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Geologists demonstrating the direction of cleavage duplex structures within the Marcellus shale during a field trip held in October 2011.

—*Photograph by Kristen Hand, Pennsylvania Geological Survey*

EDITORIAL

The World of Geology

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This issue of *Pennsylvania Geology* covers varied aspects of the natural resources of our commonwealth, from an enlightening tour de force of tiny grains comprised of members of the platinum group elements, to a review of an ongoing project related to coals whose areal footprints cover significant portions of Pennsylvania. Frankly, I am in awe of those specialists who spend time delving into the geologic mysteries of our state. Not only do these studies guide the wise use and reuse of the resources, they allow us to maintain the living standards we Americans take for granted.

We are fortunate to live in a time when scientific instrumentation allows us to look into the heart of the minerals, to unravel the elemental constituents and their arrangements. Not only is it academically stimulating, as I think you will see in the article by Bob Smith, retired from the Survey, and his co-author, staff geologist John Barnes, it is technologically rewarding. Those of you old enough to share my memory of large and clunky mechanical calculators that simply performed the four basic elements of arithmetic must admit that the new, light, extremely powerful, and blindingly fast calculators are awe-inspiring marvels. Thanks to the science of geology, there are trained geologic practitioners who are able to identify mineral deposits containing the elements critical to today's electronic tools.

Coal geology and coal petrography are studies that might seem a dying breed in today's society where the search for renewable energy and the development of "green technology" drive the conversations of our politicians and citizens. Yet the industry sustains parts of our state, contributing jobs and the very energy needed to forge the technologies of tomorrow. It may be difficult to see the value of maintaining a database that describes coals that are mined or are too thin to develop by today's standards, but consider that Marcellus shale gas shows in the last century were novelties hardly worthy of mention. Thank goodness someone kept those records! Perhaps the presence of potentially valuable elements in coals will stimulate exploration of combustion products for enrichment of the low-volatility components.

Geology is the study of the earth. That definition does no justice to the opportunities within our broad chosen field. I know geologists who lead corporations; teach school; mine limestone, gold, iron ore, and talc; investigate contamination and remediate landscapes; apply the sciences of mathematics and physics to the search for tomorrow's resources; and imagine how the world looked ten thousand years ago or even hundreds of millions of years ago. To study geology and the broader earth sciences is to delve into a world where sharp observational skills combine with imagination and creative intuition—as my 5-year old granddaughter says, "Rocks rock!"

Last, but certainly not least, this issue features some of our newer employees. It is with great pride that I say this organization continues to attract a broad perspective of interesting and interested people. The varied talents of these folks increase the synergy of the organization. The Survey has a great deal to offer the people of Pennsylvania.



Geochemistry and Mineralogy of Platinum Group Elements in Some Chromite Occurrences in the State Line District, Chester and Lancaster Counties, Pennsylvania

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Introduction

The platinum group elements (PGE) include six closely related metals: ruthenium (Ru), rhodium (Rh), palladium (Pd), osmium (Os), iridium (Ir), and platinum (Pt). Figure 1 shows the positions of the PGE in the stable portion of group 8B of the periodic table of the elements. In the State Line District of Chester and Lancaster Counties, Pa., the apparent bulk of the PGE is found as discrete, microscopic minerals occurring in chromite ores in a few of the deposits. The quantities of PGE are not large. Former U.S. Geological Survey (USGS) geologist Allen Heyl, now deceased, studied the chromite deposits of Pennsylvania and Maryland extensively and was fond of noting that a sample of chromite he had collected from the Soldiers Delight mine, near Owings Mills, Md., contained all of 1 part per million (ppm) of platinum. Chromite from that deposit was not included in this study.

The best available descriptions of the chromite deposits of the State Line District are those by Pearre and Heyl (1960) and the summary by Rose (1970). The most recent article on the history and mineralogy of the Wood chrome mine is that recently published by Wilson (2011).

The purpose of this study is to apply modern scanning electron microscopy/energy dispersive spectrometry analysis (SEM/EDS) techniques to build upon the work of previous investigators and to describe the PGE minerals that are found in the Pennsylvania portion of the State Line District.

Previous Studies

Prior to the present study, only the PGE minerals isoferroplatinum (Pt_3Fe), sudburyite (PdSb), OsIrRu , and an unnamed " Pd_3Sb_2 " had been verified from Pennsylvania. The first PGE mineral known to have been verified in Pennsylvania was a microscopic grain of isoferroplatinum in a forsterite xenolith in the Gates-Adah kimberlite dike, Greene County (Stone and Fleet, 1990). That dike has been dated at 167.7 ± 3.6 Ma by Larry Heaman, University of Alberta, Edmonton, using the U-Pb contents of perovskite (personal communication to R. C. Smith, II, July 19, 2007). In a study that focused on Pennsylvania, Smith and Barnes (2006) found that pyrope garnet from the Gates-Adah dike was the one found to have the most favorable composition with respect to diamond potential.

The second PGE mineral verified from Pennsylvania was a micrograin of OsIrRu recovered from the base of the serpentinite in Lancaster County (Smith and Barnes, 2008). Based on $^{187}\text{Os}/^{188}\text{Os}$ dating of the grain by Ryan Mathur at the University of Arizona, the Baltimore Mafic Complex, which hosts the State Line District chromite deposits, separated from the mantle at 735 Ma (Smith and Barnes,

¹Mechanicsburg, Pa.

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg	Group 8B										Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La-	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac-															
			La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
			Ac	Th	Pa	U											

Figure 1. Periodic table of the naturally occurring elements highlighting the platinum group elements ruthenium (Ru), rhodium (Rh), palladium (Pd), osmium (Os), iridium (Ir), and platinum (Pt), in orange. They form part of Group 8B, which also includes iron, cobalt, and nickel.

2008). This was the same 735 Ma mantle separation age² as that determined for the Sword Mountain olivine melilitite of northern Washington County, Md., which has an extrusive volcanic age of 433 Ma (Smith, Foland, and Nickelsen, 2004). The grain used by Mathur for ¹⁸⁷Os/¹⁸⁸Os dating contained 53.2 percent Os, 38.4 percent Ir, and 7.9 percent Ru. As such, it was mineralogically osmium, or in the older but still popular nomenclature, osmiridium.

For the Reesers Summit, York County, sudburyite PdSb study (Smith and Barnes, 2009), much of the groundwork had already been done by Harvey Belkin of the USGS, who had noted a Pd-bearing mineral in the ferrogabbro zone of the Triassic York Haven Diabase of Smith (1973). Smith and Barnes (2009) identified the primary mineral as sudburyite and documented an unnamed “Pd₃Sb₂” as well as a grain of the then relatively new mineral ungavaite (Pd₄S₃), which, unfortunately, they failed to recognize as a new mineral until the present study.

Earlier work on the identification and composition of the sulfide heazlewoodite, Ni₃S₂, and the arsenide maucherite, Ni₁₁As₈, in the State Line District did not result in the detection of any PGE minerals at the Wood mine and Cedar Hill quarry (Smith and Speer, 1980a, 1980b). Speer (in Smith and Speer, 1980a) did, however, recognize and quantify the presence of minor Sb in the maucherite. Based

²The 735 Ma mantle separation age for the Sword Mountain olivine melilitite is a model Tnd age obtained by K. A. Foland, Ohio State University. Using elemental Nd and Sm determined by isotope dilution, and isotopes by thermal ion mass spectrometry (TIMS), it is a model age of when the protomagma for the Sword Mountain was last in full communication/mixing with the earth’s mantle. Not uncommonly, such dates lack correspondence with recognized geologic processes. In this case, however, it corresponds to the independently derived ¹⁸⁷Os/¹⁸⁸Os model age for the separation of the magma that yielded the Baltimore Mafic Complex from the mantle and to initial opening of Iapetus as recorded by the early Robertson River Igneous Suite of Tollo and Aleinikoff (1996).

on the present study, the Sb substitution is one of two favorable clues to the localization of otherwise somewhat mobile Pd.

Several earlier reports of platinum group minerals from Pennsylvania are known to be spurious. These have included reports of occurrences at the Gap Nickel mine, Lancaster County, and “Bauman’s platinum mine,” Montgomery County. Ores and slags from Gap have been repeatedly analyzed for PGE with negative results. The senior author visited and sampled “Bauman’s platinum mine” around 1968. All that remained was a largely filled shaft surrounded by a small dump of what appeared to be dark gray Mesozoic siltstone. The very patient owner of the property at that time explained with a smile that it had previously been not only “Bauman’s platinum mine,” but also “Bauman’s gold mine” and even “Bauman’s diamond mine,” depending on the interests of potential investors. A composite of the “ore” was collected and a heavy mineral concentrate separated. Arthur W. Rose of The Pennsylvania State University then ran an emission spectrographic analysis of the heaviest of the heavy minerals, but found no PGE or typically associated elements. More recently observed samples of platinum alleged to have been recovered from that hard-rock mine look remarkably like placer platinum concentrates from Goodnews Bay, Alaska, that were readily available from mineral dealers. One can only wonder if the diamonds from Bauman’s mine were “found” as already faceted standard round brilliants or as the older mine cuts.

State Line District PGE Occurrences

Information on our sampling techniques, SEM/EDS analytical methods, and Tables 1 through 4 of analytical data are provided as a separate file that accompanies this article at www.dcnr.state.pa.us/cs/groups/public/documents/document/dcnr_20030637.pdf. Below, we have summarized the minerals and compounds that seem to be the carriers for each of the PGE observed in the State Line District.

