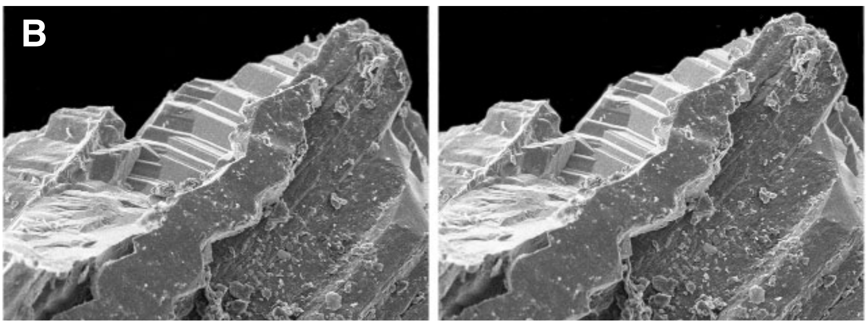


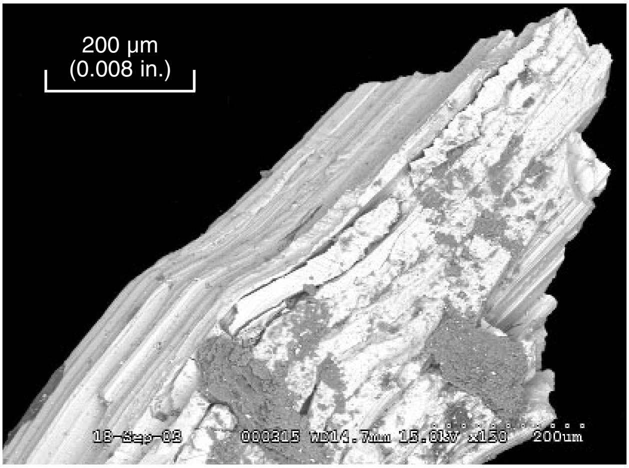
Figure 3. A. Photomicrograph of the upper tip of the celestine sample. This image was obtained using the SE detector. B. Stereoscopic images of the same area.



show up in the optical photomicrograph in Figure 2.) The relatively heavy strontium atoms (atomic number 38) in celestine scatter many electrons back out of the sample to make the celestine appear bright in Figure 4. The other minerals on the sample must consist of elements that have an average atomic number that is lower than that of the elements in celestine. The origin of the material forming the darker areas is open to question. It is possible that it is fine sediment that adhered to the celestine following its exposure to the waters of a flood that struck Harrisburg in 1972 and inundated the Pennsylvania Geological Survey headquarters (Sevon, 1972). Regardless of its origin, it serves well to illustrate the capabilities of the SEM.

Energy-Dispersive Spectrometer (EDS) Detector. To find out what the elements in the darker area are, we can use the EDS detector. When the primary beam strikes the sample, electrons in the beam collide with tightly bound electrons orbiting the nuclei of atoms

Figure 4. BSE photomicrograph of the same area shown on the cover. Celestine is white, and other minerals containing elements lighter than the strontium in the celestine are dark gray.



in the sample and knock them from their orbits. When that happens, electrons in shells, or orbits, farther from the nucleus fall toward the nucleus to take their place. As the outer electrons make the transition from a higher level to a lower level, they give up energy as X-rays. Each element emits a unique set of characteristic X-ray energies. By measuring the energies of the X-rays, it is possible to determine what elements are present in the sample. It is also possible to determine the approximate quantity of each element.

The EDS can be used to detect most elements, but it cannot detect elements lighter than boron because the energies of the X-rays they emit are too low. Another limitation is that, although each element emits a characteristic set of X-ray energies, in some cases the energy of a specific transition occurring in one element is similar to the energy of a different transition occurring in another element. When this occurs, one element can mask the presence of another element.

Figure 5 is a graph showing the X-ray energies emitted by the elements that are present in the area shown in Figure 4. The three strongest peaks correspond to X-ray energies characteristic of strontium (Sr), sulfur (S), and oxygen (O), the elements that make up celestine. There are also peaks for aluminum (Al), potassium (K), magnesium (Mg), calcium (Ca), sodium (Na), and iron (Fe), all of which are common in many minerals. These are probably components of minerals in the darker areas of the sample. If there was not a lot of strontium present, we would probably see a peak for silicon, which is also common in many minerals. We do not see the silicon peak, which would be at 1.74 keV, because the strontium peak at 1.81 keV masks it.

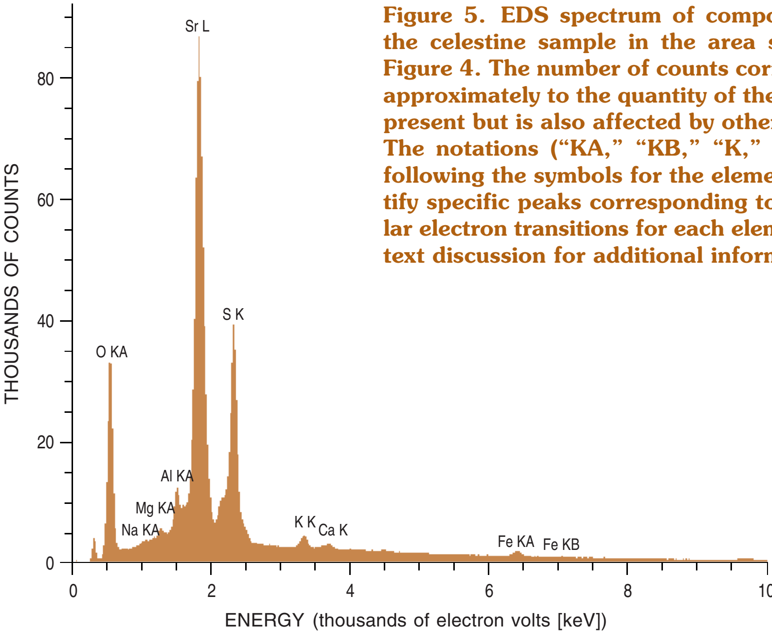


Figure 5. EDS spectrum of components in the celestine sample in the area shown in Figure 4. The number of counts corresponds approximately to the quantity of the element present but is also affected by other factors. The notations ("KA," "KB," "K," and "L") following the symbols for the elements identify specific peaks corresponding to particular electron transitions for each element. See text discussion for additional information.

