A Travelogue of Rediscovery Sites

Part 3



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Figure 1. The Urangelbfabrik in Joachimsthal had started production of the yellow color in 1855 and transferred to the location displayed here (right arrow) in 1871. This undated postcard was printed shortly after 1912, when the famous Radium Palace (left arrow) was built (see Figure 3). This postcard is displayed in the Information Center (Informacní Centrum (N50° 22.29 E12° 54.82) in Jáchymov, Czech Republic. Upper left: *Example of uranium glass, private collection, the authors.*

This is a continuation of a review of "Rediscovery' episodes, initiated in the Spring 2017 issue of The HEXAGON. *This series includes the visits to mine sites taken by Jim and Jenny Marshall over the ten-year period of 1999–2008 in their successful search for the actual original source for the elements. The present issue is devoted to Germany and Bohemia.*

Radium, polonium, actinium, protactinium. Radium and polonium were discovered in 1898 by Marie Sklodowska Curie (1867–1934) and Pierre Curie (1859–1906) in Paris, France.[1g] The following year in their laboratories their colleague André Louis Debierne (1874–1949) discovered actinium.[1g] In 1917, protactinium was discovered by two independent groups: (1) Otto Hahn (1879–1968) and Lise Meitner (1878–1968) in Germany (who gave it the modern name); and (2) Frederick Soddy (1877–1956) and John Arnold Cranston (1891–1972) in Scotland (who named it "ekatantalum" in accordance with Mendeleev's scheme).[1h]

Isolation in quantity of these four radioactive elements was made from waste disposed from uranium mining and processing in the St. Joachimsthal[1i] (original German = Sankt Joachimsthal) area of western Bohemia, now known as Jáchymov, Czech Republic. This refuse, originally deemed worthless and which was dumped near the processing plants, was sacked and shipped to the Curies for their pioneering studies. (Soddy used Joachimsthal pitchblende acquired in 1903, but during World War I, 1914–1917, when commercial trade was not possible with Germany, he used "Indian pitchblende.") By 1534, Joachimsthal had become the second largest city in Bohemia, after Prague. The abundant supply of silver coins minted in Joachimsthal led to its use as a major medium of exchange in Europe. Its most familiar coin was the "Joachimsthaler," colloquially called "Thalers," from which is derived the modern word "dollar."

The uranium processing plant in St. Joachimsthal was the "Die Kaiserliche und Königliche Urangelbfabrik" ("The Imperial and Royal Factory for production of uranium yellow color"), which produced the fluorescent yellow-green uranium glass which was in fashion in Europe at the time (Figure 1). After the Curies discovered radium in 1898 the plant also took up radium production. Today the Urangelbfabrik is gone; on its site is a memorial devoted to Marie Curie (Figure 2). The major tourist attraction is the neighboring Radium Palace (Figure 3), where visitors can take advantage of special therapeutic baths which

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Figure 2. This memorial dedicated to Marie Curie is in the Marie Park of Jáchymov, Czech Republic (N50° 21.58 E12° 56.11). The inscription (below) in Czech language reads: "In ores from this location in the year 1898, Marie Curie Sklodowska and Pierre Curie discovered the element radium so it could serve mankind: thanks to mining and science, radium rays and medicine have brought health to hundreds of thousands of people." This memorial stands directly across from the Radium Palace (see next figure).



Figure 3. This is the entrance to the Radium Palace (N50° 21.51 E12° 56.09), a luxury hotel built in 1912. Radon baths are available here to serve as therapeutic treatments for sore and tired bodies, but particularly for cancer patients. Thousands of VIPs, particularly from Eastern Europe, have taken advantage of the spa facilities for over a century.



Figure 4. The Svornost Mine (N50° 22.35 E12° 54.70) is one of the oldest mines at Jáchymov. Since the discovery of silver in 1516, many other metals have been mined including nickel, cobalt, arsenic, bismuth, uranium, and radium. Although radium itself was discovered from discarded uranium ores from the Svornost and other mines, the original discovery of uranium itself (in 1789, by Martin Heinrich Klaproth, 1743–1817) was from ore taken from a separate community in Germany (Johanngeorgenstadt), 16 kilometers west.[1d] The sign warns "Drivers beware" and announces restricted access.



