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A large eurypterid walks out of a stream onto a sand bar in what will one day become Elk County, Pa., leaving behind a set of tracks that will be on display at the Carnegie Museum of Natural History in Pittsburgh 320 million years later. Illustration by Kay Hughes. (See article on page 3.)

EDITORIAL

Thank You!

Gale C. Blackmer, State Geologist
Pennsylvania Geological Survey

In all the excitement about celebrating the Bureau’s 100th anniversary, one important group did not get the credit it deserves: you—our users/customers/constituents (there’s some discussion about the proper term). Our hundred years of good work means nothing unless you use it. We collect data, make maps, write reports, and send them out into the world. We can’t measure their success until one of you tells us that you used our products in your work. These conversations happen less often than you might think. That’s why it was so gratifying to see the turnout for our open house celebrations last year. I couldn’t help feeling a bit like Sally Field when she won an Oscar in 1985—you like us! Thank you for your support over the years and into the future.

The Bureau strives to provide basic data and services needed by the earth science and geotechnical community. You can help us by telling us what we are doing right and where we are missing the mark. Let us know if there is a new product you would like to see or a new topic you would like us to address. New technologies are always coming online, and the changing cultural and environmental landscape may necessitate different kinds of geologic information to keep up. You can help us to focus our choices and keep our services sharp by telling us what you need. Of course, I can’t guarantee that we’ll take up every suggestion—we are constrained by available resources, after all—but we’ll do our best to continue providing top-notch service.

Let’s keep the dialog going for another 100 years!

Gale C. Blackmer

Reflections on *Palmichnium kosinskiorum*—The Footprints of Pennsylvania's Elusive Elk County Monster

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INTRODUCTION

There is an exhibit in the Benedum Hall of Geology at the Carnegie Museum of Natural History (CMNH) in Pittsburgh, Pa., that consists of a large slab of conglomeratic sandstone showing the fossil tracks of something that was very large (Figure 1). The tracks include more than six sets of three "toes" (Figure 1B and 1C) arranged opposite each other, with a long, shallow indentation midway between them. Discovered in 1948 in Elk County by Michael Kosinski, they were impressed into the surface of a very large block of rock lying on a hillside above Spring Creek near the little hamlet of Hallton (Ross, 1948). Michael told his brother James, a CMNH preparator, about it, who recognized it as a true fossil; James then made plaster casts of some of the tracks and took them back to the museum. Dr. J. LeRoy Kay, then Curator of Vertebrate Paleontology at the museum, apparently became interested because he went to visit the locality soon after. Within a few days, museum staff and some contractors arrived in Hallton, carefully removed from the block a slab containing most of the trackway, and transported it back to Pittsburgh (Ross, 1948).

Dr. Kay thought the tracks must have been made by some kind of amphibian because—well, what else living at the time Elk County's bedrock was being deposited was large enough to have made them? The type of amphibian had him stumped, however, as he had never seen anything like those tracks (Ross, 1948). They were arranged in pairs that are opposite each other (Figures 1A and 1B), rather than alternating as would be expected from a walking four-legged animal. This led to speculation that the animal was hopping on two legs rather than walking on all four (Anonymous, 1948; Briggs and Rolfe, 1983). Sometime later, Dr. Rudy Eller, the museum's then-Curator of Invertebrate Paleontology, correctly identified the trackway as the trail of a very large eurypterid (Brezinski and Kollar, 2016). The slab went on display at the museum in 1949 with a caption and illustration showing the correct interpretation of the footprints and a tail-drag mark. When the former Paleozoic Hall opened in 1965, the slab became one of the main floor exhibits and received much attention by the museum visitors. It is now part of the Benedum Hall of Geology, and it helps visitors to interpret the geology of western Pennsylvania (Harper and Dawson, 1992).

Can you imagine an invertebrate animal so large that its tracks could be mistaken for those of a four-legged vertebrate? We tend to think of invertebrates as being small, similar to most of today's insects. Yes, there are large insects; the largest known living insects, however, generally are smaller than two feet (0.6 m) long; even the giant fossil dragonfly, *Meganeura,* had a wingspan ranging only from about 25.6 to 27.5 inches (65 to 70 cm). In contrast, the arthropod that made the Elk County tracks would have measured somewhere in the neighborhood of 6.5 feet (198 cm) long, about 32 inches (81

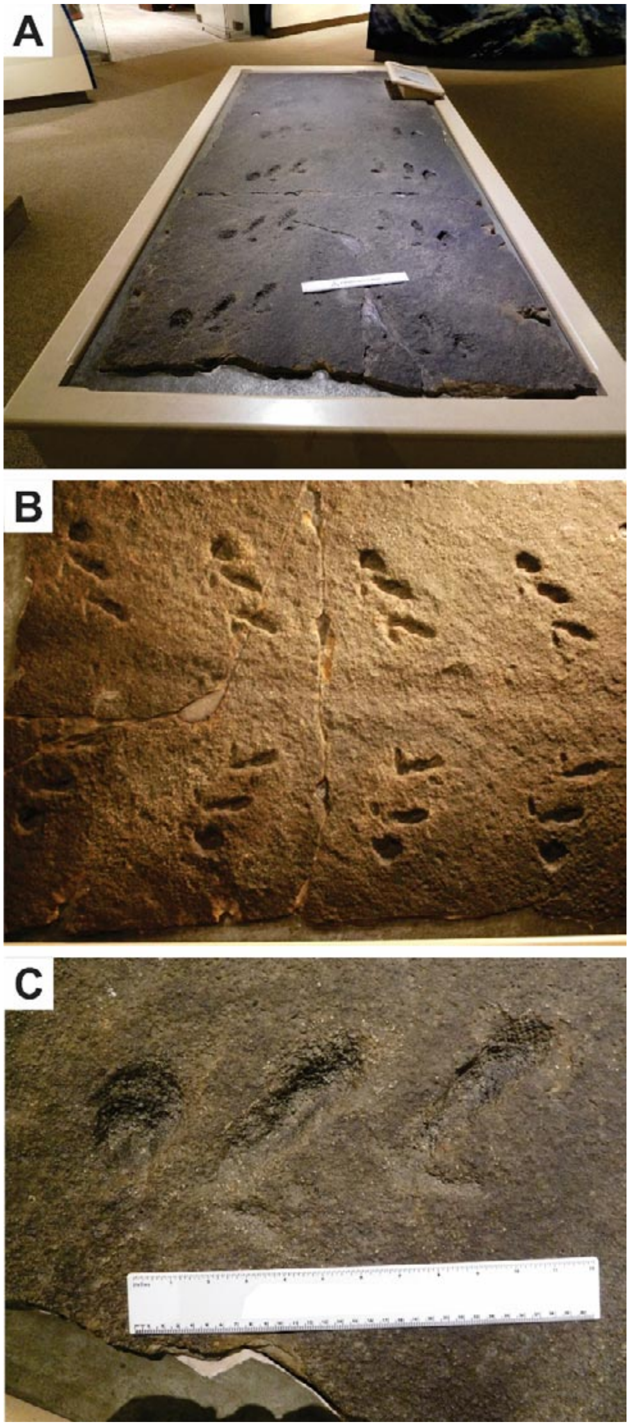

Figure 1. Photographs of a fossil trackway in coarse-grained sandstone on display at the Carnegie Museum of Natural History's (CMNH) Benedum Hall of Geology. A. The complete display. The tracks indicate that the animal was walking away from the viewer. B. A closer view showing the furrow between the track sets, indicating that the animal was dragging its tail (photograph by James Senior, CMNH Exhibits). C. One set of tracks consisting of three individual "footprints." Scale, 12 in. (30.5 cm).