To determine where the various elements are located on the sample, we can use the mapping function of the EDS. Figure 6 shows the result of mapping the locations of four of the elements that appear in the spectrum. Strontium and sulfur are concentrated in the areas that appear brighter in Figure 4, and aluminum and potassium are concentrated in the areas that appear darker.

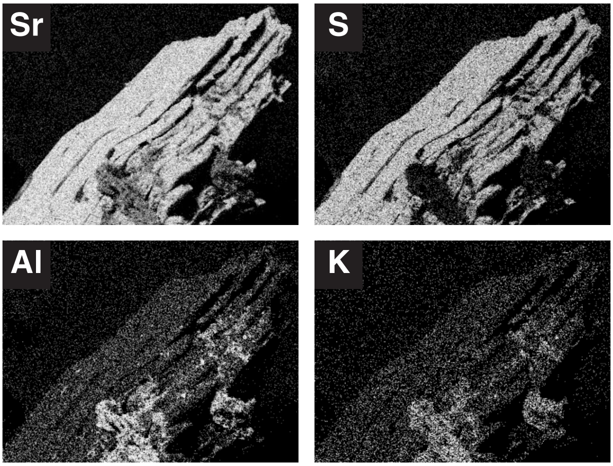


Figure 6. EDS maps showing the distribution of four of the elements identified in Figure 5. In each case, the brighter areas contain higher quantities of the element mapped. Strontium (Sr) and sulfur (S) are major components of celestine. Aluminum (Al) and potassium (K) are components of the minerals in the dark areas of Figure 4.

A closer look at a portion of one of the darker areas shows a seemingly chaotic array of particles, some vaguely hexagonal (Figure 7). The plus sign and X mark spots that produced the spectra in Figure 8. According to the spectrum for the grain under the plus sign, it is mostly silicon and oxygen—the mineral quartz. A small amount of aluminum is present, a common substitute for silicon in minerals. Tiny amounts of potassium and magnesium were also detected. The spot analysis obtained on the grain under the X shows a much larger peak for aluminum and a slightly larger one for potassium. According to semiquantitative analysis of the data, that grain might be muscovite.

The spectra also have peaks for gold, which was used in the preparation of the sample, so that it could be examined in a high vacuum. A high vacuum is required to use the SE detector. If a high vacuum is not going to be used, or if the sample is a good electrical conductor, it does not have to be prepared using gold. Gold is not present in the sample.

One interesting feature on the celestine sample is a small point projecting from an otherwise smooth, straight side (Figure 9). A spot analysis of this point showed it to be quartz. At an even higher magnification, we see that there is yet another crystal, only about 3.5 μm

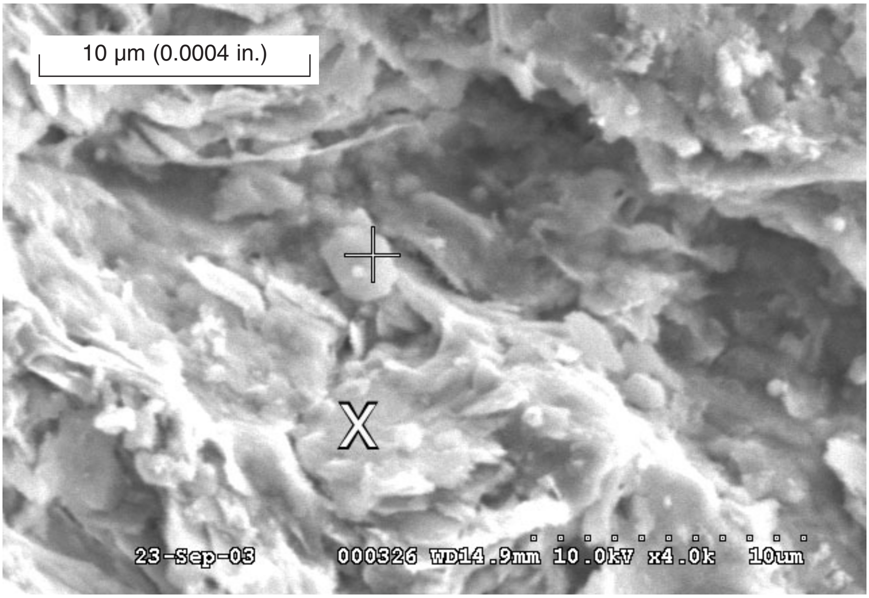


Figure 7. BSE image of the larger of the two dark areas shown in Figure 4. Spot analyses were made of the two points indicated by the + and X (Figure 8).

