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ON THE COVER

This landslide on the site of the former Dixmont State Hospital northwest of Pitts-
burgh occurred during construction for a shopping center. It is an example of the
effects of the combination of steep topography, weak claystones of the Pitts-
burgh red beds and similar rocks, geologic history, and human activities that
make many slopes in the Pittsburgh area extremely prone to landsliding. The
slide blocked all four lanes of State Route 65 and three tracks of the Norfolk and
Southern Railroad. Approximate scale is indicated by the railroad cars and heavy
construction equipment visible in the photograph. Bureau of Topographic and
Geologic Survey staff prepared testimony about the geology of the area and
presented it at a hearing before the Joint Legislative Conservation Committee,
which is investigating ways to prevent similar problems in the future. Photograph
taken on September 21, 2006, by John Weaver, Photogrammetry and Survey
Section, Pennsylvania Department of Transportation.

PENNSYLVANIA GEOLOGY

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editors at the address listed above.

VOL. 36, NO. 4 WINTER 2006
Wellhead Protection with a Vengeance

Last month, I was able to visit a place near the geographic center of South America, not far from Chapada dos Guimarães in the state of Mato Grosso, Brazil. While there, I spoke with some folks about their wonderful spring of extremely pure water at the very top of the Paraguay River watershed and adjoining the edge of the Amazon watershed. In other words, there was nothing upstream because it was the upstream! I wanted to see the spring, which was in a swampy area, but my hosts demurred, saying that there were sucuris there. *Sucuri* is another name for an anaconda, a type of boa constrictor. They can grow to 25 feet long, and they crush or suffocate their prey. After learning this, we opted not to see the actual beginning of the spring. Now *that* is source-water protection. No one is going to contaminate that spring by mistake.

Here in Pennsylvania, the Department of Environmental Protection has done a great job of protecting our water sources from contamination. One way to do that is to educate the public as to where the well or water intake is located, so they do not inadvertently pollute it, or, if they see a contaminant spill, they know to act quickly to protect the water resource. Thus, you may see signs along the road that say “wellhead protection area.” Just as it pays to tell the public where a spring is located but then add that the spring is protected by a *sucuri*, it pays to educate the public about the importance of keeping our water sources free of contamination.

Now if we could only get some *sucuris* here . . .

Jay B. Parrish
State Geologist
THE TASK. As far as it is known to the authors, the recovery of alexandrite-effect garnets in Pennsylvania began one July morning in 1968 at 5:00 a.m., when the senior author received a surprising telephone call from Professor Mackenzie L. Keith. At the time, Smith was a graduate student at The Pennsylvania State University, and Professor Keith was the director of the school’s Mineral Conservation Section (MCS). Months before, Smith had mentioned to a very Scottish “Mac,” as Professor Keith preferred to be addressed, that he would like to visit the Gates-Adah kimberlite dikes sometime (Figure 1). Unbeknownst to Smith, Mac was also interested in the Gates-Adah kimberlite dikes and, in particular, in the composition of the accessory garnets and their economic interpretation. Mac, as Smith learned while gradually waking up, was about to leave for a memorial service in West Virginia for Vinton E. Gwinn. Gwinn, a young, highly respected Appalachian geologist, had died suddenly on July 5. If Smith could be ready by 5:30 a.m., he would get a ride from Mac to the dike area and be picked up the following day for a ride home. The deal also involved enough cash for Smith to get a decent meal and stay in a tourist home nearby. As Smith continued to awaken, he found himself traveling to the Gates-Adah dike area and enjoying interesting conversation. It seemed Mac wanted him to collect some pyrope garnets, which Mac would analyze on the electron microprobe for economic reasons that were not explained.