cm) wide, and would have weighed several hundred pounds, certainly larger than most humans. What a monster it must have been!

GARGANTUAN FOOTPRINTS IN THE SAND

Strangely enough, despite the excellent preservation and the enormous size of the trackway, it took almost 35 years before anyone thought to describe the tracks and interpret what they meant. After studying it, British paleontologists Derek Briggs and Ian Rolfe (1983) called the trackway *Palmichnium kosinskiorum* in honor of James Kosinski, the museum preparator. *Palmichnium* ("palm trace") is an ichnogenus (a genus known only from trace fossils rather than body fossils) named by German paleontologist Rudolf Richter (1954) that has been interpreted as representing the unusual walking style of an amphibious eurypterid out of water. Based on the Elk County trackway, Briggs and Rolfe (1983) emended Richter's original description of *Palmichnium.* Theirs is now the accepted definition. Although they discussed several possible track makers, Briggs and Rolfe (1983) did not specifically identify the animal that made *P. kosinskiorum.* Instead, they merely interpreted it as the walking trail of a large unknown eurypterid-like arthropod.

Paleontologists currently recognize eight ichnospecies of *Palmichnium* from around the world, ranging in age from Silurian to Permian, including *P. antarcticum, P. capensis, P. culmicum, P. kosinskiorum, P. macdonaldi, P. palmatum, P. pottsae,* and *P. stoermeri.* The best-known and most abundant of these is *P. antarcticum* (Gevers and others, 1971, who referred it to the ichnogenus *Arthropodichnus*). It has been documented from the Silurian and Devonian of the southern hemisphere and the Devonian of Canada. Other than a trackway from the Lower Carboniferous of Scotland (Whyte, 2005), however, none of the other ichnospecies even comes close to *P. kosinskiorum* in size (Figure 2).

And, just when you think a eurypterid couldn't have gotten any larger than the beast that produced *P. kosinskiorum,* along comes the description of a trackway that is even wider at more than 38.6 inches (98 cm) (Whyte, 2005). Unfortunately, the author only measured the outside width of the tracks, so the trackway cannot be plotted accurately on Figure 2. Whyte estimated the eurypterid that made the tracks to have been about 5.5 feet (168 cm) long, a foot (30.5 cm) shorter than the one that made the Elk County track, but about seven or eight inches (18 or 20 cm) wider. He believed the animal to have been a species of *Hibbertopterus* Kjellesvig-Waering, 1959 (see below) because of the size of the trackway and the fact that fragmentary fossils of *Hibbertopterus* are well known from the Scottish Lower Carboniferous.

A EURYPTERID BY ANY OTHER NAME . . .

Eurypterids first appeared in the Middle Ordovician and reached their apex of diversity in the Late Silurian, declining thereafter and going extinct by the Late Permian. The order Eurypterida consists of about 235 described species, the most diverse Paleozoic chelicerate group (Tetlie and others, 2007). Their biology and life habits have been described in various ways based on comparisons with living horseshoe crabs and terrestrial scorpions, to which they are related. Although eurypterids share

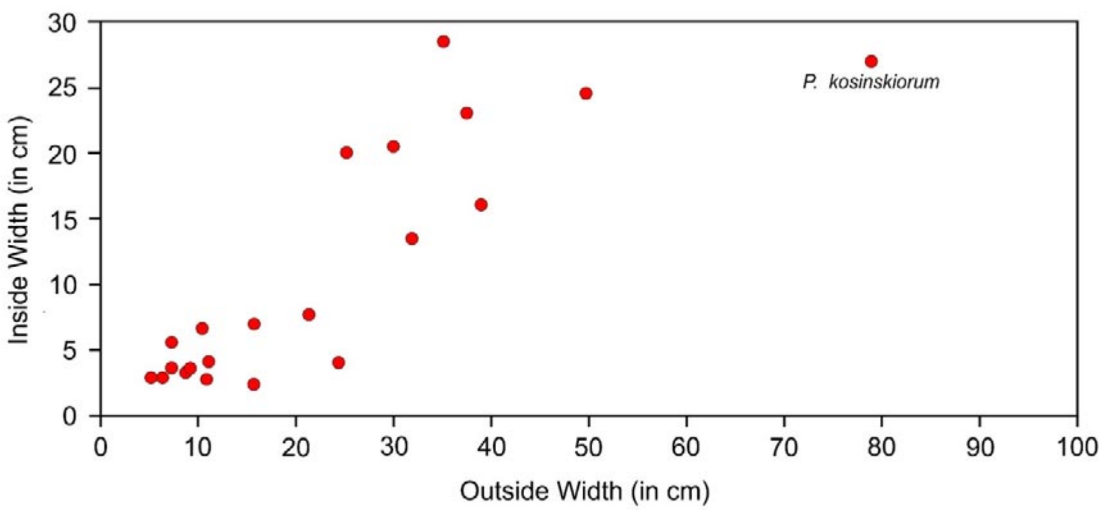

Figure 2. Graph of the internal versus external width of Palmichnium *trackways reported in the literature (based on Draganits and others, 2001). Notice the position of* P. kosinskiorum. *A trackway described by Whyte (2005) from the Lower Carboniferous of Scotland was even wider but cannot be included here (see text for explanation).*

numerous morphological characters and habitats (generally aquatic) with horseshoe crabs, they bear such a striking resemblance to scorpions that the common name of the group is "sea scorpions."

Even though eurypterid fossils had been known for centuries, often mistaken in the olden days for evidence of angels or other divine creatures by quarry workers, the earliest described eurypterid fossil, collected from the fossil-rich Silurian rocks of New York, was incorrectly identified by Mitchill (1818) as a species of the catfish genus *Silurus.* Seven years later, DeKay (1825) recognized the fossil as clearly belonging to an arthropod. He named it *Eurypterus remipes* ("broad wing oar foot") and identified it as a crustacean of the order Branchiopoda (a still-extant group that includes the fairy shrimps). He concluded that it might be a missing link between the trilobites and the branchiopods. Harlan's (1834) *Eurypterus lacustris* (Figure 3), also from the Silurian of New York, was the second eurypterid ever described. As Tetlie and others (2007) noted, these two species are so common in museum collections that they represent about 80 percent of all the eurypterid specimens known in the world.