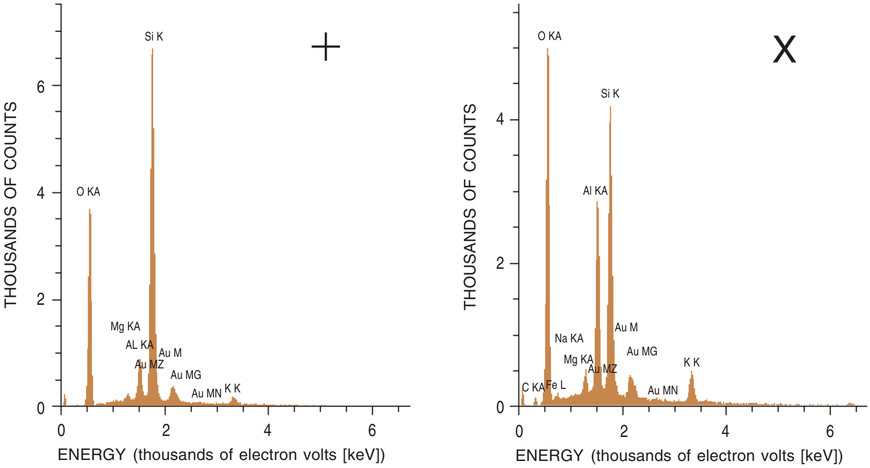


Figure 8. EDS spectra of points (+ and X) shown in Figure 7. Under the +, abundant silicon (Si) and oxygen (O) suggest quartz. Under the X, there is abundant silicon, oxygen, and aluminum (Al), and some potassium (K) and magnesium (Mg). According to semiquantiative analysis of the data, the mineral may be muscovite. The gold (Au) in both spectra is an artifact of the sample preparation method. See Figure 5 for an explanation of notations.

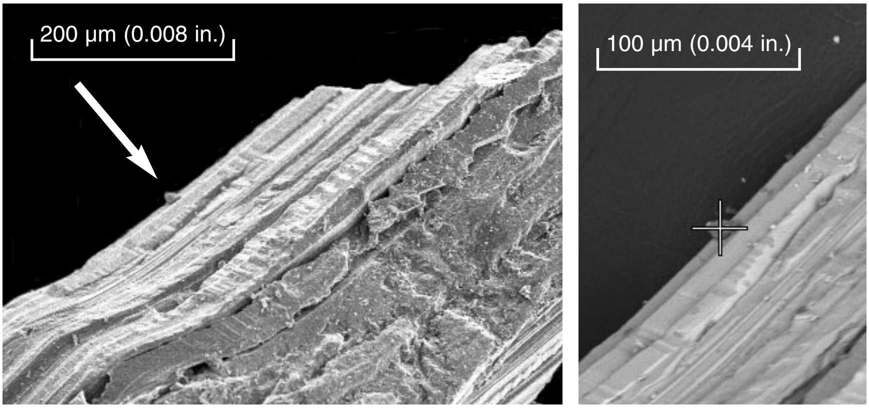


Figure 9. Upper left side of the celestine sample. The arrow in the left image points to a small bump on the celestine sample to be examined. The left image was obtained using the SE detector. The enlarged image on the right was obtained using the BSE detector and shows the spot selected for analysis (+).

(0.0001 inch) long, on the end of the quartz grain (Figure 10). A spot analysis of this crystal showed strontium, sulfur, and oxygen, the ingredients for celestine. Using the SE detector, we can zoom in even closer for a good look at this very tiny celestine crystal (Figure 11).

