

# Rediscovery of the Elements

## Agricola

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Georgius Agricola (1494–1555) was the first to differentiate bismuth and antimony, and thus was the first to move beyond the seven metals known to the ancients (Figure 1). A physician by training, he became involved with the mining industry in Bohemia and Saxony and wrote prolifically about natural processes in the earth and he described how mankind could utilize this knowledge to advance mining technology.<sup>1</sup> In addition to his scientific writings, he was a popular community leader (Bürgermeister) and humanitarian in Chemnitz, his final home (Figure 2).

Agricola's real name was Georg Bauer. He was born in Glauchau, a village of about 1000 residents. The street where his family lived and

where he was born is known (Figure 3). From a devout Catholic family, Georg Bauer attended the city parochial school (Glauchauer Parochialschule), where he learned reading, writing, arithmetic, and the rudiments of Latin.

During the years 1514–1517 Georg Bauer attended the University of Leipzig (Leipziger Universität); this was during the revival of the classics of the early Reformation, and he studied philosophy, philology, Latin, and Greek. It was in Leipzig that he adopted the Latin name "Georgius Agricola" ("Agricola" = "Bauer" = "farmer").

Next, Agricola taught at Zwickau (1517–1522) where he was schoolmaster, and he continued part-time at the University of Leipzig University. He became interested in medicine, and he traveled south to Italy to study at the famous school of Bologna.<sup>2</sup> During this period in Italy (1523–1526) he continued his studies in Latin, Greek, Hebrew, and Arabic, and he obtained his Doctor of Medicine. He also spent time at the Universities of Padua and Venice. At Venice he also spent time at the glass works of Murano (which still exist today), where his curiosity of rocks and minerals was excited by the special recipes of salts that went into the colored blends of the molten glass.

Agricola's next home was Joachimsthal (Figure 4), a silver boomtown in Bohemia (now Jáchymov, Czech Republic), where he was appointed city physician (1527–1530). This city had been founded eleven years before Agricola's arrival and had grown to a population of some several thousands. The production of silver was so great that the "thaler" (Figure 5) became a major medium of currency in Europe (Figure 5). No hint of Agricola remains in Jáchymov (Note 1), but the home of the village's founder, Stefan Schlick, remains (Figure 6). When he was not engaged in his medical duties, Agricola traveled away from his home, collecting minerals and speaking with the workers at the mines and smelters. During the evenings he would read the Latin and Greek authors who had written on mineralogy and mining. It was here that he published his first work on mining, *Bermannus*,<sup>3</sup> a catechism on mining techniques and lore. This book was fashioned



Figure 1. Statue of Agricola in Glauchau (Bahnhofplatz, N, 50° 49.63 E 12° 32.76), the city of his birth. This statue stands in the beautiful gardens of Bahnhofplatz, only 200 meters from the train station.



Figure 2. Map of places where Agricola lived. Agricola spent both his early and later life in Saxony (modern East Germany) and his first mining years in Bohemia (Czech Republic). His training as a physician was done in northern Italy. His books were published in Basel, Switzerland, at the famous Frobenius publication house. He was buried in Zeitz (Note 3).

after the Peripatetic School where Greek scholars would educate their students in a dialog format. Showing an awakening concern for politics, he wrote a pamphlet urging the ousting of the Turks (Ottoman Empire), who had laid siege on Vienna in 1529.

In 1531 Agricola became city physician of Chemnitz, which was in the heart of the silver mining region of Saxony.<sup>4</sup> (Figures 7,8). He was a prolific writer, with a profoundly sophisticated understanding of natural phenomena. Among these writings was *De Ortu et Causis Subterraneorum*, in which he described the



Figure 3. Nikolaistraße in Glauchau, the street where Agricola was born (N 50° 49.10 E 12° 32.56). This may be reached by walking 250 meters NE of the Glauchau Castle (Figure 9).



Figure 4. Jáchymov, located on the Czech side of the Erzgebirge (Krušné Hory) mountain range 5 km south of Germany, was once known as Joachimsthal, Bohemia. The two buildings are the city hall (left, which now houses the tourist bureau/museum) and the old mint (right, which dates from 1536). (Note 1).

forces of wind, water, and subterranean volcanic forces, and where he correctly interpreted the phenomenon of mountain building and erosion. He also wrote *De Natura Eorum quae Effluunt ex Terra* (subterranean waters and gases), *De Natura Fossilium* (the first systematic mineralogy), *De Veteribus et Novis Metallis* (history of metals and minerals), *De Rerum Metallicarum Interpretatio* (glossary of Latin and German mineralogical and metallurgical terms), and *De Animalibus Subterraneis* (animals that live underground).

