Mining Metals, Mining Minds:
An Exploration of Georgius Agricola's Natural Philosophy in *De re metallica* (1556)

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For my parents, Jim and Lisa

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Introduction

This is a study about authority. It analyzes the rhetoric and the practices that Georgius Agricola used to construct authority in *De re metallica* (1556). At a moment when natural philosophy was untidy and incoherent, Agricola sought to convince his readers that his thoughts were valid. Agricola's style of presentation was tactful, and his lens was unique. He framed his views on natural philosophy within the context of mining. *De re metallica* was not a treatise on natural philosophy. It was a comprehensive mining manual. Yet Agricola believed that the two were intrinsically linked. For him, natural philosophy served a practical role to miners. Agricola made deliberate choices in his presentation of the relationship between nature, man, and the mine. The central questions posed are as follows: how did Agricola fashion himself an authority on mining and what virtues did he need to demonstrate in order for his audience to be convinced of his observations' legitimacy.

The topic is worthy of study because it crosses disciplinary boundaries. Agricola wrote his mining text at a time that saw a momentous shift in religious thinking, the Reformation, coupled with a scarcity of bullion. The changing religious and economic climates had an effect on Agricola and the way he crafted his *De re metallica*. His milieu shaped his interactions with miners, his understanding of theory, and his explanations of practices. As Agricola straddled period labels, so too does this dissertation. The dissertation engages in religious, scientific, and intellectual history.

Agricola wrote *De re metallica* while working as a physician in Chemnitz, a town in Saxony, eastern Germany.[1] In 1531, at thirty-seven, Agricola began treating miners and their

[1] Many German historians have sketched Agricola's life. The German-language secondary literature on Agricola remains mostly biographical. See Helmut Bräuer, "Georgius Agricola als Chemnitzer Bürgermeister," in *Georgius Agricola, 500 Jahre*, ed. Friedrich Naumann (Basel: Birkhäuser Verlag, 1994), 230-232; Günther Wartenberg,

ailments. The men's occupation likely piqued the interest of Agricola, who himself was the son of an artisan. Agricola's father, Gregor Pawer, was a respected clothier in the Saxon village of Glauchau. Pawer's business was profitable enough to support the educational pursuits of his four sons. Agricola received a degree at the University of Leipzig and chose to continue his training as a student of medicine in Bologna. It was in Italy, while Agricola embarked on a medical degree, that he began to refer to himself as Georgius Agricola.[2]

After completing his studies in medicine, Agricola remained in Italy where he worked as an apprentice in a Venetian print shop.[3] By editing ancient Greek and Latin texts, Agricola furthered his studies in philology and translation. The print shop increased his exposure to classical texts. When he departed Venice to return to Saxony to practice medicine, he was well-equipped to argue for the importance of mining, now having gained a deeper understanding of the works of classical writers.

His training in cataloguing and editing classical sources is apparent in *De re metallica*. Agricola's inclusion and reinterpretation of classical texts was deliberate. He scattered references to antiquity in order to fashion himself as a learned man. Indeed, he chose not to shy away from revealing his medical knowledge, humanist proclivities, or religious sentiments. The ways in which he obtained his theories and communicated his findings exposed his personality, background, and virtues. What emerged was a natural philosophy that was uniquely his own. This dissertation argues that Agricola presented himself as an author who valued precision, faithfulness, and subjectivity. Those three virtues, in turn, entrusted him with an authoritative

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"Georgius Agricola und die geistigen Auseinandersetzungen seiner Zeit," in *Georgius Agricola, 500 Jahre*, ed. Friedrich Naumann (Basel: Birkhäuser Verlag, 1994), 67.

[2] See Wim François, "Ad divinarum rerum cognitionem. Petrus Mosellanus and Jacobus Latomus on biblical or scholastic theology," *Renaissance and Reformation* 29 (2005): 14; Hans Prescher, "Dr. Georgius Agricola 1494-1555: A European Scientist and Humanist from Saxony," *GeoJournal* 32 (1994): 86; and Bocchini Varani, "Agricola and Italy," *GeoJournal* 32 (1994): 151.

[3] The print shop belonged to Aldo Manuzio (1449/1452-1515). See Douglas F. Bauer, "Problems in the Aldine Pindar," *The Princeton University Library Chronicle* 76 (2015): 420.

claim to knowledge and made his natural philosophy more credible. While historians have used *De re metallica* to understand Agricola's motivations such as raising capital for Saxon mining ventures, they have yet to examine his approach to natural philosophy.

Agricola wrote *De re metallica* when western Europe was suffering from a decline in gold and silver production. In earlier centuries, the Black Death radically reduced the population of Europe and altered the European markets. The severe shortage of labor caused by the plague led to a drastic drop in output as compared to previous years.[4] In Germany, miners, smelters, and proprietors were searching for more efficient assaying methods because the Saxon and Bohemian mines were less productive and more expensive. At the same time, extracting and refining ores became more arduous because the veins were less abundant. The miners had to work harder to manipulate and extract the ores, and proprietors were compelled, simultaneously, to pay laborers higher salaries. The mines drained the German states financially and physically.[5]

Exacerbating the crisis was the influx of precious metals from the Spanish colonies in the Americas.[6] The expanding supply lowered the value of gold and created a moment of economic transformation that historians have since labeled the "price revolution." Despite disagreeing about whether specie (mostly silver) from the New World caused inflation in Europe, scholars generally agree that there was an increase in supply. On one side of the academic debate are those who believe that the bullion led to an increase in prices across Europe and produced a

[4] In the immediate aftermath of the plague, the output of the mines helped the amount of specie available per capita. See Glyn Davies, *A History of Money* (Cardiff: University of Wales Press, 2016), 166; John Day, "The Great Bullion Famine of the Fifteenth Century," *Past & Present* (1978): 3-54; Harry A. Miskimin, "Money and Money Movements in France and England at the end of the Middle Ages," in *Precious Metals in the Later Medieval and Early Modern Worlds*, ed. J.F. Richards (Durham, North Carolina: Carolina Academic Press, 1983), 79-96; John Munro, "Bullion Flows and Monetary Contraction in late-Medieval England and the Low Countries," in *Precious Metals in the Later Medieval and Early Modern Worlds*, ed. J.F. Richards (Durham, North Carolina: Carolina Academic Press, 1983), 97-158.

[5] John Day, "The Great Bullion Famine of the Fifteenth Century," 35; John U. Nef, "Mining and Metallurgy in Medieval Civilisation," in *The Cambridge Economic History of Europe from the Decline of the Roman Empire*, eds. Edward Miller, Cynthia Postan, and M.M. Postan (Cambridge: Cambridge University Press, 1987), 723.