Pyrope garnets are a bit of an oddity in Pennsylvania, only known to occur in a few kimberlites in the western part of the state. Alexandrite-effect pyropes are even more of an oddity. Containing more than 3 or 4 percent chromium (expressed as Cr_2O_3), alexandrite-effect pyropes take on different colors in different light sources (Gaines and others, 1997). (The name “alexandrite” is derived from a gem variety of chryso-
beryl exhibiting similar color change. It, in turn, is named in honor of the mineral-loving Czar Alexander II of Russia.) Alexandrite-effect pyropes from Pennsylvania appear pinkish purple or raspberry-colored in incandescent light and bluish to greenish gray in sunlight or under fluorescent light.

**THE QUEST.** Unfortunately, Mac let Smith off one hollow too far to the north, and hours were wasted whacking every slightly unusual looking rock. Mac had provided Smith with a piece of the appropriate topographic map, and Smith decided to try the next hollow to the south, which was somewhat larger and contained a small stream. As a field assistant to his advisor at Penn State, Professor Art W. Rose, Smith had begun to understand geochemical stream-sediment sampling. In that technique, clay and silt in a stream are collected, and the metals of interest in the sediments are traced upstream to find the area from which they originated. In the larger hollow, Smith simply scaled up the grain size from clay and silt to cobbles and small boulders. This logic was sort of reinventing the wheel in reverse of how stream-sediment prospecting had come to be developed, but it soon paid off when Smith found loose, weathered Kimberlite rocks. After an hour or two, he traced them to their source and collected a number of pyrope-bearing blocks, which he stashed in a blooming wild pink rose bush. A few smaller contingency samples were readied for the journey to lodging in Mason-
town, Pa. (The journey was aided by a bread-truck driver who began to have reservations about his Good Samaritan lift when Smith, upon query, truthfully explained his mission.)

Mac faithfully met Smith at the agreed-upon meeting point the next morning and asked the anticipated question “Did you find some pyrope?” It is hard to say whether the look on Mac’s face was one of total surprise, as it was characteristic of Mac to share a beaming smile. Anyway, he got out his hand lens and was quite congratulatory. Mac was even more pleased at the successful outcome when Smith led him to the rose bush stash, and he learned that he had let Smith off at the wrong hollow.

Glossary


Diatreme: A pipe from depth to the surface that is thought to have formed by explosive degassing of unusually CO₂-rich magma that plucked fragments of broken wall rock as it moved upward.

Eclogite: A rock that contains garnet and pyroxene as its primary constituents. Eclogites commonly hitchhike to the surface as nodules in other deep-seated rock types.

Harzburgite: A dark-colored igneous rock that forms at depth and contains abundant olivine and pyroxene.

Kimberlite: A CO₂- and H₂O-rich, dark-colored igneous rock that contains minerals such as olivine, carbonates, magnesian ilmenite, diopside, phlogopite, perovskite, and serpentine.

Lamproite: A poorly defined clan of dark igneous rocks of deep origin containing minerals such as phlogopite and richterite that are enriched in potassium and titanium. A Kimberlite cousin.

Melilite: A group of silicate minerals found in igneous rocks that are low in silicon content. They contain sodium, calcium, magnesium, and aluminum in varying quantities.

Olivine melilitite: A dark, basaltlike, extrusive volcanic rock containing olivine, melilitite, and clinopyroxene.

Peridotite: A general term for a dark-colored igneous rock that forms at depth and contains mostly olivine.

Pyrope: An end member of the garnet group of minerals containing magnesium and aluminum. Commonly has a deep-red color.

Tuff: Volcanic ash and coarser pyroclastic materials that have been cemented together to form a solid rock.

Uvarovite: An end member of the garnet group of minerals containing calcium and chromium. It has an emerald-green color.
**TIME PASSES.** Shortly after, Mac ran a few of the larger, red pyrope garnets on the probe, but they were not quite what he was looking for. The extra blocks, now well labeled, were returned to Smith, who took them along to the Pennsylvania Geological Survey when he got a job there in 1972—just in time for them to be submerged in a major flood caused by tropical storm Agnes. The samples Mac had so redundantly labeled survived the flood, only to sit in a cabinet for a decade or so until Smith, with assistance from the Survey’s laboratory technician, Les Chubb, crushed, panned, and concentrated the heavy minerals.