Ruthenium (Ru)

In the Pennsylvania portion of the State Line District, Ru tends to occur with lesser amounts of Os and Ir in sulfides such as laurite, $(\text{Ru}, \text{Os}, \text{Ir})\text{S}_2$, and a much more common unnamed $(\text{Ru}, \text{Os}, \text{Ir})_{.27}\text{S}_{.73}$ ³ (Figure 2), and less commonly in sulfarsenides such as ruarsite, $(\text{Ru}, \text{Os}, \text{Ir})\text{AsS}$. Still more rarely, Ru occurs as unnamed “ $(\text{Ru}, \text{Os}, \text{Ir})_3\text{S}_8$?” and unnamed “ $(\text{Ru}, \text{Os}, \text{Ir})\text{As}_3$.” A single grain of $(\text{Ru}, \text{Ni}, \text{Ir}, \text{Os}, \text{Pt})_{.72}(\text{Bi}, \text{As}, \text{Te})_{.28}$, which we are tongue-in-cheek calling “RuBi,” was also found.

Rhodium (Rh)

Rh tends to occur with variable amounts of Ir in arsenide sulfides such as hollingworthite, $(\text{Rh}, \text{Ir})(\text{AsS})$, irarsite, $(\text{Ir}, \text{Ru}, \text{Rh}, \text{Pt})\text{AsS}$, and the sulfide malanite, $\text{Cu}(\text{Pt}, \text{Ir}, \text{Rh}, \text{Ni}, \text{Cu})_2\text{S}_4$. Rh also occurs in unnamed minerals such as “ RhAs_2 ,” “ $\text{Rh}(\text{As}, \text{S})_3$,” “ $\text{Rh}(\text{As}, \text{S})_4$,” “ Rh_4As_5 ?” “ $\sim\text{Rh}_3\text{As}_4\text{S}_4$,” “ $\text{Rh}_4\text{As}_5\text{S}_5$?” “ $(\text{Rh}, \text{Ir})\text{S}_2$,” “ $(\text{Rh}, \text{Ir})_3(\text{As}, \text{S})_7$,” “ $(\text{Rh}, \text{Ir}, \text{Pd})\text{S}_2$,” “ Rh_7Sb_3 ,” “ $(\text{Rh}, \text{Cu}, \text{Pt}, \text{Ir})_3(\text{As}, \text{S})_7$,” “ $(\text{Rh}, \text{Cu})_7(\text{Sb}, \text{Sn})_3$,” “ $\sim(\text{Rh}, \text{Ir}, \text{Pt}, \text{Os}, \text{Cu})(\text{S}, \text{As})_2$,” “ $(\text{Ir}, \text{Cu}, \text{Rh}, \text{Pt}, \text{Ni}, \text{Co})\text{S}_2$,” “ $(\text{Ir}, \text{Pt}, \text{Rh}, \text{Ni})_3(\text{As}, \text{S})_5$,” “ $(\text{Ir}, \text{Rh})_3(\text{S}, \text{As})_7$,” “ $(\text{Ir}, \text{Rh}, \text{Pt})_4(\text{As}, \text{S})_3$,” “ $(\text{Ir}, \text{Rh}, \text{Pt})_4(\text{As}, \text{S}, \text{Sb})_7$,” “ $(\text{Pd}, \text{Rh}, \text{Ir})(\text{S}, \text{As})_2$,” and “ $(\text{Pt}, \text{Rh}, \text{Cu}, \text{Ir})_3\text{S}_2$.” As well as the mentioned substitution for Ir, Rh minerals also have a tendency to contain minor Cu and rarely even Sn. Unfortunately for mineralogists, in the State Line District, most of this rare Sn appears to have been oxidized to cassiterite, reducing the possibility of Sn-bearing PGE minerals such as cabriite and niggliite. This oxidation might have occurred during serpentinization of

³Some mole ratios such as those in $(\text{Ru}, \text{Os}, \text{Ir})_{.27}\text{S}_{.73}$ have the potential to correspond to different sets of subscripts such as $(\text{Ru}, \text{Os}, \text{Ir})_2\text{S}_5$ or $(\text{Ru}, \text{Os}, \text{Ir})_3\text{S}_{11}$.

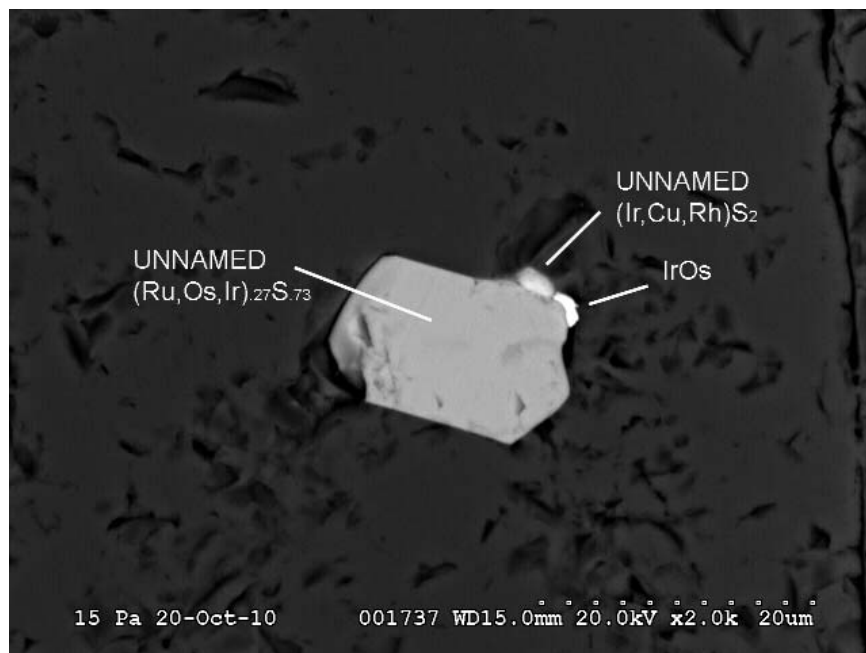


Figure 2. Subhedral grain of laurite-like $(\text{Ru,Os,Ir})_{27}\text{S}_{73}$ with attached native iridium and $(\text{Ir,Cu,Rh})\text{S}_2$. This latter may be an iridium analog of sperrylite. The laurite-like mineral is presumably early. The host mineral is chromite.

forsterite when chromian magnetite overgrowths formed on some chromite and magnesiochromite grains (Ulmer, 1974). Based on the temperature-dependent oxygen isotope fractionation between coexisting magnetite and antigorite from the Cedar Hill quarry, Lancaster County, Wenner and Taylor (1974) determined that the magnetite there formed at $300 \pm 15^\circ\text{C}$.

Palladium (Pd)

Pd typically occurs as several antimonides such as sudburyite (PdSb), naldrettite (Pd_2Sb), stibiopalladinite (Pd_5Sb_2), ungavaite (Pd_4Sb_3), unnamed “ Pd_9Sb_4 ” (possibly an Sb analog of telluropalladinite), and “ PdSb_3 .” (See Smith and Barnes,

2009, for sudburyite and “ Pd_3Sb_2 ” at Reesers Summit, York County, Pa.) This unusually wide range of Pd antimonide minerals in one district suggests that Sb has a strong affinity or ability to collect Pd, that Pd can be somewhat mobile, and that formation occurred over a range of temperatures. Because the portion of southeastern Pennsylvania that includes the State Line District was subjected to a variety of pressure and temperature conditions during several geologic events (Smith, 2010), the PdSb minerals may even have formed during more than one event. McDonald and others (2005), in summarizing the work of Kim and Chao (1996), noted that PdSb (presumably sudburyite) forms at 800°C and that Pd_2Sb (presumably naldrettite) forms between 570° and 500°C . For sudburyite, this would be consistent with the estimate of the solidus (late solidifying) stage of the York Haven Diabase ferrogabbro at the Reesers Summit sudburyite locality at about 775°C (Smith, 1973).

Some early high-temperature palladium antimonide minerals might have been armored within protective magnesiochromite grains that escaped later fracturing because they were “floating” in ductile silicates. (This may be the process whereby the State Line District osmium grain analyzed for $^{187}\text{Os}/^{188}\text{Os}$ escaped several later geologic events after it had separated from the mantle at 735 Ma.) Palladium mobilization might still be occurring in the eastern portion of the district where forsterite was geologically recently being converted to the serpentine group mineral lizardite (Wenner and Taylor, 1974). Even considering late processes such as these, it seems likely that the initial PGE mineral assemblage is such as might be obtained by gravitational settling from multiple levels. That is, it is not an equilibrium assemblage.

More rarely, Pd also occurs as arsenopalladinite, $\text{Pd}_8(\text{As,Sb})_3$, presumed braggite, $(\text{Pt,Pd,Ni})\text{S}$ (presumed braggite rather than the dimorph cooperite based on the relatively high Pd plus Ni), presumed kotulskite, $(\text{Pd,Ni,Cu,Co,Pt})_3(\text{Te,As,S,Bi})$, ferronickelplatinum, $(\text{Pt,Ir,Pd})_{53}\text{Ni}_{24}\text{Fe}_{23}$, majakite, PdNiAs , menshikovite, $\text{Pd}_3\text{Ni}_2\text{As}_3$, palladoarsenide, $\text{Pd}_2(\text{As,Sb})$, sobolevskite, (Pd,Pt,Bi,Ni)

(Bi,Te,As,Sb) (Figure 3), telluropalladinite, Pd_9Te_4 , and vincentite, $(\text{Pd,Ni})_3\text{As}$. These named minerals are in addition to the analyzed unnamed compounds “PdAs,” “PdAs₃,” “(Pd,Pt)(As,Sb,Te)₃,” “Pd₆Sn?,” “(Pd,Rh,Ir)(S,As)₂,” and “(Au,Cu)₄₅(Pd,Sb)₅₅.” Pd occurs as a component (16 percent) in native elements such as Pt and 18 percent in an IrNiPtPd alloy. Occasionally, Pd also occurs as a minor substitute for Ni in arsenides, sulfides, and tellurides such as godlevskite, heazlewoodite, maucherite, melonite, millerite, and nickeline. Several of the Pd minerals occur in chromite samples containing visible Cr-clinochlore minerals. This seems to suggest that the conditions which allowed the remobilization of Cr from the otherwise refractory oxide, chromite, into chromium-bearing silicates also allowed the remobilization of Pd. It would not surprise us if some of these Cr-clinochlores and associated silicate minerals were enriched in chlorine, with which Pd can form a mobile anion (Fuchs and Rose, 1974). As early as 1972, silicates in the Reesers Summit sudburyite-bearing ferrogabbro zone in the York