[6] Pamela Long, "The Openness of Knowledge: An Ideal and Its Context in 16th-Century Writings on Mining and Metallurgy," *Technology and Culture* 32 (1991): 341.

balance-of-payments deficit. On the other side are historians who contend that the specie did not drive up prices, rather governments did. Scholars all agree that prices across Europe changed; yet they all use different primary sources to arrive at their differing conclusions.[7]

Implicit in these debates is the instability of mining. Agricola wrote his treatise at a period of transition when the German nobility sought to make mining more profitable. Before relocating to Saxony, Agricola worked in the town of Joachimsthal (now Jáchymov, Czech Republic), which saw a steady increase in mining operations at the outset of the sixteenth century. In particular, records from the village's mint indicate a gradual increase in the silver supply from 1529 to 1533. The mint officials marked a supply of "29,709 Mark in 1529, 34,495 Mark in 1531, 46,697 Mark in 1532, and […] 56,379 Mark in 1533."[8] Evidence from the mint confirms that the mines of Joachimsthal were prosperous. News circulated about the region's veins, attracting prospectors and entrepreneurs. Between 1518 and 1529, the Mining Office issued upwards of 800 mining permits.[9] With the number of mining ventures increasing, the district government's control grew in tandem with those ventures.

The surge in mining saw a concomitant expansion in regulations across Germany. The excavation of and the trade in metals were in the hands of the regional or local ducal administration. Officials served the duke, handling the financial and legal matters.[10] The duke

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[7] The particularities of this source base introduce one of the three significant problems of this entire dispute. In his book *American Treasure and the Price Revolution in Spain, 1501-1650* (1934), Hamilton looked only at the registry lists recorded in Seville by agents of the House of Trade (*Casa de Contratación*) and then made conclusions about the economic health of all of medieval and early modern Europe. The assumption, no doubt, is that all the European economies were connected. There was a global market. The debate continues to regenerate each time a scholar asserts a conclusion about Europe as a whole after having interpreted sources from one locale. It seems more sensible to evaluate each government and state's economy on its own terms.

[8] Jiri Majer, "Ore Mining and the Town of St. Joachimsthal/Jáchymov at the Time of Georgius Agricola," *GeoJournal* 32 (1994): 94. By Majer's calculations, one Erfurt Mark was between 234.5 and 235.4 grams of silver. See Idem, 98.

[9] Majer, "Ore Mining and the Town of St. Joachimsthal/Jáchymov at the Time of Georgius Agricola," 91.

[10] This system, termed the *Direktionssystem*, was not uniquely Saxon. Many mining districts adopted this approach. Historian John Nef found that the elites across central Europe relied on ancient Roman laws to assert their ownership. In the Roman Empire, the emperor claimed lordship over all mines, thereby seizing control over the

held all of the privileges to mining in the district. Agricola in his work was reluctant to describe the duke, his patron, as holding absolute power. Rather than depicting the operations as controlling, Agricola presented them as orderly.

The mining operations engaged the skills of a host of trained artisans: miners, smelters, assayers, smiths, and diggers. Each individual had a particular role. Agricola noted not only the activities of the artisans, but also the operations of the officials.[11] Playing a prominent role in Agricola's explanation was the *magister metallicorum*, known as the *Bergmeister* in German. The *Bergmeister* was the duke's chosen official charged with overseeing mining ventures. In the mines that Agricola visited, it was the *Bergmeister* who settled disputes, managed timbering, and monitored machinery. As articulated by Agricola, the *Bergmeister* was the mine's manager.[12]

Agricola curiously omits all the legal privileges held by the *Bergmeister*, however. The duke tasked the *Bergmeister* with conferring mining rights. The *Bergmeister*'s office divided the veins into sections called meers (*area fodinarum*), presumably in the hope of creating more mining opportunities.[13] Two simultaneous mining operations could extract more ore than a single large operation. Portioning the land created more equitable mining opportunities. It also called for more capital. Wealthy investors paid the miners' expenses, including their wages. Investors purchased shares, or *Kuxen*, without being confident that the mines would eventually turn a profit. Mining in early modern Saxony was a gamble. The only predictable characteristic of the mine was unpredictability.

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money supply and minting operations. The enormous size of the empire dictated the need for overlords to watch over the emperor's property. It was these appointed officials who granted laborers the privileges to mine on behalf of the emperor. See John U. Nef, "Mining and Metallurgy in Medieval Civilisation," 707-708. See also Christoph Bartels, "The Production of Silver, Copper, and Lead in the Hard Mountains from Late Medieval Times to the Onset of Industrialization," in *Materials and Expertise in Early Modern Europe: Between Market and Laboratory*, ed. Ursula Klein and E.C. Spary (Chicago: The University of Chicago Press, 2010), 79.

[11] Throughout this dissertation, the terms *artisans* and *craftsmen* are used interchangeably to identify the miners. A thorough discussion of these terms is found in the sixth chapter.

[12] Georgius Agricola, *De re metallica*, liber quartus, 69-70.

[13] Nef, "Mining and Metallurgy in Medieval Civilisation," 712-713.

Yet, Agricola wrote about the richness of the Saxon veins. He perhaps understood the importance of the investors' contributions and wanted to participate in courting them. He had an agenda. He described the order and the abundance of the Saxon mines in an effort to attract investment. In *De re metallica*, Agricola praised both the administrators and the miners.

The organization and efficiency of the Saxon mines struck Agricola in part because he lacked familiarity with mining practices. He was not trained as a miner. *De re metallica* is an outsider's examination of the tasks and techniques of an artisan population. It was published in Basel in 1556, a year after Agricola's death. As a how-to manual on mining practices, *De re metallica* falls into the larger tradition of conduct works aimed at teaching techniques and transmitting ideas. Agricola, similar to other authors of conduct manuals, appealed to the sensibilities of an erudite readership.[14] Yet, he chose to write in Latin and not in the vernacular. Such a choice signaled a desire to captivate a larger audience as more people could read Latin than German. Selecting Latin as his language of instruction meant that he could reach an audience that spanned Europe.