Another decade or so went by and the Bureau obtained its first scanning electron microscope (SEM), which was equipped with an energy-dispersive spectrometer (EDS). The heavy minerals continued to sit until Barnes (the second author), working with a helpful software vendor, got the SEM to the point where the authors felt confident in using it for silicate analyses in 2005. After some additional effort, including learning to use the instrument’s topographic mode to find relatively flat surfaces and thus avoid miscalculations of the oxygen content, decent analyses of the alexandrite-effect garnets were achieved (Figure 2).

![Figure 2. EDS spectrum and SEM photomicrograph of one of the Gates-Adah pyrope garnets analyzed at the Pennsylvania Geological Survey. This particular sample is one of the eight grains that exhibited the alexandrite effect (see Table 1). The shadowy gray area behind the grain is the point of a round wooden toothpick that was used to mount the grain for analysis.](image-url)
MAC’S ULTERIOR MOTIVE. Fortunately, Sam W. Berkheiser, the Survey’s Assistant Director, had given Smith a copy of *Barren Lands* (Krajik, 2001), and Smith’s wife, Duffy, had given him a copy of Erlich and Hausel’s (2002) excellent book *Diamond Deposits* for the non-specialist kimberlite lover. The former is the story of Chuck Fipke, a narrowly focused Canadian diamond prospector who found a world-class diamond deposit in 1990 after two decades of tracking indicator minerals, including “G10” garnets, “up glacier” in Canada. *Barren Lands* and a traditional literature search also led Smith to a scientific paper by Dawson and Stephens (1975) of the University of St. Andrews, Scotland, innocuously titled “Statistical Classification of Garnets from Kimberlite and Associated Xenoliths.” The authors defined 12 groups of garnet compositions in kimberlites and discussed, among other things, the significance of these groups in exploring for and evaluating diamond prospects. Mac, who had a reputation for seeming to doze off during guest lectures at Penn State and then waking up to ask questions that, not uncommonly, revealed fatal flaws in the interpretation being proposed by the lecturer, appears to have done it again. It now seems likely that Mac was quietly attempting to evaluate the diamond potential of the Gates-Adah kimberlite for the MCS in 1968. Unfortunately, although Mac was able to see and analyze some of the larger red pyropes, the alexandrite-effect garnets from Gates-Adah are small and sparse and escaped his narrowly focused microprobe beam. Chubb and Smith’s separations recovered these smaller garnets, and much later Smith recognized them. Thus, it came to be that the alexandrite-effect pyropes from Gates-Adah were discovered over a third of a century after they were collected.

THE RESULTS. The median composition for the eight alexandrite-effect garnets analyzed on the SEM/EDS is listed in Table 1. For comparison, median compositions are also given for 7 orange garnets, 9 larger red pyropes, and 29 randomly selected and variously colored small garnets recovered from the remaining Gates-Adah bulk sample. Each garnet category is further broken down by the classification group of Dawson and Stephens into which the garnets fit. For further comparison, medians are reported for garnets from a kimberlite at Mt. Horeb, Va.; a lamproite diamond-bearing deposit at Crater of Diamonds, Murfreesboro, Ark.; an alnöite at Île Bizard, Quebec, Canada; and a diatreme/tuff unit associated with olivine melilitite from Clear Spring, Md. (back cover). In Figure 3, ratios of magnesium, calcium, and chromium (expressed as MgO, CaO, and Cr$_2$O$_3$, respectively) for individual analyses are plotted using a different symbol for
### Table 1. Medians of Garnet Compositions and Group Classifications

