A History of the Schemnitz (Banská Štiavnica) Silver-Gold Mines

By Peter L. Siems

The Schemnitz District in the Slovak Republic was formerly renowned as one of the major mining districts of Europe (Figure 1). The mines at Schemnitz were the second largest gold and silver producers in Europe during early medieval and renaissance times, and were generally prosperous until the last decade of the nineteenth century.

The district's miners, engineers, and officials were famous through the centuries for innovating mining techniques in their endeavors to solve the difficulties of rock breakage, underground water disposal, ore haulage, ore and water hoisting, ore preparation, and smelting. These mines led in the early use of gunpowder, and in using horses, waterwheels, dams, reservoirs, ditches, and leats to meet their energy needs. The district also pioneered in the early use of water-column engines, ventilation engines, water-drainage adits, ore preparation and smelting, and in the management of regional timber and water resources. Other innovations included training miners in an early mining school, and educating engineers, surveyors, assayers, smelter masters, and mine administrators at an early mining academy. Techniques used at the Schemnitz mines and smelters are mentioned in books about mining and smelting published from the mid-sixteenth to the early-twentieth centuries.

Schemnitz District was part of Hungary from AD 830 to 1526. It then became part of the Austro-Hungarian Habsburg Empire, part of Czechoslovakia in 1918, and part of the Slovak Republic since 1990. The district features the principal town of Banská Štiavnica, known as Schemnitz during the era of German mining under Hungarian and Austrian rule. Other communities include the small present mining community of Banská Hodruša (formerly Hodritsch, five kilometers west of Banská Štiavnica), and the former mining communities of Štiavnické

Figure 1: The location of Banská Štiavnica (Schemnitz) in the present-day Slovak Republic in central Eastern Europe. (Drafted by the author.)

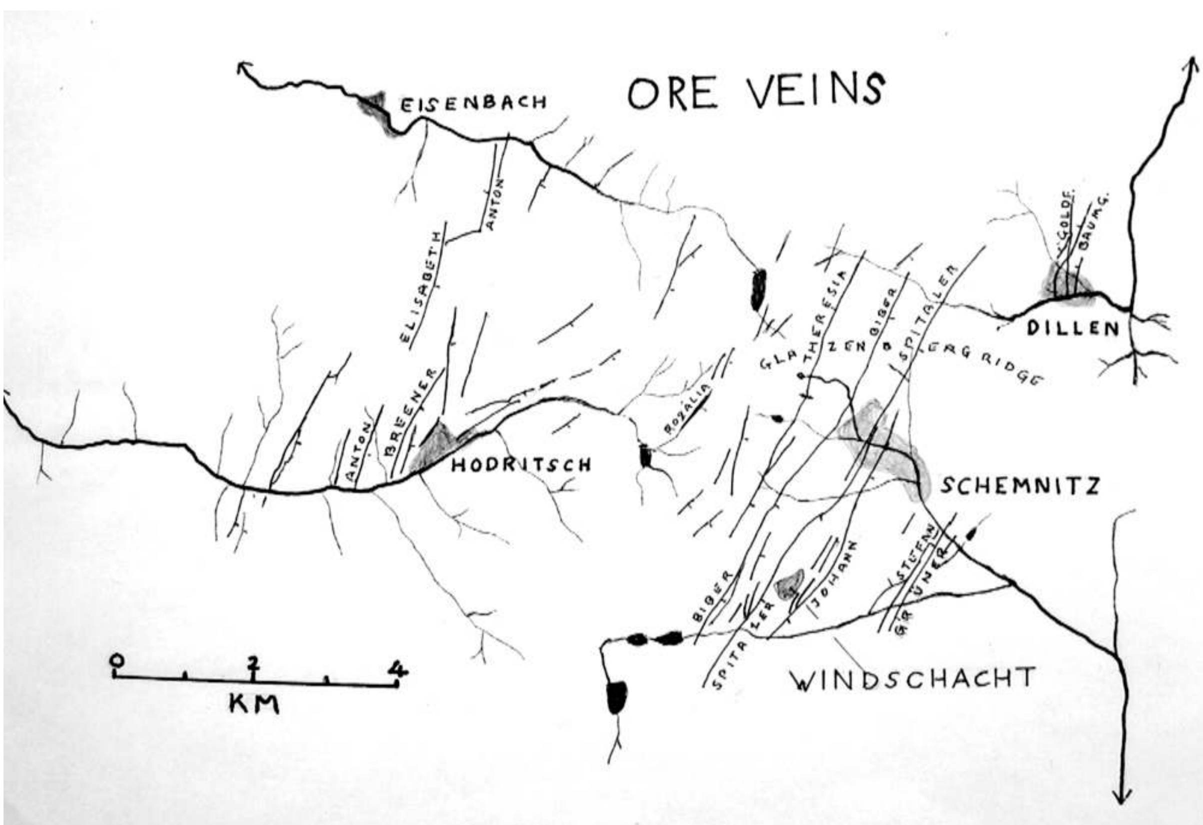

Figure 2: The Schemnitz mining district, showing silver-gold ore veins, towns, rivers, streams and reservoirs. (Drafted by the author based on Zeiller and Henry, "Mémoire," 1873.)

Bana (formerly Windschacht, two kilometers southwest of Banská Štiavnica), Banská Belá (formerly Dillen, five kilometers northeast), and Vyhne (formerly Eisenbach, twelve kilometers northwest). (Figure 2.) The German-language town names, used during the major part of this history, are used in this article.

The Schemnitz mining district is within the former Carpathians volcanic province, with country rock and ore deposits similar to those in the San Juan volcanic field of Colorado. The topography of the district is that of a mature low mountainous area, with heights of four hundred to nine hundred meters, deeply dissected by the Hron River and other river valleys. The area is somewhat remote from major cities; Bratislavia, capital of the Slovak Republic, is 105 miles by road to the west, and Budapest, Hungary, is 94 miles to the south.

This account of the history of the Schemnitz mines emphasizes two problems that the old miners found difficult to overcome and that occurred almost continuously during the many centuries of mining. The first concerned the disposal of large and ever-increasing volumes of ground water, which accumulated in and occasionally flooded the underground mines. The second was how to provide the energy required to hoist ore and water in mine shafts that, in the final years of mining, extended to a depth of 1,650 feet.

Precious Metal Veins

The principal silver-gold veins at Schemnitz and Windschacht included, from west to east, the Theresia, Biber, Spitaler, Johann, Stefan, and Grüner (Figure 2). At Dillen, the veins were the Goldfahrtner and Baumgartner. The Brenner, Elisabeth (later incorporated as Allerheiligen), and Anton veins lay in the Hodritsch area (Table 1). A less important group of seven veins existed in the Eisenbach Valley and included the northern extension of the Elisabeth vein. The Goldfahrtner and Baumgartner veins, at Dillen, were considered northern extensions of the Grüner vein.

Many of the veins were wide lodes with multiple splits or off-shoots mined either together with the veins or separately. The Spitaler vein was the longest and had an average width of about ten to twelve feet and reached sixty feet in places. It was mined to a depth of one thousand feet. The second most important find was the Biber vein. Another important vein, the Stefan, did not crop out and was discovered at depth in 1783. Ore was not always continuous along vein lengths, and in lower levels it was mostly in bodies several hundred feet in length and in depth. Principal ore minerals were native gold and silver, silver sulfosalts, and silver-bearing galena. Precious metals values decreased with depth, while lead, zinc, and copper values increased.[1]

Schemnitz-Windschacht		**Hodritisch Valley**		**Dillen Area**	
Gruner	1,400 m.	Allerheiligen	1,200 m.	Goldfahrtner	1,000 m.
Stefan	350 m.	Brenner	2,500 m.	Baumgartner	900 m.
Johann	4,000 m.	Anton	1,200 m.		
Spitaler	8,000 m.				
Biber	5,500 m.				
Theresia	4,300 m.				