Recognizing perhaps that his large audience would have had only a passing familiarity with the occupation of mining, Agricola decided to be exacting in his explanations. He divided the work into twelve detailed books, each one devoted to a particular topic. His discussions of the practices, theories, workers, instruments, and institutions depict mining as a mentally and

[14] Famous examples of conduct books include Erasmus' *De civilitate morum puerilium* (1530), Castiglione's *Il Cortegiano* (1528), and Giovanni della Casa's *Il Galateo* (1558). Historians of the early modern period have focused a great deal on these how-to manuals. A more thorough discussion of the historiography on conduct literature occurs in Chapter 5. For some works within the scholarship, see Rudolph Bell, *How to do it guides to good living for Renaissance Italians* (Chicago: University of Chicago Press, 1999); Roberta L. Krueger, "Introduction: Teach Your Children Well: Medieval Conduct Guides for Youths," in *Medieval Conduct Literature: An Anthology of Vernacular Guides to Behavior for Youths*, ed. Mark D. Johnston (Toronto: University of Toronto Press, 2009), ix-xxxiii; Elaine Leong, *Recipes and Everyday Knowledge: Medicine, Science, and the Household in Early Modern England* (Chicago: The University of Chicago Press, 2018); Helena Sanson and Francesco Lucioli, "Introduction: Women and Conduct in the Italian Tradition, 1470-1900," in *Conduct Literature for and about Women in Italy 1470-1900*, eds. Helena Sanson and Francesco Lucioli (Paris: Classiques Garnier, 2016), 9-38.

physically laborious undertaking. Agricola devoted the first book to a justification of mining as an occupation. It had two purposes: one financial and the other religious. He wished to honor his patron, the Duke of Saxony, to whom Agricola dedicated the manual.[15] The first book also demonstrated to his Christian audience that mining did not destroy God's creation. By arguing that mining was a social good, Agricola defended the expensive exploits of the duke and secured patronage for himself.

Agricola expounded upon the virtues of mining through a focus on the miners themselves. In the second, third, fourth, and fifth books, Agricola emphasized the skills that mining required. He wrote in detail about the techniques that miners deployed to locate veins and survey mountainsides. Agricola believed that the miners had unique talents that led to the betterment of civilization, including simple ore extraction and the ultimate uses to which metals would be put.[16]

Agricola featured tools and machinery prominently within the text, devoting the last six books to an explanation of the miners' machinery. He described how the miners and metallurgists relied on tools to excavate, assay, smelt, and sort the metals. By Agricola's account, mining was not so different from other arts, such as agriculture.

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[15] Agricola, *De re metallica*, Epistola, 1.

[16] Agricola wrote that metals were useful to the physician because they cleaned wounds and cured ulcers. Painters also used metals to create pigments. Architects relied on metals to buttress their structures. Most importantly, metals created currencies and facilitated trade. Agricola declared, "*Primum autem ea utilis est medicis. Etenim (sic) essundit copiam medicamentorum, quibus uulnera et ulcera solent curare, pestis etiam: ut certe si nulla alia esset causa curscrutaremur terram, tamen medicinae gratia eam sodere debermus. Deinde utilis est pictoribus. Siquidem eruit genera pigmentorum, quibus cum ipsis tectoria picta fuerint, humor allapsus extrinsecus minus, quam caeteris nocet. Tum utilis est architectis. Etenim (sic) invesnit Marmora ad firmitatem magnorum aediūapta, et adornatum decora. Utilispraeterea estiis, quorum animus ad immortalem gloriam nititur. Nam essfodit metalla, est quibus nummi et statuae aliquae siunt, quae post literarummonimenta hominibus quodammodo aeternitatem, immortalitatem que donarit. Mercatoribus etiam utilis est, quod multis de causis, ut alias dixi, moneta, quae ex metallis conficitur, oportunior sit homini, quam rerum permutatio. Postremo cui non est utilis? Nam ut nunc praeteream et relinquam opera tam concinna, tam polita, tam elaborate, tam utilia, quae ex metallis in uarias figuras formant fabri aurarii, argentarii, aerarii, plumbarii, ferrrarii, quotusquis que Artifex sine metallis aliquod opus elegans et perfectum efficere potest. Certe si non utitur instrumentis ex ferro vel ex aere factis, neque lignea, neque lapidea sine eisdem potuerunt formari*." Agricola, *De re metallica*, liber primus, 14-15.

De re metallica was not Agricola's first declaration of the relevance of mining. He published *De ortu et causis subterraneorum* in 1544, followed closely two years later by *De natura fossilium*. In *De natura fossilium*, Agricola catalogued the minerals in two ways. First, he examined and compared their properties, placing them within his own theoretical taxonomy of composition. Second, he classified the metallic material based on human utility. He made note of the minerals that clerics used in religious rituals and those that physicians utilized in medicinal remedies.[17] Questions remain regarding the innovation of Agricola's classification systems, but, all of his texts were theoretically consistent. The texts supported each other, and they never contradicted each other. In fact, he frequently made references to his other two publications in *De re metallica*.[18] By citing his prior works, Agricola refrained from repeating himself and provided an avenue by which he could represent himself as a well-informed and prolific author.

[17] Historians such as W.R. Albury, D.R. Oldroyd, and Christoph Sander have also used *De natura fossilium* to come to terms with Pliny's influence in early modern Europe. See W.R. Albury and D.R. Oldroyd, "From Renaissance Mineral Studies to Historical Geology, in the Light of Michel Foucault's 'The Order of Things,'" *The British Journal for the History of Science* 10 (1977): 187-215; and Christoph Sander, "Magnetismus und Theamedismus: Eine Fallstudie zur Kenntnis der magnetischen Abstoßung in der Naturkunde der Frühen Neuzeit/Magnetism and Theamedism: A Case Study of Magnetic Repulsion in Early Modern Natural History and Science," *Sudhoff's Archiv* 101 (2017): 42-72.

[18] In one instance, when discussing how a person can taste the minerals and metals in water, Agricola reminded the reader that he had already discussed how the sea condensed bitumen that flowed into it from hidden springs in his book *De Subterraneorum Ortu et Causis*. He acknowledged, "*ex eis capre usum, atque afferre aliquid ad commune utilitatis fructum: rigor praeterea maris liquidum bitumen, quod ex occultis fontibus influit in ipsum, densat in succinum et gagatem, ut in libris de subterraneorum ortu et causis inscriptis, dixiutrum que vero idem mare certis ventorum flatibus commotum, in litora encit quocirca etiam captura illa succini, ut corallii, aliquam curam desiderat.*" Agricola, *De re metallica*, liber secundus, 24. Emphasis my own. He also wanted the reader to take note of the definitions that he had already furnished for the *vena cumulata* in *De Subterraneorum Ortu et Causis*, declaring "*alia magnam alicuius loci partem occupant in longum et latum ducta: quam cumulatam soleo vocare: nec enim quicquam aliud est quam aliquo sossilium genere cumulates locus, ut in libris De subterraneorum ortu et causis scripsi."* Agricola, *De re metallica*, liber tertius, 31. Emphasis my own. Similarly, he made reference to *De natura fossilium* when he was discussing all the types of metals he had observed. When searching for metals, the miner did not neglect digging their duties. It did not matter if they were extracting gold, silver, or stones. In every situation, the miner had to be aware of the solidified juices that coursed through the veins. Agricola did not go into too much detail because he had already described these tasks in *De natura fossilium*, "*Nec terrarum insignia sossionem negligit metallicus, sev inventae fuerint in au rariis, sev in argentariis, sev in aerariis alique: nec reliqui fossores si vel repertae fuerint in lapicidinis, vel in propriis venis. Earum vero bonitatis significationem sapor dare solet. Nec denique metallicus omittit curarc succos concretos in venis tam metallicis quam propriis inventos: sed eos colligit et comportat: verum de his plura non, dicam, quod omnem materiam metallicam et fossilem in libris, De natura fossilium inseriptis, uberius explicavi: sed redeo ad signa.*" Agricola, *De re metallica*, liber quintus, 77.