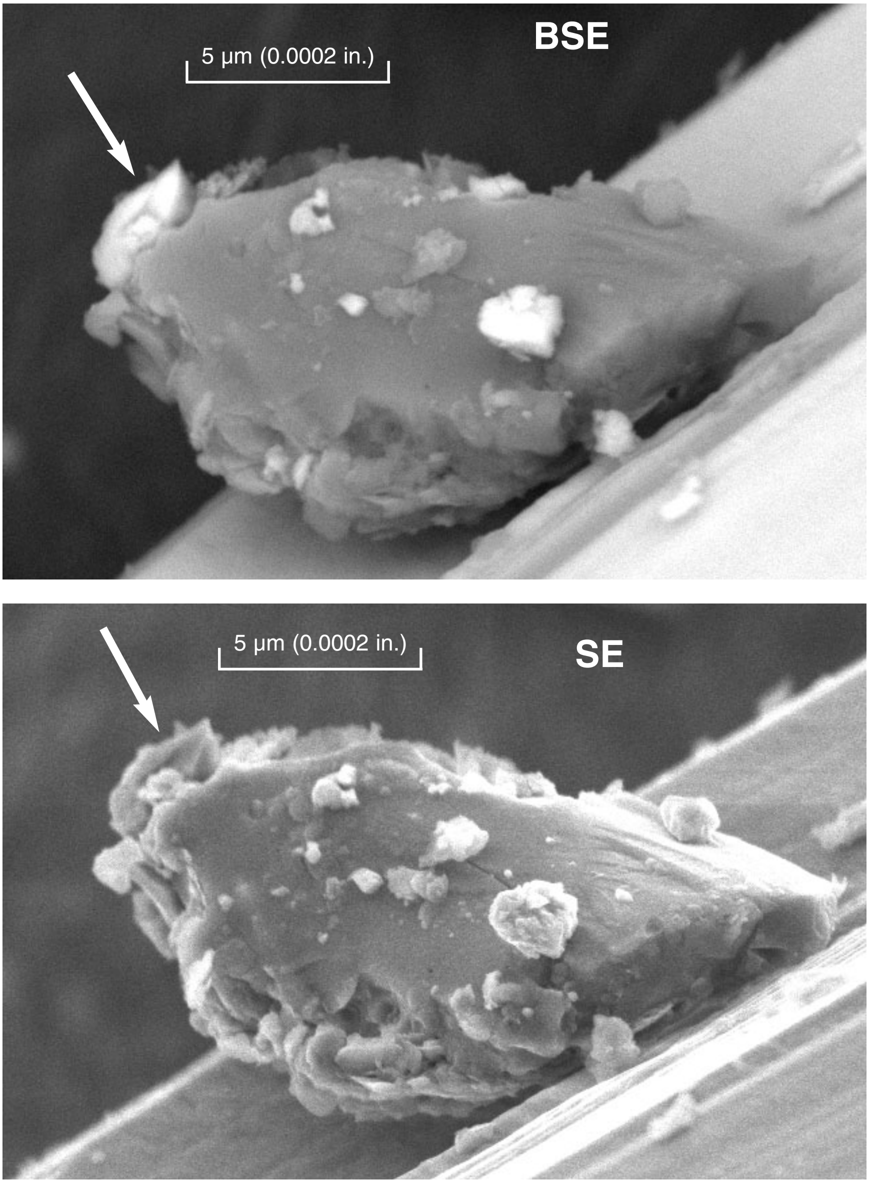


Figure 10. Photomicrographs of a very small crystal (arrows) at the end of the quartz grain shown in Figure 9. Note the differences between the BSE image (top), in which the relative brightness of the tiny crystal shows that it has a higher average atomic number than the silicon and oxygen that make up the quartz, and the SE image (bottom), which provides no clues as to composition but shows much more detail.

WHAT WE ARE DOING WITH IT. Since it was installed last March, the SEM has been put to a variety of applications. These include obtaining analytical data from samples important to ongoing studies of the geological framework of Pennsylvania, being used as a nondestructive method to verify the identification of minerals that will be sent to other laboratories for radiometric dating, and supplementing mineralogical data obtained from other equipment in our laboratory in relation to a pollution study. Presently, the SEM is being employed in a study of the Goat Hill serpentine barrens in southern Chester County.

The Goat Hill study is being carried out to support the Bureau of Forestry and its mission to conserve native wild plants. Serpentine barrens of limited extent are found in several locations in southeastern Pennsylvania. They provide a home to a number of unusual plant species that are not found elsewhere in the commonwealth. This habitat exists only because of the unusual geochemistry of the rocks that are found in the barrens. The goal of the project is to gain a better understanding of the bedrock geology and its interaction with the plant life in order to better manage the land.

One of the minerals that is found in the serpentine barrens, but not in any appreciable quantity elsewhere in the state, is chromite. This mineral was an important economic resource in the region in the nineteenth century. The Wood mine, less than a mile from the Goat Hill property, was the world's largest producer of chromite in the 1800s. It was one of many chromite mines that existed in the area (Pearre and Heyl, 1960). Although chromite is a stable mineral that

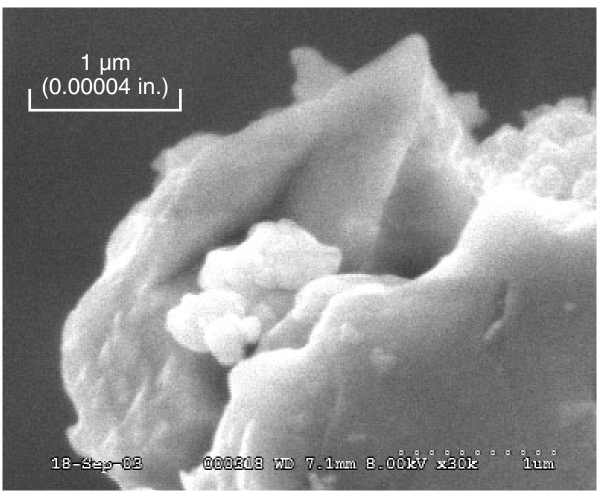


Figure 11. SE image of the tiny celestine crystal pointed out in Figure 10.

is not likely to affect plants, its abundance correlates with magnesium, which does have an appreciable effect on the vegetation.

The SEM has been used to obtain quantitative analyses of microscopic chromite grains from Goat Hill, the Wood mine, and other locations (Figure 12). The results of these analyses will help us understand the distribution of elements most favorable to the serpentine flora.

ITS ROLE AT THE SURVEY. The Pennsylvania Geological Survey has maintained an X-ray instrumentation laboratory since 1957. In the nearly half-century since then, thousands of samples have been examined by X-ray powder diffraction, which is used to perform mineral identifications, X-ray fluorescence, or both. This work has provided supporting data for Survey reports on mineral resources, geologic hazards, environmental issues, and other topics. Much work has also been done as a service for other government agencies and academia. This cooperative work has served to assist others in their studies of issues related to mining, land use, pollution, law enforcement, and other topics.

The last major change to our laboratory facilities took place in 1969, when the X-ray fluorescence spectrograph was acquired. At that time, it was reported that the new equipment would "allow the

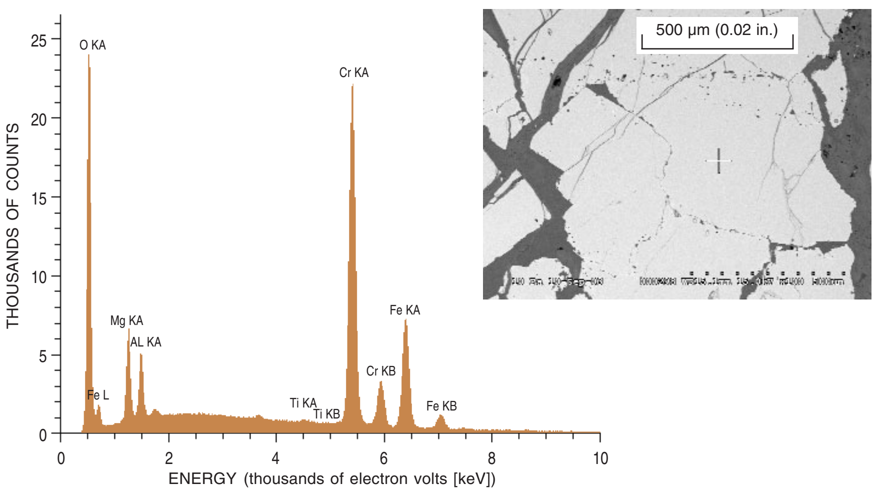


Figure 12. BSE image and EDS spectrum of a polished section of chromite from the Wood mine, Lancaster County. The light areas in the image are chromite. The darker areas are serpentine (magnesium iron silicate). The spot being analyzed is marked by the +. Chromium (Cr), iron (Fe), and oxygen (O) peaks mark the principal components of chromite. Other components include magnesium (Mg), aluminum (Al), and titanium (Ti).