Figure 5. One of the many abandoned mines scattered about Jáchymov (Bratrství, 1 kilometer east, N50° 22.40 E12° 56.18). The vertically-stacked stone compression arch at the entrance was a common theme among mines of eastern Germany and Bohemia (see Figure 14). After World War II, concentration camps were set up supplying labor to extract uranium ore from such mines to export to the Soviet Union.

use radioactive water pumped from the nearby Svornost Mine (Figure 4). Most mines in the Jáchymov area are now shut down (Figure 5). At local shops on the main street of Jáchymov, one can purchase interesting mineralogical samples from the historic mines, including specimens of uranium ore (Figure 6).

Rubidium and cesium. Robert Wilhelm Bunsen (1811–1899) and Gustav Kirchhoff (1824–1887) discovered these alkali metals during 1860–1861 at the University of Heidelberg, Germany.[1e] This was the first instance of discovery by spectral analysis, a technique which the German scientific team invented and developed. They identified the spectral lines for these two elements in the the mineral waters of Bad Dürkheim, a spa 37 kilometers west (Figure 7). The cesium was detected by its blue line and the rubidium by its red lines. The mineral waters could be easily procured by university investigators, since it was sold in bottles by the case (Figure 8).

Since the rubidium and cesium salts were available only in minute amounts, other sources were sought to prepare the elements in quantity. A better source for rubidium was lepidolite, a lavender form of mica; this mineral was discovered in Rozná, Czech Republic (Figure 9). Lepidolite was originally discovered here (1785) and material from this site was used by Bunsen to isolate weighable amounts of rubidium. Lepidolite has the formula $KLi_2AlSi_4O_{10}F_2$, with substitution of potassium by rubidium approaching 4 percent in some cases (Bunsen found 1 percent). Bunsen prepared metallic rubidium in 1863.[1e]

Cesium, more electropositive than rubidium, was more difficult to prepare in metallic form, first performed in Bunsen's group in 1846. The best source for cesium was pollucite, $(Cs,Na)Si_2O_6(H_2O)$, discovered in 1846 in La Speranza quarry, 1 km south of San Piero de Campo, Elba Island, an island off the Tuscany coast of Italy (Figure 10)—the same island to which the Emperor Napoleon was exiled in 1814.

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Figure 6. (left) On the main street of Jáchymov, some buildings date as early as 1520, when silver production was at its peak. This is a mineral shop on the main street—the sign announces (in Czech): "Minerals-Jewelry." (Right) The specimen of uranium ore (pitchblende) purchased here by the authors contains a complex radioactive mixture of 14 different isotopes of decay chain elements from uranium (at. no. 92) to stable lead (at. no. 82).[1h] When the authors visited Europe in 2003, there was no problem carrying such samples back to the U.S., but today it can be a different story!



Figure 7. At Bad Dürkheim (N49° 27.87 E8° 10.49) a Gradierbau ("salt works building") is filled with bundles of sticks, over which hot mineral water is percolated, creating a therapeutic atmosphere for people with respiratory ailments. Patients can wander along the boardwalk along the stacks of steaming sticks, which stretch over 300 meters—or alternatively sit in special "air inhalation rooms" beyond the bundles of steaming wood.



LEFT: Figure 8. "Healing water" of the "Super Spring" was guaranteed to cure "diseases of the blood, loss of appetite, weakness of the body, scourges of the skin." Bunsen concentrated 40 tons of mineral water to obtain small amounts of crude salt for chemical tests.

BELOW: Figure 9. The Hradisko Hill (N49° 28.82 E16° 14.50) on the eastern outskirts of Rozná, Czech Republic, is a rich source of unusual minerals embedded in outcroppings of pegmatites. This site was known in Germany at the time as "Rozena in Mähren" (Moravia), on the eastern edge of Bohemia. Lepidolite from this site was used by Bunsen to prepare metallic rubidium. The specimen of lepidolite shown here (left) is from this site (private collection, J. Marshall).





Figure 10. San Piero de Campo, Elba Island (N42° 44.83 E10° 12.55)—well known to mineralogists as an excellent source of semi-precious gemstsones such as tourmalines—was the original source of pollucite, the best source of cesium. The sample of pollucite shown here (upper left) was collected from this site (private collection, J. Marshall). (Photo of San Piero de Campo, Courtesy, Creative Commons, Da Wikipedia, l'enciclopedia libera.)