<table>
<thead>
<tr>
<th>Location and rock type</th>
<th>Color</th>
<th>Number of grains analyzed</th>
<th>Garnet group&lt;sup&gt;2&lt;/sup&gt;</th>
<th>Garnet type</th>
<th>MgO</th>
<th>CaO</th>
<th>TiO₂</th>
<th>Cr₂O₃</th>
<th>FeO</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gates-Adah kimberlite</td>
<td>Blue gray/ purple&lt;sup&gt;3&lt;/sup&gt;</td>
<td>8</td>
<td>“9½”</td>
<td></td>
<td>21.8</td>
<td>6.20</td>
<td>0.15</td>
<td>8.21</td>
<td>5.38</td>
<td>Most plot as G9, a few as G10</td>
</tr>
<tr>
<td>Orange</td>
<td>3</td>
<td>1</td>
<td>20.3</td>
<td>4.52</td>
<td>.37</td>
<td>.48</td>
<td>9.92</td>
<td>7.82</td>
<td>Groups 1 and 2 probably overlap</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>2</td>
<td>20.5</td>
<td>4.74</td>
<td>.92</td>
<td>1.02</td>
<td>8.28</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red&lt;sup&gt;4&lt;/sup&gt;</td>
<td>5</td>
<td>1</td>
<td>21.8</td>
<td>4.34</td>
<td>.48</td>
<td>1.85</td>
<td>7.82</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>20.3</td>
<td>4.85</td>
<td>1.02</td>
<td>.91</td>
<td>9.36</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>9</td>
<td>21.6</td>
<td>4.63</td>
<td>.28</td>
<td>3.21</td>
<td>6.37</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Various&lt;sup&gt;5&lt;/sup&gt;</td>
<td>14</td>
<td>1</td>
<td>21.5</td>
<td>4.43</td>
<td>.50</td>
<td>1.84</td>
<td>8.56</td>
<td></td>
<td>MgO too high for garnet?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>19.7</td>
<td>4.99</td>
<td>1.14</td>
<td>1.04</td>
<td>10.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>9</td>
<td>21.7</td>
<td>4.54</td>
<td>.20</td>
<td>3.27</td>
<td>6.71</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>11</td>
<td>22.7</td>
<td>5.28</td>
<td>.19</td>
<td>6.71</td>
<td>4.70</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>A&lt;sup&gt;6&lt;/sup&gt;</td>
<td>34.1</td>
<td>.86</td>
<td>.16</td>
<td>.94</td>
<td>6.40</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mt. Horeb kimberlite</td>
<td>Red</td>
<td>6</td>
<td>20.7</td>
<td>4.57</td>
<td>.19</td>
<td>.68</td>
<td>6.61</td>
<td>Rather uniform</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crater of Diamonds lamproite</td>
<td>Pink</td>
<td>5</td>
<td>21.6</td>
<td>1.29</td>
<td>.07</td>
<td>.03</td>
<td>24.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Red</td>
<td>1</td>
<td>19.2</td>
<td>6.42</td>
<td>.12</td>
<td>3.24</td>
<td>8.25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Île Bizard alnöite</td>
<td>Pinkish lilac</td>
<td>3</td>
<td>20.3</td>
<td>5.40</td>
<td>.18</td>
<td>1.19</td>
<td>7.40</td>
<td>All from one nodule</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clear Spring diatreme/ tuff&lt;sup&gt;7&lt;/sup&gt;</td>
<td>Pinkish orange</td>
<td>2</td>
<td>21.5</td>
<td>4.21</td>
<td>.55</td>
<td>2.94</td>
<td>4.76</td>
<td>FeO low</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pinkish lilac</td>
<td>2</td>
<td>20.3</td>
<td>6.12</td>
<td>.42</td>
<td>4.88</td>
<td>6.40</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>1</sup> Median compositions are based on SEM/EDS analyses, which are posted online at [www.dcnr.state.pa.us/cs/groups/public/documents/document/dcnr_20031595.pdf](http://www.dcnr.state.pa.us/cs/groups/public/documents/document/dcnr_20031595.pdf).