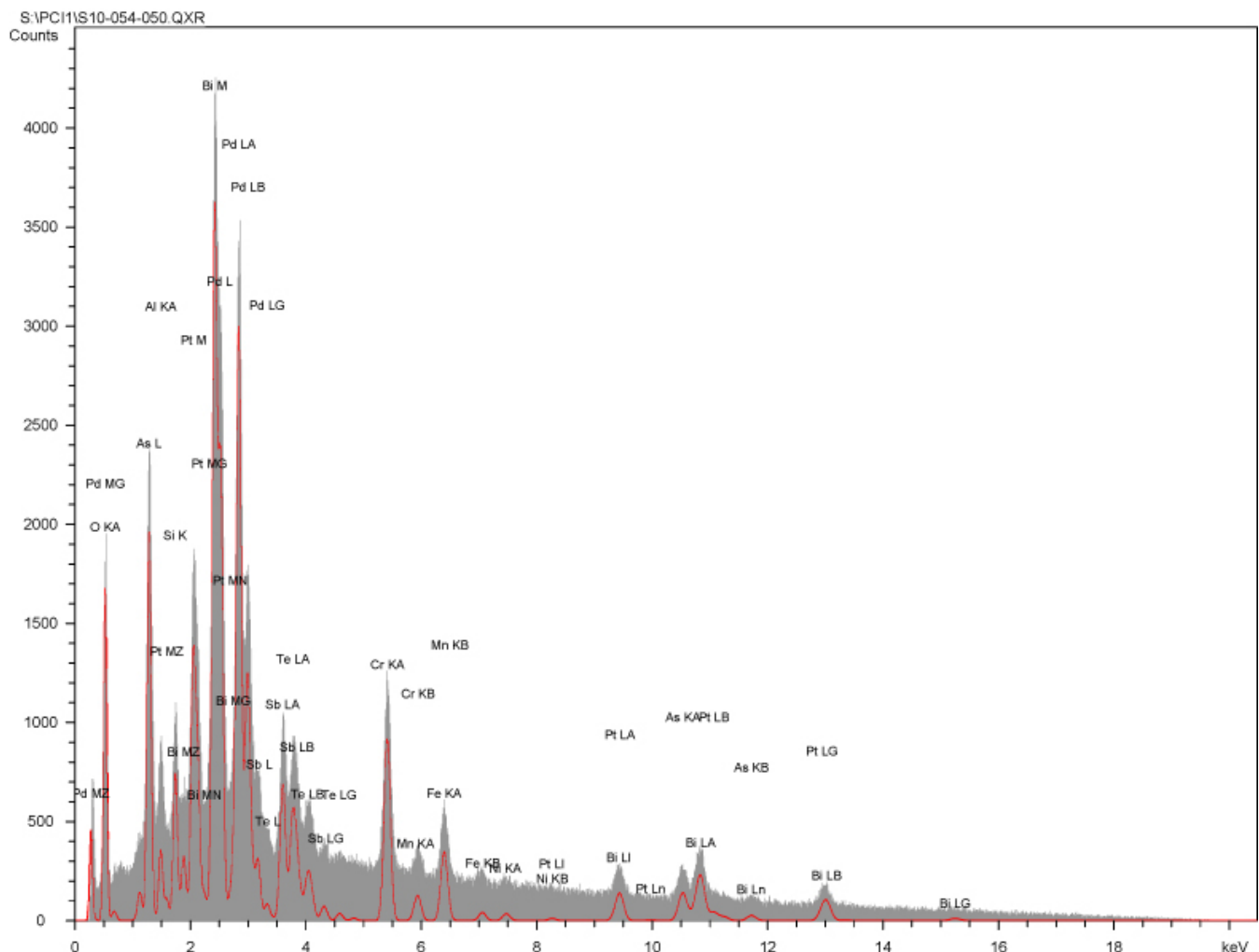


Figure 3. X-ray spectrum from a 3- x 8-micron grain of sobolevskite that occurred in a chromite matrix. The majority of the peaks identified correspond to $(\text{Pd,Pt,Bi,Ni})_{50}(\text{Bi,Te,As,Sb})_{50}$, which can be simplified to theoretical PdBi. Because many elements have substituted for both the cation and anion, it might have formed at higher temperatures than normal for this mineral. The peaks for O, Al, Si, Cr, Mn, and Fe are coming from the host chromite by both a skirt effect (effectively a scattering of the electron beam), and polishing smear. These peaks must be removed mathematically after first analyzing the adjacent chromite.

Haven Diabase were known to be highly enriched in Cl^- . Thus, Cr-chlorites may be a second clue to Pd remobilization.

Osmium (Os)

Os occurs in the minerals erlichmanite, $(\text{Os,Ru,Ir})\text{S}_2$, and omelite, $(\text{Os,Ru,Ir})(\text{As,S})_2$. However, more commonly, it occurs as a substitute for Ru in the sulfide laurite, the still more common unnamed $(\text{Ru,Os,Ir})_{27}\text{S}_{73}$, as the sulfide iridisite, $(\text{Ir,Os,Ni})\text{S}_2$, the arsenide-sulfide ruarsite, $(\text{Ru,Os,Ir})\text{AsS}$, and as native metal alloyed with Ir. Thus, Os seems to be a good substitute for either or both Ru and Ir and to have a moderate affinity for S and As. Many, but not all, of these RuOsIr-rich mineral grains are subhedral to euhedral and occur within chromite (Figures 4 and 5). As such, they may have formed early.

Iridium (Ir)

Ir occurs as a minor substitute in the relatively common sulfide mineral laurite, the unnamed $(\text{Ru,Os,Ir})_{27}\text{S}_{73}$, in sulfarsenides such as irarsite, $(\text{Ir,Rh,Ru,Os})\text{AsS}$, and as a minor substitute for Pt in arsenides such as sperrylite, PtAs_2 , and the relatively common unnamed $(\text{Pt,Ir})_3\text{As}_7$. Ir also substitutes for Rh in hollingworthite, $(\text{Rh,Ir})\text{AsS}$, and for Ru as an 18.50 percent component of ruarsite, $(\text{Ru,Ir})\text{AsS}$. It is a minor component (6.8 percent) in native Os. It is found rarely as unnamed “ IrNiS_2 ” (perhaps a variety of the unapproved but reported mineral “iridisite”) and several other unnamed minerals listed in Table 1. Ir seems to be the most “universal” substitute for the other PGE. Its complex geochemistry and mineralogy suggest caution when using the presence of trace Ir as sole proof of a meteorite impact layer.

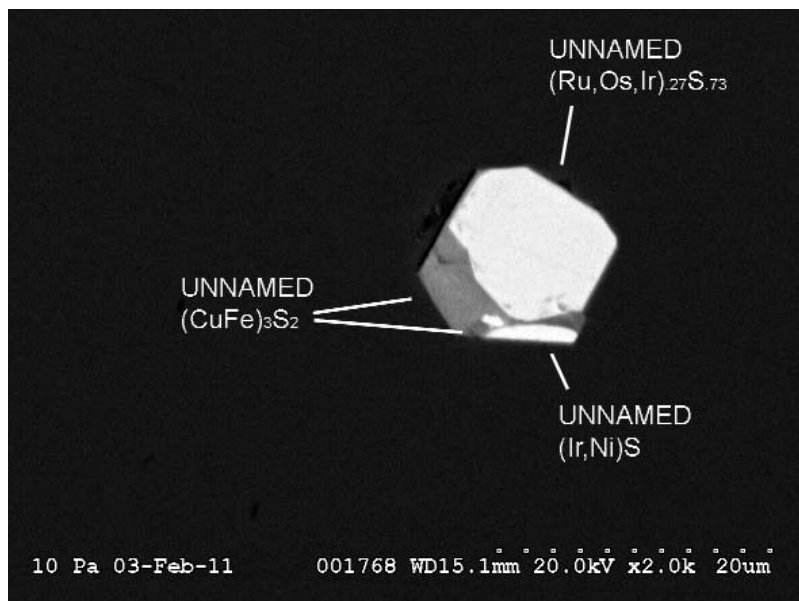


Figure 4. Laurite-like crystal having sectors of unnamed $(\text{Cu,Fe})_3\text{S}_2$ and “iridisite.”

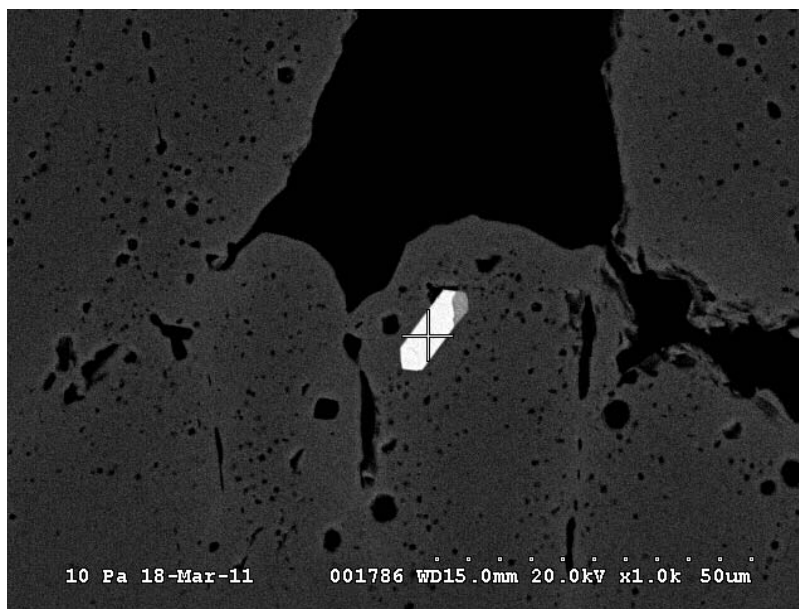


Figure 5. Bright (high mean atomic number) euhedral nickeline and dull (lower mean atomic number) euhedral cobaltian millerite or godlevskite.