Figure 13. After a mile's walking and scores of identifying signs, we found it!—deep in the woods was this marker (N51° 38.01 E11° 19.13). The sign informs us that this was originally an iron ore mine, but gold-containing selenium ore was discovered in 1825. The bottom line reads "Hier wurde der Selenkupferkies entdeckt" — Here in this shaft "Selenkupferies" (selenium copper pyrite, $CuSeS_2$) was discovered: It was this seleniferous ore that eventually made its way to the laboratory of Crookes and which yielded the green spectral flash signaling the presence of thallium.

Thallium. This element was discovered by William Crookes (1832–1919) in 1861 in London.[1i] It was the third element discovered spectroscopically, after cesium and rubidium. Crookes was investigating selenocyanide compounds, and as a source of raw material obtained a copper-selenium ore from the Harz Mountains, Germany.[1j] Serendipitously, he discovered a new element—thallium—when he took a spectrum of the ore and saw an unexpected green flash. He named the element thallium from the Greek "green twig."

The search of the authors for the original mine took them to the Harz Mountains, the source of the ore given to him by his teacher, August Wilhelm von Hofmann (1818–1892) in London, who had obtained the material from his homeland Germany.[1j] The Harz Mountains is a mountainous area stretching 110 kilometers east-to-west. Its forests and rugged terrain echo its ancient lore and fairy tales; Goethe's *Faust* took place at Brocken peak, the highest elevation in Northern Germany (1141 m). Hofmann explained his selenium ore was from Tilkerode in the eastern Harz Mountains. For the "Rediscovery" team, the search was on for the mine which provided the selenium ore! (Figure 11). The authors were successful after exploring a number of hikers' trails (Figure 12) which led through the fields, hilly terrain, and forests, where historical markers have been erected by dedicated local citizenry (Figure 13).



Figure 11. This photograph is near Tilkerode in eastern Harz Mountains. In this scene the fields are full of green peas, sweet and edible straight away, reminding the authors of the succulent "snap beans" from their native Texas. Other neighboring fields, surrounded by red poppies. support cultivated rye. Local citizenry brag about their delicious "Erbsen und Rogen" ("peas and rye bread"). In the background are the forest areas where the mines were found.

A co-discoverer of thallium was Claude-Auguste Lamy (1820–1878) of Lille, France, who a year after Crookes' announcement, isolated thallium from iron sulfides mined in Belgium[1i] (Mine de le Rocheux, village of Oneux, now a nature reserve, N50° 32.43 E05° 49.84), with its original mines covered and the landscape reworked.

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Figure 12. Jenny beside the tourist's guide to "Bergbau-Wanderpfad Tilkerode" — "Mining trail of Tilkerode." The sign shows maps outlining the various hikers' trails available to one wanting to roam the lush meadows and dense forests which are dotted with historic mines, now all filled in and inaccessible for exploration.





ABOVE: Figure 15. An occasional Denkmal (memorial) at Himmelfürst announces a historic shaft or reminds us the area is a environmentally protected park. Above left: "Halde des Bärschachtes" = "Landfill of 'Bear'-Shaft. The sign informs us the 18th/19th century mine entrance was equipped with a winch reaching down to a rich vein of ore. Above right: Literally translated, "Scenery-sanctuary."

Figure 14. The mine entrance shown here (N50° 51.57 E13° 17.40) is one of the few actual entrances still remaining of the large Himmelfürst mining complex.

Germanium, Indium. These elements were discovered from mineral samples taken from the Himmelfürst Mine, 6 kilometers south of Freiberg, Saxony, in Eastern Germany.[1a] Mines of this region were historically copious sources of silver. Once a banquet was held deep in a mine, served on a table made entirely of this precious metal! In Freiberg, a famous Mining Institute was established—"Bergakademie"—which served as the training school for Alexander Humboldt (1769–1859) and others. This is the same university where Friedrich Mohs (1773–1839) created the classic scale of hardness of minerals from talc (1) to diamond (10). Here Clemens Alexander Winkler (1838–1904) in 1886 discovered germanium from argyrodite (Ag_8GeS_6), and Ferdinand Reich (1799–1882) and Hieronymous Theodor Richter (1824–1898) in 1863 discovered indium from sphalerite (ZnS), also known as zinkblende. Indium—which gave an indigo spectral line—was the fourth element discovered spectroscopically, after cesium, rubidium, and thallium. Germanium, predicted by Mendeleev and Meyer, helped validate the usefulness of the Periodic Table. The present site of Himmelfürst is now abandoned; the present site is a park with only an occasional reminder (Figure 14) of the mining of centuries past and the untold wealth of silver extracted. The once bare areas are now green and have returned to meadows and forests, mining shafts have been filled in, and the entire area has been converted to a nature preserve (Figure 15). No trace of argyrodite or zinkblende, in which the germanium and indium were discovered, can now be found at the Himmelfürst Mine area—any such minerals which still exist are buried deep underground.