Table 1: Principal Veins and their Strike Lengths in Meters, Schemnitz District. (From Zeiller and Henry, "Mémoire," 1873.)

The Early Medieval Era

The Schemnitz Mines and Town

Mining of the Schemnitz District began some time after AD 830 when the Magyar (Hungarian) people gained control of the area. The first discovery of the rich silver and gold ores was probably made at the All-Saints vein in the Hodritsch Valley in the ninth or tenth century. Some mining started earlier for copper at nearby Sitno, where a workshop from the early Bronze Age has been excavated. Alluvial gold was panned from the Hron River, fifteen kilometers west of Schemnitz, as early as the eleventh century, according to manuscripts.[2]

The earliest discoveries at Schemnitz were the outcrops of the important veins, with parallel northeast strikes on the Glanszenberg Ridge, one kilometer north of the center of the old Schemnitz town abandoned in medieval times. These veins were traced to the south into the Windschacht area. Mining of precious metal veins on the Glanzenberg Ridge at Schemnitz occurred during the reign of King Stephan the Saint before AD 1156.[3] Miners first sank shallow pits on the veins. As the pits deepened, the porous volcanic rock allowed water inflow. This required excavating adits from the floors of the Hodritsch Valley and other incised valleys at Windschacht, Dillen, and Eisenbach to drain the water and provide haulage for miners and broken rock. Miners later reached veins at depths below the valley floors through vertical and inclined shafts.

During the twelfth and thirteenth centuries the country around Schemnitz was thinly populated, consequently the Hungarian kings invited German miners from the Tyrol and Saxony to settle and mine the district. King Bela IV guaranteed the miners and Schemnitz town German law in a royal charter in 1235, granting the town the right of self-government and the miners the freedom to move in and out. Mine officials and workers of German and Austrian origin brought their language and culture to these communities before and during Habsburg rule.[4]

Invasion by Mongols and Tatars in 1241 forced the mines' abandonment, and it was left to King Bela to return them to production. His swift successes against the invaders by 1250 allowed mining to resume. The invaders continued to cut off the influx of African–Arabic gold to central Europe, however, so renewed Hungarian gold production enjoyed a remarkable appreciation in price.[5]

Only one annual production total from the Schemnitz mines has survived from medieval times: three hundred marks of silver in 1217—one mark being a unit of weight equal to 197.8 grams. No other production records survive from the thirteenth and fourteenth centuries, although the Schemnitz mines were the second most productive precious-metal mines in Europe after the Kremnitz mines (today Kremnica in Slovakia). One author estimates production from Schemnitz at five thousand kilograms of silver per year in the first quarter of the fourteenth century. Production then fell slightly in the last quarter of the fourteenth century due to the difficulties of deeper mining.

Schemnitz was the third largest town in Hungary for many years. About 1,230 dwelling houses and church buildings stood in old Schemnitz. It cannot be described as a town in the conventional sense, because the plans of single small dwelling houses—identified in excavations as miners' houses—are on many terraces, spread out among the former mine shafts. Initially, an extensive stone-walled fortification enclosed only a small castle and the first administrative center. But the increasing importance of Schemnitz resulted in the royal award of a seal and coat of arms as a free mining city in 1275. A hospital church (*spital)* was finished in 1310, and the town had two churches and a castle by 1330.[6]

In 1329, Kremnitz became the center for precious-metal minting of the bullion from Schemnitz and other mines in western and central Slovakia. The Kremnitz mint had existed since at least 1225, as in that year King Andreas II gave Thebanus Judaeus, a Jewish Chamber-Earl in Kremnitz, the right to lease the mint and mines at Kremnitz. After 1329, gold-silver doré ingots from the Schemnitz smelters went by wagon twenty-eight miles to the royal mint at Kremnitz, where the Royal Chamber of Mines collected the tax. Kremnitz mint records start only in 1493, and they combine the production from Schemnitz, Kremnitz, and Transylvania. From 1493 to 1900, the totals from the three districts combined are recorded as 9,017 metric tons of silver and 515 metric tons of gold.[7]

In 1351, King Ludwig I proclaimed the right of expropriation by the monarchy for the precious-metal production of the Hungarian mines, although the monarchy did not purchase all of that production until 1405, when King Sigmund granted himself the right to purchase the entire output from the Schemnitz mines. Companies of free miners were still taxed on their production, still owned their mines, and their ores were smelted by private companies in the nearby valleys.[8]

Ground and Surface Water Problems at the Mines

The seepage of ground water into the mines became critical as the mines at Schemnitz town and Windschacht reached greater depths during the early medieval era. The permeable volcanic wall rock in the areas of the veins allowed large quantities of ground water to flow into the underground galleries. The earliest method of removing this water from the vertical shafts was by man-worked windlasses and suction pumps. The windlasses could only be used to hoist water and

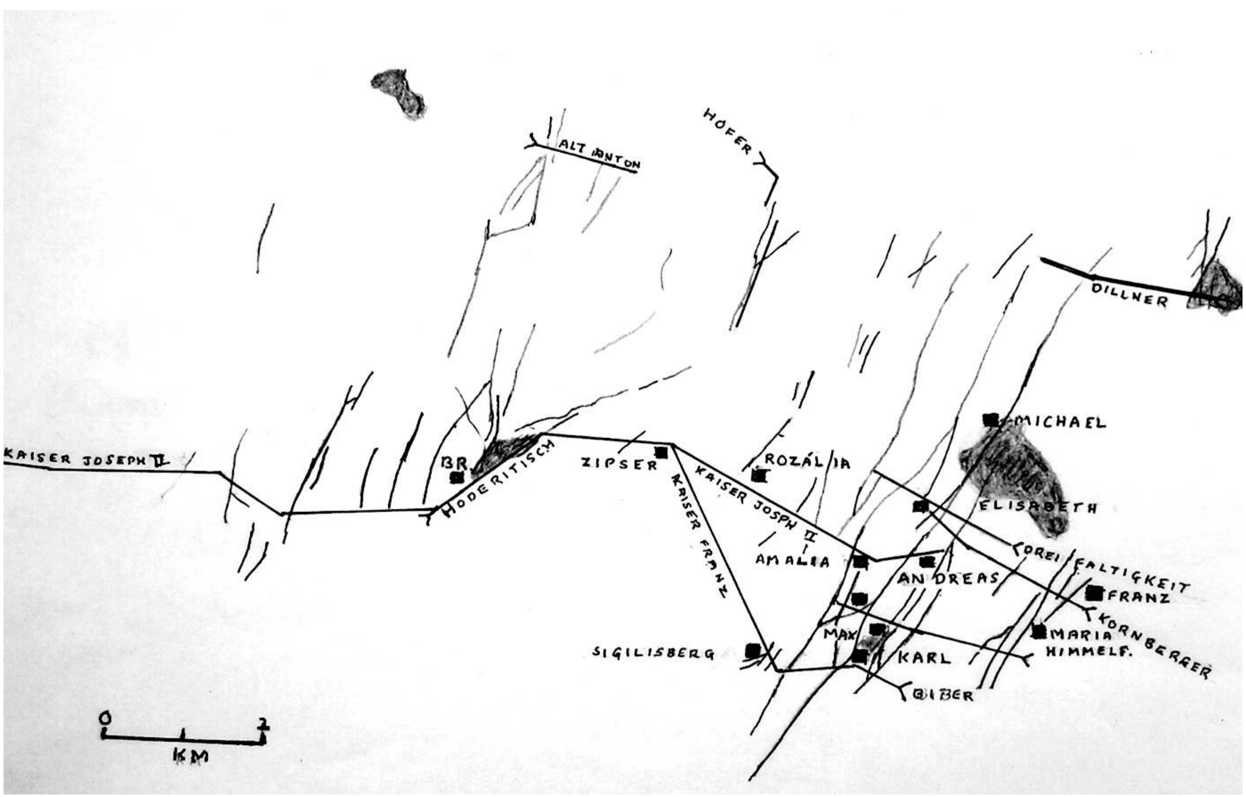

Figure 3: The Schemnitz mining district, showing mine shafts active from 1865 to 1873, and water-drainage adits (Erbstollen) active and inactive. (Drafted by the author based on Zeiller and Henry, "Mémoire," 1873, and Faller, Der Schemnitzer Metall-Bergbau*, 1865.)*

ore from shaft depths of less than 120 feet. By about the year 1200 some shafts had gone deeper and water inflows had increased, exceeding the hoisting capacity of the windlasses. Change to horse- or oxen-driven whims and pumps became necessary. Whims increased the volume of water that could be hoisted and were used into the nineteenth century, although they proved to be slow, inefficient, and expensive with ever-increasing depths.