Figure 3. Eurypterus lacustris *(Harlan, 1834), a typical eurypterid from the Upper Silurian Bertie Group of Erie County, N.Y. From the collections of Carnegie Museum of Natural History (catalog number CM 33812). Scale is in cm.*

Even after Burmeister (1843) erected Eurypteridae as a family containing the single genus *Eurypterus,* eurypterids continued to be considered crustaceans well into the late 1800s (even trilobites were considered an order of crustaceans during that time). Roemer (1848) allied the eurypterids with horseshoe crabs such as the extant genus *Limulus,* but still regarded them all as crustaceans. He wrote (p. 193, translated from German):

> ". . . *Eurypterus* seems closer to *Limulus* than to any other division of the crustaceans. The big differences, which are sufficient to justify a separation as a separate family, should not be overlooked. The chief difference would be, in particular, that the last pair of feet, which in the xiphosures [horseshoe crabs] all have, in a strange way, the double function of organs of gripping and of chewing (at their base), are here transformed into a body intended for swimming with a great fin-like tail. In addition, the separation of the limbs, which in *Limulus* are covered with a common piece of shell, would be distinctive."

Eurypterids had streamlined bodies and a pair of appendages adapted as paddles to aid in swimming in aquatic environments (Figure 4).

By the time Clarke and Ruedemann (1912) published their seminal work on the eurypterids of New York, eurypterids were recognized as an order of Merostomata, which was transferred from the crustaceans to the arachnids (trilobites were still considered to have been crustaceans). This classification scheme lasted until around 1950; even the well-known *Index Fossils of North America* (Shimer and Shrock, 1944) followed it. Finally, biologists and paleontologists recognized the modern classification of chelicerates. In this scheme, eurypterids form an extinct order of arthropods (Eurypterida) that, along with the horseshoe crabs (order Xiphosurida), form the class Merostomata.

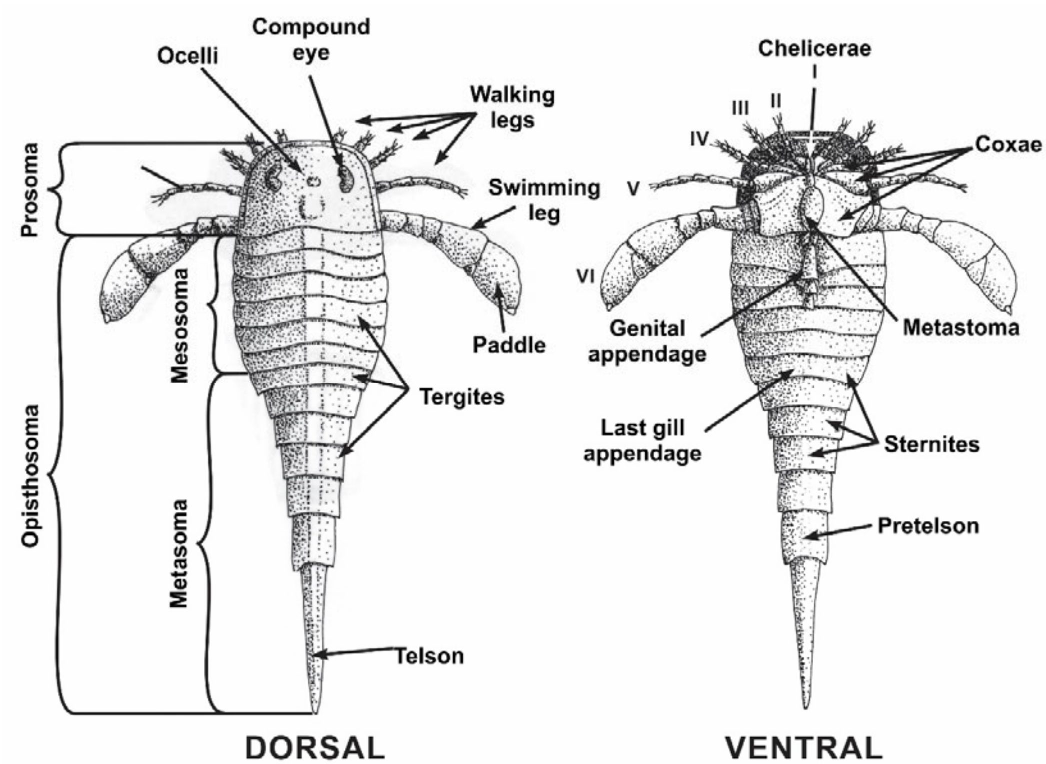

Figure 4. General morphology and anatomical terminology of a typical eurypterid such as Eurypterus lacustris *(see Figure 3).*

Merostomata, in turn, along with the orders Arachnida (spiders and scorpions) and Pycnogonida (sea spiders) form the subphylum Chelicerata. (The trilobites finally were recognized with their own subphylum, Trilobitomorpha.)

More recently, systematists and developmental biologists have been using molecular methods, along with new discoveries of spectacular Cambrian fossils, to attempt an understanding of the evolution of arthropods as a whole. These studies have shed new light on the phylum, requiring a radical reordering of the relationships among some extant classes as well as their closest nonarthropod relatives (Budd and Telford, 2009). It is interesting to note that even with the use of molecular systematics, the relationship of spiders, mites, ticks, scorpions, and horseshoe crabs has not been challenged, and paleontologists would point out the undeniable relationship of eurypterids to horseshoe crabs as well.

WATER, WATER EVERYWHERE, EXCEPT . . .

Over the years, paleontologists have debated the life and feeding habits of eurypterids, with some thinking they lived and fed more like horseshoe crabs than the predatory scorpions. Others, such as Braddy (2001), described them as a diverse group of predators, but he was dealing exclusively with Silurian and Devonian species. Based on the fossil evidence, eurypterids apparently started out as predators, but by the end of their lineage they had become “sweep feeders.” This lifestyle involved modifications to the spines on their appendages II–IV (Figure 4) that acted like trawling nets and scrapers for raking through soft sediment to capture small invertebrates. Regardless of predatory or sweep feeding behavior, the eurypterids left many clues about where they lived, including footprints such as *Palmichnium.*

Eurypterid trackways are known from the Middle Ordovician to the Lower Permian. Both body and trace fossils have been found in rocks representing a wide range of paleoenvironmental settings, including deep and shallow marine, hypersaline, brackish, and freshwater. Early eurypterids (Early and Middle Paleozoic) were predominantly nearshore shallow marine dwellers. There are some very old trackways that occur in rocks where mudcracks are present on the tracks, indicating at least temporarily emergent conditions. This suggests that some eurypterids were able to go ashore, at least briefly, early in their family histories (Braddy, 2001). By the beginning of the Carboniferous, however, the surviving groups were confined to nonmarine settings, and some forms were able to take short walks onto the shore and even inland.

