Pennsylvania Geology

Vol. 39 No. 1

Bill Kochanov, Pennsylvania Geological Survey, admires a spring spilling into the Fairfield Quarry, Adams County, Pa. This spring originates in fractured (faulted?) Beekmantown carbonate rocks in a quarry operated by Valley Quarries, Inc.

COMMONWEALTH OF PENNSYLVANIA
Edward G. Rendell, Governor
DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES
John Quigley, Acting Secretary
OFFICE OF CONSERVATION AND TECHNICAL SERVICES
Cindy Adams Dunn, 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

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.

This Edition's Editor: 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 editor at the address listed above. To subscribe send an email to RA-pageology@state.pa.us.

Table of Contents

Editorial

All shook up

Jay Parrish
State Geologist
Pennsylvania Geological Survey

Moving from a paper *Pennsylvania Geology* to a digital version has us all shook up. Change can be difficult. But as we put together this issue, I found it remarkably freeing to realize that I could include color photos without extra cost, and another article without worrying about exceeding the page count. As a result, we can save about $12,000 per year in these difficult times.

In recent months, central Pennsylvania has been "all shook up" as well, as we have experienced a number of small earthquakes. They have mostly been in York County, but one, a magnitude 3.3 quake, was located in Lancaster County. The York County quakes have been in the 2 range and, therefore, are relatively small, although they seem to have produced a lot of noise. The Lancaster County quake was big enough to feel at some distance and produced audible noise as well.

Fortunately, local universities have functioning seismometers running and all of this activity was captured. The Survey also has a research quality seismometer installed as part of a network run in conjunction with Penn State University (PSU). Dr. Andy Nyblade has overseen the installation of a seismometer at PSU's Brandywine campus as well as one here in our Middletown office. We are purchasing two more seismometers this year and hopefully two more the following year. Combined with existing systems run by PSU and seismometers run by other universities, we think we can pretty well cover the state. This is in anticipation of Earthscope, a National Science Foundation-funded project to place an array of seismometers about 50 km apart. After recording for 18 months, we should have a pretty good idea of exactly how much seismic activity is occurring, and perhaps something about the geologic structure.

The Lancaster County earthquake of December 27, 2008 was recorded at our Middletown office on our new seismograph (Fig. 1):

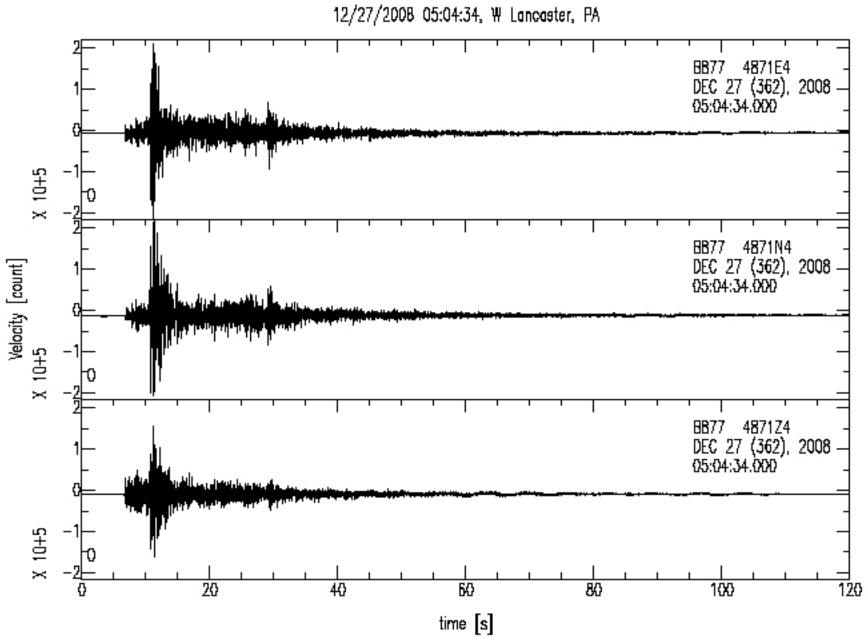


Figure 1. Seismograms from the Middletown three-component seismometer, showing the E-W, N-S and vertical components.

It was also recorded at the Brandywine campus of PSU, which gave us the following record (Fig. 2):

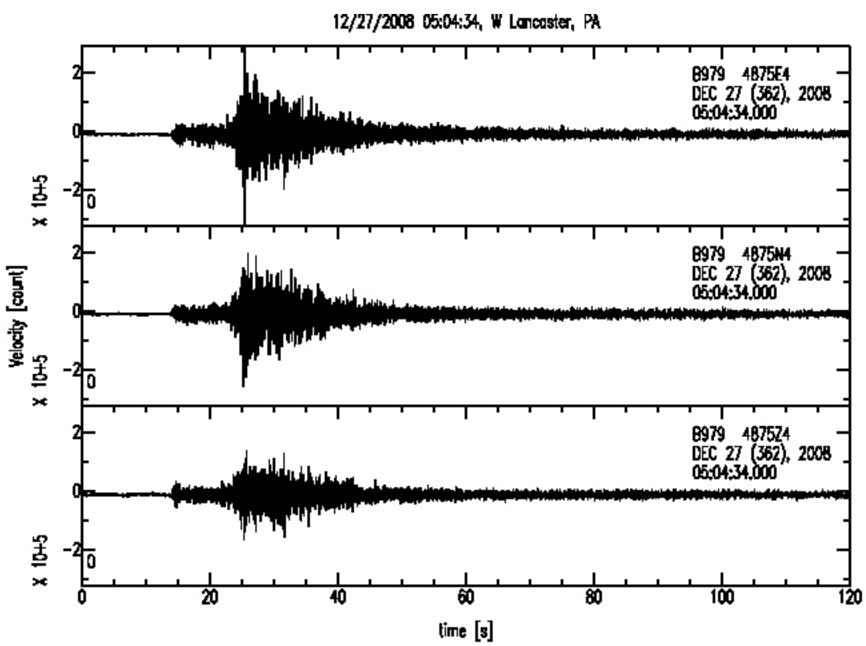


Figure 2. Seismograms from the Brandywine three-component seismometer, showing the E-W, N-S and vertical components.

Notice the difference in p-s times (first movement to first big squiggle), showing that Brandywine is indeed farther from Lancaster than Middletown!

As this network grows, you will be able to see each seismometer on-line, allowing you to see for yourself where a local quake may be, or how a large quake somewhere else in the world is recorded in a different geologic setting.

Finally, some of you have asked to see that photograph of me atop a piece of rock in color instead of black and white. (I don't know why). For you rock hounds, it is a piece of the Conestoga Formation, a dirty Cambro-Ordovician marble. It is found in Lancaster County and shows multiple periods of deformation. So, through the wonders of a digital age, here it is!

Multiple deformations and no extra printing costs.