By 1300 a more efficient power source was needed, as mine shafts continued to deepen and water inflows to increase. In the thirteenth and fourteenth centuries many European mines used water power from rivers and streams to drive waterwheels to hoist water by bags, rag and chain, or suction pumps. However, the high topographic position of the mines near Schemnitz did not allow year-round use of water power. A few small sources of water upstream from the mines were impounded in reservoirs, but summer droughts and winter freezes frequently stopped the waterwheels.[9]

The problem of removing water was partly solved by mining water-drainage adits with hereditary rights, known as *Erbstollen* in German (Figure 3). These adits were driven on low-angle inclines from the valleys towards the mine galleries. The earliest drainage adit was the Biber Erbstollen, started in the fourteenth century to drain the mines working the Biber and Spitaler veins at Windschaft. The Biber Erbstollen was completed to a length of approximately 2,700 meters in 1426, after many decades of mining. It was ultimately lengthened to 5,670 meters and was in use until 1765, when it was replaced by the deeper Kaiser Franz Erbstollen. The Dillner Erbstollen, in use by 1504, served those mines above the valley at Dillen and later reached a final length of 8,700 meters.[10]

These adits were excavated by hammer and pick, and some fire-setting. Slow advances in driving often caused completed adits to be higher than the active mining levels, resulting in only a partial solution to the water problem. That these adits intersected their narrow targets at all is a tribute to the skill of early mine surveyors, given the primitive surveying instruments then available.[11]

The Late Medieval Era

The Schemnitz Mines and Town

In the fifteenth century, the Hussite religious wars from 1428 to 1475 extensively damaged the town, largely depopulated the district, and caused the closure of many mines. Soldiers burned much of Schemnitz to the ground in 1442, and an earthquake the following year completed the town's destruction and abandonment. A new enlarged town was built on a site lower on Glanzenberg.

Intermittently decreased productivity occurred in the mines in the sixteenth century due to a variety of causes. Ottoman Turkish advances threatened the mines in 1526 and resulted in the building of the New Castle on Frauenberg Hill and a double wall of fortifications around Schemnitz from 1564 to 1571. A widespread famine occurred in 1570, with associated outbreaks of the plague in 1572. Despite these problems, silver production amounted to three hundred thousand kilograms in the sixteenth century. In 1569 the district produced 203 marks of gold and 20,870 marks of silver, one mark equaling 197.8 grams.

But high food prices and inflation in the 1590s resulted in further decreases in production, and a Protestant revolt in Hungary in 1605 caused many German miners to leave Schemnitz. By the time King Matthias of Hungary revoked the freedom rights of the German miners in 1608, German immigration to Schemnitz had largely ceased.[12]

Further Ground and Surface Water Problems

Serious flooding of the deeper mines at Schemnitz in 1449 resulted in the excavation of the Dreifaltigkeit Erbstollen to drain the mines that

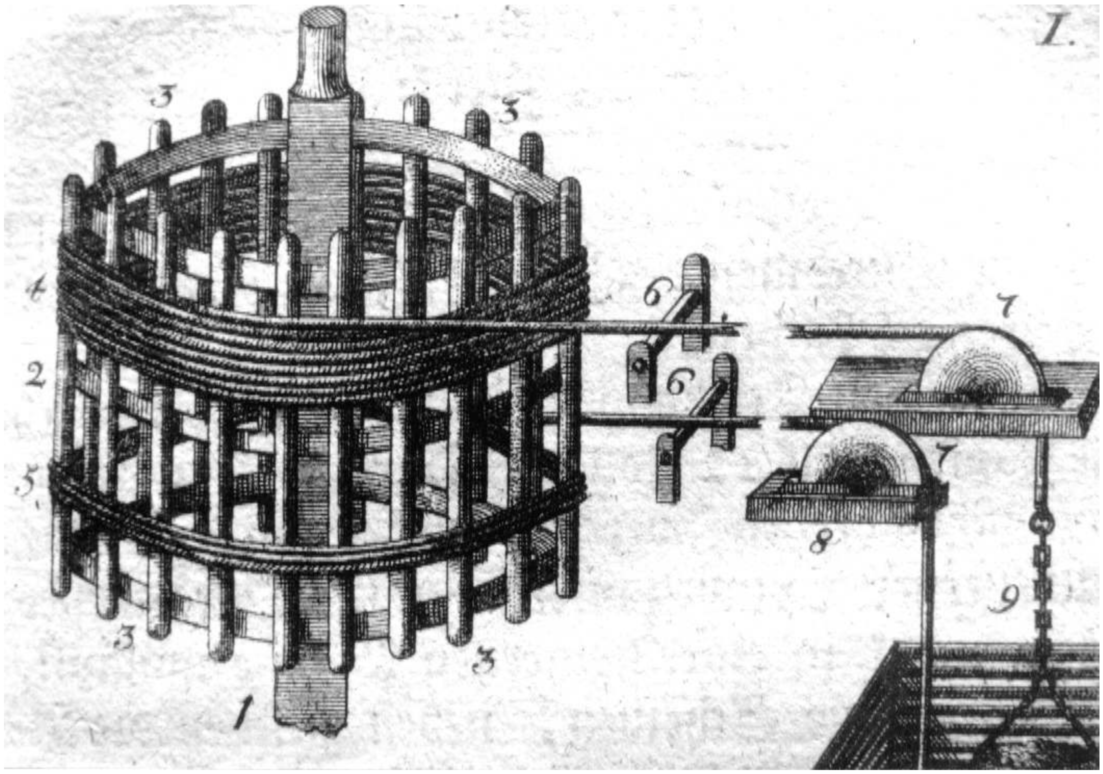

Figure 4: A Horse-driven double whim for hoisting ore, water, and men, powered by teams of either two or four horses harnessed to a yoke attached to the lower part of the spindle. (Poda, Kursgefasste Beschreibung*, 1.)*

underlay Schemnitz town. This project took 122 years of intermittent work to complete in 1671, at a cost of three million guilders during its last sixty years of excavation. The adit discharged below and southeast of the town of Schemnitz near the Antaler Thor, and was situated about forty meters vertically below the Biber Erbstollen.

Miners commenced another drainage project, the Kornberger Erbstollen, from southeast of Schemnitz town in the mid-sixteenth century, intending to intersect all of the principal veins on Glanzenberg at a depth of thirty-three meters below the Biber Erbstollen. After reaching the Grüner vein, however, they abandoned this project in 1614 because of the extreme hardness of the rock.[13]

Mines at Hodritsch town had reached depths below the valley floor in 1494 and were experiencing considerable inflow of water. The Hodritsch Erbstollen was started in that year from a point in the valley west of the town. When finished in 1637, it had a length of 984 fathoms. It was lengthened and connected to the Kaiser Franz Erbstollen in the eighteenth century.[14]

Agricola described a system of pumps used in a Schemnitz mine that consisted of three ball-and-chain pumps, mounted on three different levels, driven by horses. The lowest pump lifted water from a sump in the shaft 660 feet from the surface, the middle pump raised water to a sump on an intermediate level, where the upper pump could, in turn, discharge that water to an adit, probably the Biber Erbstollen. Ninety-six horses gained entry to the underground levels by means of an inclined spiral shaft.[15] The increased use of waterwheels to lift water from the Schemnitz mines created a corresponding demand for additional water power. The water for this was supplied by the dams, reservoirs, ditches, and leats constructed from the beginning of the sixteenth century.