Trackways from Silurian and Devonian formations often indicate more than single eurypterids. Gevers and others (1971, p. 91), for example, in describing trackways in Antarctica, stated, “The sand of one large slab . . . must have been a veritable stamping ground of [*Palmichnium*] *antarcticum.* It shows some 180 individual foot imprints in negative relief (pits) with which are associated 7 well-marked telson grooves.” Examples such as this led Braddy (2001) to speculate that, like modern horseshoe crabs, eurypterids migrated in large groups into nearshore and marginal environments to molt and mate. Eventually, the juveniles tended to prefer the marginal marine and nearshore habitats, and later groups remained there. As evidence, Braddy (2001) cited changes in respiratory and reproductive biology that suggested amphibious excursions, as well as the occurrences of abundant, variously sized, subparallel eurypterid trackways, indicating migrations en masse, in a similar direction, across marginal environments similar to those made by extant semiterrestrial crabs and horseshoe crabs that employ similar behaviors. For example, Braddy (2001) discussed a Devonian formation in India characterized as nearshore or littoral where the abundance, straightness, and subparallel orientation of trackways suggested that the animals were not just wandering aimlessly—they were migrating as a group. The trackways exhibited a wide range in size, meaning they were not the tracks of one or a few individuals.

Instead, this indicated that the animals were of many sizes and were all involved in the same venture, implying that they represented an entire population either of a single species or several species moving at the same time. It reminded him of the tracks left by extant semiterrestrial crabs.

When Briggs and Rolfe (1983) described and named the Elk County trackway, they thought the block of rock bearing it, which measured 44.3 by 24.6 feet (13.5 by 7.5 m) wide by 13 feet (3.9 m) thick, was part of the local bedrock. Although they recognized that it was not in place, they considered the block too large to have moved very far. According to the *Geologic Map of Pennsylvania* (Berg and others, 1980), the local bedrock is Lower Mississippian "Pocono Group," which Briggs and Rolfe thought was likely to have been the Shenango Sandstone. Where the undisputed Shenango crops out in northwestern Pennsylvania, it is a sequence of marine sandstones and shales. A Lower Mississippian paleogeographic map indicated that the area lay within "marine shelf and lower delta-plain sediments" close to the boundary with "upper delta-plain sediments." Briggs and Rolfe (1983, p. 378), however, wrote, "On the evidence available it is not possible to discriminate between a dominance of wave or fluvial processes, but it is not improbable that the trackway was formed in very shallow water to emergent conditions." All they could determine for certain was that the eurypterid was walking south when it formed the tracks because the trackway was oriented to the south.

Museumgoers often ask how a trackway becomes a fossil. The answer is: by luck, mostly. Just consider the actual moment a several-hundred-pound creature with pointed "feet" and dragging its tail crawled out of the water onto a sandbar (see cover illustration). The weight of the animal's body and tail (the technical term is "telson") (see Figure 4) depressed into the soft sediment as it moved, pushing out the sediment to form footprints and a drag mark with its tail. You can imagine, then, the sun beating down on the trackway, heating up the sediment where any water would be evaporated, thus setting in place (think of concrete as it sets up) a fossil trackway that would be found hundreds of millions of years later.

During a visit to the museum in 2009 to examine the trackway, world-renowned paleontologist Adolph Seilacher of Yale University suggested that the trackway sand could not have been deposited in a marine environment, but rather was eolian (wind blown), similar to what he had seen in Egypt. He suggested going out to take another look at the block (Kollar, personal communication, 2009). Brezinski and Kollar (2016) revisited the Hallton area and found the block containing what is left of the *P. kosinskiorum* trackway (Figure 5A). They re-evaluated the rock containing the trackway and realized immediately that it and the other large blocks, or boulder trains, of sandstone float in the area consist of cross-bedded layers of pebbles and medium- to coarse-grained rounded white quartz (Figure 5B). This lithology is very different from the marine Shenango Sandstone, which consists of interbedded very fine and fine-grained greenish-gray sandstones and dark-gray silty shales. Brezinski and Kollar (2016) then interpreted the blocks as typical of stream-channel deposits, and the part of the block where the trackway occurred specifically as the top of a stream-channel sandbar (not characteristic of an eolian environment). Using aerial imagery, they traced the float blocks to a ledge at the crest of the hill to the north where the Lower to Middle Pennsylvanian Pottsville Group crops out. The physical description and lithology of the blocks correlate very well with the typical Lower Pennsylvanian Olean Conglomerate (part of the Pottsville), whose type locality at Olean, N.Y., is about 50 miles (80 km) north-northeast of the trackway locality. The blocks, which separated from the outcrop near the top of the hill along joints by the action of freeze-thaw cycles and through intense Pleistocene frost action, traveled about 800 feet (244 m) downslope to rest where they are today (Brezinski and Kollar, 2016). More than 50 years ago, Meckel (1967) had determined that the Olean represents a thick deposit of sand and pebbles transported by a localized incised river flowing south from New York. This interpretation

Figure 5. Photographs of the float boulder that contained the Carnegie rock slab. A. Top view, Albert Kollar for scale. B. Close-up view of the surface of the rock showing its composition of coarse quartz grains and pebbles. Ballpoint pen for scale. Modified from Brezinski and Kollar (2016).

indicates that the trackway represents the walking action of a very large eurypterid across a stream channel during the Early Pennsylvanian (323–315 million years old).

BIG, BIGGER, BIGGEST

Gigantism was widespread among Paleozoic arthropods. Think *Meganeura,* the giant dragonfly, a model of which is on display in the Pennsylvanian swamp diorama at CMNH's Benedum Hall of Geology. Many eurypterids actually grew very large (Lamsdell and Braddy, 2010), especially in the Middle Silurian-Middle Devonian family Pterygotidae, where about half of the known species grew to more than two feet (0.6 m) long (Anderson and others, 2014). An unrelated family, the Late Devonian-Late Permian Hibbertopteridae, also grew to enormous sizes. In all likelihood, a hibbertopterid, possibly a species of *Hibbertopterus,* created the *Palmichnium kosinskiorum* trackway (see cover illustration). The carapaces of *Hibbertopterus* species are more than 2 feet (0.6 m) wide. Since they are very wide relative to their lengths, a typical hibbertopterid species that was 2 feet (0.6 m) wide would have been about 6.5 feet (2 m) long (Figure 6A). Can you imagine an arthropod that was more than 6 feet (1.8 m) long and 2 feet (0.6 m) wide? Would you have wanted to be around when they existed? Well, don't fret. Hibbertopterids have been interpreted as sweep feeders rather than predators.