Sudburyite, Safflorite and Other Microminerals in the Platinum-Group Element Enriched Ferrogabbro, York Haven Diabase, Reesers Summit, York County, Pennsylvania

Robert C. Smith, II*
and
John H. Barnes
Pennsylvania Geological Survey

* Mechanicsburg, Pennsylvania 17050

A relatively fresh road cut for Interstate 83 at Reesers Summit, one mile south of the exit for the Pennsylvania Turnpike between Harrisburg and York in York County, was examined by the senior author and his advisor at Penn State University, Dr. Arthur W. Rose, in the winter of 1967. At that time, they collected a sample of chilled York Haven Diabase 0.2 m from the upper contact of the sheet as part of a study of the regional variation in diabase geochemistry and a possible relation to Cornwall-type iron (Fe)-copper (Cu)-silver (Ag)-gold (Au)-cobalt (Co) ore deposits (Smith, 1973). After collecting, preparing, and analyzing 23 composite rock samples and 1 mineral separate through what was to become the type section of York Haven Diabase, 16 km to the southeast of Reesers Summit at York Haven, as well as at Falmouth and portions of the exposed low-water Susquehanna River bed in between, they had returned to Reesers Summit to collect a chilled diabase sample less than 3 cm from the upper contact and a ferrogabbro from the center of the exposure. The lighting was favorable and Smith noted trace chalcopyrite in the ferrogabbro. The chalcopyrite, as well as bornite and covellite, were confirmed by ore microscopy. Their initial field identification of the ferrogabbro was based on its anomalously great heft as well as the deflection of the compass needle of a Brunton pocket transit.

Although the chemical compositions of the chilled margins at York Haven and Reesers Summit are almost identical, it was recognized that the ferrogabbro interior of the sheet at Reesers Summit was complimentary to the orthopyroxene ($En_{78}Fs_{18}Wo_4$)-rich cumulate zone at York Haven. Accordingly, a lateral flow mechanism was proposed (Smith, 1973,

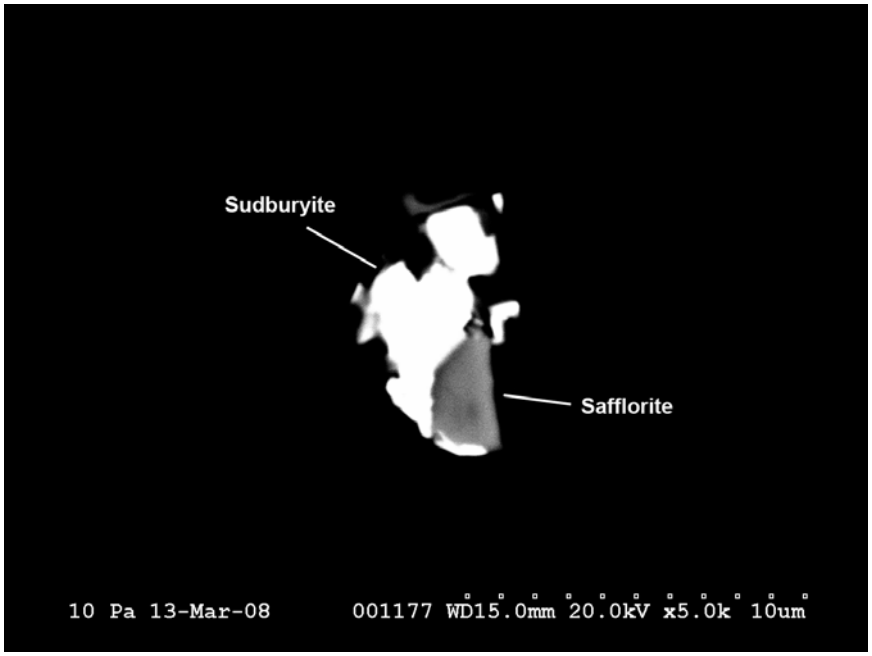


Figure 1. Scanning electron photomicrograph of sudburyite and safflorite from Reesers Summit. The grain is about 4 micrometers (0.004 mm) across and 7 micrometers long.

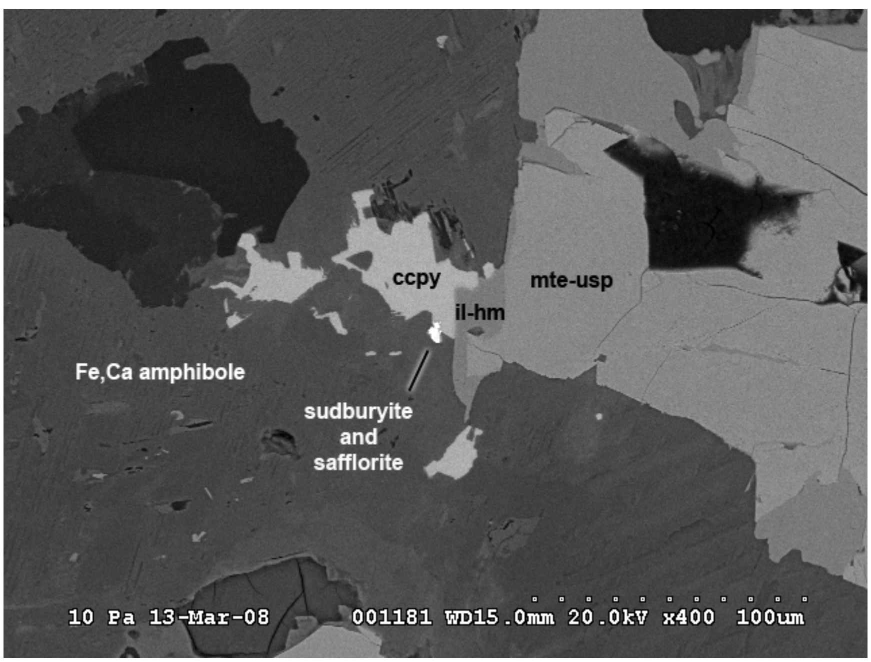


Figure 2. The neighborhood surrounding the sudburyite safflorite shown in Figure 1. The minerals include an Fe, Ca amphibole containing 1.6 percent Cl; chalcopyrite (ccpy) containing 0.2 percent Pd; ilmenite-hematite (il-hm); and magnetite-ulvöspinel (mte-usp).

p.119). Further, petrographic examination of thin sections of the ferrogabbro at Reesers Summit revealed fortuitous equilibrium assemblages of quartz-fayalite (an iron-bearing olivine)-magnetite and magnetite-ulvöspinel. From quantitative electron microprobe analyses done with assistance from Lee B. Eminhizer of Penn State University, the temperature of solidification of the diabase, availability of oxygen, and other parameters were calculated (Smith, 1973, p. 122-128). The extreme enrichment of chlorine (Cl) in the ferrogabbro (0.28% Cl) and the role chlorine would have in hydrothermal transport of Cu were noted (Smith 1973, p. 128).