<sup>2</sup> Group classifications use scheme of Dawson and Stephens (1975).

<sup>3</sup> Alexandrite-effect garnets.

<sup>4</sup> Red garnets are larger.

<sup>5</sup> Garnets labeled “various” are smaller and randomly chosen.

<sup>6</sup> A, anomalous.

<sup>7</sup> Garnets are small and rare at this locality.

Each locality and group. In all likelihood, the G10 garnets sought by Fipke and the high-chromium, low-calcium garnets of Dawson and Stephens’s group 10 are one and the same. (The 12 groups of Dawson and Stephens are referred to by the popular and probably equivalent terms of G1 through G12 in the remainder of this article.)

The authors interpret the new SEM/EDS data for the Gates-Adah garnets as follows. The eight Gates-Adah blue-gray and purple alexandrite-effect garnets are part of a G9 (high-chromium) pyrope group that came dominantly from a peridotite environment that was unlikely to contain commercial diamonds. It is even less likely that any such diamonds
Figure 3. Classification diagrams showing areas of G9 (enclosed by dashed gray line on the left) and G10 (enclosed by solid gray line on the right) for the individual garnets analyzed using the SEM/EDS. G9 garnets occur in kimberlites having a minimal potential for commercial diamonds, whereas G10 garnets occur in kimberlites having a slightly better potential for including minerals formed at sufficient depth to include diamonds. This differentiation does not address the issue of diamond preservation on the way to the surface. Fields for other garnet groups overlap the field for G9 and are omitted for simplicity. Adapted from Figure 4 of Dawson and Stephens (1975).
would have been preserved to the surface. Figure 4 shows that a few of these alexandrite-effect garnets verge into the more favorable G10 group (high-chromium, low-calcium pyrope derived from harzburgitic peridotite), but not in the abundance associated with a commercial diamond deposit. The seven Gates-Adah orange garnets come from two groups, G1 and G2, which may form a continuum of moderate- to high-titanium pyropes and which are found only in kimberlites. The nine Gates-Adah larger red garnets (probably representing what Mac analyzed in polished sections) consist of five G1, one G2, and three G9. Results of the SEM/EDS analyses for the 29 Gates-Adah randomly selected and variously colored garnets are similar: fourteen G1, one G2, eleven G9, one G11 (a titanium uvarovite group associated with a peridotite environment and very rarely diamonds), and two unclassified pyropes having anomalously high magnesium and low calcium.

In summary, the alexandrite-effect garnets have been classified as G9 high-chromium pyropes, the Gates-Adah kimberlite does not appear to be a good target for commercial diamond exploration, and a chapter in the geologic saga begun in 1968 is drawing to a close. Thirty-eight years might seem like a long time, but not to geologists who appreciate that the garnets have been in the ground waiting to be collected and analyzed since the intrusion of the Gates-Adah kimberlite, approximately 170 million years ago (Bikerman and others, 1997).

**ACKNOWLEDGMENTS.** The authors thank Art Rose, Professor Emeritus of Geochemistry, The Pennsylvania State University, for his review of the manuscript.
Meet the Staff—Part 3

In the last issue of the magazine, one of the described work areas of the Pennsylvania Geological Survey was Database Services. Since that time, a new employee has joined Database Services, and we begin by introducing him. We will also describe Local Government Outreach Services and meet the two staff members assigned to that area.

DATABASE SERVICES.

Kyle A. Imbrogno. Kyle began working for the Bureau as an IT Technician in our Pittsburgh office on November 27, 2006. Prior to that time, Kyle spent two years as an A+ Certified Lead Technician at CompUSA in Pittsburgh, Pa. He also served our country during the past four years as a machine gunner in the Marine Corps and recently completed a seven-month tour in Iraq. Kyle is now a Corporal in the Marine Corps Reserves.