Agricola was a contemporary of Martin Luther (1483–1546) and sympathized with

some of his views, and even prepared some epigrams against the Pope. However, he was soon repulsed by the activities of Luther, who sometimes appeared to him as an undisciplined rabble-rouser, appealing to the masses rather than to reason. Amidst this Protestant stronghold, Agricola remained a staunch Catholic. Nevertheless, his devotion and care for his community, as well as his lack of bigotry and his sense of fair play, brought him into such esteem and reverence that he commanded respect and support during all his days in Chemnitz until his death in 1555. He was appointed *Bürgermeister* for four terms by



Figure 5. This silver “Joachimsthaler,” minted in 1561, portrays Ferdinand I, Emperor of the Holy Roman Empire. Thalers are the etymological source of the word “dollar.”

Protestant authority and participated in the various Diets in the region.

**De Re Metallica.** The most famous work of Agricola was *De Re Metallica*,<sup>1</sup> thirty years in the making and published the year after his death. The book is an astoundingly modern contribution to the technology and science of mining. Graced with over 350 woodcuts, it details the methods of mining: finding the proper sites; the construction of the mines; smelting; and assaying. The book is written in excellent Latin; Agricola knew the classic literature well and referred to it often. When there did not exist a term he needed, he coined one, and he recognized new mineral species and named them. Agricola abandoned the medieval divining rod and replaced it with observation and logic. With a perceptive eye, he proposed that the formation of veins (“canales”) in beds of rock was caused by the deposition of flowing water—a prophetic interpretation that anticipated the modern view of sedimentary and hydrothermal deposition. Agricola’s education was founded on ancient scholasticism and yet was not bound by it; he exemplified the brave approach taken by the first scientists who broke out of old thinking molds. Indeed, he appeared to be the first to use the term “chemistry” (chymia) instead of “alchemy” (*alchymia*).<sup>5</sup> Agricola’s *De Re Metallica* was used as the principal guide for miners and metallurgists for almost 200 years.

For the modern reader, *De Re Metallica* is difficult to read—technical terms are used which don’t exist in any Latin dictionary, and the sixteenth century chemistry is obscure. Fortunately, a translation in English exists, complete with detailed footnotes. This monumental work<sup>6</sup> was performed by a successful mining engineer, partnered with his wife versed with the classics in the original tongues—Herbert Clark and Lou Henry Hoover—fourteen years before he assumed the Presidency of the United States. With the



Figure 6. The home of Stefan Schlick, the founder of Joachimsthal in 1519 (N 50° 22.16 E 12° 54.65), lies up the mountain, 300 meters SW from the city hall/mint. Schlick oversaw the largest silver producing enterprise in Europe at the time.

Hoovers' translation, one can read *De Re Metallica* almost leisurely. The extensive footnotes not only explain just what Agricola meant by confusing Latin terms, but also include historical notes on the development of metallurgy of quicksilver, copper, lead, zinc, etc.

It may seem strange that a successful and rich business man would pause to translate a hefty Latin volume, but Hoover found a connection with Agricola, because both were motivated to promote the professional image of the mining industry.<sup>7</sup> In ancient times the slaves did mining labor, but by Agricola's time mining was assuming a high standing with the formation of guilds. This higher status of miners is celebrated to this day in the "Festparaden" of Freiberg and other historical mining towns of Saxony.<sup>4</sup>

When Agricola found a discrepancy with the ancients, he did not hesitate to correct the error. In this way he recognized the separate identity of new metals.<sup>6</sup> In the dialog in *Bermannus*<sup>3</sup> we read:

"I will show you another kind of mineral. . . that appears to me to have been unknown to the Ancients; we call it *bisemtum* [bismuth]."

"Then in your opinion there are more kinds of metals than the seven commonly believed?"

"More, I consider. . ."