So far, the two recognized species of *Hibbertopterus* occur only in the Lower Carboniferous rocks of the British Isles. That does not preclude one of these, or an as yet unknown species, from being the maker of *Palmichnium kosinskiorum.* Other hibbertopterids are known from Pennsylvanian-equivalent rocks elsewhere in the world. One species of *Cyrtoctenus* Størmer and Waterston, 1968[1], is known from Early Pennsylvanian-equivalent rocks of the Czech Republic; three species of *Mycterops* Cope, 1886[2], have been described from Middle to Late Pennsylvanian rocks in Belgium (Iowa) and northeastern Pennsylvania. But none of these eurypterids reached the physical dimensions of *Hibbertopterus,* nor of the animal that made *P. kosinskiorum.*

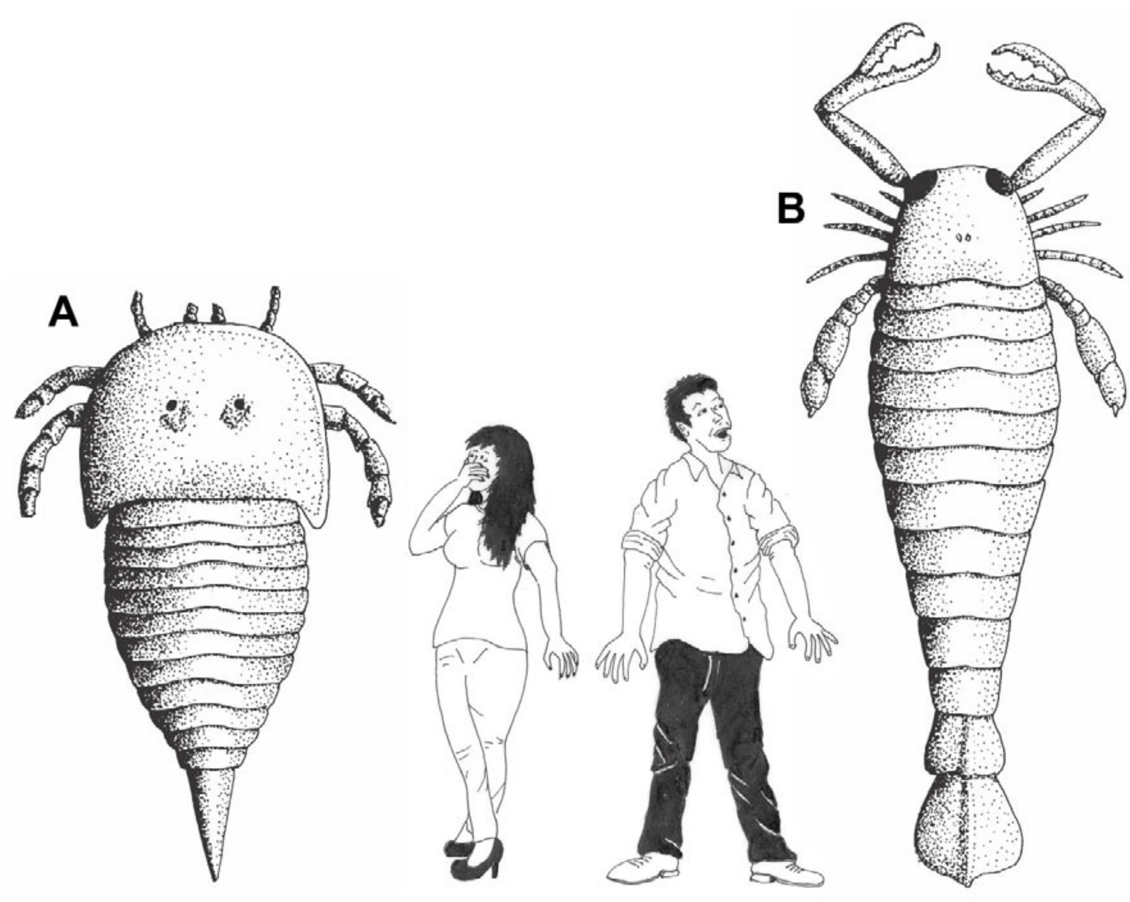

Figure 6. Illustrations of some gigantic eurypterids next to average-sized humans for scale. A. Hibbertopterus *from the Lower Carboniferous of Scotland (based on Whyte, 2005). B.* Jaekelopterus, *from the Middle Devonian of Germany (based on Braddy and others, 2007).*

[1] Some researchers think that the smaller *Cyrtoctenus* and the larger *Hibbertopterus* are different ontogenetic stages of a single genus. If so, the name *Hibbertopterus* has priority.

[2] Edward Drinker Cope, of "Cope-Marsh dinosaur wars" fame, mistakenly described *Mycterops* as a jawless fish.

But, other than hibbertopterids, which vaguely resembled our old friend the horseshoe crab (only tremendously larger) (see Figure 6A), the eurypterids you definitely would NOT want to meet while swimming were the pterygotids, a family of actively swimming predators that were even bigger than hibbertopterids. *Pterygotus* and *Jaekelopterus,* for example, developed giant body sizes, strong puncturing or crushing chelicerae (pincer-like claws), and advanced visual acuity from forward-facing compound eyes. *Jaekelopterus rhenaniae* (Jaekel, 1914), in particular, probably was at least 8.2 feet (2.5 m) long and had gigantic chelicerae as well (Figure 6B). Its robust and enlarged claws would have allowed it to puncture and grasp large prey. It also apparently had clarity of vision comparable to modern predatory arthropods. But the really big predatory eurypterids did not last beyond the Late Devonian. Lamsdell and Braddy (2010) suggested that their line became extinct because of competition with active predatory vertebrates such as the even larger arthrodire placoderm, *Dunkleosteus,* known to have been about 20 feet (6 m) long. By adopting a sweep-feeding strategy in freshwater environments, however, the hibbertopterids avoided competition with vertebrates and thereby stuck around for an additional 140 million years (Lamsdell and Braddy, 2010).

AND IN THE END . . .