Platinum (Pt)

Pt occurs mainly as the arsenide sperrylite, $(\text{Pt},\text{Ir})(\text{As},\text{Sb})_2$, and the above-mentioned, more common, unnamed “ Pt_3As_7 ”. It is found as the native metal (up to 97.66 percent), especially where sperrylite and unnamed PtAs minerals have been hydrothermally attacked, leaving a thin outer rim of Pt surrounding a core of platinum arsenide (Figure 6). Very rarely, Pt occurs in malanite, $\text{Cu}(\text{Pt},\text{Ir})_2\text{S}_4$. Rare grains of unnamed “ Pt_2As_3 ,” “ Pt_3S_5 ,” and “ $\text{Pt}_8\text{Se} (?)$ ” have also been found.

Pt is effectively excluded from the lower temperature antimonide naldrettite but accepted in the higher temperature antimonide sudburyite (reported by McDonald and others, 2005, and observed herein). This phenomenon appears to be an example of the ready substitution of elements in minerals formed at high, even near magmatic, temperatures vs. the typically cleaner, that is, less substituted, minerals formed at lower temperature hydrothermal and supergene conditions.

Many of the more interesting, less common PGE minerals found in the State Line District occur as compound grains. Many compound grains appear to have formed when high-temperature PGE-Ni-S-As intermediate-composition minerals cooled and separated into distinct minerals. This separation typically occurs by solid-state diffusion at hot, but nonmagmatic, temperatures (Figure 7). In a few cases, compound grains fit more loosely together, suggesting the possibility that they collected together during crystal settling. In Figure 8, the maucherite and hollingworthite may be the result of solid state diffusion, with the stibiopalladinite being the result of physical collection with the AuPd alloy, separating from it by solid state diffusion. In Figures 9 and 10, the sperrylite may have been an early nucleus that physically collected later minerals.

Summary

A listing of the various minerals and unnamed species that we observed in or associated with chromites from the State Line District is shown in Table 1 (provided at www.dcnr.state.pa.us/topogeo/pub/pageolmag/pdfs/supplement.pdf, along with Tables 2, 3, and 4). Table 2 provides analyses of platinum group minerals and Table 3 lists some of the associated arsenides, sulfides, and sulfarsenides. Godlevskite, $(\text{Ni},\text{Fe})_9\text{S}_8$, heazlewoodite, Ni_3S_2 , and possibly a moderately substituted NiS millerite may have first formed at relatively high temperatures. Table 4 provides our analyses of some minerals from better-known districts to provide others with a way to evaluate our analytical work. Table 2 of Smith and Barnes (2008) provides major and minor element analyses of chromites for 15 prospects and mines in the State Line District. Their Figure 2 provided plots of cation percent $\text{Cr}/(\text{Cr}+\text{Al})$ vs. $\text{Mg}/(\text{Mg}+\text{Fe}^{2+})$ using the method of Stowe (1994). The high and relatively constant $\text{Cr}/(\text{Cr}+\text{Al})$, vari-

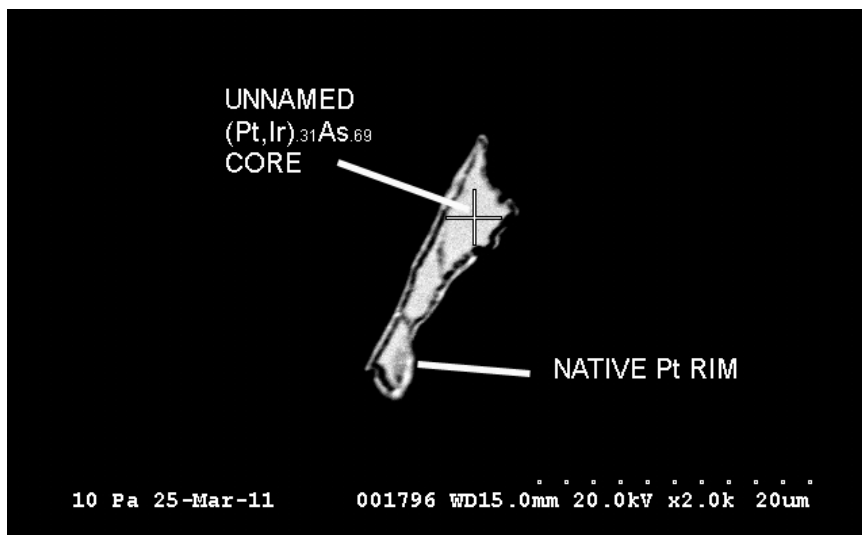


Figure 6. Thin rim of native platinum surrounding core of unnamed $(\text{Pt},\text{Ir})_{31}\text{As}_{69}$ that has apparently been etched and the arsenic leached out.

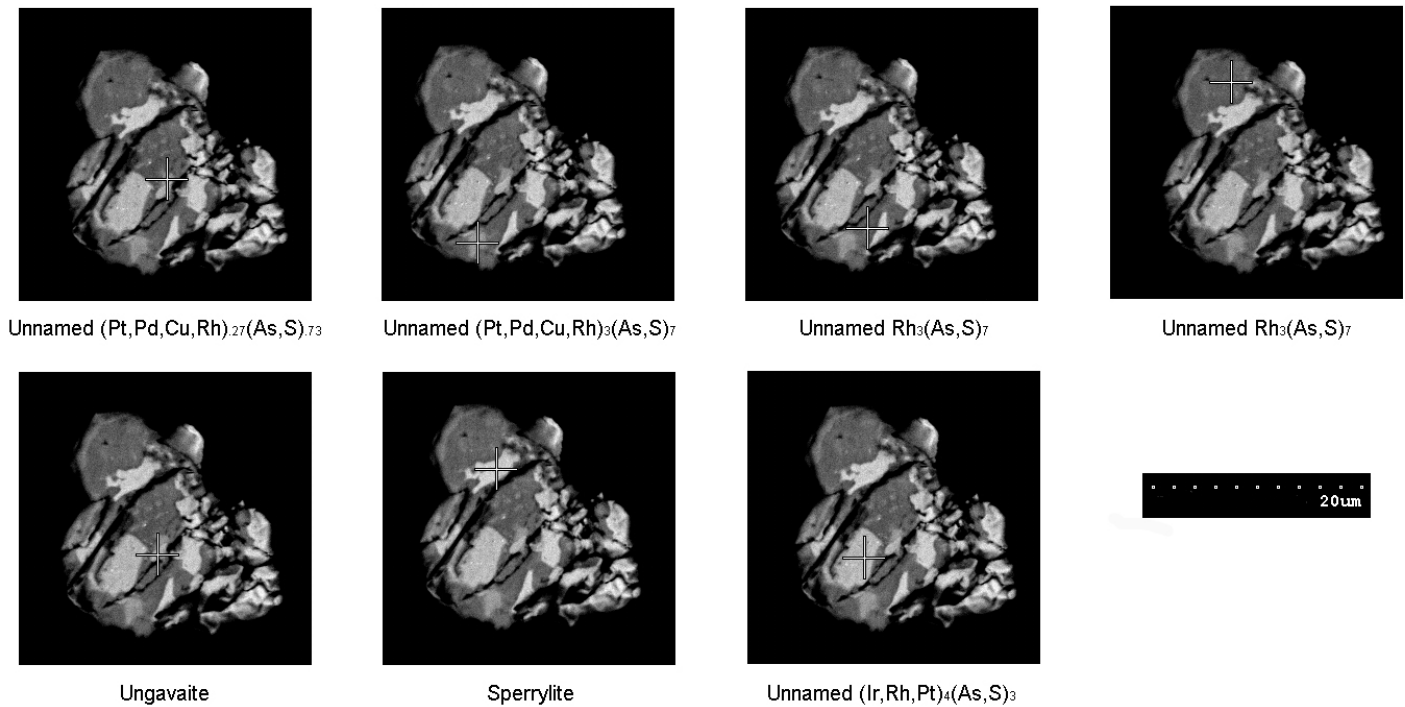


Figure 7. Approximately 16- x 26-micron composite of Pt, Rh, and Ir arsenide-sulfide minerals, the palladium antimonide ungavaite, and sperrylite. The minerals likely separated by solid state diffusion while still hot from a once-homogeneous droplet.

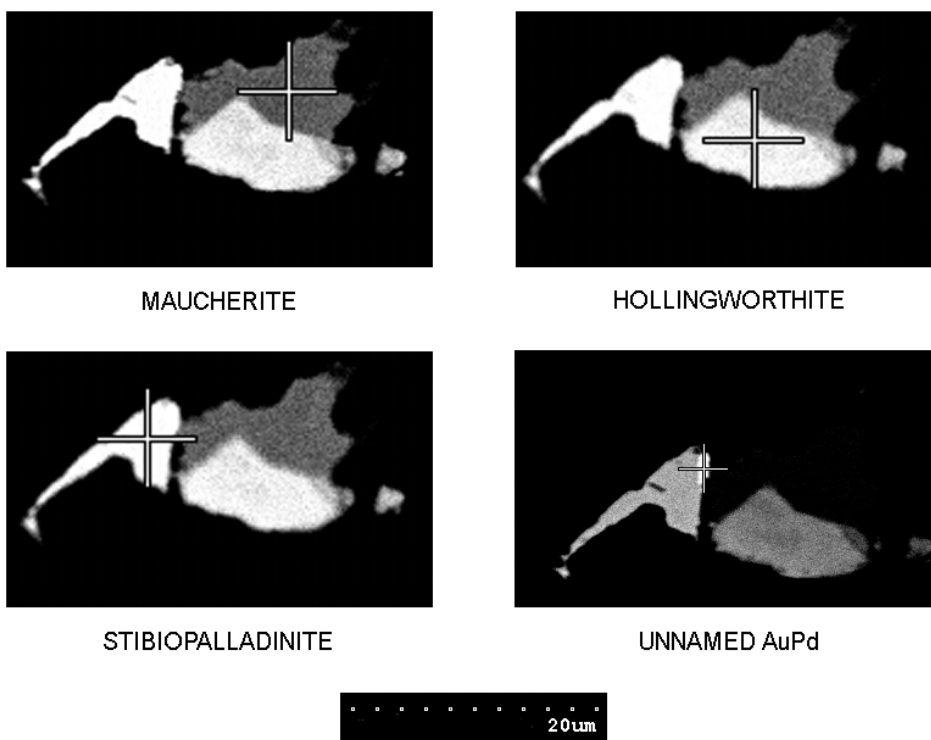


Figure 8. Complex composite grain.

able $\text{Mg}/(\text{Mg}+\text{Fe}^{2+})$, and low TiO_2 suggest chromite accumulation in a lower cumulate zone of a magma chamber in an arc or backarc setting. Comparison of chromite data for the State Line District with Figure 4 of Stowe (1994) suggests that the State Line District data would be atypical for tectonite-hosted podform chromites.