Years later, Dave Gottfried, an out-of-the-box-thinking geochemist at the U.S. Geological Survey (USGS), Reston, Virginia, remembered low-temperature work by Art Rose and Bill Fuchs in the Stillwater Complex, Montana (Rose and Fuchs, 1974). Rose and Fuchs suggested that, in some environments, palladium (Pd) would “piggyback” on Cu. Gottfried alleged that recognition of a possible connection between this Pd-Cu piggybacking in Montana and the report of chalcopyrite at Reesers Summit came to him during a reading from Smith’s thesis at early morning “daily devotions” he led with an eastern Mesozoic working group and coffee klatch that included Al Froelich and James M. McNeal, both of the USGS. As a result, on July 18, 1984, Smith, of the Pennsylvania Geological Survey; Rose; Gottfried; McNeal; and Froelich converged at the Interstate 83 road cut on Reesers Summit. Despite the strong, sickening smell of burning brakes along this steep grade, Smith, Rose, and McNeal collected 15 composite samples at 21-m vertical intervals measured from the projection of the upper contact, Each composite was initially drawn from three blocky chunks of rock, one each collected by Rose, Smith, and McNeal at each interval. These blocks were scrupulously trimmed by Froelich and Gottfried in the field that day.

Analyses of these samples for palladium and platinum (Pt) by the U.S. Geological Survey established the existence of a diffuse, enriched anomaly in ferrogabbro, defined by the four samples collected ~115 to ~190 m below the top of the sheet; however the anomaly lacked an apparent direct economic significance (D. Gottfried, personal communication 2/27/86 and Froelich and Gottfried, 1988). Al Froelich (personal communication, 2/23/88) provided plots for Pd, Pt, Au, Cl, and sulfur (S). Gottfried and others (1990) reported follow-up results based on similar field sampling on September 28, 1988, by Smith and Sam W. Berkheiser, also of the Pennsylvania Geological Survey, but at a closer, 5-m spacing, and similar analytical methods. This seemed to yield a more erratic series of Pd-enriched subzones (Gottfried and others, 1990, Table 7 and Figure 3), but, as shown below, more detailed subsampling, larger analyzed aliquots, and an improved analytical method tend to support a more uniform anomaly.

Mineralogical studies by Harvey E. Belkin, USGS, on a sample Smith collected 173.0 m below the projected upper contact, resulted in reports of an unspecified microscopic palladium bismuth antimonide on the margin of bornite, which was on the margin of chalcopyrite. This, in effect, nicely confirmed Gottfried’s application of the Pd-Cu piggyback hypothesis to Reesers Summit! Belkin also reported a 1-micron electrum grain

(H. Belkin, personal communication, 3/2/89). Belkin (1989) reported that chalcopyrite is the most abundant sulfide, but that lesser amounts of bornite, galena, and sphalerite were present. Unnamed Pd, Co, nickel (Ni), antimony (Sb), ±Fe, ± S arsenides, the presence of Pt and Au in the associated chalcopyrite, as well as a high concentration of Cl in the amphiboles, were also reported.

Smith, unconvinced that the thorough retrimming of the samples cut by Rose, McNeal and himself for the USGS had not introduced "nugget-effect" errors or even caused a thin, higher grade palladium-platinum zone to be missed, resampled the section with the assistance of John H. Way of the Pennsylvania Geological Survey. This sampling by Smith and Way "after hours" on July 27, 1984, took place when the right-hand lane of I-83 was closed for repair and was carried out at 21-m intervals from the projection of the upper contact. Smith and Way collected 17 composites, each consisting of three approximately 1-kg blocks. For final sampling through the Pd-enrichment zone, Smith was ably assisted on April 3, 1989, by Sam Berkheiser. Analyses of samples collected by Smith, Way, and Berkheiser through the center of the Pd-Pt enrichment zone are presented in Table 1. (This center was estimated earlier by Smith using the less precise and less accurate fire assay-I.C.P. method on samples covering the intervals 159.6-169.2, 169.2-178.9, and 178.9-188.5 m from the projection of the upper contact.) Based on the preferred iridium (Ir) and Pt data in Table 1, the center of the zone was located and sampled. Thus, despite subsampling on 20-cm intervals and obtaining analyses with better accuracy and precision, the data tend to confirm the initial supposition of the USGS that the mineralized zone was too diffuse to be of direct economic interest.

Nevertheless, interest in the economic geology of the eastern Mesozoic Basins and cooperation between the U.S. Geological Survey and the Pennsylvania Geological Survey continued. Froelich and Gottfried encouraged Smith to sample and analyze a wide variety of Mesozoic Cu deposits in Pennsylvania for a forthcoming publication. Once again recruiting willing help from Sam Berkheiser and from Donald T. Hoff of the State Museum of Pennsylvania, composite samples were collected from 21 locations and analyzed for Cu, Au, Ag, Co, Ni, As (arsenic), Bi (bismuth), and Mo (molybdenum). Smith wrote a rather thin saga to accompany the analyses and forwarded it to Gottfried. A few months later, Smith received a marked-up copy indicating that a significant upgrade was desired in order for it to be included in the flagship U.S. Geological Survey Bulletin series. The authors gladly complied and obtained a review from Art Rose, who also noted the usefulness of examining the Au/Cu ratio. Needless to say, the authors were pleased when they later learned that their efforts were accepted for inclusion in USGS Bulletin 1776! Analyses of two composite samples from Reesers Summit were included in that report. Analyses of a Reesers Summit veinlet composite therein suggested that hydrothermal remobilization of Cu, Co, Ni, and As into veinlets in the ferrogabbro was possible.

PRESENT STUDY For the present study, the authors examined the microscopic, metallic minerals in the center of the ferrogabbro Pd-Pt zone at Reesers Summit. This was done by examining five ~ 2x3-cm polished slabs from the 169.2-to-178.9-m assay