The Habsburgs Appropriate the Mines

Ferdinand I, a Habsburg who succeeded the last Hungarian king in 1526, prohibited exports of precious metals by free miners after 1 March 1543. By then the mines faced high expenses from water and energy problems as their shafts went deeper. Some mines had difficulties paying their royal taxes, whereupon the monarchy took shares in those mines as payment. Those shares increased as company debts reoccurred over the decades, until many mines became royal property. Emperor Maxmillian II terminated the mining rights of the remaining companies in 1573, and in 1587 Emperor Rudolph II ordered the royal administration, known as the *Kammerhof* (Chamber), to control exploitation of the king's mines and maintain tighter control over free miners—an early example of the nationalization of a basic industry.[16]

By 1600, His Majesty's Chamber held many mines at Schemnitz through a royal company named the Oberbiberstollen Haupthandel. That company controlled four major Erbstollen and some shafts at Schemnitz, the Dillner Erbstollen at Dillen, and seven mines at Hodritisch. The Chamber also held separately shares in eight other mines.[17]

An inventory of the district's mines from before and during the sixteenth century includes 141 names at Schemnitz, 52 at Windschacht, 136 in the Hodritsch Valley, 13 at Dillon, and 84 in the Eisenbcher Valley, for a total of 426 mines.[18] Few of these mines could be located in the mid-nineteenth century.

The Early Modern Era

The Schemnitz Mines and Town in the Seventeenth Century

The difficulties and disappointments of driving the Kornberger Erbstollen and then having to abandon it in 1614 resulted in the decision to try black powder in a Schemnitz mine. Trials were made by Casper Weindl, from the Tyrol, in the Oberbiber Erbstollen in the presence of the Council of Mines. Results showed that firing the powder had some inconveniences: "it gave rise to smoke but this disperses itself in a quarter of an hour and is not, by the grace of God, in no wise harmful; but to the contrary it displaces much bad air," according to the Council's written entry of 8 February 1627.

The counselors optimistically decided that the trails had succeeded and their conclusions were much publicized in European mining districts. It was not long, however, before the first fatal mine accident due to powder occurred. On 11 January 1631, Lorenz of Dillen, using black powder to blast a mine face, died in a premature explosion. A judicial investigation into powder sales was held in the same year.[19]

Black powder was adopted only slowly at Schemnitz and other European mines because of the dangers from fumes, the absence of reliable fuses, the hazard of misfires caused by leakage of water into shot holes, and the lack of facilities to store and transport it. Black powder was also in short supply in all of Europe during period of the Thirty Years War, from 1614 to 1648. For these reasons, it found only limited use in mining for many decades, and perhaps only in exceptional cases. Schemnitz miners continued to use the hammer and chisel and fire-setting through most of the eighteenth century.

The town of Schemnitz suffered another earthquake in 1639 and a fire in 1680. A Hungarian revolt against their Habsburg rulers from 1678 to 1682 caused significant damage to the town and interrupted mining. Renewed Ottoman Turkish advances at intervals also threatened the district. Finally, in 1680, a defensive wall was built around the town and eight adjacent mine shafts—the Old and New Windschacht, Josefi, Caroli, Spitaler, Eleonora, Leopoldi and Magdalena—at an expense of forty thousand florins. Despite continuing declines in silver and gold production due to deeper and poorer ore bodies, Schemnitz prospered, and had water and sewer systems and street paving by 1681, although these improvements did nothing to prevent outbreaks of the Black Death in 1700 and from 1710 to 1712.[20]

Resumption of Groundwater Problems in the Seventeenth Century

The depth of the mines under the Biber Erbstollen, the deepest existing water-drainage adit, become a critical issue by the start of the seventeenth century. Lack of efficient water-hoisting engines raised the mines' expenses and caused a steep decline in production. Water hoisting from the deeper levels of the Oberbiberstollen mines depended largely on hand- and horse-powered hoists with ox-skin buckets. Pumping systems powered by man, horse, or waterwheel dewatered other mines. Water hoisting already cost over three hundred florins weekly in 1623. During dry weather, as in 1632, the reservoirs and lock gates held little water to turn the waterwheels.

The Oberbiberstollen mine galleries stood the biggest danger of being flooded. The monarchy ordered companies of miners in the surrounding country to allocate men to the Schemnitz mines to help hoist water. The long drought and the bad financial state of the Schemnitz mines at the start of the seventeenth century caused the Royal Chamber in Kremnitz to forward over 324,000 florins to the Chamber in Schemnitz in the forty-three-year period between 1591 and 1633. Annual silver production between 1600 and 1650 ranged from 8,400 to 8,960 kilograms.[21]

The Biber Erbstollen was already 2,600 meters long in 1604, and had intersected fourteen veins before reaching the Biberstollner vein. Sinking of the new Wolf Shaft began, the Eben (formerly Rowna) Shaft was deepened, and the Ferdinand Shaft was planned in 1624. In March 1626, low income from the workings, heavy capital expenses, and the monarchy's debts caused King Ferdinand to order a devaluation of the Hungarian currency from six florins, seventy-five pfennigs to eight florins, seventy-five pfennigs against the mark of fifteen Löthigen silver. Furthermore, in order to revive the mines, Ferdinand ordered miners at Rattenberg in the Tyrol to be transferred to Schemnitz in 1629. The Georg Adit at Dillen, having exhausted its silver-gold ore, was listed as an "acid, alum and sulfur mine" in 1632.[22]

An English traveler in Schemnitz in 1671 wrote that the "Windschacht, the Dreifaltigkeit, at the Drei Konigen, St. Mathias, St. Johannes and St. Benedictus shafts were hoisting ore and that they did not use the divining rod in Schemnitz for the exploration of the ores, as miners did at Freiberg in Meissen [Saxony]." The same observer noted that "no fewer than 2,000 men" worked in the mines.[23]

Conditions improved in the Schemnitz mines in the last quarter of the seventeenth century, largely due to completion of the Dreifaltigkeits Erbstollen in 1671. By then, however, the Oberbiberstollen Haupthandel mines were already about thirty-three meters deeper than the Biber Erbstollen. Sinking the Leopold Shaft began in 1673. In this period, miners began to use lines of reciprocating rods to transfer power from those waterwheels located some distance from mine shafts. Production increased so that in 1671 and after, not only was the three millions guilders (florins) cost of excavating the Erbstollens recovered, but a profit of three millions guilders resulted.

Another period of drought affected the mines in the years from 1690 to 1700. The six waterwheels at the Oberbiberstollen mines could no longer lift the mines' water, and this caused the flooding of some deep mine levels. The king ordered one thousand men brought in from other mining districts to man the pumps.[24]

Schemnitz Mines and Groundwater Problems in the Eighteenth Century

The heavy expense of mining new drainage adits, together with the many decades needed for their completion, prevented the mines' water problems from ever being totally solved. Also the hoisting capacity of the Schemnitz mines scarcely increased, as the old methods continued in use (Figure 4). One or two shafts at Windschacht, on the slopes of the lower Steplitzhof Valley to the southwest of Schemnitz, were provided with better reservoir systems and could rely more on waterwheels connected by lines of reciprocating rods to suction pumps in their shafts.