Historians have previously studied Agricola's vast literary output. *De re metallica* is not a newly discovered primary source. Agricola's how-to manual has captured the attention of historians of science and historians of technology and even the thirty-first President of the United States, Herbert Hoover.[19] The secondary literature on *De re metallica* can be divided into two categories: those analyzing the text's contents and those investigating the text's legacy. Histories falling into the first category have studied the innovativeness of Agricola's descriptions. Some have acknowledged the ingenuity of his illustrations. Pamela Long described the mental acuity required to perfect the woodcuts featured in the printed book. Agricola's publisher would have tasked only skilled illustrators to carve the image into the wood. The illustrators used chisels and knives to create ridges. They would have then poured ink over the wood, guiding it to fix itself onto the grooves and thus transferring the image onto the page.[20] Most recently, Thomas Morel has examined the geometry and the mathematics Agricola included in his text.[21] In the article "De Re Geometrica: Writing, Drawing, and Preaching Mathematics in Early Modern Mines" (2020), Morel concluded that Agricola grasped complex geometrical patterns and communicated them in a cogent manner. Morel stressed the importance of avoiding the classification of Agricola's endeavors as contributing to the rise of modern science.[22] Instead, Morel presents a compelling argument, but he fails to ask *why* Agricola would have been inclined to include "complex" geometrical equations or *why* he believed it necessary to make a reference to the

[19] Herbert Hoover and his wife Lou Henry Hoover took up the task of translating Agricola's text. It took them five years to complete the English translation. Hoover and his wife have been celebrated for introducing the text to the English-reading public. See Annette Bouheiry, "The Iron Library and its Agricola Collection," *GeoJournal* 32 (1994): 161-167.

[20] See Pamela Long, "Of Mining, Smelting, and Printing: Agricola's 'De re metallica,'" *Technology and Culture* 44 (2003): 97-101.

[21] Thomas Morel, "De Re Geometrica: Writing, Drawing, and Preaching Mathematics in Early Modern Mines," *Isis* 111 (2020): 22-45.

[22] He may have been aiming his assertion at Pamela Long, who believed that Agricola was the bridge between the speculative and mechanical arts. See Pamela Long, *Openness, Secrecy, Authorship, Technical Arts and the Culture of Knowledge from Antiquity to the Renaissance* (Baltimore: The Johns Hopkins University Press, 2001).

geometry used by ancient mathematicians.[23] What is missing from Morel's analysis is an investigation of Agricola's intellectual setting and an understanding of his audience.

Those historians wishing to sketch *De re metallica*'s readership and the work's impact on early modern mining fall into the second category. In "The Spread of Georgius Agricola's 'De Re Metallica' in Late Ming China" (1991), for example, Pan Jixing showed how the text reached mainland China in 1621. These Chinese miners used it as an instructional manual and guide. Jixing concluded that the specialized knowledge presented in the text filled a void in China.[24] The Chinese were in need of technical mining information, and Agricola's work provided a source.

Similarly, Pamela Long and Eric Ash have also used *De re metallica* to examine the dissemination of mining knowledge. In both *Openness, Secrecy, Authorship, Technical Arts and the Culture of Knowledge from Antiquity to the Renaissance* (2001) and "Trading Zones in Early Modern Europe" (2015), Long questioned the notion of ownership of technical knowledge.[25] She located and tracked the instances where technicians eagerly shared their knowledge. In her works, Long used *De re metallica* as evidence of artisans teaching outsiders their craft. She asserted that Agricola was representative of a trend in authorship. The miners imparted their knowledge to him. Agricola then published the artisans' knowledge-set. The publication helped to bring an awareness to the technical craft and introduced it to the "world of the learning."[26] Long was not wrong in assuming that the publication would attract a learned audience, but she

[23] Morel, "De Re Geometrica: Writing, Drawing, and Preaching Mathematics in Early Modern Mines," 26; 45.
[24] Jixing traced the impact by cataloguing Chinese mining texts' attributions to *De re metallica*. After Jesuit missionary Nicolas Trigault introduced it to them, Chinese miners and authors began quoting Agricola and sharing the mining knowledge with others. See Pan Jixing, "The Spread of Georgius Agricola's 'De Re Metallica' in Late Ming China," *T'oung Pao* 77 (1991): 108-118.
[25] See Long, *Openness, Secrecy, Authorship, Technical Arts and the Culture of Knowledge from Antiquity to the Renaissance*; and Pamela Long, "Trading Zones in Early Modern Europe," *Isis* 106 (2015): 840-847.
[26] Long, *Openness, Secrecy, Authorship, Technical Arts and the Culture of Knowledge from Antiquity to the Renaissance*, 176.

failed to show in what ways Agricola himself presumed that his text would have intrigued an educated reader. Agricola knew and appreciated that his readership was educated and Christian. He thus made deliberate choices to make the text more appealing to them. My analysis of Agricola's social and religious context is the missing piece to Long's analytical puzzle.

Where Long assumed Agricola's readership, Eric Ash had a record. In his book *Power, Knowledge, and Expertise in Elizabethan England* (2004), Ash studied the dynamic between English shareholders and their German mining partners in sixteenth-century England. The historian used *De re metallica* as proof of the Germans' technical expertise. Agricola's work established the Germans as mining experts. According to Ash, the English recognized this expertise and invited the Germans to participate as consultants to the English in their mining operations in Cumberland in northwest England.[27] In Ash's analysis, Agricola played a role in furthering English mining operations.