Agricola goes on to show how to distinguish bismuth from *plumbum candidum* (tin) and *nigrum* (lead) by specific characterizing tests, including color, staining (modern "streak"), and friability (brittleness). He also recognizes antimony (*stibium*) and describes how it can be used with tin as an alloy for printers' type (antimony had previously been confused as a species of lead). He also mentions *cadmia sublimate* (zinc). He describes various compounds of arsenic (orpiment, realgar, the sulfides; and arsenic oxide), but apparently was not familiar with the metal itself. Agricola identifies a certain *cadmia*, called *kobelt* in German (a cobalt arsenide) that "eats away the feet of workmen"; the discovery of metallic cobalt itself was made some two hundred years later.<sup>8</sup>

Agricola did not believe in alchemy, but he did report on the miners' superstitions and interpretations of Nature. The miners believed in *Kobolde* (gnomes) who caused mischief in the shafts. Although he himself did not believe in transmutation,<sup>5</sup> he reported the miners'

belief that bismuth was "the roof of silver"—the evolutionary stage before silver. According to the miners beliefs, the metals transmuted naturally, tending toward perfection (gold) over a long period of time. The miners believed bismuth was the stage before silver because they observed silver commonly associated with bismuth in nature.

**The Legacy of Agricola.** Hoover appears to claim that Agricola belonged to the modern age, while in fact the humanist Agricola wanted to connect with the classical past.<sup>7</sup> Nevertheless, Agricola's dependence on systematic classification and his sense of exploration anticipated Linnaeus (1707–1778). He may have been steeped in Aristotle, but he was progressive and anticipated the future. Agricola's insight to geological processes and his recognition of new minerals gave birth to modern geology and mineralogy.

At the Glauchau castle (Figure 9) a large museum is devoted to the history of the region, and a full section is devoted to Agricola. With mining artifacts and other exhibits of historical interest, the Agricola room describes the greatness of this humanitarian, scientist, and doctor.

In 1999, the 500th birthday of Agricola was celebrated in Chemnitz, and annually a symposium is held commemorating Agricola's contribution to humanitarianism and science. In the "Agricola cloister" across the street (Innere Klosterstraße) from the Tower (Note 2), a plaque reads [translated]:

"In honored memory of the outstanding scientist and once burgermeister of our city Dr. Georgius Agricola born 24–4–1494 in Glauchau died 21–11–1555 in Chemnitz. He served the progress of mankind as the founder of modern mineralogy, geology, mining, and smelting, as doctor and apothecary, teacher and lecturer, diplomat, and historian. He lived here from 1531 until 1555." (Note 3) ○

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## Notes.

Note 1. The museum and tourist bureau of Jáchymov lie on the main street (highway 25), 1 Náměstí Republiky (N 50° 22.28 E 12° 54.81) on the upper (northern) section of the town. Downhill and southeast along Nám. Republiky, 1.0 km from the museum and tourist bureau, stands a memorial (in German) to Schlick in a city park (N 50° 21.89 E 12° 55.36). There was a great deal of mining history in subsequent centuries, including the manufactory and the mine of the uranium ore used by the Curies to isolate

polonium and radium; these sites will taken up in a future "Discovery" article.

Note 2. During the period 1953–1990, the days of the Deutsches Demokratische Republik (DDR), Chemnitz was known as "Karl-Marx-Stadt." On Brückenstraße a 7.1-meter high sculpture of Karl Marx's head still stands, an anachronism from earlier times (N 50° 50.12 E 12° 55.39).

Note 3. Tragically, upon Agricola's death in 1555, anti-Catholic sentiment was strong and Agricola was not allowed to be buried in St. Jakobikirche (St. Jacob's church) in Chemnitz. Instead, his remains were transported to a Catholic cathedral in Zeitz. A plaque dedicated to Agricola was erected but disappeared in the 1600s. Fortunately, a replica was prepared and was delivered to Dom St. Paul und Peter (St. Peter and Paul Cathedral) in 1935 (Schloßstrasse, St. Moritz, N 51° 03.05 E 12° 07.59).

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Figure 9. Castle of Glauchau (Schlossplatz, N 50° 48.99 E 12° 32.41) A historical museum now resides in the castle and includes an entire room devoted to Agricola. In another section of the museum, an exhibit is presented on the cloth trade which was the occupation of his father in Glauchau. This castle is 1.2 km south of the statue of Figure 1.



Figure 7. The Altes Rathaus (old city hall) in Chemnitz, the same building where Agricola worked as Bürgermeister (Marktplatz, N 50° 49.95 E 12° 55.13). Plaques and a bust of Agricola are located in the Agricola cloister, across the street (extreme lower left of figure, in far building). (Note 2). The St. Jakobikirche, where Agricola was refused burial, is behind and to the right (just out of view).



Figure 8. This restaurant/shop complex is the site where Agricola lived in Chemnitz (Kirchgäßchen, N 50° 49.96 E 12° 55.07), located 50 meters behind the Cloister of the previous figure. A lovely beer garden is located on the other side.