Survey to perform a wider range of rock and mineral analyses with greater accuracy than was previously available" (Pennsylvania Geological Survey, 1970). Thirty-four years later, we have replaced the spectrograph with twenty-first century SEM and EDS equipment. This, along with the recent replacement of a major component of our X-ray diffractometer, allows us to once again offer new capabilities and improved service to the people of Pennsylvania. We anticipate many years of productive work with this equipment.

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Early Petroleum Discoveries in Washington County, Pennsylvania

by Kristin M. Carter
Bureau of Topographic and Geologic Survey

ONCE UPON A TIME . . . Petroleum has been used for at least 6,000 years by people of many cultures. Ancient Egyptian, Chinese, Hindu, and European peoples (just to name a few) used oil and gas for heating, lighting, construction, and medicinal purposes (Flaherty and Flaherty, 2002). Here in Pennsylvania, the existence of petroleum has been acknowledged for more than 500 years, first by Native Americans, who tapped the oil pools along Oil Creek in Crawford and Venango Counties for use as medicine, and then in the 1800s by European settlers, who discovered that oil and natural gas could be used to heat and light their homes (Harper and others, 1999). In the early to mid-1800s, salt well drillers were troubled by the occurrence of black, greasy oil in the briny aquifers they targeted. The hydrocarbons were a nuisance and fouled prized salt wells. Capitalizing on this situation, an entrepreneur by the name of Edwin L. Drake used salt-well-drilling techniques to drill a shallow well specifically for the purpose of extracting oil from the ground. Completed in Titusville, Pa., in August 1859, Drake's well was drilled to a depth of just under 70 feet. This well produced about 2,000 barrels of oil in its first year, gaining recognition for Pennsylvania and spawning the modern petroleum industry (Harper and others, 1999). For more information on this historical perspective, refer to *Pennsylvania Geology,* volume 29, number 1, Spring 1998.

"LITTLE" WASHINGTON STRIKES IT BIG! Petroleum exploration began in Washington County in 1881 (Carll, 1886), 100 years after the county was formed from a portion of Westmoreland County (Pennsylvania Historical and Museum Commission, 2003). The county seat, the city of Washington, is affectionately known as "Little" Washington to distinguish it from Washington, D.C. A handful of natural gas wells drilled in the northwestern section of Washington County in the early 1880s (most notably the McGuigan gas well in Mount Pleasant Township, shown in Figure 1) (Ashburner, 1886) inspired the residents of Little Washington to drill gas wells that would provide residential heating and lighting (Carll, 1886). They had a limited amount of success. By the fall of 1885, three wells, the Gantz well, Gordon well, and Gabby well (Figure 1), had penetrated Upper Devonian geologic rock units comparable to those penetrated by the McGuigan well (Carll, 1886). The only problem was that these three wells did not produce natural gas; instead, they struck oil! In fact, the Gantz and Gordon wells are considered "discovery" wells because their locations were the first ones at which the geologic units penetrated by the wells were tapped for oil.

The Citizens Natural Gas Company completed the Gantz well to a depth of 2,191 feet on January 1, 1885. The lowest 20 feet of this well was drilled through a fine- to coarse-grained, coffee-colored sandstone that yielded approximately 50 barrels of oil per day during drilling and sustained flows on the order of 20 barrels per day once it was completed (Carll, 1887; Boyle, 1898; and McGlade, 1967). On March 7, 1885, the first oil ever shipped from Washington County came from this well (Boyle, 1898). The Gantz well was located at Gantzs Mill near the Pennsylvania Railroad Freight Station in Washington. The oil-producing rock unit was named the Gantz sand after the farm on

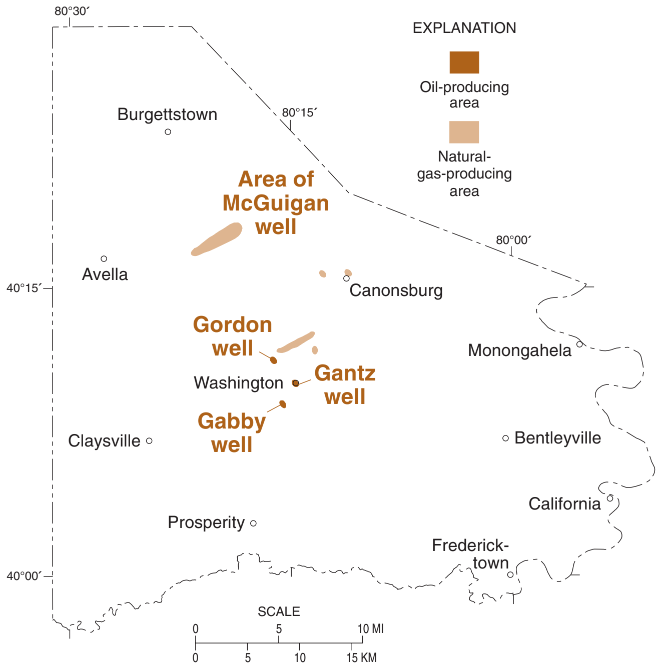

Figure 1. Oil and gas exploration progress in Washington County as of 1885 (from Ashburner, 1886). The Gantz, Gordon, and Gabby wells are represented by three separate oil pools. Natural-gas-producing areas were limited to central and northwestern Washington County.

which the well was drilled. This well has particular acclaim because it was the first commercially productive oil well in Washington County and the first well situated in what is now known as the Washington-Taylorstown oil field (Carll, 1887; McGlade, 1967). Based on current information from the Wells Information System (WIS) database of the Pennsylvania Geological Survey, the Washington-Taylorstown field includes more than 1,100 producing or abandoned oil and gas wells.