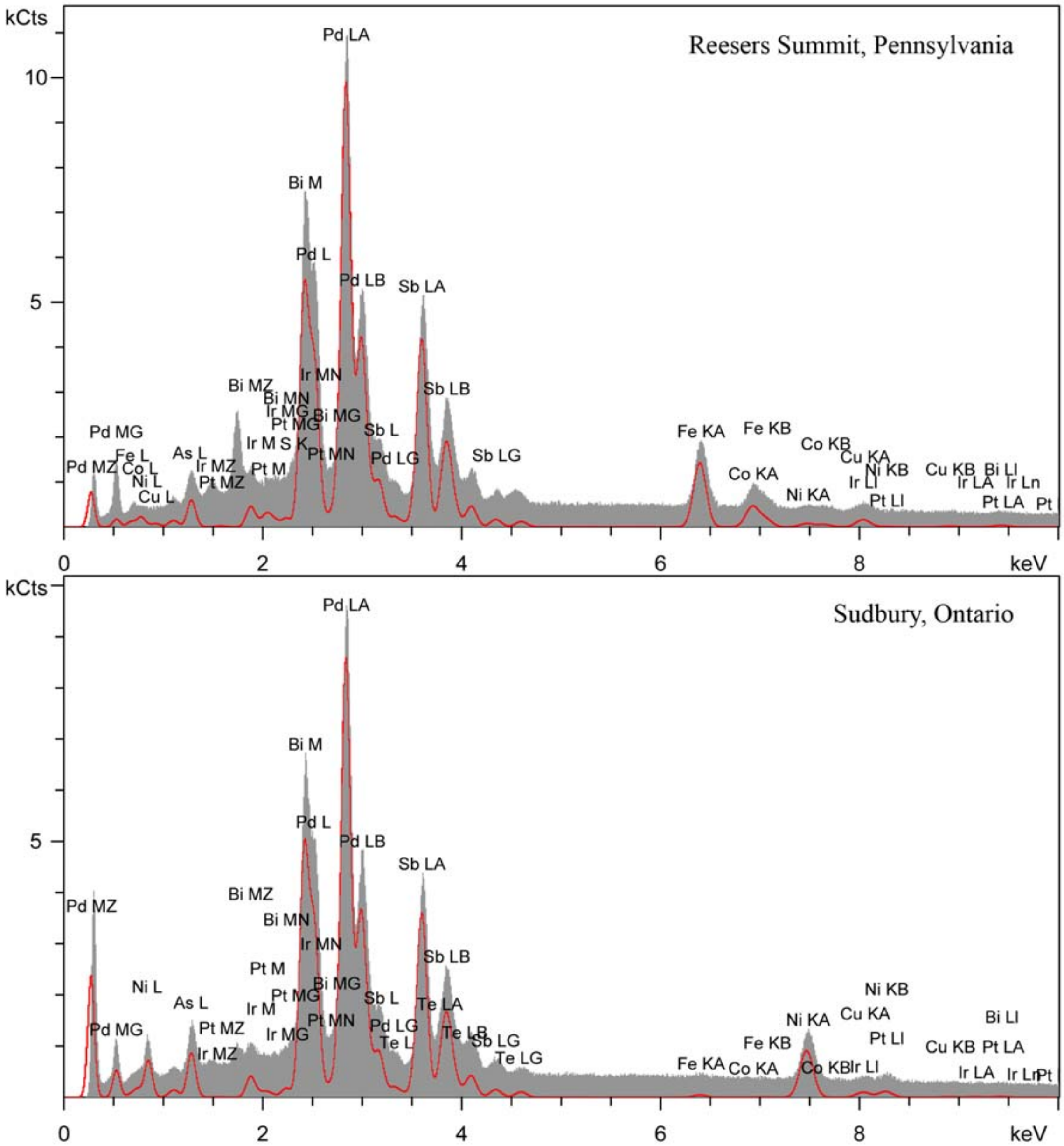


Figure 3. Energy dispersive spectra obtained for the sudburyite grain in Figure 1 (top) and sudburyite from near Sudbury, Ontario (bottom). Although sudburyite has the ideal formula of (Pd,Ni)Sb, at Reesers Summit Pd has been partly replaced by Pt and Ir; Ni by Co, Cu, and Fe; and Sb by Bi, As, and S.

zone plus two from as close as practical to 173.0 m below the projected upper contact, the zone at which Harvey Belkin had found the microscopic palladium bismuth antimonide. Each slab was carefully examined using a scanning electron microscope at 120x in a dimly lit room and then magnifying the barely visible dots to 1000 to 5000X. Grains having a reasonable size were analyzed using energy dispersive spectrometry (EDS). This resulted in the recognition of three minerals containing essential Pd and another two containing accessory Pd. The metallic minerals observed are listed in Table 2.

It is presently believed that the most abundant Pd mineral is sudburyite (Figures 1 and 2). It has the ideal formula of (Pd,Ni)Sb, but at Reesers Summit Pd has been partly replaced by Pt and Ir; Ni by Co, Cu, and Fe; and Sb by Bi, As and S (Figure 3). (Calculating the stoichiometry, i.e., ratios of cations and anions, is especially difficult in this case because Bi may be behaving as either a cation or an anion or both.)

The second most abundant Pd mineral observed seems to have the approximate formula of $Pd_3(Sb,Bi)_2$. It has not been matched to a known species. The third, also unmatched to a known species, has an approximate formula of (Pd,Pt)(As,Sb). A classic positive correlation between the contents of As and Pt in these Pd minerals was noted. The two observed minerals containing minor Pd are probably cobaltite and safflorite. The cobaltite (?) was found only in a composite grain with sudburyite and an apparent, unexplained (Pb (lead),Fe,Cu,Co)(As,S**)**. This analysis might, in reality, represent the compositions of two extremely small, adjacent grains of minerals such as safflorite and galena. The more abundant safflorite occurs both as anhedral composite grains with sudburyite (Figure 1), as euhedral crystals adjacent to chalcopyrite, and as isolated, anhedral grains. Rims on safflorite tend to be slightly enriched in Co and Pt and lower in Fe and Ni relative to cores. Chalcopyrite typically carries Pd, Pt, and Ir at the few tenths of a percent level. The Pd is likely piggybacking Cu, as predicted by Dave Gottfried, and the Pt and Ir may be substituting for Fe in the chalcopyrite.

Some of the minerals identified in the ferrogabbro at Reesers Summit are new to Pennsylvania, some are rare, and two may not even have been previously recognized as species, but all add to a better understanding of the mineralogy of the ferrogabbro. It is likely that some of the aeromagnetic anomalies identified by the Bethlehem Steel Company and drilled to locate iron-ore deposits (Wharton, 2003) were caused by ferrogabbro but were never checked for metals other than iron. Chloride complexing to mobilize Pd (Boudreau, 1993) and Cu (Rose, 1976) has been long known. If a York Haven Diabase ferrogabbro, such as the one at Reesers Summit, had been fractured by a late fault or fluid pressure, where might the departing chloride-rich hydrothermal fluids have taken the copper and palladium (Smith, 1973, p. 128)?

Table 1. Analyses of platinum-group metals plus gold and silver in the center of the Pd-Pt enrichment zone in ferrogabbro at Reesers Summit, York County, Pa. Ruthenium (Ru), rhodium (Rh), and rhenium (Re) are <1 ppb in all samples. Analyses by NiS fire assay/I.C.P./M.S. on 25-g splits of samples from composites of fist-size pieces collected on 20-cm centers by R. C. Smith, II, S. W. Berkheiser, and J. H. Way. Upper sample contains 1.3 ppm selenium (Se) and 1.7 ppm tellurium (Te) and lower sample contains 0.7 and 0.9 ppm, respectively, by an atomic absorption hydride method. All analyses except Ag by SGS Canada, Toronto, Ontario, Canada. Ag analyses by Pb fire assay/I.C.P. on 10-g splits by Activation Laboratories, Ltd., Ancaster, Ontario, Canada.

Sample Name	**Meters below upper contact.**	**Pd ppb**	**Ir ppb**	**Pt ppb**	**Au ppb**	**Ag ppm**
YKRS163-89	165.8-167.7	95	<0.1	14	24	0.3
YKRS162-89	167.7-169.2	85	<0.1	13	47	0.2
YKRS28-88	169.2-170.8	103	0.1	12	63	0.3
YKRS29-88	170.8-172.5	148	0.5	37	11	0.2
YKRS30-88	172.5-174.1	138	0.3	30	29	0.2
YKRS31-88	174.1-175.6	141	0.1	19	16	0.3
YKRS32-88	175.6-177.4	121	0.1	17	16	0.4
YKRS33-88	177.4-178.9	131	<0.1	16	16	0.5

Table 2. Metallic minerals from the center of the Pd-Pt zone in ferrogabbro, Reesers Summit, York County, Pennsylvania, analyzed in the present study. Analyses done by standardless, variable pressure SEM/EDS, calculated using the ZAF algorithm.