This dissertation places *De re metallica* at the center. Scholars who have previously studied the text have dismissed the ways in which Agricola promoted his own personal and distinct understanding of natural philosophy. Historians have taken for granted the multiplicity of natural philosophies that existed in the early modern period. If nothing became standardized, how then did certain knowledge-claims come to be matters of fact? Presumably aware of the competing modes of thought, Agricola chose to demonstrate his medical knowledge, humanist proclivities, and religious sentiments. His rhetoric and practices exposed his personality,

[27] Eric H. Ash wrote, "Without the sort of expertise they would need to run a mining operation themselves, the English partners were forced to rely entirely upon the German partners to provide it. Yet the introduction of German mining expertise created a fresh crisis of management for the English, who found themselves unable to monitor or control to their satisfaction the experts they had acquired, and thus they were unable to trust them. The Englishmen's ignorance had made the German experts necessary, but it also made them a threat, because there was no independent means to verify their competency and honesty." Eric H. Ash, *Power, Knowledge, and Expertise in Elizabethan England* (Baltimore: The Johns Hopkins Press, 2004), 53-54.

background, and virtues, which in turn made him a more credible authority on the subject not just of mining but also of natural philosophy.

Natural philosophy is an amorphous category that has become somewhat of a catch-all for historians of the early modern period. Some scholars have even used *natural philosophy* in the place of *scientia*, but they end up employing *natural philosophy* to imply (modern) science.[28] Historians have attempted to skirt the issue of anachronism by analyzing the particularities of natural philosophy, such as the discipline's characteristics[29] and its practitioners.[30] These studies all illuminate patterns of growth in the formation of the discipline, but the authors' gazes were strained. In attempting to define the field of natural philosophy in the early modern period, historians of science positioned early modern natural philosophy with respect to the contributions of seventeenth-century English men, such as Francis Bacon (1561 – 1626) and Robert Boyle (1627 – 1691). These histories have all proved instructive as they encouraged historians to

[28] The perfect example of this occurs in David Lines's article, "Natural Philosophy in Renaissance Italy: The University of Bologna and the Beginnings of Specialization." He wrote, "The role of science ("natural philosophy") in the early modern universities has not been the object of much serious investigation, due to the common assumption that the universities were either hostile to new approaches to science or were simply too sclerotic to be able to entertain new ideas." David A. Lines, "Natural Philosophy in Renaissance Italy: The University of Bologna and the Beginnings of Specialization," *Early Science and Medicine* 6 (2001): 267.

[29] See Andrew Cunningham, "The Identity of Natural Philosophy. A Response to Edward Grant," *Early Science and Medicine* 5 (2000): 259-278; Peter Dear, *Discipline & Experience: The Mathematical Way in the Scientific Revolution* (Chicago: The University of Chicago Press, 1995); Peter Dear, "The Meanings of Experience," in *The Cambridge History of Science, volume 3*, eds. Katharine Park and Lorraine Daston (Cambridge: Cambridge University Press, 2008), 106-131; and Rob Iliffe, "The Masculine Birth of Time: Temporal Frameworks of Early Modern Natural Philosophy," *The British Journal for the History of Science* 33 (2000): 427-453.

[30] See Ann Blair, "Mosaic Physics and the Search for a Pious Natural Philosophy in the Late Renaissance," *Isis* 91 (2000): 32-58; Justin Robert Niermeier-Dohoney, "A Vital Matter: Alchemy, Cornucopianism, and Agricultural Improvement in Seventeenth-Century England," (PhD, diss., The University of Chicago, 2018); Adrian Johns, "Identity, Practice, and Trust in Early Modern Natural Philosophy," *The Historical Journal* 42 (1999): 1125-1145; Vera Keller and Leigh T.I. Penman, "From the Archives of Scientific Diplomacy: Science and the Shared Interests of Samuel Hartlib's London and Frederick Clodius's Gottorf," *Isis* 106 (2015): 17-42; Steven Shapin, "Pump and Circumstance: Robert Boyle's Literary Technology," *Social Studies of Science* 14 (1984): 481-520; Steven Shapin, *The Scientific Life: A Moral History of Late Modern Vocation* (Chicago: The University of Chicago Press, 2008); Steven Shapin, and Simon Schaffer, *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life* (Princeton: Princeton University Press, 1985); Koji Yamamoto, "Reformation and the Distrust of the Projector in the Hartlib Circle," *The Historical Journal* 55 (2012): 375-397.

describe how social, financial, and religious circumstances affected early modern individuals' definitions of their own enterprises. Yet, the concept of natural philosophy still remains vague.

What is more challenging is analyzing the characteristics of natural philosophy found within a mining text. *De re metallica* is different from scientific treatises that historians of the early modern era have traditionally examined. *De re metallica* does not contain methods for experiments, nor does it include correspondences with other so-called natural philosophers like those included in Steven Shapin and Simon Schaffer's foundational text *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life* (1985).[31] It is certainly not the early modernist's ideal primary source because it is not a straightforward presentation of a natural philosophy. It does not fit historians' mold. However, with some effort, *De re metallica* offers glimpses into Agricola's unique and utilitarian philosophy about the natural world. Agricola theorized that mining, and therefore nature, could serve humanity.

The utilitarian dimension of natural philosophy often gets examined through a Baconian lens. Peter Dear, Benoît Godin, Sarah Irving, James A.T. Lancaster, and Rhodri Lewis have turned to Francis Bacon's endeavors to argue that he brought a practical and utilitarian approach to both natural history and natural philosophy.[32] They see Bacon as overthrowing the Aristotelian ideal focused primarily on *theorica*. Instead, he called for the merging of *theorica* and *practica*. This fusion changed the content of natural philosophy, and what emerged was an emphasis on

[31] Steven Shapin, and Simon Schaffer used the methods and correspondence between Thomas Hobbes and Robert Boyle to establish how matters of fact were negotiated and later became solidified in early modern England. See Steven Shapin, and Simon Schaffer, *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life* (Princeton: Princeton University Press, 1985).

[32] See Peter Dear, "What is the History of Science the History of?: Early Modern Roots of the Ideology of Modern Science," *Isis* 96 (2005): 393-395; Godin, Benoît. "Representation of 'Innovation' in Seventeenth-Century England 'A View from Natural Philosophy.'" *Contributions to the History of Concepts* 11 (2016): 24-42; Sarah Irving, "Rethinking Instrumentality: Natural Philosophy and Christian Charity in the Early Modern Atlantic World," *HOPOS: The Journal of the International Society for the History of Philosophy of Science* 2 (2012): 55-76; James A.T. Lancaster, "Natural Knowledge as a Propaedeutic to Self-Betterment: Francis Bacon and the Transformation of Natural History," *Early Science and Medicine* 17 (2012): 181-196; and Rhodri Lewis, "Francis Bacon and Ingenuity," *Renaissance Quarterly* 67 (2014): 113-163.

utilitarianism.[33] Agricola, however, disproves this timeline of events. A century before Bacon ushered in the "new" era of natural philosophy, Agricola was already blending *theorica* and *practica* to better understand how nature could help humanity. He believed that the extraction of minerals and metals required both theoretical and practical components.