The Manufacturers Heat and Light Company completed the Gordon well to a depth of 2,408 feet on August 21, 1885. This well was located on the Gordon farm, about a mile northwest of the Gantz well, and it produced more than 100 barrels of oil per day (Carll, 1887; Boyle, 1898; McGlade, 1967). The oil-producing rock unit in this well was a 16-foot-thick sandstone named the Gordon sand. The productivity of the Gordon well provided the incentive for active oil exploration and development in Washington County and surrounding areas (Carll, 1887; McGlade, 1967).

The Gabby well was drilled over the course of several months in 1885, even as the Gantz and Gordon discovery wells were being completed. By November 5 of that year, the Gabby well reached the Gordon sand, the drillers having finally overcome drilling-related problems such as cave-ins and loss of drilling tools in the borehole (Boyle, 1898). The total depth of this well was reported at 2,608 feet as of December 4, 1885 (Boyle, 1898). Shows of oil and gas occurred from the Pennsylvanian Dunkard sand at a depth of less than 1,000 feet and from the Gantz sand at a depth of 2,294 feet. In addition, a show of oil was reported from the Gordon sand at approximately 2,550 feet (Carll, 1886; Boyle, 1898; McGlade, 1967). However, this well did not produce much oil until it was stimulated using nitroglycerin torpedoes on December 14, 1885 (Boyle, 1898). This process increased porosity and permeability of the bedrock so that oil flowed more easily into the well.

LAYING IT ON THICK. The Gantz and Gordon penetrated two of several oil- and gas-producing horizons in the Upper Devonian Venango Group. Named by members of the Second Pennsylvania Geological Survey in the late 1800s, this sequence of rocks is on the order of 360 to 370 million years old and consists of interbedded layers of shales, siltstones, sandstones, and conglomerates (Harper and Laughrey, 1987). In southwestern Pennsylvania, the Venango Group ranges from less than 100 feet to more than 600 feet in thickness, averaging about 400 feet within the city of Washington (Harper and Laughrey, 1987).

The Venango Group consists of up to seven different sandstone units, including the Hundred-Foot, Nineveh, Gordon, Fourth, Fifth, Bayard, and Elizabeth zones. Figure 2 is a representative stratigraphic column of the Venango Group in Washington County. The Bayard and Elizabeth zones are not included in this column because these units are absent in the Little Washington area of Washington County. As shown in Figure 2, the Gantz sand is at the very top of the Venango Group (the Hundred-Foot zone). The Gordon sand is located within the third sandstone unit, appropriately named the Gordon zone, and lies approximately 200 feet below the Gantz sand (Harper and Laughrey, 1987).

WHERE ARE THEY NOW? Figure 3 is a more detailed map of Little Washington and vicinity, and shows where the Gantz, Gordon, and Gabby wells were drilled. These three wells had a significant influence on the location of petroleum drilling in the greater Washington area,

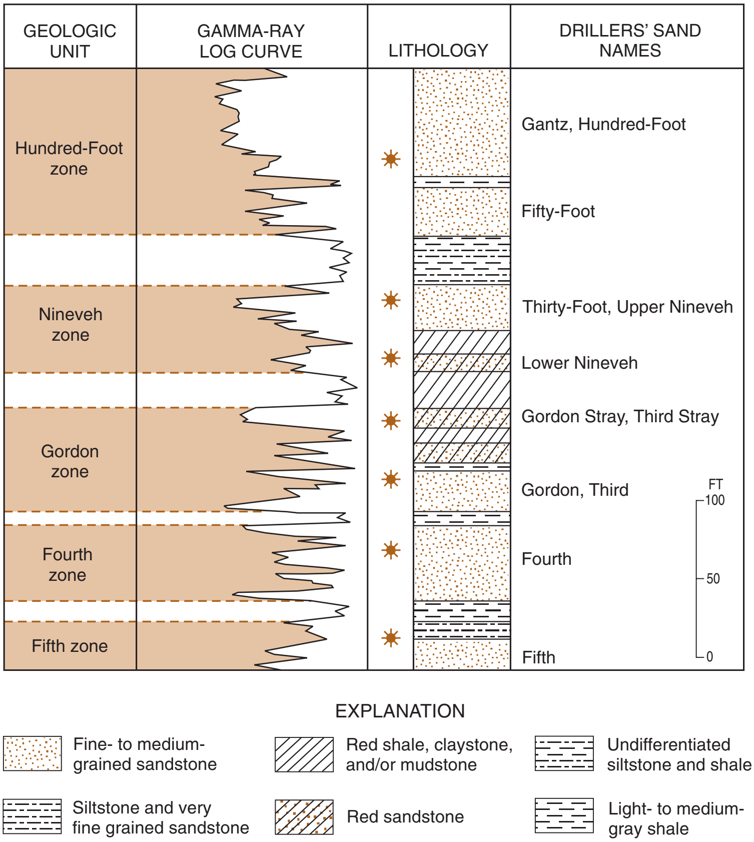

Figure 2. Generalized stratigraphy of the Upper Devonian Venango Group (from Harper and Laughrey, 1987, Plate 1). Much of the oil and gas production in Washington County is from the five sand zones, as indicated by the oil-and-gas-production symbols.

as is evidenced by the large number of oil wells located there. Most of these wells, including the Gantz, Gordon, and Gabby, have since been plugged and abandoned.