Mineral	**Weight percent**	**Comments**
Bornite	Cu 60.6, Fe 14.1, S 25.2	Bleb in chalcopyrite
Chalcopyrite	Cu 33.7, Fe 31.3, S 35.0	Has core of sphalerite (analysis below). Many chalcopyrite grains contain a few tenths of a percent Pd and Pt.
Cobaltite	Co 20.8, Fe 7.1, Ni 4.4, Pd 4.5, Pt 0.6, As 42.5, S 17.5	Between grains of Pd(Sb,Bi) and Pd (As,Sb)
Galena	Pb 85.3, S 14.7	Other galena grains contain up to 7.3% Se.
Idaite (?)	Cu 54.0, Fe 17.6, S 28.4	Small lamella in chalcopyrite
Safflorite* or clinosafflorite	Co 16.4, Fe 11.6, Ni 1.1, Pd 1.2, Pt 1.0, As 68.2, S 0.4	
Safflorite* or clinosafflorite	Co 16.2, Fe 12.0, Ni 2.1, Pd 0.1, Pt 0.4, As 68.4, S 0.8	Core to euhedral.

Safflorite* or clinosafflorite	Co 17.4, Fe 10.0, Ni 1.9, Pd 0.1, Pt 1.6, As 68.2, S 0.9	Thin rim to above euhedral. Suggests later fluids richer in Pt.
Safflorite* or clinosafflorite	Co 16.1, Fe 12.6, Ni 2.0, Pd 0.2, Pt 0.9, As 67.1, S 0.7	Euhedral, associated with chalcopyrite. Ir 0.4 % also detected in this grain.
Safflorite* or clinosafflorite	Co 16.0, Fe 11.8, Ni 1.9, Pd 0.3, Pt 0.4, As 69.3, S 0.4	Anhedral.
Safflorite* or clinosafflorite	Co 14.1, Fe 11.5, Ni 2.0, Pd 2.9, Pt 0.3, As 66.3, S 1.5	Composite grain with sudburyite (Figures 1 and 2).
Sphalerite	Zn 60.1, Fe 4.6, Cu 2.8, Cd 0.4, In 0.2, S 31.5	Has rim of chalcopyrite (analysis above) and very small Pb-bearing inclusions.
Sudburyite	Pd 26.9, Pt 6.2, Ir 0.3, Fe, 5.9, Cu 1.3, Co 3.1, Ni 0.7, Bi 8.0, Sb 27.5, As 16.3, S 2.8	
Sudburyite	Pd 29.7, Pt 5.5, Ir 0.2, Fe 5.6, Cu 1.9, Co 1.4, Ni 0.7, Bi 10.0, Sb 31.5, As 12.2, S 1.5	
Sudburyite	Pd 29.9, Pt 0.6, Ir 0.7, Fe 10.8, Cu 0.2, Co 1.4, Ni 0.6, Bi 13.1, Sb 33.4, As 6.2, S 1.4	
Sudburyite	Pd 31.0, Pt 2.0, Ir 0.7, Fe 8.7, Cu 2.1, Co 1.8, Ni 0.7, Bi 13.7, Sb 33.7, As 4.6, S 1.0	
Sudburyite	Pd 33.7, Pt 2.1, Ir 0.2, Fe 6.4, Cu 1.9, Co 0.5, Ni 0.4, Bi 5.9, Sb 41.3, As 5.3, S 2.2	
Sudburyite	Pd 32.9, Pt 1.2, Ir, 0.4, Fe 6.6, Cu 2.5, Co 1.4, Ni 0.2, Bi 22.8, Sb 27.4, As 2.5, S 2.2	
Sudburyite	Pd 32.7, Pt 0.8, Ir 0.3, Fe 6.1, Cu 1.1, Co 2.2, Ni 0.4, Bi 20.8, Sb 26.4, As 9.2, S 0.0	Illustrated in Figures 1, 2, and 3.
Sudburyite	Pd 27.1, Pt 0.3, Ir 0.2, Fe 10.1, Cu 5.4, Co 3.6, Ni 1.2, Bi 19.1, Sb 20.5, As 6.1, S 6.4	

Sudburyite	Pd 30.2, Pt 8.4, Ir 0.5, Fe 7.5, Cu 0.9, Co 0.1, Ni 0.1, Bi 19.5, Sb 21.8, As 10.8, S 0.0	
“Pd_3Sb_2”	Pd 37.4, Pt 0.5, Ir 0.4, Fe 5.6, Cu 0.8, Co 0.0, Ni 0.2, Bi 24.4, Sb 29.5, As 1.2, S 0.0	Core to below
“Pd_3Sb_2”	Pd 38.2, Pt 0.4, Ir 0.7, Fe 5.4, Cu 0.8, Co 0.1, Ni 0.3, Bi 23.1, Sb 30.2, As 0.8, S 0.0	Rim to above
“Pd_3Sb_2”	Pd 33.6, Pt 1.0, Ir 0.5, Fe 4.4, Cu 3.8, Co 2.8, Ni 0.2, Bi 22.5, Sb 29.7, As 1.4, S 0.0	
“Pd_3Sb_2”	Pd 33.4, Pt 0.0, Ir 0.9, Fe 4.6, Cu 5.5, Co 2.7, Ni 0.1, Bi 24.1, Sb 28.1, As 0.8, S 0.0	
“(Pd,Pt)(As,Sb)”	Pd 29.4, Pt 19.6, Ir 0.9, Fe 5.4, Cu 1.7, Co 0.8, Ni 0.3, Bi 1.9, Sb 19.9, As 18.2, S 1.9	
Unknown A	Ag 31.6, Au 7.8, Cu 7.2, Fe 39.3, S 14.1	Possibly an uytenbogaardtite or penzhinite-like mineral. Cannot rule out at least some Cu, Fe, and S from adjacent chalcopyrite grain.
Unknown A	Ag 28.3, Au 11.2, Cu 9.3, Fe 34.2, S 17.1	
Unknown A	Ag 20.8, Au 18.1, Cu 3.4, Fe 47.3, S 10.5	
Unknown B	Pb 51.3, Fe 10.3, Cu 6.5, Co 5.0, S 17.7, As 9.3	Associated with Pd (Sb,Bi), (Pd,Pt)(As,S), and cobaltite listed above. Cannot rule out mixture.

*Safflorite verified elsewhere in York Haven Diabase by X.R.D. (Smith, 1978, p. 96).

ACKNOWLEDGEMENTS

The authors gratefully acknowledge helpful review by Harvey E. Belkin, U. S. Geological Survey, Reston, Virginia, who studied many of the minerals at Reesers

Summit in the late 1980's, and Art W. Rose, Pennsylvania State University, who served as Smith's mentor.