The eurypterids disappeared sometime during the Permian, probably during the mass extinction that saw the demise of about 90 percent of all known species on Earth. The animal that made the large eurypterid trackway on display at CMNH may never be known for certain. Considering the scale of the trackway, the eurypterid would have been enormous, but so far, the really large Late Paleozoic hibbertopterids, represented by the genus *Hibbertopterus,* are known only from the Lower Carboniferous (Mississippian equivalent) of Scotland and Ireland. Although we know that the hibbertopterids survived into the Pennsylvanian (Upper Carboniferous) and Permian, there is as yet no preserved evidence for body fossils that could give us an indication of the beast that made *Palmichnium kosinskiorum.* Perhaps someday soon a hunter traipsing through Elk County in search of a venison meal will stumble over a chunk of Olean Conglomerate containing some body fossils and, recognizing their significance, will contact someone at CMNH with information that will change the face of eurypterid paleontology. We can only hope.

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Open House Held in Recognition of the Centennial of the Fourth Pennsylvania Geological Survey

Gary M. Fleeger[1], John H. Barnes[1], and Brian J. Dunst
Pennsylvania Geological Survey

The current (Fourth) Pennsylvania Geological Survey celebrated its 100th anniversary in 2019. An article reviewing the history of the Fourth Survey appeared in the last issue of *Pennsylvania Geology* (Faill and others, 2019). In recognition of the centennial, the staffs of both the Middletown and Pittsburgh offices of the Survey (Figures 1 and 2) hosted open houses in their offices on August 5 (Pittsburgh) and December 6 (Middletown).

One hundred attendees from industry, academia, and government from New York and New Jersey, as well as Pennsylvania, joined 23 current Survey staff members at the Middletown event. The open house showcased the current facilities and research of the Survey. Morning and afternoon guided tours of the building allowed attendees to see the geographic information systems, library, core storage, and laboratory facilities. Books were available for giveaway in the library. Five staff geologists gave presentations concerning their current research and mapping projects, and State Geologist Gale Blackmer spoke about the history of the Fourth Survey (Figure 3). Attendees also had the opportunity to tour the building on their own to observe posters containing information on current and recent projects, as well as to talk to staff regarding their work. A lunchtime catered meet and greet gave the attendees the opportunity to interact and network with each other.

At the Pittsburgh open house, the staff created new posters of recent and current work in addition to displays of past projects. An engaged group of visitors interacted with staff and discussed the history of the Survey and its work. Timely research includes carbon capture utilization and storage, regional subsurface mapping, climate adaptation, hydrocarbon distribution, and Pennsylvania seismicity.

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[1] Retired.

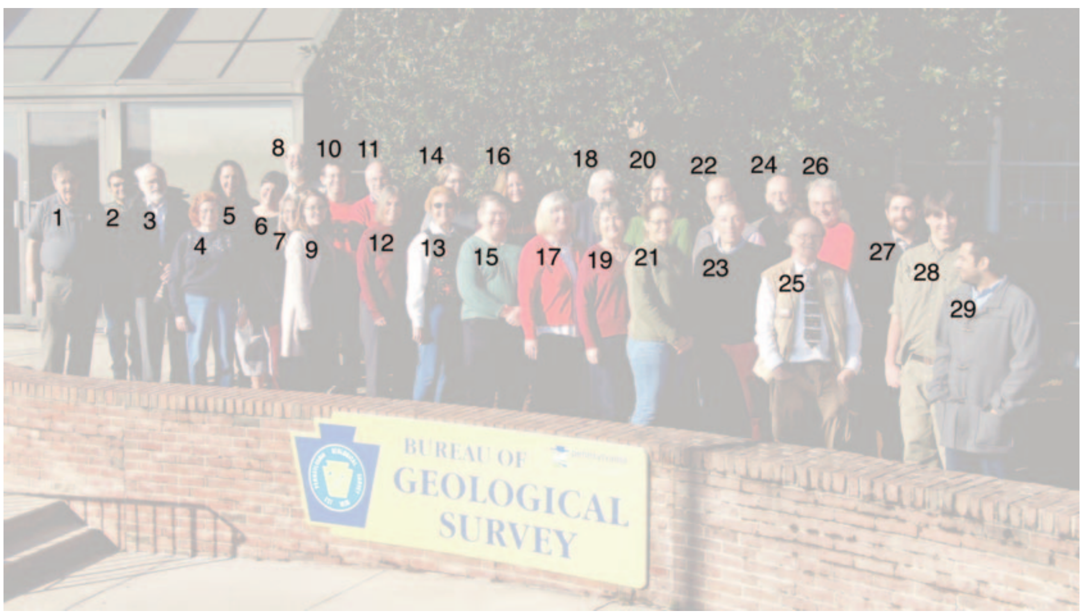


Figure 1. Staff of the Fourth Pennsylvania Geological Survey's Middletown office at the end of its centennial year. Absent are Mark A. Dornes, John C. Neubaum, Sandipkumar P. Patel, and Caron E. Pawlicki. Photograph obtained using the Survey's drone controlled by Craig Ebersole.

1. *John H. Barnes (volunteer)*
2. *Bavesh Patoliya (contractor)*
3. *Robert C. Smith, II (volunteer)*
4. *Anne B. Lutz (volunteer)*
5. *Connie F. Cross*
6. *Amy Randolph (volunteer)*
7. *Jody R. Zipperer*
8. *Gary M. Fleeger (volunteer)*
9. *Ellen R. Fehrs*
10. *Zachary C. Schagrin*
11. *Stuart O. Reese*
12. *Jody L. Smale*
13. *Antonette K. Markowski*
14. *Emily A. Hernandez*
15. *Helen L. Delano*
16. *Kristen L. Hand*
17. *Audrey A. Kissinger*
18. *Leonard J. Lentz*
19. *Victoria V. Neboga*
20. *Gale C. Blackmer*
21. *Rose-Anna Behr*
22. *Simeon B. Suter*
23. *Clifford H. Dodge*
24. *Stephen G. Shank*
25. *James R. Shaulis*
26. *Michael E. Moore*
27. *Craig M. Ebersole*
28. *Aaron D. Bierly*
29. *Gibson Gomes (contractor)*

Figure 2. Staff of the Fourth Pennsylvania Geological Survey's Pittsburgh office at the end of its centennial year.

1. *Robin V. Anthony*
2. *Lynn J. Levino*
3. *Renee H. Speicher*
4. *Brian J. Dunst*
5. *Katherine W. Schmid*
6. *Aron Schmid (volunteer)*
7. *Kristin M. Carter*
8. *David F. Fletcher*
9. *John A. Harper (volunteer)*

Figure 3. State Geologist Gale Blackmer presenting a talk on the history of the Fourth Pennsylvania Geological Survey at the Middletown open house.