When PGE data for chromite composites from the district are organized by the ratio $(\text{Pd}+\text{Pt})/(\text{Ru}+\text{Rh}+\text{Os}+\text{Ir})$, the values range from lower than 0.06 for chromites believed to have a podform habit and to be located near the base

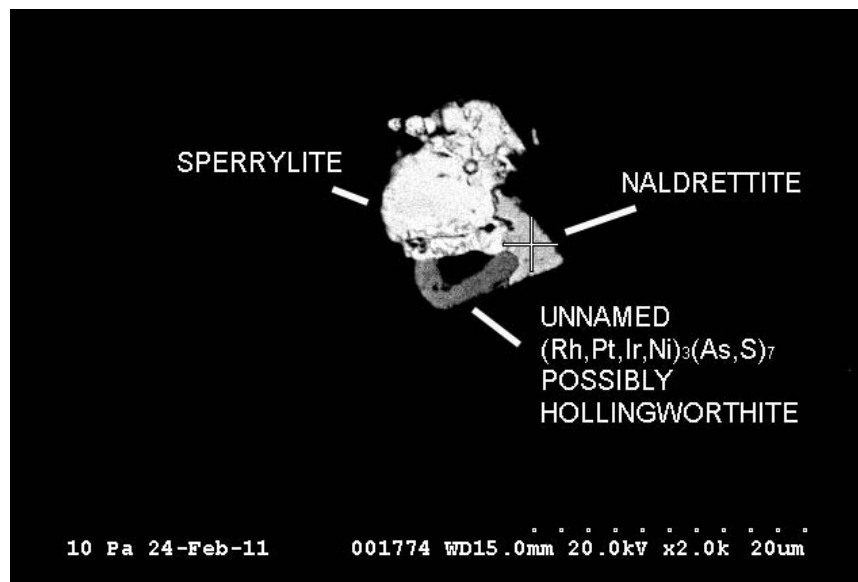


Figure 9. Complex composite grain.

per billion (ppb). This low Pd content may mean that these podform chromites were either never enriched by contact with magmatic sulfides (Naldrett and others, 2009) or that they lost Pd to a sulfide phase. Plots of PGE in chromite, normalized to the PGE contents of carbonaceous chondrite meteorites, also suggest that S is important in collecting Pd and probably Pt as well.

Different platinum group metals also seem to have an affinity for other metals and semimetals. For example, Pd seems to have an affinity for Ni, directly above it in the periodic table (Figure 1), and to a lesser degree Cu as well as a dominant affinity for Sb. Rh seems to have an affinity for Cu, Ni, and Sn (tin), but some of the Sn seems to have oxidized to cassiterite (SnO_2), which is now not directly associated with the PGE. Rh seems to be able to readily substitute for Ir, directly below it in the periodic table, in many minerals. Pt has a strong affinity for As and, when it occurs as a native metal, with Fe. Many of the PGE form minerals with Bi and Te. Because there are 6 PGE, each of which tends to have a wide range of valence states, and because many of these elements substitute for one another and for other elements with which they have affinities, the number of potential PGE minerals is very large. It is not surprising that we have found what appear to be numerous additional new PGE minerals beyond the lengthy list already plaguing the International Mineralogical Association. Most simply do not occur in grains that are large enough

of the Baltimore Mafic Complex to as high as 2.1 and even 3.4 for others believed to be stratigraphically higher. It is these latter chromites, having the higher $(\text{Pd}+\text{Pt})/(\text{Ru}+\text{Rh}+\text{Os}+\text{Ir})$ ratios, that yield the more interesting minerals. Based on the work of Naldrett and others (2009), stratiform chromites having such higher $(\text{Pd}+\text{Pt})/(\text{Ru}+\text{Rh}+\text{Os}+\text{Ir})$ ratios may contain Pd and Pt initially collected by magmatic sulfides. The Fe in such sulfides was later incorporated into the mineral chromite itself. The Pd content of probable podform chromites in the State Line District tends to range from only <2 to 3 parts

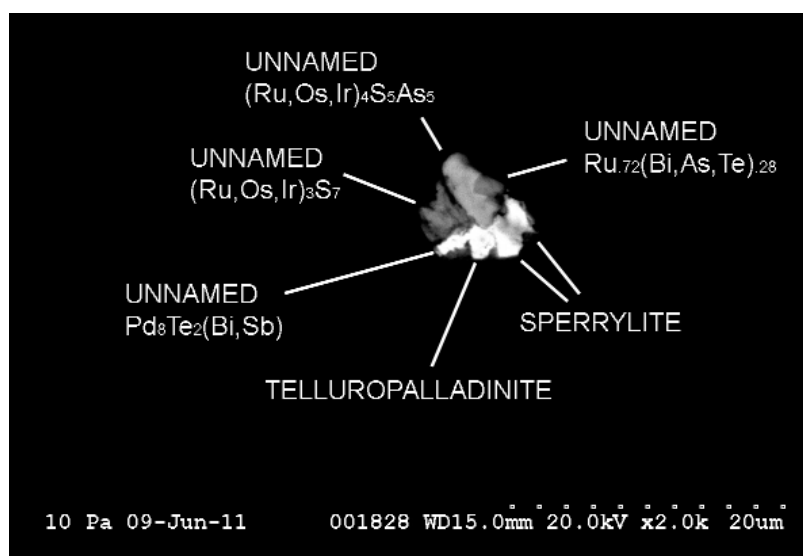


Figure 10. Nonequilibrium composite of grains that formed at different stages. The sperrylite is probably an early-formed mineral.

for the standard methods of characterization by X-ray diffraction, optical properties, or even hardness, to define them well enough to be accepted as new minerals.

Economic Potential

As to the economic potential for PGE in the State Line District, it is small for the presently known occurrences. The PGE occur, at best, as microscopic grains in refractory chromite deposits. Chromite composites from the district range from only 100 to 5,000 ppb total PGE. However, some of these are atypically high in PGE compared to tectonite-hosted podform chromites. For the leanest of these, about ten polished sections were required to find a single microscopic platinum group mineral grain, though that grain did turn out to be an interesting multimineral composite. Unlike gold, for which there are reagents such as chlorine, cyanide, and mercury that are capable of leaching leanly mineralized ore, no such magic elixirs are known for PGE. Selective ion exchange resins are known, but one has to first figure out how to get the PGE into solution. It is no easy task.

The largest of the known State Line District chromite deposits occurs in the form of boudons (sausage-like pods) having hard-to-follow “links” connecting the “sausages.” In the past, even geophysical exploration methods failed to prove particularly helpful in tracing them. In 1967, at the end of a 7-year drought, Arthur W. Rose and the senior author entered an upper level of the Wood chrome mine at the request of Peter Lavin of The Pennsylvania State University. Rose and Smith managed to “horse” an approximately 20-kg mass of chromite out of the mine for Lavin to examine using geophysical methods. After a few months, Lavin reported that, to the methods available at the time, the chromite sample “geophysically doesn’t exist.” Today, high-precision gravity surveys might have some success, but podform chromite deposits of normal size (typically less than 100,000 tons in the State Line District) are not in demand. At present, chromite occurring in bands of great lateral extent is typically far easier to mine. Even if such bands were found in the State Line District, they would likely be offset by numerous faults. However, if the senior author’s hypothesis that podform chromites in the State Line District formed as negative diapirs from stratiform chromites has some validity, then one might consider reexamining the anorthosite to pyroxenite transition zone, perhaps locally altered to sulfide-bearing anthophyllite-talc, of the Baltimore Mafic Complex (McKague, 1964) and its lateral equivalents in Quebec for PGE-bearing Ni-Cu sulfide cumulates. The fact that many of the identified PGE minerals typically occur at Bushveld- and Noril’sk-type deposits rather than in tectonite-hosted podform chromites is somewhat encouraging. Certainly, many of the chromite compositions themselves do not fit tectonite-hosted podform deposits.

Acknowledgments

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The National Coal Resources Data System (NCRDS)— An Update (and the End of an Era for a Federal-State Cooperative Program?)

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Pennsylvania Geological Survey

Introduction

The National Coal Resources Data System (NCRDS) was developed in the 1970s by the U.S. Geological Survey (USGS) as a repository for coal lithostratigraphic information and coal chemistry. It was originally comprised of three components: USTRAT, for the lithologic information; USCHEM, for the trace elements in coal; and USALYT, for the general coal chemistry, usually ultimate and proximate coal analysis values. Proximate analysis determines the weight percent moisture, volatile matter, fixed carbon (by difference), and ash content of the coal reported on an as-received, moisture-free, and moisture- and ash-free basis, whereas ultimate analysis determines the ash, carbon, hydrogen, nitrogen, oxygen (by difference), and sulfur content of the coal. It is primarily used to determine coal rank, and the quantities of each substance are reported on an as-received, dried at 105°C, and moisture- and ash-free basis. In 1978, the Pennsylvania Geological Survey entered into a cooperative agreement with the USGS to provide data for the NCRDS; in turn, the USGS would provide some funding support for this activity. This cooperative work has continued into 2011. Most coal-bearing states participate in this program in some way or another. The federal grant money for the Pennsylvania Geological Survey over the years has provided for coal analysis, hiring of interns in the summer, and fieldwork expenses.