References

Belkin, H. E., 1989, Fluid inclusion and mineralogical studies of a PGE anomaly zone in the Reesers's [sic] Summit (PA) diabase: evidence for hydrothermal transport: Program and Abstracts, Second biennial pan-American conference on research on fluid inclusions, p. 10.

Boudreau, A. E., 1993, Chlorine as an exploration guide for the platinum-group elements in layered intrusions: Journal of Geochemical Exploration, v. 48, p. 21-37.

Fuchs, W. A., and Rose, A. W., 1974, The geochemical behavior of platinum and palladium in the weathering cycle in the Stillwater Complex, Montana: Economic Geology, v. 69, p. 332-346.

Gottfried, David, and Froelich, A. J., 1988, Variations of palladium and platinum contents and ratios in selected Early Mesozoic tholeiitic rock associations in the eastern United States: . *in* Studies of the Early Mesozoic Basins of the Eastern United States, U. S. Geological Survey Bulletin 1776, p. 332-341.

Gottfried, David, Froelich, A. J., Rait, Norma, and Aruscavage, P. J., 1990, Fractionation of palladium and platinum in a Mesozoic diabase sheet, Gettysburg basin, Pennsylvania: implications for mineral exploration: , Journal of Geochemical Exploration, v. 37, p. 75-89.

Rose, A. W., 1976, The effect of cuprous chloride complexes in the origin of red-bed copper and related deposits: Economic Geology, v. 71, p. 1036-1048.

Smith, II, R. C., 1973, Geochemistry of Triassic [sic] diabase from southeastern Pennsylvania: unpublished Ph.D. thesis, The Pennsylvania State University, 262 p.

Smith, II, R. C., 1978, The mineralogy of Pennsylvania, 1965-1975, Special Publication No. 1, Friends of Mineralogy, Pennsylvania Chapter, 304 p.

Smith, II, R. C., Berkheiser, S. W., and Hoff, D. T., 1988, Locations and analyses of selected Early Mesozoic copper occurrences in Pennsylvania: *in* Studies of Early Mesozoic Basins of the Eastern United States, U. S. Geological Survey Bulletin 1776, p. 320–332.

Wharton, H. M., 2003, The 1949 discovery of the Grace Mine iron deposit: Pennsylvania Geology, v. 33, no.1, p. 2-9.

Step by Step – Sustaining and Protecting Water Resources

Stuart Reese
Pennsylvania Geological Survey

Even a casual observer recognizes that water is our most precious resource. However, sometimes water doesn't get noticed unless there is too much (that's flooding!) or too little (a drought).

In a typical year, about 40 inches of precipitation falls on Pennsylvania. This is equivalent to about 31 and a half *trillion* gallons of water. The Department of Environmental Protection estimates that daily water use in Pennsylvania is about 10 billion gallons, which works out to over 10 percent of annual precipitation. Seems like we have plenty of water! But when you consider that about half of precipitation evaporates or transpires back into the atmosphere, and that precipitation and use are not evenly distributed across the state, you quickly realize that there might be situations where there is not enough water for all the wants and needs of an area.

On Thursday, December 18, 2008, the Statewide Water Resources Committee voted to approve the new State Water Plan, culminating a 5-year process to update the plan that had not been updated since the 1970s. One of the main objectives of the State Water Plan is to identify areas where the demand for water exceeds, or is projected to exceed, available supplies. This process points to a desire to be good stewards of our natural resources, and to plan for sustainable use of our water resources.

Another part of the State Water Plan recommends legislative action to address water concerns as determined by the State Water Resources Committee and public testimony. The top recommendation is for the establishment of water well construction standards and licensing of water well drillers based on proficiency.

Pennsylvania and Alaska are the only two states in the country that do not regulate the construction of private water wells. To be a licensed water well driller in Pennsylvania, one only has to pay the $60 fee. Most states require an exam for the certification or licensing of drillers, and nearly all states stipulate how water wells should be constructed in order to protect both the well owner and the water resource.

Because private water supplies are unregulated in Pennsylvania, homeowners who have private water supplies must take responsibility for their own water quality and well maintenance. No state requirements prescribe grouting or construction materials, minimum yield, or acceptable quality.

State law does require drillers to have a valid rig permit and a Water Well Drillers License, issued by the Bureau of Topographic and Geologic Survey. They must also give the state and homeowner a copy of the Water Well Completion report. This report describes where, when and how the well was constructed. A few local and county governments have adopted standards for private water supplies. Mortgages associated with federal housing may require certain water analyses for the water well. Other lending institutions also may have sampling requirements.

For the sake of the homeowner and the environment, the Survey has been in favor of water well construction standards for many years. Construction standards provide technical methods to protect groundwater and the homeowner through proper practices and materials. There is no more direct way that has such immediate benefits to protect groundwater than to start with your own private water supply that is protected through proper placement and construction. And for a state that has the second most private water wells in the nation (after Michigan), it's the right step to take.

Water seeps from a fracture in Catskill Formation, Clinton County, Pa. – Photograph by Stuart Reese.

Geologic Research in Pennsylvania

If you would like to include your research in future issues of Pennsylvania Geology, please send your information to RA-pageology@state.pa.us

ONGOING RESEARCH

Barnes, John H., *Directory of the Nonfuel-mineral Producers in Pennsylvania.* Pennsylvania Geological Survey. Update of the Survey's periodic listing of producers of industrial minerals in Pennsylvania, including names, contact information, formations and lithologies mined, and marketed products. Publication as an interactive database on the Internet is planned for 2009.

Behr, Rose-Anna, *Bedrock Geologic Map, Coal-Resource Maps, and Digital Datasets of the Frenchville Quadrangle, Clearfield County, Pennsylvania.* PA Geological Survey, field work completed 2008. Will submit as Mineral Resource Report in 2009.

Blackmer, Gale and Bosbyshell, Howell, *Bedrock geologic map of the Kirkwood quadrangle, Chester and Lancaster counties*. PA Geological Survey and West Chester University. Continuing the Survey's examination of formation boundaries and tectonic interpretations in the Piedmont. Field work is in progress. Will be released as an open-file bedrock geologic map late in 2009. Prepared in part under the USGS National Cooperative Geologic Mapping Program.

Dodge, C. H., *Regional Framework of the Upper Devonian and Mississippian Lithostratigraphy for Part of Northwestern and North-Central Pennsylvania*. Pa. Geological Survey. Integrated study of the identification and correlation of principal lithostratigraphic units for parts of northern Pennsylvania, involving the use of numerous published and unpublished measured sections, sample (cuttings) and core descriptions, and geophysical logs, and supplemented with additional, selected fieldwork. This investigation is in support of anticipated, future geologic mapping, which is a prerequisite to further understanding of the region's groundwater and other natural resources. The region includes significant State Parks and State Forest lands and much of the "Pennsylvania Wilds" (see http://www.dcnr.state.pa.us/info/pawilds/about.aspx). The final report will be submitted for publication in 2010 and will include text and cross sections.