During the long drought at the beginning of the eighteenth century it became necessary to employ a thousand pump men and 192 pairs of horses to pump and hoist continuously, at a weekly expense of five thousand florins. Even with these resources committed, the miners could not lower the water level below the Dreifaltigkeit Erbstollen. Schemnitz mines experienced a steep drop in production and increased debt for several years. In 1707, Emperor Joseph I ordered abandonment of the mines he controlled, as by then the Royal Chamber held 5,536 shares out of a total of 6,144 shares in the Oberbiberstollen mines and company.[25]

The emperor stayed the execution of this order because of the advocacy of the district engineer, Mathias Cornelius Hell (or Holl, 1651–1743). By the time the king reissued the edict in 1710, Hell had started construction of a system of new and larger reservoirs, a new and deeper drainage adit, and had introduced a new type of pump engine. The abandonment order was again postponed, and finally canceled after completion of the large Windschacht Reservoir in 1711. The absorption of the Dreifaltigkeit Erbstollen into the Oberbiberstollen Haupthandel in 1716, and the completion of deeper sinking at the old Neuhanget shafts—the former Neuschacht and Elisabeth shafts—in 1717, improved the finances of the emperor's mines. Despite these improvements, eight hundred horses were still used for hoisting by the mines in 1731.[26]

The deeper mine levels steadily increased production, and the record for annual production by the Schemnitz mines might have been the 1740 figures of 600 kilograms of gold and 25,835 kilograms of silver. This was the "golden age" for the Schemnitz mines, one that continued into the nineteenth century. The Kremnitz mint processed almost 420,000 kilograms of silver from this district alone between 1760 and 1800.[27]

Mathias Hell designed many additional engineering improvements, with their construction directed by his son and successor as district engineer, Joseph Carl Hell (1713–89). In 1744, the Reichauer Reservoir, on the River Thal southeast of Windschacht, and the Lower Hodritscher Reservoir were completed. Three more distant reservoirs, the Krechesengrunder and two named Kollbacher, were completed from 1731 to 1740. The younger Hell installed a Newcomen "fire engine" at the Josef Shaft between 1733 and 1736, the first Newcomen steam engine to be used on the European continent. The engine was apparently somewhat successful, notwithstanding its distant source and the expense of the large amount of wood fuel it required.

The Hells, father and son, also designed an improved balanced-beam steam engine to drive piston pumps. In 1738, they installed two of these at the Siglisberg Shaft, one above the other. These engines pumped 282.5 cubic meters of water from a depth of 162 meters without failure for a period of four years. The savings, in either case, could not have been substantial, however, because no other steam engines were erected at Schemnitz for one hundred years.[28]

The first hydraulic water-column engine for a Schemnitz mine was erected at the Leopold Shaft in 1749 (Figure 5), only one year after the machine's introduction in the Harz mines. The Leopold's engine raised water 575 feet to discharge into a drainage adit. Found more economical than steam engines, six similar water-column engines were installed later in other mines.[29]

Joseph Carl Hell designed and constructed a novel water-driven ventilation engine at the Amalia shaft on the Biber vein in 1753, using the same

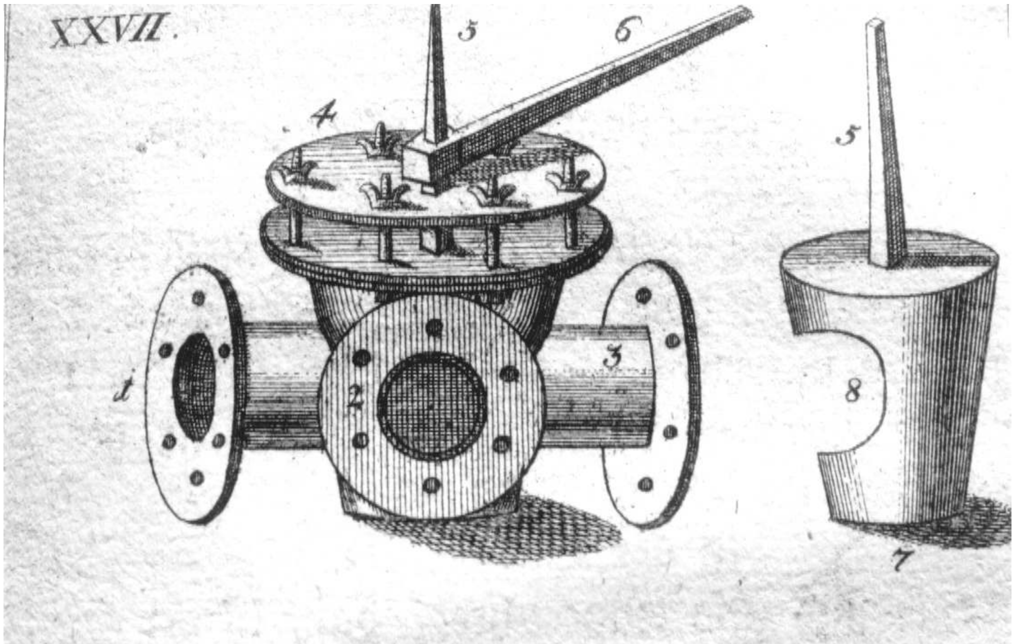

Figure 5: The metal tank of a water-column engine constructed by J. K. Hell in 1754 and used to drain mine water. Similar tanks were used in the hydraulic ventilation engine illustrated in Figure 6. (Poda, Kursgefasste Beschreibung*, 60.)*

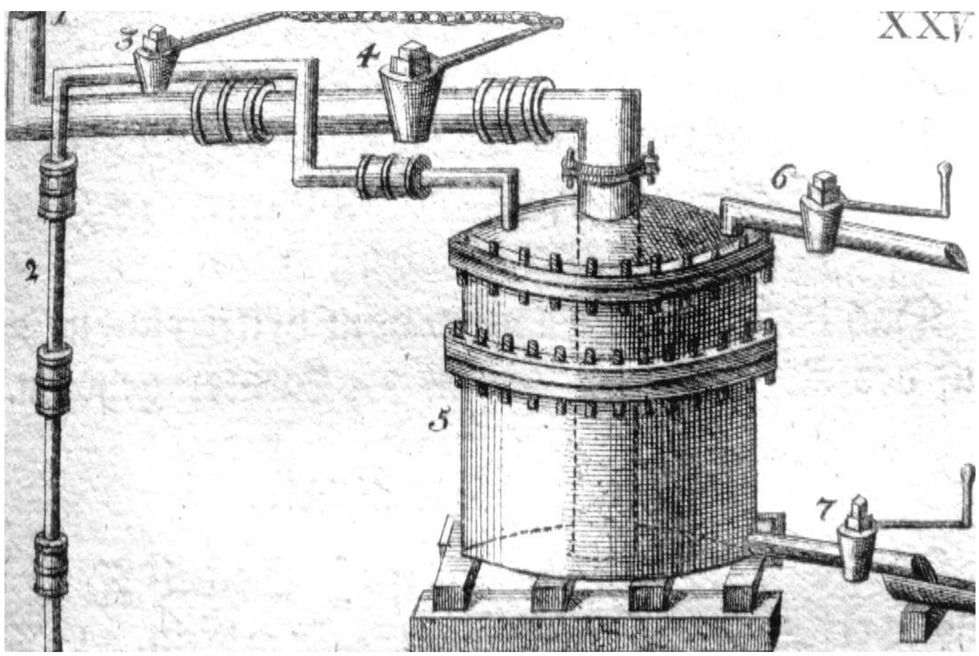

Figure 6: Parts of a ventilation engine constructed by J. K. Hell, 1753. The hydraulic pressure of water compressed air in a metal tank and forced it down to a lower level in the mine. Additional tanks and pipes were added to reach lower levels. (Poda, Kursgefasste Beschreibung*, 1771, 57.)*

hydraulic principle as the water-column engine. The Hell engine had pressure tanks, each holding water and air, vertically mounted on different mine levels. Descending water was used to drive air out of the lower tanks in order to ventilate the deeper levels of the mine. The engine required miners on each level to be within hearing distance to be able to judge when to open or close the water and air valves (Figure 6).[30]

The royal Oberbiberstollen Haupthandel profited again after 1735 because of the renovation of old buildings and the opening of new rich deep galleries in the Siglisberg, Windschacht, Theresia, and Wasser shaft areas. Profit increased to over one million guilders yearly in 1741. The Oberbiberstollen Haupthandel was able to remit eighty thousand guilders monthly to the Chamber in Vienna in 1748. Shortly thereafter, however, the expenses of reservoir excavation and constructing a new silver smelter in Zsarnowirz reduced these profits.[31]