Cadmium and zinc. The western section of the Harz Mountains is home to the Goslar area, historically rich in zinc mining (Figure 16). The Mining Museum in Rammelsberg advertises "1,000 years of mining" in the region—over a millennium this area has been active in mining zinc and lead, and more recently, in producing sulfuric acid from pyrites (sulfides).[1j] Inside the museum is an exhibit which explains that the Western World first became acquainted with zinc (called "tutty") in 1272 when it was observed by Marco Polo in Persia. The first historic use of the word "Zinck" was in 1556 by Agricola[1b] (see below) and in 1570 by Paracelsus[1j] (1493–1541). "Zincken" means "tooth" and refers to the property of zinc, being volatile, can be heated and sublimed on the walls of the smelter to form long prongs (Marco Polo also observed this phenomenon during his travels in Persia). Additional exhibits in the museum include zinc compounds found in the mines, such as zinc sulfate ("goslarite"), appearing as bizarre jumbles of knobby bones (Figure 17).

In the medicinal trade, zinc oxide was a common ointment for skin rashes. Certain pharmaceutical companies in the area were preparing medical ointments of zinc oxide which turned yellow upon heating. Friedrich Stromeyer (1776–1835), General Inspector of Pharmacies of the Kingdom of Hanover and professor at the University of Göttingen, investigated this problem in 1817 and found the coloration was not due to iron impurities as previously suspected, but instead to a new element, which he named cadmium. This element, directly below zinc in the Periodic Table, was shown to be a common impurity of zinc mined in the region. Exhibits within the Rammelsberg Museum show the chemical process for separation of cadmium, as well as an artist's presentation of cadmium dyes (Figure 18).

Phosphorus. Hennig Brandt (1630–1710) discovered phosphorus in 1669 in Hamburg, Germany.[1k] The original crude process involved merely distilling urine into water, but later was improved by adding charcoal to the heated retort. Robert Boyle (1627–1691), who first defined "chemical element" in *The Sceptical Chymist* (1661), was very interested in this substance which would glow in the dark and spontaneously ignite. The laboratory setting where Brandt effected this reaction is long gone. The site itself is now found in Michaelisplatz (Figure 19).

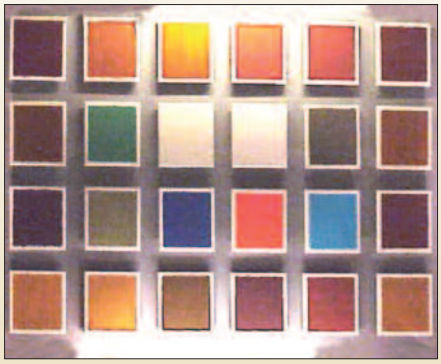


Figure 18. Oil paint artists are well aware of cadmium yellows, oranges, and reds. In the Rammelsberg Museum is a display of various dyes, including cadmium sulfides and sulfoselenides (top row). VanGogh was particularly known for his use of vivid cadmium pigments.