Kyle’s information-technology (IT) expertise and leadership skills will be put to good use at the Survey. His duties include providing help-desk support to our Pittsburgh staff, especially in geographic-information-system (GIS) applications; 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. He will also be using his technical skills while
working with staff geologists to develop independent geologic mapping projects that incorporate GIS.

**LOCAL GOVERNMENT OUTREACH SERVICES.** The Bureau’s Local Government Outreach program provides contacts and resources for county and local governments, state agencies, and other organizations using geologic and topographic information. The greatest part of its efforts in recent years has been the PAMAP program, a cooperative project between county, state, and federal agencies, which will result in a statewide, seamless, digital base map for Pennsylvania. More information on PAMAP, including how to access data, is available on the Bureau’s web site at www.dcnr.state.pa.us/topogeo/pamap/index.aspx. The Local Government Outreach Services staff are also active in educating the public on geology and geologic hazards such as landslides and sinkholes; providing information on geology applied to land-use planning; offering teacher workshops and educational tools; and presenting information on the Survey and its resources at professional meetings and conferences.

**Helen L. Delano.** Helen, who has an M.A. in geological sciences, began working for the Survey in our Pittsburgh office in September 1980. Prior to that time, she spent a year and a half doing archaeology work on Cape Cod for the U.S. National Park Service. Helen is now assigned to our Middletown office, where she works as a Senior Geologic Scientist for two areas of our Bureau. Her longer term assignment has been in Geologic Mapping Services (an area that will be introduced in a future column of “Meet the Staff”), and since August 2003, Helen also has been assigned to Local Government Outreach Services. The assignment was fitting. As a geologist specializing in environmental issues, Helen has been doing outreach since the beginning of her career at the Survey. Over the years, her projects have included such topics as landslides, coastal geology along Lake Erie, and low-level radioactive waste disposal.

As part of her duties in Local Government Outreach Services, Helen works with officials in county governments and other agencies to develop partnerships in the PAMAP program, and she shares in PAMAP project and data-management tasks. Outside requests for information or assistance with PAMAP data are filtered through Helen,
as are many other requests for topographic and geologic information. Helen also coordinates Bureau exhibits for meetings.

In her other role as a geologist in Geologic Mapping Services, Helen provides information on landslides and other geologic hazards, coastal geology, geomorphology, and engineering geology. She is currently involved in a research project at Kings Gap Pond in Cumberland County, Pa. A sediment core at this site, which is well south of the glacial border in Pennsylvania, was found to contain latest Pleistocene tundra vegetation. Helen is working with several outside partners to characterize the site.

Recently, Helen completed a small project for the U.S. Geological Survey and the Association of American State Geologists that involved testing methods for determining the costs of landslides. Landslides are an issue of national concern, and Helen continues to gather cost-related data as they become available. She is also developing a digital inventory of landslides for Pennsylvania that will include information such as location, type, dates, and cost of repairs.

George E. W. Love. George is a recent addition to the Pennsylvania Geological Survey, having been hired at the end of October 2006 as a Geologic Scientist. His degrees include an M.S. in geology and an M.B.A., and he has an extensive work history. George’s experiences include mineral-resource exploration in the Western U.S., Canada, and Central and South America; engineering geological studies for dams, power plants, tunnels, and pumped-storage power facilities; phosphate exploration and mining in central Florida; and most recently, underground limestone mining in northern Kentucky. His jobs have ranged from coffee carrier for the rodman while at General Analytics, Inc., in Pittsburgh, Pa., to Operations Manager for the phosphate mining division of Mobil Corporation in Lakeland, Fla.

Currently, George is immersing himself in the PAMAP project so that he can be a knowledgeable advocate for the program. He plans to familiarize himself with the projects of the Bureau staff so he can “market” our expertise as part of our outreach program. It is likely that he also will be working with Pennsylvania mining and natural-resource groups, to understand their needs with regard to our expertise here at the Survey.
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VOL. 36, NO. 4  WINTER 2006
LOCATIONS OF ANALYZED GARNETS
(See article on page 2.)

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