The Gantz well was situated near the present-day Pennsylvania Railroad Freight Station within the city of Washington (Figure 3). The Gantz discovery well is recognized on a historical marker (located just west of the original well) as the first oil well ever drilled in Washington County (Figure 4).

The Gordon well was drilled in Canton Township, on the floodplain of Chartiers Creek (Figure 3). By the late 1950s, this area was the home of Brockway Glass Plant No. 7, and by the 1990s, it was an industrial complex of several companies (Figure 5). The author has nominated this site for a historical marker to acknowledge the Gordon discovery well and its role in the petroleum industry in Washington and neighboring counties.

The Gabby well was drilled in North Franklin Township, south of the Washington city limits (Figure 3). This part of town is now dominantly residential. Although initially not as productive as the Gantz and Gordon wells, the Gabby well, once stimulated, produced oil volumes comparable to those of the Gantz well (Boyle, 1898).

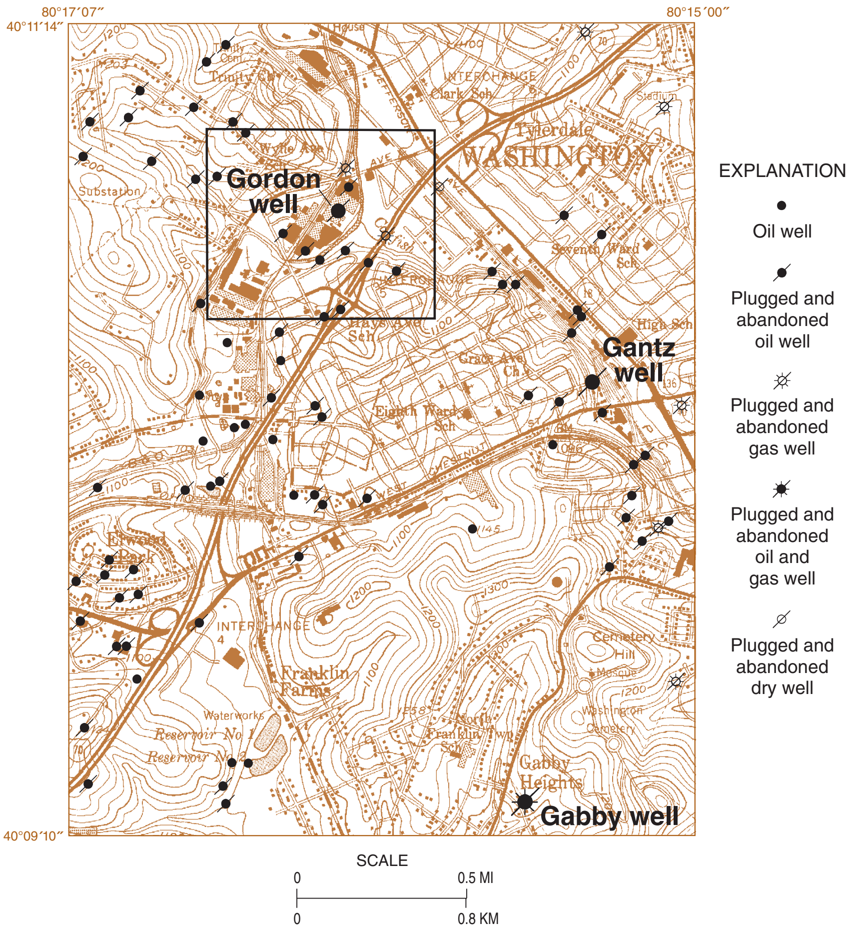

Figure 3. Present-day oil and gas well distribution near Little Washington. This area was heavily drilled for oil and gas through the early 1900s. The petroleum came from the Washington-Taylorstown field. The black box encloses the area shown in Figure 5.

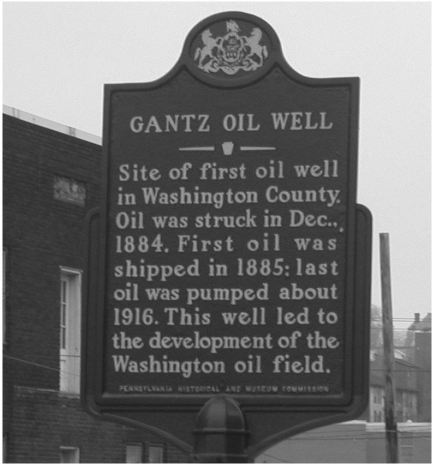

Figure 4. Historical marker for the Gantz discovery well. This particular marker is one of several such markers in the greater Washington area.

'WIS'H YOU COULD LEARN MORE? Would you like to get information about an oil or gas well on your property, or perhaps obtain a map of oil and gas wells in your area? If so, the Pennsylvania Geological Survey can help you. The WIS is a comprehensive database in which detailed information associated with drilled oil and gas wells, in addition to undrilled, canceled, void, or expired drilling permits, is stored and organized. Whereas the WIS database is used to keep track of

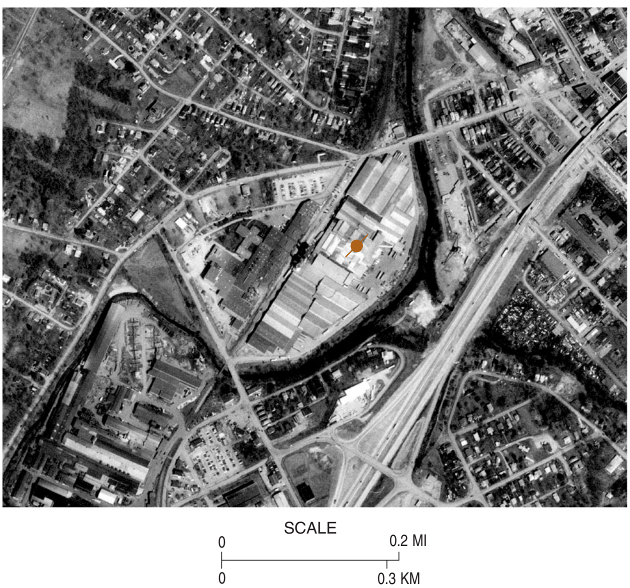

Figure 5. Location of the Gordon discovery well (brown symbol) shown on part of the U.S. Geological Survey Washington West SE digital orthophoto quarter quadrangle, 1993. This area along Chartiers Creek is now largely industrial. See Figure 3 for the location of this photograph.