Project Work

Over the next ten years (1978–1988), Survey geologists actively collected coal information from coal companies, other state agencies, measured sections, surface and deep mines, and drillhole cores; much of these data were gathered as part of the bureau's Temporarily Available Stratigraphic Information Collection (TASIC) program. An example of a TASIC site is depicted in Figure 1. This activity slowed somewhat during the 1990s as the ability to collect coal information by staff geologists outstripped the capacity to enter it into the database in a timely matter, both at the bureau and at the USGS, and slowed also upon the redirection of the author and staff geologist John Neubaum to a series of newly awarded grants for coal availability studies in Pennsylvania (discussed below). In the last ten years, shifting of bureau priorities into other areas of research has brought data collection down to a trickle, with only occasional field descriptions and collection of coal samples occurring. However, editing of previously submitted data and input of the backlogged new data continues. Lentz and Neubaum regularly proof the coal stratigraphic data and add new lithostratigraphic information into the NCRDS.

The Three Components of NCRDS—A Refresher

As mentioned previously, the NCRDS was originally meant to be a data warehouse of coal lithostratigraphic information, coal trace element composition, and general coal chemistry. Bureau geologists collected lithologic information from a number of sources, especially from strip-mine highwalls and cores from drillholes (Figure 2). These lithologic data were formerly entered into the USTRAT portion of the database in a two-step process. Paper forms were filled out with the stratigraphic information by the geologist or an intern and then sent to the USGS in Reston, Va., for entry into the data-



Figure 1. Example of Temporarily Available Stratigraphic Information Collection (TASIC) site in the Rockwood 7.5-minute quadrangle.

base by USGS personnel. In recent years, this activity has been accomplished by the geologist in the office using a desktop computer and an Internet interface application provided by the USGS. This refinement of computer technology has meant the loss of some early software applications, such as those for making maps, yet it has improved the ability to make database edits in real time, which is a plus.

When coals were encountered in drill cores or in highwalls, they were sampled using American Society for Testing and Materials (ASTM) methods, followed by two procedures. First, the whole sample of coal was sent to the bureau's contracted vendor to be pulverized to the ASTM's standard size requirement and then split into two parts. Second, one part of the split was retained by the vendor for proximate and ultimate analysis, and if needed, other tests. The other part of the split was sent to the USGS in Reston for laboratory testing for trace elements.

The USGS trace element test results went into the USCHEM database. The USCHEM information for each state was then compiled by USGS personnel and incorporated into a larger database called COALQUAL, burned to CD-ROM, and published in 1994 as Open-File Report 94-205 (Bragg and others, 1994). The last update to this dataset occurred in 1998 as Open-File Report 97-134 (Bragg and others, 1998).

The proximate and ultimate coal analyses returned to us from the bureau's contracted laboratory, as well as coal chemistry data from coal company records, were stored as paper copies in our files. Geologists and interns filled out new paper forms formatted to USGS database rules that included location information, sample thickness, and the laboratory's coal chemistry parameters. Copies of this information were then sent to the USGS, and the information was entered into USALYT, an in-house digital database of coal chemistry values. Various staff geologists at the bureau over the years proofed and edited this information, but at present, it remains unfinished, becoming a lower priority to the

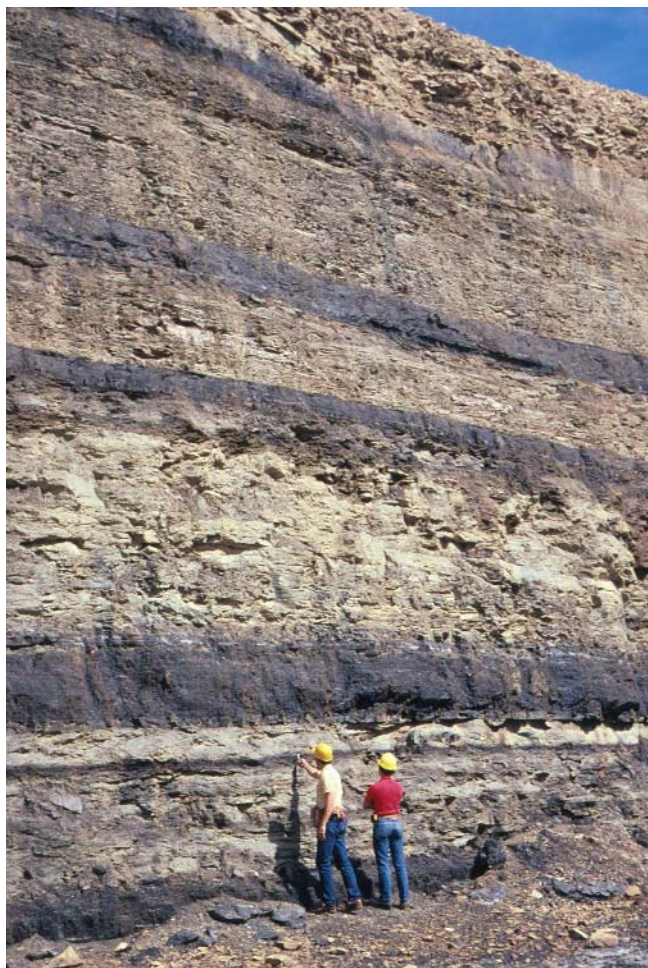


Figure 2. Geologists collecting coal lithostratigraphic information from a mine highwall.

stratigraphic data portion of the database in the late 1990s.

Current Status of the Program

Between roughly 1978 and 2010, bureau geologists collected about 26,160 discrete data points, representing approximately 624,660 individual line entries of information, which are stored in our paper filing system known as the Stratigraphic Data File (SDF). As data were collected, the locations for the data were obtained in the field and were plotted on 7.5-minute topographic maps using standard topographic grid sheets and also noted on the filed paper copy of the record. Information contained in these paper records was entered into the NCRDS computer. Initially, it was manually entered at the USGS; later, data entry was done at the bureau via software on a desktop computer; and today it is accomplished directly over the Internet via a USGS interface software program.

Lentz and Neubaum continue to proof and edit the data found in the NCRDS database via the online interface. There are now more than 6,600 points representing more than 234,000 individual line entries in the NCRDS database.

Practical Applications

The NCRDS data over the years have proven useful to bureau geologists when answering service requests—requests from the public about coal in Pennsylvania. For example, two such questions have required determining the depth of overburden for a coal bed and determining the chemistry of a coal seam in a particular area.

One important use of the data came in the early 1990s when the USGS began a program called Coal Availability. Kentucky was the first state to actually test the framework for coal availability as proposed by the USGS in Circular 1055 (Eggleston, Carter, and Cobb, 1990). Once the methodology was established, the USGS sent out a request for proposals to the other NCRDS participants. Pennsylvania made a proposal in 1992 to begin a quadrangle study in 1993. This study would not have been possible without the data entered previously by the bureau into the NCRDS database.

In the process of naming coal beds for the database, it became necessary to construct geologic cross-sections in individual quadrangles so that the stratigraphy might be better understood and a more precise name could be applied to a coal seam in the area of interest. For example, it was necessary to construct a series of cross-sections for use in the Clymer 7.5-minute quadrangle coal availability study to better understand how to name coal beds, due to the very confusing stratigraphy found there. Several

years later these cross-sections would once again prove useful. Retired professor Edward Belt of Amherst College, Mass., incorporated several of them in a report related to the middle to late Pennsylvanian strata in the Northern Appalachian basin (Belt and others, 2011).

The Future of NCRDS

Although only under consideration at this time, it is anticipated that the NCRDS data for Pennsylvania will be used in coal studies involving coal thickness, aerial extent, overburden thickness, and structure. Studies are envisioned that would result in updates of older bureau publications, such as M 68, "Bituminous Coal Resources," and the county coal Mineral Resource Reports, or that would even result in the creation of new digital products. And with the advent of GIS software and lidar imagery, it might be possible to create entirely new, useful products for public consumption not yet anticipated.

The USGS has anticipated this need for public information and is in the process of making much of the NCRDS truly in the public domain. Lentz and Neubaum are in the process of adding new data and proofing and editing the older data so that they may be incorporated in this new USGS endeavor. The USGS in the meantime is constructing a public interface to the NCRDS database on the Internet that will allow the public to access a wealth of coal lithostratigraphic data, not for just Pennsylvania, but for the entire United States.

However, the future is uncertain for all states' participation in NCRDS. As has become apparent, the economy of the United States is still on shaky ground in 2012. Congress is demanding deep budget cuts to try to restore fiscal soundness. Unfortunately, like many federal agencies, the USGS is taking on its share of budget cuts due to this fiscal belt-tightening, and that has meant that many long-time funded projects, like NCRDS, are in jeopardy of losing their monies. Unless something changes in the near future or the budget is amended and money is restored to their budget, it is anticipated that the state cooperatives funded through the NCRDS grant program will cease after June 30, 2012. Pennsylvania may lose its grant funding, but it is hoped that we will still be able to continue to enter new data and update the old data, as time and bureau resources allow, so that Pennsylvania's coal information can be made public for future end-users. For a while at least, the bureau should still have access to the NCRDS database to do just that, as there have been some assurances from the USGS in Reston that the database will remain active despite the cutbacks in funding at the USGS. It would truly be a tragedy to lose such an important resource as the NCRDS.