Samuel Mikovini (1686–1750), royal surveyor for the district, planned some fourteen or fifteen new reservoirs. Many reservoirs were interconnected by ditches, leats, and tunnels. They received drainage from large catchments and provided sufficient power to the mines until the beginning of the twentieth century.[32]

In December 1747, J. K. Hell decided to extend the Hodritsch Erbstollen, originally completed in 1637, to connect with the Siglisberg Shaft on the southern edge of the Windschacht group of mines. The excavation of this four kilometer distance, using gunpowder, cost 350,000 florins and took eighteen years. In 1767, two years after this Kaiser Franz Erbstollen was completed, the working levels of some Schemnitz and Windschacht mines were already eighty-five meters below it. Nevertheless, the Kaiser Franz Erbstollen gave good service to the district.[33]

The Oberbiberstollen Haupthandel had nineteen ore-producing shafts, ranging from seventeen to four hundred meters in depth, and employed five thousand workers in its mines and smelters and a similar number in lumbering and transportation in 1749. In that year, private entrepreneurs owned as many as thirty small mining companies in addition to the monarchy's Haupthandel holdings.[34]

The Magdalena Shaft at Windschacht was badly affected by a mine fire in 1753. The Königsegger Shaft, southeast of Windschacht, had been deepened in 1753, and a Hell "fire engine" installed five years later. Hydraulic water-column engines were constructed in the Sigmund Shaft on the Johann vein in 1759, and in the Hoferstollner Mine in 1768. Excavation of Podschuwadler Reservoir commenced in 1768, and the sinking of the Johann Shaft followed in 1774. Pine-tree oil for miners' lamps replaced tallow candles for lighting in the Schemnitz mines during the period from 1770 to 1775.[35]

The Max Shaft in the footwall of the Johann Vein was completed in 1765, and this led to the discovery of an unexpected rich ore shoot, the Stefan Vein, in 1783. The Stefan vein was a fortunate development for the Oberbiberstollener Haupthandel, as many Schemnitz ore shoots had played out and production had fallen. The company made good profits from the Stefan vein for approximately two decades. Consequently, the less than two million guilders in the Oberbiberstollen treasury in Schemnitz in 1775 climbed to more than 4.5 million by 1800. Profits from the mines flowed into the imperial treasury, to be used mostly to pay the expenses of the long wars that maintained the Austrian Empire in the eighteenth century.[36]

On 19 March 1782, Mining Councillor Earl Joseph von Collorede inaugurated mining of what became the longest water-drainage adit in Europe. The portal of the Kaiser Joseph II Erbstollen, in the lower Hodritisch Valley, was at first designed to drain water from the mines near Hodritsch into the Hron River. This new adit was positioned to follow the alignment of the Kaiser Franz Erbstollen about 190 meters below it. Black powder blasting was used for most of the mining, and this adit was later lengthened to the east, to a total of 14.5 kilometers, to drain both the Windschaft and the Schemnitz mines.[37]

The Modern Era

Schemnitz Mining in the Nineteenth Century

The vitality of the mining industry and of the Oberbiberstollen Haupthandel weakened in the early years of the nineteenth century. The Haupthandel experienced major declines in productivity in the last half of the eighteenth century, but had always been saved by timely ore discoveries: by the Stefan vein, by a new Pacher gallery on the Spitaler vein, and in the Franz Shaft on the Grünner vein.[38]

But due to exhaustion of the richest parts of the Stefan vein, the disruptions caused by the Napoleonic Wars, and inflation in the prices of food and mine supplies, the mines could no longer sustain their former levels of productivity. Their decline was reflected in the outward flight of mine personnel from the Oberbiberstollen mines. At the start of the nineteenth century, 4,000 men worked these mines, in 1812 only 2,620, and in 1817 only 2,184. In addition, as many as 1,400 miners working for private companies had left the Schemnitz District by 1812.[39]

Although building the Hodritsch Reservoir dam cost 78,319 florins in 1811, it and a number of other projects produced some resurgence of the district's production. These undertakings included reopening the fire-damaged Magdalena Shaft at Windschacht in 1816, organizing the Andreas Shaft Company in the old Pacher adit area in 1821, sinking the Johann shafts beginning in 1825, constructing the first horse-driven mine railroad in the Dreifaltigkeits Erbstollen and Pacher Adit from 1825 to 1828, and building the dam for the Klingen adit reservoir from 1829 to 1834. The flight of miners from the district was partially mitigated in 1826 by transferring miners to the Oberbiberstollen Haupthandel from mines closed in the Tyrol, Slovenia, Kärnten in southeast Austria, and Croatia.[40]

Royal Council Minister Peter R. von Rittinger made a number of beneficial innovations. He introduced wet stamping at the district's gold mills in 1824, drum washers in 1844, and an ore crusher for the Windschacht dry stamping works in 1848. Rittinger also designed a steam-driven stamp works in Windschacht for reworking waste dumps at the Karl Shaft in the years from 1826 to 1828, with improvements in 1841. In 1832, he designed a water-column-driven stamp works at the Georg Adit in Dillen, however this soon proved too expensive to run and was discontinued. A water-turbine engine, possibly designed by Rittinger, was mounted at the Moder Adit stamping works in nearby Kohoutowathal in 1846.[41]

The construction of a factory to fabricate steel cables at Windschacht in 1837, the first such factory in Europe, led to general use of these cables for hoisting throughout the European mining industry. Experiments on blasting with gun cotton in 1847 did not give good results, but in 1850 the introduction of locally manufactured safety fuse—originally invented by the Englishman William Bickford in 1831—reduced miners' deaths and injuries from blasting at Schemnitz mines.[42]

Quantities of some of the mining materials used by the Schemnitz mines in 1863 were as follows: 412 hundredweight of rape-seed oil for miners' lamps, and 376,000 cartridges of blasting powder weighing 463 hundredweight and 63,255 fathoms of safety fuse weighing 12,651 hundredweight for blasting.[43]

The smelting methods used to treat Schemnitz's auriferous silver ores in the first three decades of the nineteenth century included fusion, crude smelting, and cupellation in the district. The product of these processes, a gold-silver-lead matte, went to refineries at Kremnitz (now Kremnica), Neusohl (now Banská Bystrica), and Zscharnowitz (now Žarnovica, ten kilometers west of Banská Hodruša).[44]

Groundwater Problems in the Nineteenth Century

The centuries-old problem of water flooding the deeper workings continued, however. The deep galleries in the Schemnitz mines, submerged to a depth of fifty-eight feet in 1828, were drained in the course of a year. A second flood, of the Oberbiberstollen deep workings in 1844, required six years and an expense of one hundred thousand florins to drain. A third flood of the Oberbiberstollen galleries occurred in 1861, followed by a three-year drought, meaning that reservoirs could not be replenished sufficiently to drive the waterwheels. Consequently, the lower levels were not entirely drained by 1866.[45]

New and more powerful hydraulic water-column engines installed in the Andreas Shaft in 1854 and in the Leopold Shaft in 1857 provided only partial solutions. In addition to those plants, miners installed new water-column engines in the Zipser Shaft in the Hodritsch Valley in 1852, at the Neue Anton Adit in 1855, and in the Eisenbach Valley at the Alte Anton Adit in 1856. The number of water-column engines operating in the district had increased to seven by the middle of the nineteenth century (Table 2).[46]

The great expense of purchasing and operating modern hoisting machinery could only be justified in the larger mines of the nineteenth century; smaller mines continued to use older equipment. In 1865, eight underground waterwheel engines and 24 whims driven by 140 horses still worked at Schemnitz. The late introduction of Watt-type steam engines to Schemnitz in the mid-nineteenth century was probably due to the scarcity of surface water, the absence of nearby coal fields, and to their purchase and operating costs. A steam engine was installed at the Mariahimmelfahrt Shaft in 1860–61, two others at the Sigmund and Leopold shafts in 1862. A fourth, associated with an underground water-column engine, was installed in 1872 (Table 2).[47]