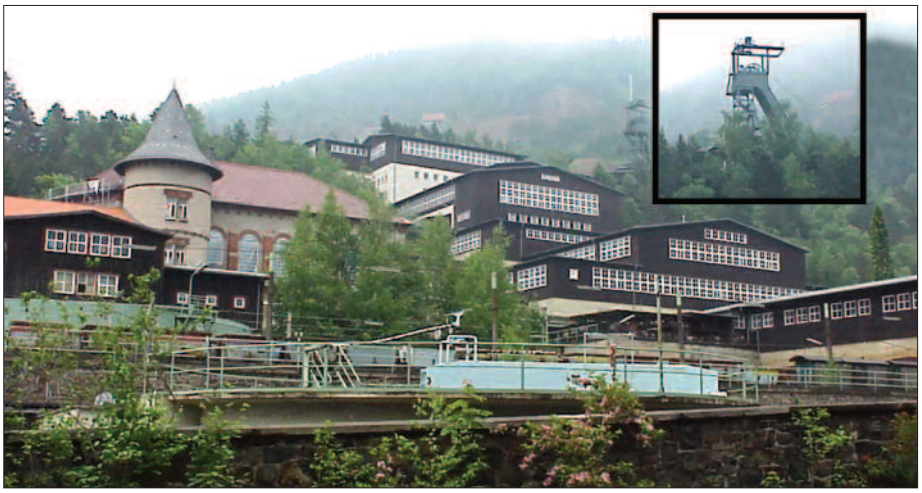


Figure 16. The Rammelsberg Museum (N51° 53.39 E10° 25.09) sits on the slopes of a hill against the backdrop of terrain scattered with scores of historic mines extending in an area several kilometers to the east of Goslar. A mine shaft of one of these mines can be seen from the museum (upper right). Goslar and the mines of Rammelsberg are designated as UNESCO World Heritage Sites.



Figure 17. "Goslarite," named for the city—an unusual mineral because of its high solubility compared to usual ores, such as sulfides, which cannot be dissolved except in boiling acids. The formula is $ZnSO_4$-$7H_2O$. It is also known as "zinc vitriol." Zinc and cadmium have similar chemical properties and cadmium is frequently admixtured with zinc.

Bismuth, antimony, arsenic, etc. The formal discovery of these elements cannot be attributed to one specific site or discoverer. However, Agricola (1494–1555) was the first to differentiate antimony and bismuth, and considered them separate from lead.[1b] Hence, he was the first to move beyond the seven classic metals of the ancients—gold, silver, copper, tin, lead, iron, and mercury. He also studied the harmful effects of arsenic upon miners, and he was acquainted with zinc and its compounds and with cobalt blue. This work was performed while he was city physician at St. Joachimsthal (1527–1530). In 1531, he moved on to Chemnitz where he wrote most of his works. His masterpiece, *De re Metallica*,[2] was translated into English by mining official and U.S. President Herbert Clark Hoover (1874–1964) and his wife Lou Henry Hoover (1874–1944) and serves as a brilliant insight into the methods and science of mining during the 16th century. No hint remains of Agricola at Joachimsthal—no tributes—but Chemnitz honors his legacy with a number of plaques and monuments (Figure 20.)

References

1. J. L. and V. R. Marshall, *The HEXAGON of Alpha Chi Sigma*, (a) **2001**, *92(2)*, 20–22; (b) **2005**, *96(3)*, 58–61; (c) **2005**, *96(4)*, 72–78; (d) **2008**, *99(2)*, 20–24; (e) **2008**, *99(3)*, 42–46; (f) **2008**, *99(4)*, 68–71; (g) **2010**, *101(1)*, 6–11; (h) **2010**, *101(4)*, 68–71; (i) **2011**, *102(4)*, 62–67; (j) **2012**, *103(1)*, 4–9; (k) **2013**, *104(1)*, 4–6.
2. G. Agricola, *De re Metallica*, **1556,** Frobenius, Basel, Switzerland translated into English by H. C. and L. H. Hoover, **1912**, *The Mining Magazine*, London.



Figure 19. Phosphorus was discovered by Brandt in Michaelisplatz, at a location now unknown, but near the St. Michaelskirche (St. Michael's Church) in the middle of Michaelisplatz (N53° 32.90 E9° 58.67). The church is now surrounded by a park, office buildings, shops, and residences.



Figure 20. On the Old City Hall at Chemnitz, Germany (N50° 49.95 E12° 55.13) (left), is placed a plaque (far lower left of building) of Agricola (right). As the plaque informs us, he served as Bürgermeister during four separate years. Behind the Old City Hall is an alcove where a bust and a plaque of Agricola are presented: "To the memory of the scientist and burgermeister of our city Dr. Georgius Agricola born 24/3/1494 in Glauchau, died 21/11/1555 in Chemnitz, who served mankind as the founder of mineralogy and mining geology, and as a doctor and apothecary, philologer, diplomat, and historian. He lived here 1531–1555."