RECENT PUBLICATIONS

Progress Report **(December 2019)**

- Bedrock geologic map of the Saltillo 7.5-minute quadrangle, Fulton and Huntingdon Counties, Pennsylvania (ZIP)

Open-File Miscellaneous Investigations **(December 2019)**

- Water depth of East Branch Lake—Elk State Park, Elk County, Pennsylvania (ZIP)

Open-File Oil and Gas Report **(November 2019)**

- Subsurface lithostratigraphy of the oil- and gas-producing regions of Pennsylvania (ZIP)

BUREAU NEWS

Bureau Staff Members are WISE Volunteers

Staff geologists Aaron Bierly, Helen Delano, Ellen Fehrs, Victoria Neboga, Caron Pawlicki, and Zachary Schagrin had the pleasure of participating in the Women in Science and Engineering (WISE) Career Connection Days event at the Da Vinci Science Center in Allentown, Pa., November 13–15, 2019. This year, the Career Connection Days attracted about 400 students in grades 4 through 12 eager to explore a variety of STEM-related (science, technology, engineering, and mathematics) careers and businesses. The facility was also open to the general public, and our two tables attracted interested guests ranging in age from two to older adults.

The Pennsylvania Geological Survey station featured a variety of minerals and rocks and the ever-popular stick-on tattoos, as well as a laptop PowerPoint presentation showing geologists at work. Our geologists discussed our displays and answered a variety of questions about developing STEM skills, work habits, teamwork, and experiences outside of school.

One table displayed products derived from rocks and minerals, and staff members helped the visitors match these products to the provided rock and mineral samples. Children were shocked to learn such facts as these: they eat minerals, and there is gold in their cell phones. The other table had hands-on activities related to mineral identification. At this station, students tested the hardness of minerals, learned about naturally magnetized materials, and scratched specimens on streak plates to observe the color of their powder. Overall, it was an enjoyable experience for both the visitors and the volunteers.

BUREAU NEWS

New Staff Member

Emily A. Hernandez. A Cumberland County, Pa., native, Emily Hernandez joined the Bureau's Groundwater and Environmental Geology Section in October 2019. Prior to that, Emily spent a year with the Washington State Department of Natural Resources. During this time, she was the Lead Project Manager for their Forest Practices Adaptive Management Program, a multi-caucus program that provides science-based recommendations and technical information to assist in the guidance and rulemaking processes for improving resource management practices.

Before joining state government, she spent seven years with Rex Energy Corporation, an exploration and production company that was headquartered in State College, Pa., where she held the positions of Geological Technician and Geologist before being promoted to Manager of Geology for the Appalachian region. In these positions, Emily was part of the operational team responsible for planning and drilling more than 150 horizonal wells. She was also actively engaged in exploration and business development efforts of the company's Upper Devonian, Marcellus, and Utica Shale assets.

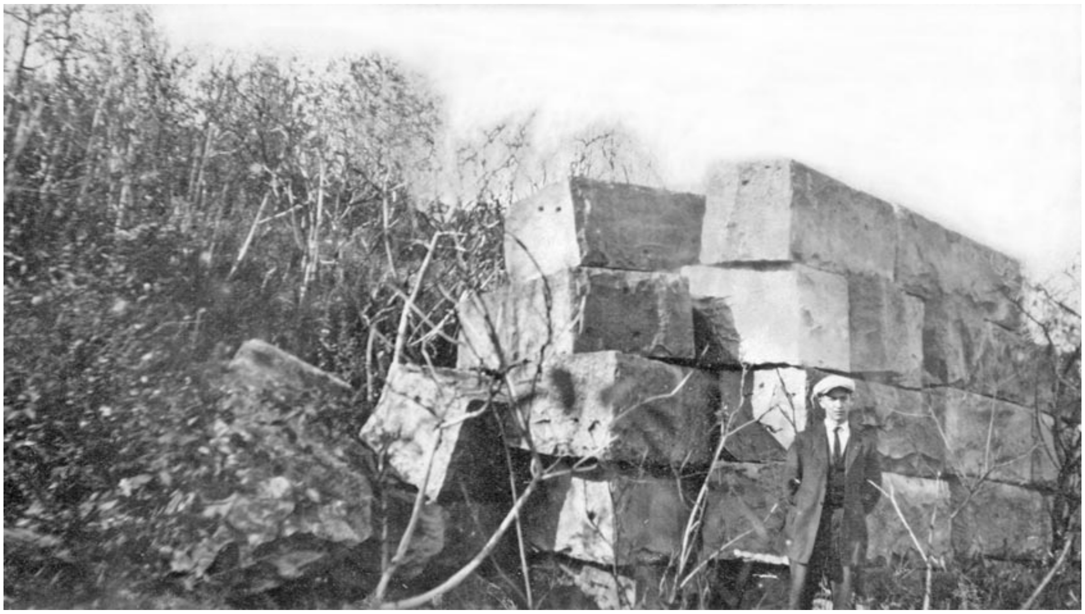
Prior to her work in the oil and gas industry, Emily was a Geologist and Project Manager for the environmental consulting industry in southern California. However, she began her career in Pennsylvania in the Geotechnical and Mining Services industries.

Emily completed her undergraduate studies at Kutztown University of Pennsylvania in 2005, earning a B.S. in geology with a minor in political science. In 2010, Emily obtained an M.S. in global energy management from the University of Colorado School of Business.

In her free time, she enjoys spending time with her family, traveling, hiking, drawing, and watercolor painting. She currently lives in Hummelstown with her two-year-old daughter, Sophia, and husband, Noel.

BUREAU NEWS

A Look Back in Time



An unidentified man (most likely an assistant to former Bureau geologist Ralph Stone) poses next to building stone (Pottsville conglomerate) at Bloom Run quarry in Clearfield County. The quarry was located about four miles north of Grampian at what is now known as the Bloom Run Vista. It was known for producing large blocks of sandstone suitable for masonry and construction. Pennsylvania Railroad bridges and subways in Philadelphia, and most notably, the Pennsylvania Railroad bridge across the Susquehanna River at Rockville, are made from the stone from this quarry. Bloom Run quarry ceased operation in 1920, but Ralph Stone visited the site and was able to photograph some of the remaining large blocks of stone there on October 19, 1924.

To learn more about the Bloom Run quarry and the stone found there, please see the following:

Edmunds, W. E., and Berg, T. M., 1973, Geology and mineral resources of the southern half of the Penfield 15-minute quadrangle, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Atlas 74cd, second printing, p. 139–141.

Stone, R. W., 1932, Building stones of Pennsylvania: Pennsylvania Geological Survey, 4th ser., Mineral Resource Report 15, p. 114–115.

To see more photographs from the Bureau's archives, please visit the library's [Historical Photographs Collection page].