the well details, a linked mapping system is used to create maps showing the locations of the wells and other important geographical features. This mapping system is part of a geographic information system (GIS), a complex computer system that allows the user to capture, analyze, and display data digitally according to its location (Figure 3 is an example). To date, the latitude and longitude data for several tens of thousands of wells have been entered into the WIS database for the purpose of GIS mapping, and more than 4,000 of these wells are located in Washington County. Using the WIS database, Survey employees can provide well information valuable to regulatory authorities, the oil and gas industry, other mineral resource industries, land use planners, environmental consultants, and many others.

As digital oil and gas base maps have been completed for certain counties in the commonwealth, they have been released to the public. The figure on the back cover shows the current availability of these maps. Please contact the Pittsburgh office of the Pennsylvania Geological Survey at 412–442–4235 to learn more.

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NEW RELEASE

Survey Publishes Digital Karst Density Map

For the first time in its history, the Bureau of Topographic and Geologic Survey is releasing a formal map publication solely in a digital format. **Map 68, Density of Mapped Karst Features in South-Central and Southeastern Pennsylvania,** by staff geologists William E. Kochanov and Stuart O. Reese, is now available as a free download on the Survey web site at www.dcnr.state.pa.us/topogeo/map68. On the map, the density of karst features is depicted by a range of colors. The map was created by Reese using ESRI ArcMap software and exported at 1:300,000 scale in Portable Document Format (PDF).

The information shown on Map 68 represents years of work. In 1985, Kochanov began a series of investigations to map karst features of carbonate rocks in Pennsylvania. The investigations led to a succession of county-based open-file reports that were published by the Bureau. The density values on Map 68 portray the density of the central point locations of these mapped karst features, which include surface depressions, sinkholes, and cave openings. More than 111,000 data points from 107 7.5-minute quadrangles in 14 counties were digitally compiled.

Map 68 provides a clear regional view of the trends and concentrations of known karst features. Karst terrains are often associated with ground instability and the damage that occurs to buildings, utilities, and roads when the underlying earth surface gives way. Karst features represent pathways for direct groundwater recharge and, with them, an increased vulnerability for groundwater contamination. Map 68 is useful for regional planning and preliminary site studies in karst terrain, but it is not a substitute for site-specific subsurface investigations.

Map 68 is 43 by 27 inches and has a PDF file size of 2.49 MB. It can be viewed using Adobe Reader software. In addition to the full-size map, a series of “mapbook” images are available on the Map 68 web site. These 14 images, each of which is centered on one of the 14 counties in the map area, are at the map scale of 1:300,000 and can be printed on legal-sized paper. Like Map 68, they are PDF files.

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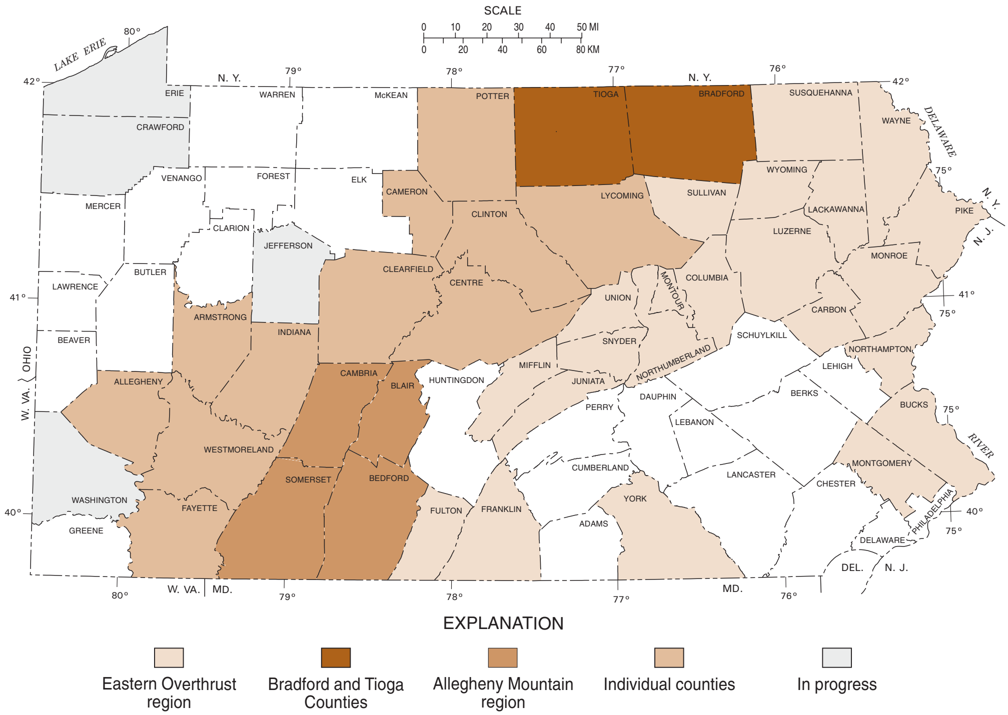
AVAILABILITY OF OIL AND GAS BASE MAPS

Status of Pennsylvania Geological Survey oil and gas base maps. CD-ROMs are available for the 39 counties shown in shades of brown. (See article on page 12.)



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