Because he accumulated and catalogued information about the natural world, Agricola may belong under the umbrella of natural history. In fact, other scholars have tried to define natural philosophy in comparison to natural history. Early modern natural historians followed in the footsteps of Pliny, aiming to produce practical effects and choosing to concern themselves with particulars.[34] Natural historical endeavors were qualitative and taxonomical.[35] Natural philosophers, on the other hand, sought to explain natural phenomena. Theirs was a contemplative pursuit. The early modern label of natural philosophy inherited its characteristics from Aristotle. Natural philosophy was purely speculative.[36]

Historians have attempted to distinguish between the two fields as Aristotle would have done. Yet they encounter difficulty because the identifying appellations were not necessarily employed consistently and uniformly by their historical actors. Paula Findlen, for instance, examined natural history's formation in Italy through the prism of museums. In *Possessing Nature* (1994), Findlen argued that museums sparked and nurtured a curiosity about nature that encouraged the formation of natural history as a discipline. Her focus was on natural history, but

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[33] Dear, "What is the History of Science the History of?: Early Modern Roots of the Ideology of Modern Science," 393-395.

[34] Sorana Corneanu, Guido Giglioni, and Dana Jalobeanu, "Introduction: The Place of Natural History in Francis Bacon's Philosophy," *Early Science and Medicine* 17 (2012): 4; Brian W. Ogilvie, *The Science of Describing: Natural History in Renaissance Europe* (Chicago and London: University of Chicago Press, 2006), 1.

[35] See Sarah Irving, "Rethinking Instrumentality: Natural Philosophy and Christian Charity in the Early Modern Atlantic World," *HOPOS: The Journal of the International Society for the History of Philosophy of Science* 2 (2012): 65; Paula Findlen, *Possessing Nature: Museums, Collecting, and Scientific Culture in Early Modern Italy* (Berkeley: University of California Text, 1994), 58.

[36] Dear, "What is the History of Science the History of?: Early Modern Roots of the Ideology of Modern Science," 393-394.

she conceded that her historical actors identified themselves as "natural philosophers…as it allowed them to traverse the boundaries between medicine, natural history, and natural philosophy."[37] For Findlen, the distinction between natural philosophy and natural history was ambiguous.

However, unlike Findlen's Italian protagonists, Agricola never identified himself as a natural historian nor a natural philosopher. And yet he practiced a natural philosophy that had elements of natural history. He observed and catalogued natural phenomena like natural historians, all the while theorizing about his surroundings. His methods may have been reminiscent of a natural historical approach, but they were in the service of the theoretical framework of natural philosophy.

Agricola does not quite fit into the categories established by historians of science. Contributing to the difficulty of placement is the fact that historians of science focus on either steady growth or cataclysmic change. That is, the historiographical tradition favors "uniformitarian and catastrophist terms."[38] Undoubtedly, this approach builds on the research of Thomas Kuhn.[39] Historians of science have searched for conformity and nonconformity in

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[37] Findlen, *Possessing Nature: Museums, Collecting, and Scientific Culture in Early Modern Italy*, 9.
[38] Lorraine Daston and Peter Galison, *Objectivity* (New York: Zone Books, 2010), 49.
[39] In *The Structure of Scientific Revolutions* (1962), Kuhn separates the unique Scientific Revolution from standard scientific revolutions. He does not consider the Scientific Revolution a sweeping historical phenomenon; nor does he confine himself to Hessen's limited temporal scope. Most crucially, Kuhn's sequence of normal science—anomalies—crisis/revolution—normal science accommodates other disciplines that Hessen excluded from his analysis, namely nonmathematical physics. Revolutions, or paradigm shifts, are the engines of creative growth. They are, however, rare occurrences. Normal science and puzzle-solving is key to scientific research. By examining research activities, Kuhn demonstrates how there exists a structure to scientific revolutions. His proposed trajectory of scientific 'progress' begins with normal science, "research firmly based upon one or more past scientific achievements, achievements that some particular scientific community acknowledges for a time as supplying the foundation for its further practice." Normal science is goal-oriented; its aim is refinement, not novelty. But then anomalies appear. These inexplicable facts or experiments that do not comply with existing models can only be recognized against the tradition of normal science. The entire enterprise of normal science, it should be noted, is dependent on faith. The rejection of an old paradigm occurs once "an alternate candidate is available to take its place." The decision to accept one paradigm and jettison another involves the comparison of both paradigms with nature and with one another. The switch constitutes a theory choice, which makes science what it is today. This transition to a new theory (or paradigm) is a scientific revolution. Thomas Kuhn, *The Structure of Scientific Revolutions* (Chicago: The University of Chicago Press, 2012), 10; and 77.

scientific thought and practice. Trouble arises, however, for early modernists who feel compelled to situate their historical actors in relation to the great paradigm-shifting Scientific Revolution.[40] This dissertation dispenses with the trappings of the Scientific Revolution. It discusses Agricola without relying on the concept. Studying Agricola on his own terms leads to a more careful, less teleological view of the nuances of knowledge claims in the early modern world.

This dissertation contributes to the on-going historicizing of natural philosophy in the early modern period. Agricola composed a study of the natural world from information that he gathered first-hand. He witnessed the tasks performed by miners, and then he articulated those observations to his readers. He brought the reader into the miners' workspaces. Agricola presumably desired that his audience experience the mine as he had done—through the senses. *De re metallica* represents a process of sensory engagement and logical reasoning. In his descriptions, Agricola drew upon a vast literary and philosophical repository. He reconciled his experiences to ancient texts. In this way, Agricola reconfigured existing resources to make sense of his findings. He reshaped theories, while introducing his own. Agricola's depiction of the natural world suited his purposes. It was a uniquely personal endeavor.