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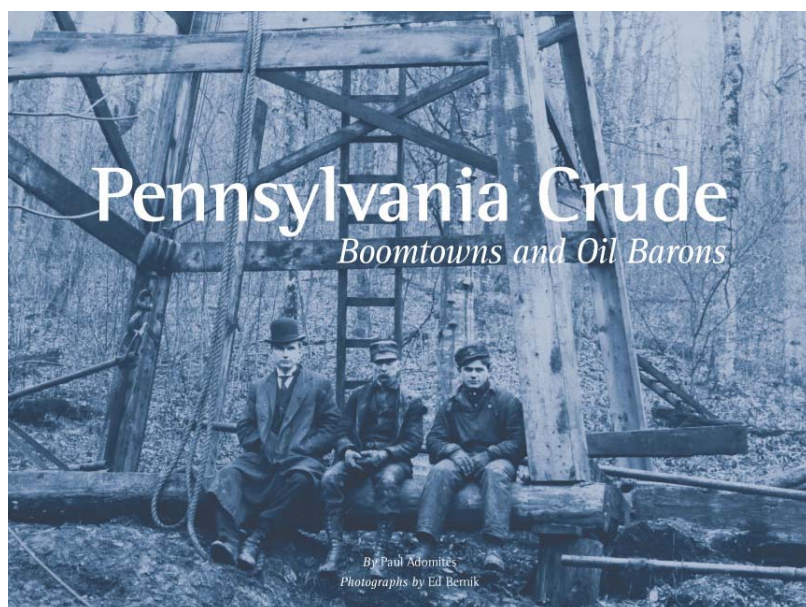
BOOK REVIEW

“Pennsylvania Crude—Boomtowns and Oil Barons”

John A. Harper
Pennsylvania Geological Survey

Forest Press, a nonprofit multimedia company from Bradford, McKean County, Pa., has published *Pennsylvania Crude—Boomtowns and Oil Barons*, a stunning 9- x 12-inch coffee-table book about the oil industry in northwestern Pennsylvania and southwestern New York. It is replete with photographs by Ed Bernik, a freelance photographer and cinematographer from North East, Pa., that illustrate the beauty of western Pennsylvania and the story of oil. Color, black-and-white, and sepia-toned photographs of oilfield equipment, people, buildings, and serene settings (for example, a deer wading across Oil Creek and a tree-covered island on the Allegheny River partly shrouded in early-morning mist) are interspersed with reproductions of historical photographs from the region’s museums and historical societies. Each illustration is accompanied by an explanatory caption.

But the book isn’t just photographs. Paul Adomites, a freelance writer from Emlenton, Pa., tells the story of Pennsylvania Grade crude oil from the time of the early European settlers to the present.



Discussions include those about Pittsburgher Samuel Kier, who created a market for oil in the 1850s by finding a cheap method of refining it into kerosene; Edwin L. Drake, the man who started the modern petroleum industry; Pennsylvania’s world-leading role in oil production in the late 1800s; famous oil wells and the tragedies that accompanied the “get-rich-quick” aspect of oil’s early years; the oil refining industry and people like John D. Rockefeller who shaped the course of the petroleum industry; and the future of crude oil in the Appalachian basin, among many others.

Adomites also provides a short presentation on the geology and geologic history of the oilfields, but his

text, unfortunately, is not entirely accurate. For example, in a discussion of the Devonian Period, he lists diatoms as inhabitants of the sea, yet these shelled organisms didn’t arise until the Mesozoic (the earliest known forms are from the Jurassic). If only he’d said “algae,” rather than “diatoms,” this part of the story would have been correct. He also suggests that Pennsylvania’s oil and natural gas were produced from organic matter encased in shale layers between the reservoir sandstones, yet we’ve known for many years that these interbedded shales do not have that capability. Pennsylvania’s oil and

natural gas are, instead, the products of much older, deeper, and more organic-rich shales such as the Marcellus that is currently a hot item in the Appalachian basin.

As beautiful as the photographs are in this book, they also have their flaws, due mostly to inaccuracies in the figure captions. One blatant error is a photograph of an Eocene fish fossil from the Green River Formation of Wyoming used to illustrate the concept that oil came from the remains of once-living organisms. By itself, the photograph is very nice, but it is unfortunate that the caption, “Fossils from the Paleozoic Era,” destroys the credibility of the explanatory text. Another admirable photograph, of skunk cabbage growing near the Drake Well Museum, bears a caption stating that the lush vegetation growing in the region 300 million years ago provided a key ingredient to the development of hydrocarbons. First of all, the reservoir rocks are about 365 or 370 million years old, so the lush vegetation of 300 million years ago (the Pennsylvanian Period) would have had no effect on the production of oil and natural gas in Devonian rocks. Second, as mentioned above, the source rocks for Pennsylvania’s oil and gas are much older still, around 380 or 390 million years. A beautiful photograph of flat-lying crossbedded sandstone layers in McKean County has a caption that refers to these rocks as being the products of, among other things, folding. The same caption also includes the explanation that the oil-bearing “layer” averages 10 to 70 feet in thickness. In reality, there are numerous oil-bearing layers in the region. I can only assume that the author of the figure caption was referring specifically to the Bradford Third sand, which has been the primary producer in the Bradford oilfield, but certainly not the only one.

In short, for those nit-pickers among us, this book would have benefitted greatly by reviews from geologists familiar with Pennsylvania’s oilfield geology. That said, don’t let the minor flaws mentioned above detract from what is an exceptionally beautiful and noteworthy book. It is a handsome and educational contribution to any personal or public library on Pennsylvania and/or oilfield history and memorabilia. It comes with an interactive DVD that includes a self-guided driving tour of the region’s oil fields, and pdf (portable document format) files of road maps of the particular counties in Pennsylvania and New York that are on the tour.

Pennsylvania Crude—Boomtowns and Oil Barons, with photographs by Ed Bernik and text by Paul Adomites, was published in 2010. The project that resulted in the book was partially funded by a grant from the Department of Conservation and Natural Resources to the Oil Heritage Region. It is available from the Oil Region Alliance of Business, Industry and Tourism in Oil City for \$39.95 plus a \$5.00 shipping and handling fee, a very reasonable price for a hardbound 116-page book of gorgeous photographs. You can order online at www.oilregion.org/Store, or call to order at 800-483-6264. If you are in the Oil City-Titusville area, you can stop in at the Oil Region Alliance’s offices at 217 Elm Street, Oil City, and pick up a copy. The Alliance has many other book titles and items of oil history in stock. Be sure to check out all their products.

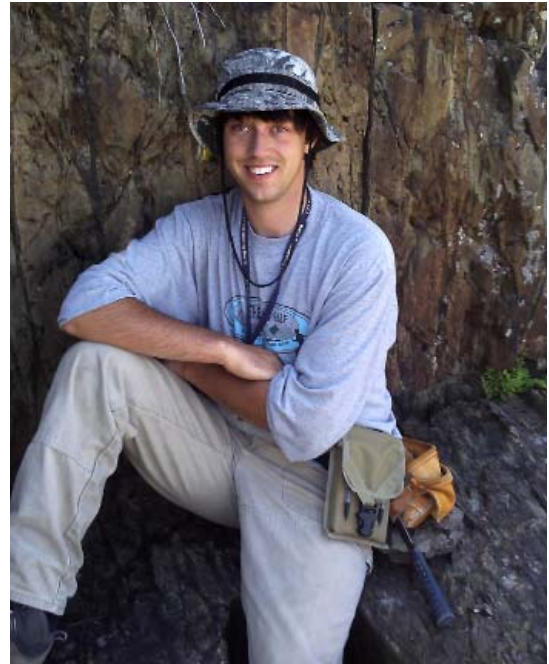
SURVEY NEWS

New Staff Members

Over the past few years, the Survey has lost a number of staff members due to retirement or other job opportunities. In order to maintain our ability to continue our mandate to provide geologic information to the commonwealth, we have brought on board several new staff members in the last year and a half. Their varied expertise is most welcome, and they are introduced below, in alphabetical order.

Aaron D. Bierly. Aaron started working at the Survey at the end of September 2011 as a Geologic Trainee in the Mapping Division. He graduated in August 2009 from the University of Pittsburgh at Johnstown with a B.S. degree in geology. Aaron's other geologic experiences include a paleontology field course with the Pittsburgh Honor College near Rock River, Wyoming, in 2007, an internship with the Survey in 2008, and Iowa State/University of Nebraska-Lincoln field camp in the Bighorn basin of Wyoming in 2009. He was briefly employed with the Southeast Regional Office of the Department of Environmental Protection before accepting the position here.

Aaron recently assisted Donald Hoskins (retired State Geologist) and staff geologist Kristen Hand in running a tour for the field examination of lithologies and geologic structures in the Marcellus shale of Pennsylvania's Ridge and Valley province. Aaron has also begun research and field data collection in support of bedrock mapping of the Elizabethtown 7.5-minute quadrangle.



Mark A. Brown. Mark is a native of Kansas and a graduate of Wright State University. He joined the Geologic and Geographic Information Services Division of the Survey in July 2011, where his first task was to learn GIS software and principles. As a Geologic Scientist, he assists other geologists in the bureau to produce geologic maps and related GIS datasets, which are released as Survey open-file reports. Mark is currently using GIS to create surficial geologic maps for 7.5-minute quadrangles located within the Allentown and Williamsport East 1:100,000-scale maps. When time permits, he is involved with public outreach by visiting local schools to discuss Pennsylvania geology and how it impacts our lives.

Mark comes to the survey with a varied background and has spent much of his time as an educator. His first and only job as a geologist was with an environmental geology consulting firm in the late 1990s. After leaving the consulting field, his career path transitioned from a geocentric focus to one that was astronomical in nature (before he came back to geology

in his present position). Mark worked at Troy State University in Montgomery, Ala., as an astronomer at the W. A. Gayle Planetarium. From there, he went on to work as Senior Astronomer in the James S. McDonnell Planetarium at the St. Louis Science Center. He also landed a job at McKendree University in Illinois, where he taught college astronomy. Mark received an M.S. degree in astronomy from Swinburne University of Technology (Australia) in June 2009 and still teaches introductory astronomy during the evenings, at Dickinson College in Carlisle, Pa.