—Jody Smale, Librarian

EARTH SCIENCE TEACHERS' CORNER

Integrating Geologic Toolkits into Elementary Education—Bradford, Lycoming, Sullivan, and Tioga Counties, Pennsylvania

Logan A. Wiest[1] and Jennifer Demchak
Mansfield University of Pennsylvania[2]

Geology can be a fascinating way to explore and to try to understand our planet. Geology is an interdisciplinary and largely descriptive science that can open up new opportunities and perspective for people of all ages. All too often, however, a student's first experience with geology involves an overwhelming assortment of rocks and/or mineral samples with unfamiliar names that have to be memorized for an exam. We encourage an alternative pedagogical approach, which places an emphasis on developing foundational skills in an effort to enhance long-term interest in the science.

In an effort to promote kindergarten through grade 12 (K–12) educational outreach, Mansfield University and BLaST Intermediate Unit 17 (an educational service agency meeting the needs of Bradford, Lycoming, Sullivan, and Tioga Counties) have a variety of geologic toolkits and educational resources that can be signed out by K–12 teachers from these four counties (STEM on the Move, 2019). Through this collaboration, Mansfield University faculty members visit grade-school classrooms to conduct age-appropriate lessons in geology; toolkits for other STEM (science, technology, engineering, and mathematics) fields are also available through this program. These lessons are designed to give students a hands-on approach to developing foundational skills, as well as access to samples, equipment, and/or technology that may not be available to them otherwise. Fossil, rock, and mineral identification are among several lessons that are available. To date, this outreach program has been predominantly utilized by elementary educators, although a few secondary institutions have enrolled in lessons as well.

When introducing clastic sedimentary rocks to an elementary class, for example, we place emphasis on "seeing" the sediment that eventually became the rock. In an attempt to achieve this, students are first presented with unconsolidated sediment samples (e.g., fluvial gravel, well-sorted sand, and clay/mud) that are held within separate plastic containers and placed at different stations. They use a variety of "tools" such as handouts showing scaled, labeled circles corresponding to a simplified Wentworth grade scale, a Dino-Lite digital microscope attached to an overhead projector, and metric rulers (Figures 1 and 2) (Wentworth, 1922; Folk, 1954, 1974). Once students demonstrate a level of understanding for grain size, grain shape, and sorting, they are then presented with large blocks of consolidated, analogous sediment (e.g., conglomerate, sandstone, and shale/mudrock) for description. Drawing attention to the fact that the consolidated sediment (the rock sample) does not need to be held in a plastic container seems to help the students "see" the role of cementation in forming sedimentary rocks. Samples, worksheets, and PowerPoint slides are left with the classroom teacher after the lesson for use in future years.

In a kindergarten through grade 6 lesson involving mineral classification, emphasis is placed on developing the ability to describe the physical properties of a sample that are commonly used in

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Figure 1. Kindergarten through grade 6 students learning about geologic concepts with a Dino-Lite digital microscope attached to an overhead projector in a one-room schoolhouse. Photograph courtesy of Lili Crum, West Branch School.

geology. The concept of relative hardness can be introduced with tools for measuring each sample and comparing it to the Mohs hardness scale (King, 2020). In addition, streak, luster, and magnetism are characteristics of minerals that can be assessed with the proper tools and explored in the classroom. Other physical properties, such as size or color, may not be useful for mineral classification, and this is discussed. We highlight the importance of developing these foundational skills for a positive, engaging, and lifelong learning experience.

Geology can be incorporated across a wide array of disciplines. Students in English, for example, can practice how to communicate their geologic observations through writing. Art students can convey geologic concepts through various artistic media. Therefore, non-STEM teachers are also encouraged to utilize these resources in creative ways.

ACKNOWLEDGMENTS

This project was funded by PAsmart Advancing K–12 Computer Science and STEM Education Grant #154–18–0000 awarded to Mansfield University and BLaST Intermediate Unit 17. The authors would also like to acknowledge Phillip Swank, Rebecca Gibboney, Mikailla Nolasco, and Kara Grosso, in particular, for their contributions to logistical and organizational aspects.

Figure 2. Elementary students comparing unknown (sand) samples to a worksheet with scaled circles corresponding to a simplified Wentworth grade scale. Photograph courtesy of Lili Crum, West Branch School.

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Wentworth, C. K., 1922, A scale of grade and class terms for clastic sediments: Journal of Geology, v. 30, no. 5, p. 377–392.

Calling All Authors

Articles pertaining to the geology of Pennsylvania are enthusiastically invited.

Pennsylvania Geology is a journal intended for a wide audience, primarily within Pennsylvania, but including many out-of-state readers interested in Pennsylvania's geology, topography, and associated earth science topics. Authors should keep this type of audience in mind when preparing articles.

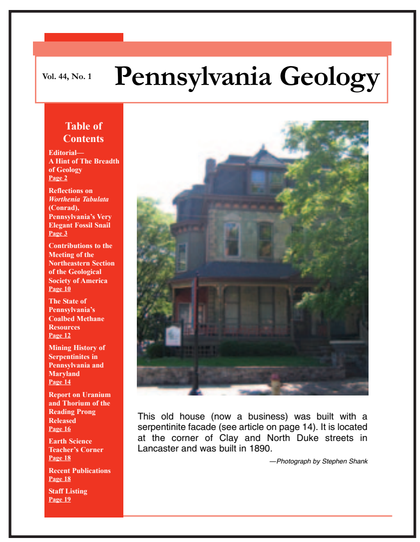
Feature Articles: All feature articles should be timely, lively, interesting, and well illustrated. The length of a feature article is ideally 5 to 7 pages, including illustrations. Line drawings should be submitted as CorelDraw (v. 9 or above) files if possible. Line drawings may also be submitted as jpg files. Ensure that black and white drawings are not saved as color images.

Articles should be submitted as Microsoft Word files. Feature articles will be reviewed by at least one Bureau staff member. It is the author's responsibility to obtain approval for use of any illustrations that are copyrighted, including those taken from the Internet.

Earth Science Teachers' Corner: Articles pertaining to available educational materials, classroom exercises, book reviews, and other geologic topics of interest to earth science educators should be 1 to 2 pages in length and should include illustrations where possible.

Announcements: Announcements of major meetings and conferences pertaining to the geology of Pennsylvania, significant awards received by Pennsylvania geologists, and other pertinent news items may be published in each issue. These announcements should be as brief as possible.

Photographs: Photographs should be submitted as separate files and not embedded in the text of the article. Please ensure that photographs as submitted are less than 10 inches wide in Photoshop or equivalent. Also ensure that black and white photographs are not saved as color images.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This old house (now a business) was built with a serpentinite facade (see article on page 14). It is located at the corner of Clay and North Duke streets in Lancaster and was built in 1890.

—Photograph by Stephen Shank

Submittal: Authors may send their article and illustrations as email attachments to RA-pageology@state.pa.us if the file sizes are less than 6 MB. For larger sizes, please submit the files on CD–ROM to the address given below. All submittals should include the author's name, mailing address, telephone number, email address, and the date of submittal.

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