[40] The Scientific Revolution has come to signify such an upheaval of science. The Scientific Revolution is often considered to be the central episode in the history of science because it saw the emergence of modern empiricism in Europe. Here the infinite Newtonian universe supplanted the finite Aristotelian cosmos. The revolution rescinded and then smashed the authority of both the ancient and medieval worlds. Nature became mathematized. Experience challenged tradition. The growth of the scientific spirit heroically triumphed to form modern science, or so the argument goes. But was the Scientific Revolution a mere accident? Assessing its depth and scope, historians have attempted to answer what it was, *why* did it happen, and why did it happen *when* and *where* it did. See H. Floris Cohen, *The Scientific Revolution: A Historiographical Inquiry* (Chicago: The University of Chicago Press, 1994), 14-16; Harold J. Cook, "Moving About and Finding Things Out: Economies and Sciences in the Period of the Scientific Revolution," *Osiris* 27 (2012): 105; and Steven Shapin, *The Scientific Revolution* (Chicago: The University of Chicago Press, 1996). Historian of science Marwa Elshakry has claimed that the invention of the Scientific Revolution "sealed off the West from the rest and helped to create a convenient time frame for science's own modern incarnation. It also helped to set the agenda for how the discipline itself would subsequently view the world, as a new emphasis on a universal and unilinear history of science merged seamlessly with postwar modernization theories." Marwa Elshakry, "When Science Became Western: Historiographical Reflections," *Isis* 101 (2010): 108.

Agricola's analysis of mining prompts historians to reevaluate their presentation of natural philosophy as a monolith. Agricola demonstrates how dynamic the field actually was. There existed a multiplicity of natural philosophies in the early modern period. By cataloguing his findings about mining, he made a bold claim about natural philosophy. He practiced an iteration of natural philosophy that was methodological and normative. He described to his audience what natural philosophy could be. Experiencing and understanding the natural world, for Agricola, was a personal endeavor.

Agricola's observations about mining offer an opportunity to study the epistemic virtues in the inchoate field of natural philosophy. If every experience were personal and singular, then how could Agricola's be considered legitimate? Certainly, his readers would have held competing natural philosophies. Agricola established his credibility to his audience because he valued precision, faithfulness, and subjectivity. These three epistemic virtues imbued his writing with authority. He managed his own epistemological challenges by recording precise measurements, remaining faithful to ancient authors, and reminding the reader of his own bias. Precision, faithfulness, and subjectivity helped to promote Agricola as a man of authority.

Lorraine Daston and Peter Galison were the first to introduce epistemologists' concept of epistemic virtues to historians of science. In their book *Objectivity* (2010), Daston and Galison traced the "emergence of epistemic virtues though atlas images."[41] They located a change in these images' evolutions. In the nineteenth century, objectivity became more visible and valued. Daston and Galison identified this new emphasis on objectivity as mechanical objectivity. The prominence of mechanical objectivity occurred in consequence of the scientists' use of the camera. The camera removed the scientist from the image's production. Machines could thusly buff away the dreaded human taint upon research. In their study, Daston and Galison

[41] Daston and Galison, *Objectivity*, 27.

demonstrated that scientific knowledge was as much about the world as it was about the knowers. For this reason, they examined the epistemic virtues of historical actors that molded the picturing of nature.[42]

Epistemic virtues, such as impartiality and curiosity, had an effect on the investigators of nature. These were the virtues that intellectuals would have internalized and enforced in an attempt to secure knowledge.[43] Epistemic virtues could exist in "quiet compatibility" or in severe conflict.[44] Agricola's epistemic virtues of precision, faithfulness, and subjectivity were not in competition. These three epistemic virtues shaped the collection and presentation of mining knowledge in *De re metallica*. Agricola's range of epistemic virtues affected the content of his view on nature. This dissertation focuses on the epistemic virtues found in Agricola's practices and rhetoric, arguing that the specific combination increased his authority. That is, he established his credibility though an appeal to his personability, thus producing and advocating an approach to the study of nature that was uniquely his own.[45]

The chapters of this dissertation proceed thematically with each focusing on a particular context in which Agricola did his writing. Each chapter relates Agricola's natural philosophy to another cultural tradition. The diversity of traditions impacted his methods of presentation. The first chapter is biographical, considering the ways in which Agricola's education in Germany and in Italy contributed to his intellectual growth. In particular, I examine how his university experience in Italy exposed him to the writers of antiquity, particularly Galen. The pedagogical culture of the Italian faculties of medicine stressed the importance of reading classical texts. The

[42] Daston and Galison, *Objectivity*, 28.
[43] Daston and Galison, *Objectivity*, 40-41.
[44] Daston and Galison, *Objectivity*, 28.
[45] Steven Shapin explored the celebrated "mark out" of impersonability in the natural sciences in his text *The Scientific Life* (2008). He contended that people and their virtues "have always been pertinent to the making, maintenance, transmission, and authority of knowledge." Shapin, *The Scientific Life: A Moral History of Late Modern Vocation*, 4.

teaching at Bologna equipped him uniquely, for instance, to discuss the ailments of the miners by making reference to ancient writers' explanations of bodily functions. His knowledge of medicine appears throughout *De re metallica*. He did not disassociate the doctor from the writer. Quite the opposite occurred. His experiences as a doctor provided a subjective lens to study mining practices and theories.

The second chapter continues the focus on education by examining more closely Agricola's training in the *studia humanitatis*. Agricola matriculated through a pedagogical system that valued grammar, poetry, rhetoric, history, and moral philosophy. Most significantly, acquiring a command of ancient Greek and Latin was imperative. The goal, according to some historians, was to emulate the writers of classical Athens and Rome.[46] Historians who have studied Agricola have flippantly described him as a humanist without defining the term with any specificity.[47] Who qualified as a humanist? What were humanist attributes? This chapter addresses the historiography of the heated debate. It also explores the ways in which Agricola affirms some historians' characteristics of humanism and the instances where he does not fit the category. I focus on Agricola's rhetoric here and argue that the culture of humanism did exist, and it influenced his writing. His desire to cull examples from classical authors reveals a humanist predilection. Yet, at the same time, he rejected his intellectual inheritance. He refused to follow the dialogue form of Cicero. He remained faithful to his ancient philosophical forebearers to the point when their ideas clashed with his own observations. He was loyal to their words, but he was not blindly devoted to them. The issue in this second chapter is two-fold:

[46] Paul Oskar Kristeller, "The Philosophy of Man in the Italian Renaissance," *Italica* 24 (1947): 93-94.
[47] See Owen Hannaway, "Georgius Agricola as Humanist," *Journal of the History of Ideas* 53 (1992): 553-560; Prescher, "Dr. Georgius Agricola 1494-1555: A European Scientist and Humanist from Saxony," 85-89; and Isabel Fay Barton, "Georgius Agricola's De Re Metallica in Early Modern Scholarship," *Earth Sciences History* 35 (2016): 265-282.

whether Agricola's text on mining is a recognizable humanist tract and whether his faithfulness hindered his claims about the natural world.