Connie F. Cross. Connie joined the Pennsylvania Geological Survey in September 2010 as an Administrative Officer in our Middletown office. She supervises an Administrative Assistant 1 and a Clerk Typist 2, who have overall responsibility for the administrative support of the Survey. Connie is responsible for maintaining the bureau's budget, working closely with the bureau director and Fiscal Management. She monitors several grants and contracts, approves invoices for payment, approves travel expenses, and submits Position/Personnel Action Requests to fill vacant positions. She is also treasurer for the Field Conference of Pennsylvania Geologists. Her team is responsible for purchasing supplies and equipment, submitting shopping carts to develop purchase orders, completing travel arrangements and timekeeping duties, distributing publications and rock hound kits, coordinating vehicle maintenance, and monitoring water well license/rig permits and drilling records within the Survey.

Connie graduated from Central Dauphin East high school. Before joining the Survey, she worked with the Department of Environmental Protection, Bureau of Air Quality, for 16 years as a Clerk Typist 2, Clerk Typist 3, and Administrative Assistant. Connie grew up in Bressler and Middletown, Pa. She has three children, Jesse, Amber, and Cory. Connie spends most of her free time playing with her grandson, Dominic, and traveling to Ohio to visit her fiancé, Bruce. She enjoys photography, walking, reading, traveling, and going to yard sales.



Mark A. Dornes. Mark began working for the bureau in February 2011 as an IT Technician in the Geologic and Geographic Information Services Division. Mark helps with the daily operation of the Survey's computer systems and frequently updates its website with new content. As geologists complete new open-file reports and other content, Mark converts the reports to a web-friendly format and publishes them on the website. In addition, he is currently moving the website to a new system. Prior to joining the Survey, Mark worked for the Department of Labor and Industry, and he has put in more than two and a half years with the commonwealth. Mark completed his associate degree in 2007.

Mark has been married for 13 years to Sherri and enjoys reading and traveling. He likes working for the Survey because he is working with a great team and is learning new technologies that he otherwise would not have been exposed to.

Pedro A. Forero. Pedro was hired as an IT Generalist in the Geologic and Geographic Information Services Division in our Pittsburgh office in June 2011. He earned a B.S. in computer science in 2010 and has prior experience as an IT Technician. He served in the U.S. Marine Corps from 1997 to 2005 and is currently a member of the 911th Airlift Wing, Air Force Reserve. Pedro's duties include providing help-desk support to our Pittsburgh staff; assisting PA*IRIS partners and training PA*IRIS users; maintaining computer hardware, software, and servers; and recommending hardware and software to be purchased by the bureau.



Katherine W. Schmid. Katherine Schmid joined the Pennsylvania Geological Survey in 2010 and currently serves as a Geologic Scientist in the Petroleum and Subsurface Geology Section in Pittsburgh. Previously, Katherine worked for five years in the oil and gas industry, where she worked with organic shales and more conventional reservoirs across Pennsylvania. Before moving to Pennsylvania, she was employed by a geotechnical company in Ohio, collecting rock and soil samples across the state of Ohio and in northern Michigan. She received a B.S. degree in geology from The Ohio State University (OSU) in 1999 and an M.S. degree in geological sciences from the University of Pittsburgh in 2005. Prior to attending OSU, Katherine spent a summer working for an environmental restoration project. There, she showed high school students how to collect and test water and soil samples and write reports presenting the results.



Katherine now researches oil, gas, and subsurface geology for the commonwealth. She is also the contact person for people with questions about oil or gas wells on their property. Her experience in the oil and gas industry has proved to be very helpful.

She also functions as one of the stewards of the state's core and cuttings libraries and assists staff geologist Kristin Carter with the Midwest Regional Carbon Sequestration Partnership project.

Jody L. Smale. Jody is the most recent arrival, having joined the Survey in December 2011 as Librarian in the Geologic and Geographic Information Services Division in the Middletown office, where she is responsible for managing and maintaining our research library. Her primary duties include library



acquisitions, cataloging library materials, interlibrary loans, and assisting library visitors.

Jody graduated from Shippensburg University with a B.A. degree in English education in 1999. She went on to earn an M.S. degree in library science from Clarion University in 2010. Prior to joining the Survey, Jody worked for the Department of State and the Department of Education. She has put in more than nine years of service with the commonwealth.

Jody's interest in libraries grew when she volunteered and then was later employed as a Library Aide with the Joseph T. Simpson Public Library in Mechanicsburg, Pa. She enjoys helping library patrons find the resources they need as well as assisting them with the use of library materials. Jody continues to support the

Joseph T. Simpson Public Library by participating in their fundraising activities, including the annual "Bowling for Books" campaign.

Jody has enjoyed her short time with the bureau and is looking forward to learning more about it and the resources it offers.

Carrie L. Tropasso. Carrie is a Natural Resource Specialist. She joined the Survey in May 2011 in the Geologic and Geographic Information Services Division. Prior to joining the Survey, Carrie worked as a Water Pollution Biologist for the Department of Environmental Protection and most recently as a GIS Analyst for a Harrisburg area consulting firm. In addition, she is a certified Geographic Information Systems Professional. She received a B.S. in environmental biology from Millersville University and an M.S. in Geographic Information Systems from The Pennsylvania State University.

Since starting with the Survey, Carrie has worked on several department-wide projects in conjunction with other Department of Conservation and Natural Resources staff, including a data-sharing web mapping application and a central database to house geographic information and data. At the Survey, she has been working on developing a living geological map, which will be an interactive map of significant geologic data statewide. In addition, she has been working on other geologic maps and GIS datasets, as well as community outreach and training.

Carrie was recently married—actually within less than 48 hours of her first day at the bureau—to her wonderful husband, Thomas. In her spare time, she enjoys camping, hiking, photography, stargazing, collecting seashells and anything related to the beach.



Staff Members Receive Longevity Awards and Recall Interesting Times

Four staff members were recently honored for their many years of service to the commonwealth and the bureau. Leonard Lentz, Michael Moore, Caron O’Neil, and Thomas Whitfield were each presented with a keystone-shaped plaque in recognition of 25 years of service. Several recollections of memorable events from their years at the Survey were shared at a recent staff meeting. Here are two.

Caron O’Neil: I’ll always remember my second trip to the abandoned Bear Valley strip mine in the Western Middle Anthracite field. Not because of the wonderful Whaleback anticline—although that was a reason to remember it when I went my first time while attending the 1983 Field Conference of Pennsylvania Geologists—but rather because of my driver.

I spent my first 22 years at the Survey working as an editor. Early in my career, I had the pleasure of getting away from my desk for a staff field training trip that included a visit to the Bear Valley strip mine. I had the fortune of riding with David MacLachlan (better known as Mac), a seasoned field geologist, in one of our state-owned trucks. In addition to his mapping skills, Mac was known for his exuberance. When we turned into the heavily pitted dirt parking lot near the mine, Mac floored it with a loud “YEE-HA!” As we bounced crazily along, he grinned from ear to ear. It was kind of like a roller coaster ride—terrifying and thrilling. I know I’ll never forget it. Thanks Mac.

Leonard Lentz: There were two times when I helped fellow staff geologists pick up core from their drilling projects in southwestern Pennsylvania that stand out in my memory. In the first instance, I helped pick up core stored at the old bathhouse at Ryerson Station State Park. We managed to fill “to the gills” an old Department of General Services (DGS) truck that we had borrowed for the occasion. The truck bed was really riding low on its springs. I also remember that the truck’s taillights did not work right for some reason. So we had an overweight truck with no taillights. Someone from our group



Left to right: Michael Moore, Caron O’Neil, Leonard Lentz, and Thomas Whitfield display their 25-year plaques.

drove the truck and the rest of us followed behind in the survey SUV, always staying close behind the truck to provide brake lights until we got to our motel for the night. I have always marveled that we ever made it to Hollywood, Pa., to drop off the core for storage, which brings me to a second incident involving a different DGS truck. Former staff geologist Jim Phillips and I were recruited to haul a load of core-filled boxes to Hollywood from Harrisburg. It was an iffy proposition at best. The truck had a terrible lean to it once full and we were concerned with how the truck would respond to any corner we went around. We had one other obstacle. We had to climb the U.S. Route 22/322 grade up Seven Mountains. We did not think the listing, overweight truck could make it up the grade and around the curves without some sort of calamity occurring. But to both Jim's and my amazement, we managed to limp very slowly up and over the top of that stretch of road. Nothing happened, and we could relax a little. The final hurdle, the Allegheny Front on I 81 westbound, would be a piece of cake in comparison.

Bathymetry Update

The Pennsylvania Geological Survey continues to fulfill its commitment to the Department of Conservation and Natural Resources and the boaters and anglers in the commonwealth to provide bathymetric maps for four state parks per year. This year, Ricketts Glen, Chapman, Memorial Lake, and Raccoon Creek state parks were selected largely from the list of highest priority lakes as outlined by the State Parks Resource Management.

Ricketts Glen's Lake Jean was surveyed in July. Lake depths were recorded and tree stumps, old beaver lodges, downed trees, and rock pile locations were noted. Two versions of the lake map were created. One is a full-color version that is posted at the park office and at kiosks at both boat launches. A black-and-white version was also created, showing water depth and locations of all the fish habitats and boat obstacles. This version was designed to be affordably copied by park staff to distribute freely to interested parties.

Memorial Lake was surveyed in September and Chapman Lake in October. Raccoon Lake at Raccoon Creek State Park was not on the highest priority list, but data had already been collected by the U.S. Geological Survey in 2007. Data processing and map compilation will take place this winter for these three parks.

These bathymetric maps, and the 11 that were completed in years past, will be available on our website soon. If you have questions about the bathymetric program at the Survey, please contact Rose-Anna Behr at rosbehr@pa.gov, telephone 717-702-2035.

RECENT PUBLICATION

Bedrock geology [open-file report](#): **(November 2011)**

[Bedrock Geologic Map of the McCoysville Quadrangle, Juniata, Mifflin, and Perry Counties, Pennsylvania](#)

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