Kochanov, W.E., *Bedrock geologic map of the Chester Valley, Chester, Delaware, Montgomery, and Philadelphia Counties, Pennsylvania*. Pennsylvania Geological Survey. Open-File Report, map scale 1:50,000. Composite of bedrock geologic maps of the Chester Valley from Downingtown, Chester County eastward to Ambler, Montgomery County emphasizing the Cambrian carbonate section between the North and

South Valley Hills. The high points: the Antietam is out, the Octoraro may be the Harpers, the Kinzers is alive and well in the Downingtown quad, the Elbrook may be on the chopping block, and there was visual evidence of fault contact between the Octoraro and Conestoga in the Malvern quad.

Lutz, A. B., *Expanded Pennsylvania Paleontology Bibliography,* Pennsylvania Geological Survey, in progress. This project involves the compilation of a bibliography of Pennsylvania paleontology in a searchable database that will be released online. The bibliography will consist of reference, taxonomic, geologic, and location information. The first stage will include information from *Pennsylvania Geology* magazine, and it is expected to be released in the first quarter of 2009.

Markowski, A.K., *Pennsylvania Coalbed Methane Wells Database*. PA Geological Survey. Conversion and expansion of Open-File Report 00-01 spreadsheet to an Access database for various users based on service requests and presentations, especially within the past five years. Project results will support energy seekers as they continue to explore for and develop more important coal gas energy resources in the Appalachian basin to help offset the nation's anticipated natural gas shortfall and to supplement the total energy mix. This will also aid in determining the carbon-holding capacity of the coalbeds for carbon sequestration studies by providing thicknesses and depths of coal intervals and associated non-coal strata.

McElroy, Thomas A. and Hoskins, Donald M ., *Bedrock geologic map of the McVeytown 7 ½ minute quadrangle, Mifflin and Juniata Counties, Pennsylvania.* Field work will continue through spring of 2009. Will be published as an open-file map by the Pennsylvania Geological Survey. Preliminary results show uncommonly large sinkholes in the Tonoloway Formation, limestone in the Wills Creek Formation that is similar to limestone in the Tonoloway Formation, and a mountain crest underlain by the Juniata Formation, not the Tuscarora Formation.

Thrust fault exposed in a quarry in the Tonoloway Formation, near McVeytown, Pennsylvania. Photograph by Tom McElroy.

Reese, Stuart, *Estimated Mean Annual Groundwater Recharge Rates of Pennsylvania Watersheds, Pennsylvania Geological Survey, Map 71*. 1:500,000-scale map summarizing groundwater recharge in Pennsylvania based on USGS 2008 report, "Regression Method for Estimating Long-Term Mean Annual Ground-Water Recharge Rates from Base Flow in Pennsylvania" (USGS SIR 2008-5185), by Dennis W. Risser, Ronald E. Thompson, and Marla H. Stuckey. Publication will provide map of statewide recharge, and inset maps precipitation and percent recharge of precipitation with shaded relief. In cooperation with the U.S. Geological Survey, New Cumberland, Pa.

Reese, Stuart, *Bedrock Geology of Middletown 7.5-Quadrangle, Dauphin, Lancaster, and York Counties, Pennsylvania.* Pennsylvania Geological Survey. Field work will begin in 2009 and continue into 2010.

Shank, Steve. *Serpentinites*. Pennsylvania Geological Survey. Field based study of serpentinites and related rocks including mapping, mineralogy and geochemistry to better define the extent, origin and resources of this unique area in southeastern Pennsylvania. Probably best known for their distinctive flora, the serpentinite bodies may offer the potential for CO_2 sequestration.

Shank, Steve. *North American Soil Geochemical Landscapes Project*. The North American Soil Geochemical Landscapes Project is a continent wide sampling program developed by the Canadian, Mexican and United States Geological Surveys to better define baseline values for inorganics, organics and microbiology in soils. The data produced will aid the environmental and public health communities in evaluating the effects of urbanization, industry and agriculture on natural background levels. The Pennsylvania Geological Survey will conduct the sampling at 80 sites in the Commonwealth over the next two years.

PUBLICATIONS/THESES

Elsea, Jarrett, 2006, Discrete-fracture dual-permeability simulation of heterogeneous drawdown in the Brunswick Group, North Penn 6 Superfund site, Lansdale, Pennsylvania, Unpublished MS Thesis, Temple University

Freyer, Paul, 2006, Using marine resistivity to map groundwater-surface water interaction within the Burd Run watershed, Pennsylvania Unpublished MS Thesis, Temple University

Gross, Kathy, 2007, Metal concentrations of sediments in a karst aquifer in Valley Creek basin, Chester County, Pennsylvania, Unpublished MS Thesis, Temple University

Ham, Jeffrey, Toran, Laura, and Cruz, Jay, 2006, Effect of upstream ponds on stream temperature. Environmental Geology DOI: 10.1007/s00254-006-0186-4

Herman, E.K., Tancredi, J.H., Toran, L., and White, W.B., 2007, Mineralogy of suspended sediment in karst springs in relation to spring water chemistry. Hydrogeology Journal, v. 15, n. 255-266

Herman, E.K., Toran, L., and White, W.B., 2008, Threshold events in spring discharge: evidence from sediment and continuous water level measurement. Journal of Hydrology, Volume 351, Issues 1-2, 30 March 2008, Pages 98-106

Jedrejczyk, C. and Toran, L., 2008, Monitoring the effectiveness of stormwater management practices in the Pennypack Creek watershed, Philadelphia, Pennsylvania. Geological Society of America Annual Meeting, 5-9 October 2008, Houston, TX.

Kochanov, W.E. and Parrish, J., 2008, Infrared imagery of the karst terrain of Lancaster County, Southeastern Pennsylvania, in Yuhr, L.B., Alexander, E.C., Jr., and Beck, B.F. (eds.), Eleventh multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impacts of Karst, Proceedings, ASCE Geotechnical Special Publication No. 183, p. 165-174.

Heaney, Matt, 2007, Marine resistivity as a tool for characterizing zones of recharge at Lake Lacawac, PA. Unpublished MS Thesis, Temple University

Mathur, R., Mutti, L., Barra, F., Gold, D., Smith, R.C., Doden, A., Detrie, T., McWilliams, A., 2008, Fluid inclusion and Re-Os isotopic evidence for hot, Cenozoic mineralization in the central Pennsylvanian Valley and Ridge Province. Mineralogy and Petrology, v. 93, 309-324.

Nyquist, J.E., Freyer, P.A., and Toran, L., 2008, Stream Bottom Resistivity Tomography to Map Ground-Water Discharge. Ground Water, v. 46, p. 561-569.

Smith, R.C., II, and Barnes, J.H., 2008, Geology of the Goat Hill serpentine barrens, Baltimore Mafic Complex, Pennsylvania: Journal of the Pennsylvania Academy of Science, v. 82, p. 19-30.

Smith, R.C., II, and Barnes, J.H., 2008, Bedrock composition of the Goat Hill serpentine barrens and a proposed serpentine factor for predicting floral response: Journal of the Pennsylvania Academy of Science, v. 82, p. 31-47.

Toran, L., Gross, K., and Yang, Y,, in press, Effects of restricted recharge in an urban karst system. Accepted in Environmental Geology.