In the last quarter of the nineteenth century, steam technology defused throughout the district. In 1878, a steam-driven water-hoisting engine was placed underground in the Franz Shaft in Schemnitz, steam being supplied to the engine by pipe from the surface. Two similar water hoisting engines were installed at the Heiligen Dreifaltigkeits Shaft in Eisenbach in 1879 and 1880. A fourth engine was placed on the first deep level at the Franz Shaft in Schemnitz in 1886 and, three years later, another three engines were added on

Shafts	Water-column engines	Steam engines	Horsepower
At Schemnitz-Windschacht			
Sigmund Shaft	-	1	100.0
Andreas Shaft	1	-	45.8
Leopold Shaft	2	1	64.6
Mariahimmelfahrt Shaft	-	1	28.0
Michael Shaft	1	-	28.0
At Hodritsch			
Zipser Shaft	1	1*	100.0
Neu Anton Shaft	1	-	9.2
At Eisenbach			
Alt Anton Shaft	1	-	4.0

** This engine pumped water from the Kaiser Joseph II Erbstollen before it was moved to the Zipser shaft.*

Table 2: Mine-Water Disposal Capacity of Schemnitz Mines in 1872 (From Zeiller and Henry, "Mémoire," 1873, p. 383.)

the second deep level of the same shaft.[48]

Seven shafts were active hoisting ore and water in the Schemnitz-Windschacht area in 1873: the Michael, Elisabeth, Andreas, Amalia, Max, Carl, and Franz (on the Grüner vein). The Zipser Shaft in the upper Hodritisch Valley was used to pump to the surface some of the water discharge in the Kaiser Joseph II Erbstollen.[49] The extension of that adit from the Hodritisch Valley to Schemnitz, completed in 1878, made the Kaiser Joseph II the world's longest underground gallery, with a total length of 16,538 meters, or 10.25 miles. It intersected and ended at the bottom of the Amalia Shaft in Windschacht.[50]

Compressed air drills and electric blasting were employed for the first time in the empire in the final years of excavating this drainage adit. Schemnitz miners adopted electricity at the beginning of the twentieth century, installing the first electrically driven water-hoisting engine at the Franz shaft in 1903. Electrically driven centrifugal water pumps were placed in the Oberbieberstollen Mine at Hodritsch in 1906.[51]

After 1878, Schemnitz had the world's most complex mine-water management system, with fifty-four dams and reservoirs, forty of which provided power to mining operations, ore treatment facilities, forges, and mills. The remainder supplied water to inhabitants or served as fish ponds. Although the Hodritsch and Steplitzhof valleys contained the major reservoirs, others lay in the surrounding watersheds and required seventy-two kilometers of collection canals and fifty-seven kilometers of race canals, tunnels, and leats to serve the engines and waterwheels. Many of these reservoirs still exist and are used for water supply and recreation.[52]

Mine Closures, Production Figures, and the District Today

District production from 1790 to 1858 amounted to 9,814 kilograms of gold, 440,540 kilograms of silver, and 331,785 metric tons of lead. The district's production dropped after 1858, however, with many mines closing because of lack of ore in the last half of the nineteenth century and the production of lead virtually abandoned. Even so, the district's precious-metals production remained considerable in 1891, at 437 kilograms of gold and 14,155 of silver. By 1907 those figures had declined to 114 kilograms of gold, and 4,541 of silver. Operating these mines became unprofitable in the late 1890s, but the state continued to subsidize them for about ten years. The Chamber of Mines closed the last mine in 1908, and the Habsburg Empire itself survived only another decade.[53]

Mining resumed in a small way at Banská Hodruša (formerly Hodritsch) for a few years before 1939, and the Czechoslovakian communist government restarted mining and milling at Banská Štiavnica after 1945. It is doubtful that this renewed mining ever became profitable by free-world standards, and the mines largely closed before 1990. Mining in the district collapsed completely with the end of state subsidies in 1993, but the Rozália Mine in the Hodruša District resumed gold mining in 1996, and was still operating when the author visited in 1999.

Total production of precious metals by the Schemnitz District is unknown, but one estimate is approximately five hundred tons of gold and nine thousand tons of silver from 1493 to 1908.[54] The Allerheiligan Mine in Hodritsch produced for over five hundred years. Schemnitz precious-metal production was important for Hungarian rulers, particularly the Hapsburgs, who derived wealth from it over almost four centuries. Schemnitz mining was known throughout Europe for its technological expertise in drainage adits, water supply systems, the early use of gunpowder, improvements in hoisting and ventilation machinery, and the first mining school and second mining academy in Europe.

The old center of Banská Štiavnica is now a UNESCO World Heritage Site and offers much of interest to mining historians. Features in the

Figure 7: The Klopačka (miners' knocking tower) in Banská Štiavnica (Schemnitz), built in 1681 from funds of the miners' fraternal union to house their office and a dwelling. The tower was used to summon miners to work by striking a resonant board with a wooden mallet. This summons is still sounded daily and for miners' funerals.

Figure 8: The Klopačka that summoned miners to work in Banská Hodruša dates from the beginning of the seventeenth century.

Figure 9: The former Kammerhof (mining chamber) in Banská Štiavnica, built in the sixteenth century on foundations of smaller thirteenth- and fourteenth-century structures joined by fortifications. This building was renovated in the baroque style after a fire in 1806, and now houses the Slovak National Mining Museum. (Author's photos, 1999.)

older part of town include miners' churches, the old and new castles, and many gothic and sixteenth- to eighteenth-century houses of metal traders and mine officials. Among other attractions are the mining academy's original buildings. The academy's former administration building now houses the Slovak central mine archive, containing over forty thousand documents, mine and geological maps, and art on the mining and smelting industries.[55]

The Slovak National Mining Museum is in Banská Štiavnica in the building that formerly housed the Chamber of Mines, which administered the mines and collected their taxes (Figure 9). The building that housed the Schemnitz mine court is now occupied by a mineral museum containing numerous Schemnitz and Kremnitz ore specimens. Another national mining museum lies outside of the town and has surface exhibits and an underground tour of two levels of an abandoned mine. A visitor could spend a week touring the town and its surroundings, for few mining districts display as much of their history as does Banská Štiavnica, whose residents are proud of its well-deserved World Heritage designation.

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Notes:

1. A. Zeiller and A. Henry, "Mémoire sur les Roches Eruptives et les Filons Métalliféres de District de Schemnitz (Hungarie)," in *Annales des Mines* 5 (1873): 283-355, 368.
2. Jozef Labuda, "Untersuchungen zur frühen Montangeschichte von Banská Štiavnica," *Der Anschnitt* 48, no. 2-3 (1996): 91. Viera Dvořáková and Štefánia Tóthová (ed.), *Banská Štiavnica, World Culture Heritage* (Bratislava: Pamiatkový Ústay, 1995), 6.
3. Gustav Faller, *Der Schemnitzer Metall-Bergbau in seinem jessigen Bustand* (Schemnitz: August Joerges, 1865), 4 (an off-print from "*Berg- und Hüttenmännischen Jährbuch XIV*").
4. Helmut Schröcke, "Mining and Settlement in Slovakia: An Historical Summary," *Geo-Journal* 32, no. 2 (1994): 127-35. Zeiller and Henry, "Mémoire," 364.
5. Helmut Wilsdorf, *Montanwesen—Eine Kulturgeschichte* (Leipzig: Edition Leipzig, 1987), 138.
6. Eugen Kladivik, "Zur Geschichte des Edel- und Buntmetallbergbaus im Slowakischen Erzgebirge," *Der Anschnitt* 50, no. 1 (1998): 14. Labuda, *Untersuchungen*, 92.
7. Vinc. Lipold von Marc, "Der Bergbau von Schemnitz in Ungarn," *Jahrbuch der Kaiser Kon. Geologischen Reichs-Anstalt* 17, no. 3 (1867): 355-6. Dvořáková and Tóthová, *Banská Štiavnica*, 16. F. Beyschlag, J. H. L. Vogt, and P. Krusch (S. J. Truscott, trans.), *The Deposits of the Useful Minerals and Rocks* (London: Macmillan, 1916), II, 538. Precious metal production at Kremnitz declined more rapidly with increased depth of mining than it did at Schemnitz.

   Lipold has an excellent bibliography on Schemnitz (321-9) and he used many manuscripts in archives at Vienna and Schemnitz. His account has the most detailed historical information on the geology, veins, mines, and precious-metals production of the Schemnitz district.
8. Zeiller and Henry, "Mémoire," 365.
9. Zeiller and Henry, "Mémoire," 354. Lipold, *Der Bergbau*, 356.
10. Eugen Kladivik, "Bergbau und Bergbautechnik im Slowakischen Erzgebirge," in R. Slotta and J. Labuda (eds.), *Bei diesem Schein kehrt Segen ein. Gold, Silber und Kupfer aus dem Slowakischen Erzgebirge* (Bochum: German Mining Museum, 1997), 50-9. Kladivik, "Zur Geschichte des Edel," 14-8.
11. Zeiller and Henry, "Mémoire," 364-5. Lipold, *Der Bergbau*, 356.
12. Zeiller and Henry, "Mémoire," 364-5. Lipold, *Der Bergbau*, 356. Faller, *Der Schemnitzer Metall-Bergbau*, 5.
13. Faller, *Der Schemnitzer Metall-Bergbau*, 5, 29. Zeiller and Henry, *Mémoire*, 366-7.
14. Faller, *Der Schemnitzer Metall-Bergbau*, 29.
15. Georgius Agricola, *De Re Metallica* (Lou and Herbert Hoover, trans.), (London: The Mining Magazine, 1912), 194-5.
16. Zeiller and Henry, *Mémoire*, 565-6. Fernand Braudel, *Civilization and Capitalism 15th-18th Century: The Wheels of Commerce* (Sian Reynolds, trans.), (New York: Harper and Row, 1982), 2, 323. Lipold, *Der*

Bergbau, 356-64, 366.
17. Lipold, *Der Bergbau*, 356-64, 366.
18. Zeiller and Henry, "Mémoire," 366. Lipold, *Der Bergbau*, 367.
19. Zeiller and Henry, "Mémoire," 366. Lipold, *Der Bergbau*, 367. Many authorities claim that this was the first use of black powder in an underground mine, but that appears to be doubtful.
20. Lipold, *Der Bergbau*, 366-8.
21. Lipold, *Der Bergbau*, 366-8. Kladivik, "Zur Geschichte des Edel," 14.
22. Kladivik, "Zur Geschichte des Edel," 14. Lipold, *Der Bergbau*, 367.
23. Lipold, *Der Bergbau*, 367 (quoting Eduard Brown, *Gantz sonderbare Reisen durch Niederland, Teutschland, Hungarn, Serbien etc.* (Nurnberg, 1711), 173). Brown (or Browne) spent much time in Vienna and in the Habsburg Empire and reported on the Hungarian mines. His travel account was first published in London in 1673.
24. Faller, *Der Schemnitzer Metall-Bergbau*, 29. Lipold, *Der Bergbau*, 367.
25. Lipold, *Der Bergbau*, 369-70. Zeiller and Henry, "Mémoire," 367.
26. Aleš Mázač, Ján Brehuv, and Ján Fabián, "Water-related Problems in the Banská Štiavnica Mines: The Past and the Present," in *Wasser Fluch und Segen.Schwazer Silber, 2nd Internationales Bergbausymposium, Schwaz 2003* (Bruneck: Berenkamp, 2004), 144.
27. Kladivik, "Zur Geschichte des Edel," 14.
28. Lipold, *Der Bergbau*, 370. Jozef Vozár, "Das Schemnitzer Bergwesen und die Gründung der Bergakademie," *Der Anschnitt* 50, no. 1 (1998): 21.
29. Zeiller and Henry, "Mémoire," 367.
30. Nicolaus Poda von Neuhaus, *Kursgefasste Beschreibung der, bey dem Bergbau zu Schemnitz in Nieder-Hungarn, errichteten Maschinen* (Prague: Walther, 1771), 66-74. Mázač, "Water-related Problems," 148.
31. Lipold, *Der Bergbau*, 370. Detailed descriptions and illustrations of the calcining and smelting methods used in Schemnitz in the first decades of the eighteenth century are available in: C. A. Schlutter, *De la Fonte des Mines, des Fonderies, &C* (2nd ed.; trans. and augmented by M. Hellot), (Paris: Chez Herissant, 1764), II, 185-6, 302-8. An account of mining and ore treatment techniques based on those practiced at Schemnitz in the eighteenth century appears in: Christoph Traugott Delius, *Anleitung zu der Bergbaukunst* (Vienna: Kaiserlich, Königlich, Hofbuchdruckern, 1773), passim. Delius' descriptions of techniques are based on those in use at Schemnitz in the eighteenth century, as this volume was intended for students at the Schemnitz mining academy.
32. Mázač, "Water-related Problems," 145.
33. Vozár, *Das Schemnitzer Bergwesen*, 20. Zeiller and Henry, "Mémoire," 367-8. Lipold, *Der Bergbau*, 370-1.
34. Vozár, *Das Schemnitzer Bergwesen,*20. Zeiller and Henry, "Mémoire," 367-8.
35. Lipold, *Der Bergbau*, 370-1. Poda, *Kursgefasste Beschreibung*, 63.
36. Lipold, *Der Bergbau*, 370-1. Zeiller and Henry, "Mémoire," 368.
37. Lipold, *Der Bergbau*, 371-3.
38. Lipold, *Der Bergbau*, 371-3.
39. Lipold, *Der Bergbau*, 371-3.
40. Lipold, *Der Bergbau*, 371-3.
41. Lipold, *Der Bergbau*, 371-3.
42. Lipold, *Der Bergbau*, 371-3.
43. Faller, *Der Schemnitzer Metall-Bergbau*, 32.
44. Arthur J. Phillips, *The Mining and Metallurgy of Gold and Silver* (London: E. and F. N. Spon, 1867), 427-32. Milan Hock, "Der Vorhüttung von Edel- und Buntmetallerzen vom 15. bis 20. Jahrhundert im Slowakischen Erzgebirg," in Slotta and Labuda, *Bei diesem Schein kehrt Segen ein*, 64. Kladivik, "Zur Geschichte des Edel," 14-5.
45. Lipold, *Der Bergbau*, 372. Faller, *Der Schemnitzer Metall-Bergbau*, 33-4.
46. Lipold, *Der Bergbau*, 372. Faller, *Der Schemnitzer Metall-Bergbau*, 33-4.
47. Lipold, *Der Bergbau*, 372. Faller, *Der Schemnitzer Metall-Bergbau*, 33-4.
48. Zeiller and Henry, "Mémoire," 368-9. Kladivik, "Zur Geschichte des Edel," 18-9. A disadvantage of underground steam engines was the corrosion caused by the condensation of steam in long cast-iron pipe lines.
49. Zeiller and Henry, "Mémoire," 368-9. Kladivik, "Zur Geschichte des Edel," 18-9.
50. Zeiller and Henry, "Mémoire," 368-9. Kladivik, "Zur Geschichte des Edel," 18-9.
51. Kladivik, "Zur Geschichte des Edel," 16, 19.
52. Mázač, "Water-related Problems," 145.
53. Kladivik, "Zur Geschichte des Edel," 14-5. Beyschlag, *Deposits,* 539.
54. Beyschlag, *Deposits*, 538-9.
55. E. Kasiarova and E. Sikorova, "Die künstlerische Gestaltung der im Staat. Zentralbergbauarchiv in Schemnitz aufbewahrten Bergkarten vom 17 bis 19 Jh." abstract in *Proceedings of the Cultural Inheritance in the Mining and Geosciences. Libraries – Archives - Museums, Leoben,* 1997, 13-4.