Toran, L., and Grandstaff, D., 2007, Variation of nitrogen concentrations in stormpipe discharge in a residential watershed. Journal of the American Water Resources Association. v. 43, n. 3, p. 630-641.

Toran, L, Herman, E.K., and White, W.B., 2007, Comparison of Flow Paths to a Well and Spring in a Karst Aquifer. Ground Water, v. 45: p. 281-287.

Weinrich, Matthew, 2006, A detailed sedimentological and geomorphological investigation of Wisconsinan tills near the Lavery type section, Northwest Pennsylvania. unpublished Master's thesis, University of Akron.

Yang, Youa, 2006, Characterizing storm response in an urban karst aquifer at Valley Creek, Chester County, PA, unpublished MS Thesis, Temple University.

Survey News

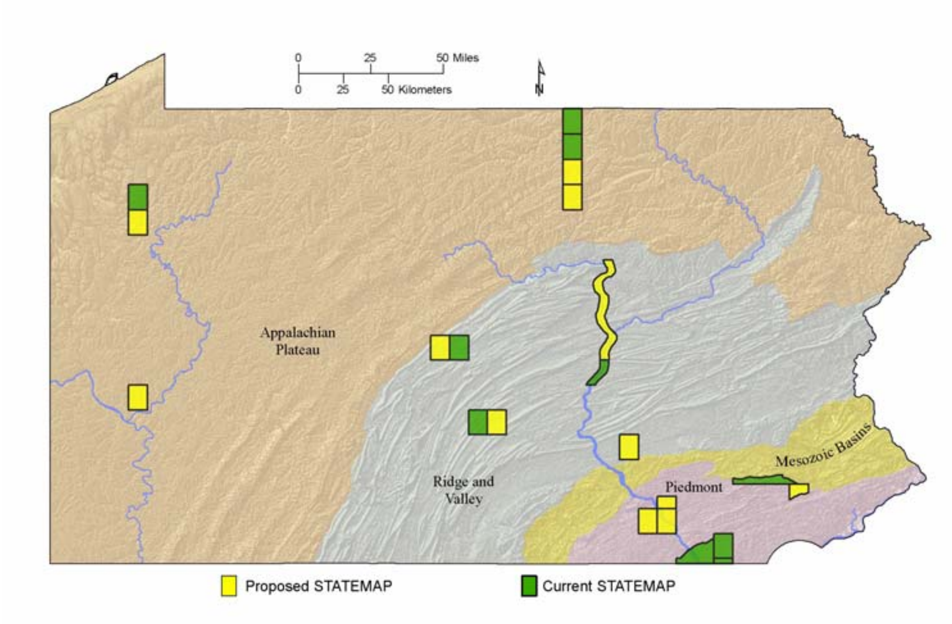
PAMAP- State funding for the PAMAP program was cut such that only Federal funds are currently available for data processing. As a result, not all of eastern Pennsylvania (acquired in 2008) will be processed this year. Lidar and orthos from 2006 are available for western Pennsylvania and the 2007 eastern Pennsylvania data will soon be available. www.dcnr.state.pa.us/topogeo/pamap Contact- Helen Delano.

Drill hole Database – The Survey is currently scanning western well descriptions and putting them into a database. Contact- Bill Bragonier.

Carbon Sequestration – Work continues on a major carbon sequestration effort with a short deadline (March 2009). Much of the Pittsburgh office's time is consumed by this. Contact- Kristin Carter (412-442-4234) (krcarter@state.pa.us).

Preliminary water map – A water recharge map is being prepared for publication at 1:500,000. Contact- Stuart Reese.

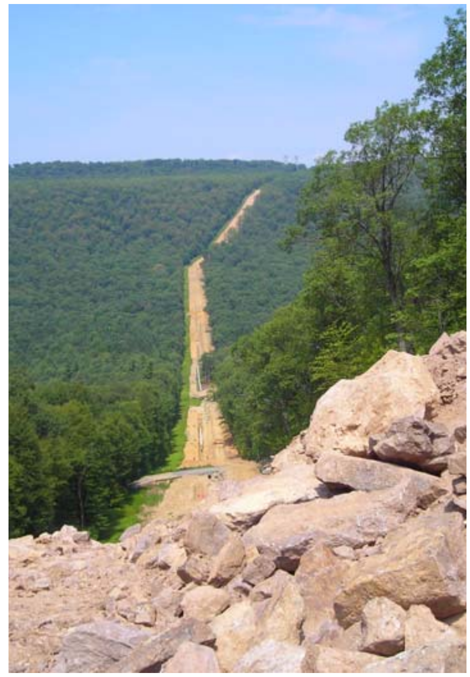
State Map - The Pennsylvania Geological Survey was awarded $214,950 for FY2008 under the USGS National Cooperative Geologic Mapping Program (STATEMAP). The award funds ongoing geologic mapping projects in southeastern, central, and north-central Pennsylvania, as well as a new project in northwestern Pennsylvania. The Bureau has submitted a proposal for $299,510 to continue funding for those projects and to start new projects in the Pittsburgh and Harrisburg areas for FY2009. Contact- Gale Blackmer.



Pipeline survey - Staff members of the Pennsylvania Geological Survey were especially busy during late summer and early fall of this year. We took advantage of a rare opportunity to examine temporary exposures of rock along a continuous 50-mile length of the state. The Dominion Transmission Company, as part of its Cove Point Expansion Project, excavated a trench next to an existing pipeline right-of-way to accommodate a 30-inch diameter natural gas pipeline from the village of Perulack in Juniata County to the Leidy gas storage field in Clinton County, a distance of approximately 80 miles. Dominion kindly cooperated with the Pennsylvania Geological Survey and allowed us to inspect their open trench. Due to some technical problems, we were only able to inspect the 50-mile section of the trench in the Ridge and Valley physiographic province, from north of Bellefonte in Centre County through portions of Huntingdon and Mifflin Counties to the southern terminus of the project in Juniata County.

We sent teams of at least four geologists every day for approximately five weeks to examine the trench and materials extracted from it. We took extensive field notes, photographs, and rock samples and recorded all field station locations with a GPS unit. The field work was finished in early September. Since then, we have been busy transcribing the field notes and entering the information into a computerized database. Once the data are compiled, we plan to generate a map of the field station locations and key the observations, samples, and photographs to the map. All of the data and photographs will be available to the public on our website sometime in the spring of 2009. We are already intrigued by some of the results: new faults have been documented and the locations of geologic formation contacts have been revised in several areas. A consequence of this is that some geologic interpretations that were previously published will require updating. Contact – Anne Lutz


Photograph by Antonette Markowski


Photograph by Stuart Reese


Photograph by Helen Delano

Jack Kuchinski – Jack passed away November 4, 2008. Jack was a draftsman who shared his great skill and lively sense of humor with us at the Survey for more than 30 years. He was recently featured in the vol. 35, no. 3/4 (Fall/Winter 2005), page 20, issue of ***Pennsylvania Geology***. He will be greatly missed.

Position changes - George Love has changed position from Manager of the Geologic Resources Division to Manager of Data Distribution. John Harper has been promoted to Carbon manager.