The third chapter continues the exploration into Agricola's intellectual setting through an examination of his thoughts on alchemy. He presented a new and different approach. Agricola identified metallurgists as alchemists and relied on the theories of his intellectual predecessors, namely Albertus Magnus (1200 – 1280) and Paracelsus (1493 – 1541). Agricola argued, rather controversially, that alchemists contributed to the betterment of civilization. Alchemists, according to Agricola, created tools and machinery for other craftsmen. At the time that Agricola wrote *De re metallica*, alchemy had the reputation of being a secretive, dishonest occupation. Agricola rejected the pejorative characterization by detailing the skills required to perform the alchemists' tasks. Agricola observed how it required intelligence and experience to understand when to remove an ore from a scorching furnace.[48] He recorded with precision his observations in awe of the smelters and assayers. By noting their techniques and providing his own commentary, Agricola re-characterized alchemy. This chapter discusses the theme of secrecy in knowledge-making alchemical practices. The techniques were not so secretive that Agricola could not observe and then document them.

In the fourth chapter, I explore the rhetoric Agricola used to justify mining as an honest and virtuous undertaking. Agricola believed that mining involved careful study of the landscape. The miners demonstrated how they searched for signs and indications of prosperous veins below the earth's surface. Agricola took the language further, and he noted the difference between those signs and miracles. While he made few overt references to his faith, *De re metallica* does contain

[48] When melting a small amount of ore, the experienced smelter would have used a gentle blast with the medium-sized quantities. A more violent blast was required for the later amounts. However, he would have used a much less fierce flame for the smelting of gold, silver, or copper. "*Quinetiam cum minutulos excoquit, leni folium flatu utitur: cum mediocres, mediocri: cum maiusculos, vehementi…multo tamen minus acri quam cum venas vel auri vel argenti, vel aeris excoquit*." Agricola, liber nonus, 331

evidence of a religious man synthesizing human behavior, financial woes, and mining profits. By examining the instances where Agricola invokes God's name, we can sort out how he practiced his religion. His beliefs worked their way, subtly, into the pages of this seemingly secular text.

Mining was a problematic topic. In some ways, Agricola crafted *De re metallica* as a response to critics who claimed that mining exploited God's creation. By drawing on the teachings of Augustine of Hippo (354 – 430) and Thomas Aquinas (1225 – 1274), Agricola argued that a miner's success was not exploitation, but a sign from God. He articulated that only God could determine the success of a given mine, and He could choose not to reward a miner or deny him success. Here I argue that by revealing his religious convictions, he appeared more human and thoughtful to the reader. His subjectivity buttressed his attempts to advocate for the ultimate good that mining ventures accomplished.

The fifth chapter takes up the previous chapter's religious themes by examining how Agricola crafted *De re metallica* with a specific readership in view. Agricola knew that his audience was educated and Christian. He thus appealed to logic and ethics in order to convey to the reader the virtues of mining and the integrity of its participants, while at the same time raising the status of mining. It is also essential to note that he wanted to reach a broad spectrum of the then literate public. He did not write in the vernacular. He used Latin because he wanted an expansive, informed readership. His stylistic and argumentative choices were deliberate, and they helped to rehabilitate curiosity as an essential element in understanding and examining the natural world.

The final chapter speaks to Agricola's invitation into the artisans' space and explores the social dynamics between Agricola and the miners. The miners taught Agricola to measure and smelt ore. They shared their knowledge with him. Theirs was a technical craft, and Agricola

appreciated the miners' precision. He aimed to describe the miners' tasks in their language. He used their own vocabulary. For Agricola, these artisans participated in a community of learning. Here the third chapter's themes of practice and precision are explored in the context of the miners themselves. Agricola respected their acquisition of knowledge.

For convenience, the chapters of this dissertation focus on a distinct context; but in truth, the contexts overlapped. Agricola did not write in a vacuum. The socio-political and socio-economic climates affected his contribution. At a moment when natural philosophy was still an embryonic field, Agricola relied on precision, faithfulness, and subjectivity to promote his own ideas of the natural world. It was revolutionary that he used mining to reshape natural philosophy. This dissertation focuses on how Agricola's humanist proclivities, medical training, and religious sensibilities provided him with a foundation to advocate for an epistemological mining framework. Still unexplored are issues involving Agricola's patronage, Saxony's religious strife, and the text's broader reception. These topics can be elucidated in future studies. The chapters of this dissertation provide a launching pad from which scholars could begin raising questions as to how other social, religious, and economic dimensions affected Agricola's study of nature.

Chapter 1

All about Agricola: A Biographical Sketch

Agricola's training as a doctor and an editor in Italy made him uniquely qualified to write about mining practices in *De re metallica*. His exposure to ancient texts guided his transcriptions as an interpreter, influenced his work as a physician, and affected his writings as a scholar. His education began as a student in Germany learning Latin and Greek, continued as he applied Aristotelian doctrine to medicine in Italy, and crystallized in his Galenic translations in Venice. In order to grasp his approach to natural philosophy, it is essential to understand the education, experiences, and professions that would have inspired it. His experiences as a doctor provided a subjective lens to study mining practices and theories.

On 24 March 1494, Georgius Agricola was born in the town of Glauchau, in west Saxony. His father, Gregor Pawer, was a clothier, a trade that generated enough cash to support the educational pursuits of his four sons. His three daughters married well-regarded burghers of Glauchau.[49]

Agricola traversed the continent to receive his university training. After having gone to grammar school in Chemnitz, where he presumably learned the fundamentals of Greek and Latin, Agricola attended the University of Leipzig in 1514.[50] He enrolled in classes at a moment

[49] Hans Prescher, "Dr. Georgius Agricola 1494-1555: A European Scientist and Humanist from Saxony," *GeoJournal* 32 (1994): 85.

[50] Günther Wartenberg, "Georgius Agricola und die geistigen Auseinandersetzungen seiner Zeit," in *Georgius Agricola, 500 Jahre*, ed. Friedrich Naumann (Basel: Birkhäuser Verlag, 1994), 64. Agricola received an education at universities across Europe at a moment when universities were popping up across the European landscape. In the Middle Ages, twenty-nine institutions served the aristocracy of Europe. By the fifteenth century, twenty-eight new universities had appeared, and by 1625, there was a total of seventy-three. Undoubtedly, the increase in the number of universities correlates to a surge in student interest in higher education. The evidence of student enrollment encourages us to link university growth with student demand. See Paul Grendler, "The Universities of the Renaissance and Reformation," *Renaissance Quarterly* 57 (2004), 2.

when humanism was taking hold. Historian Günther Wartenberg saw the 1515-appointment of Englishman Richard Crocus, a well-regarded professor who taught Greek, as an indication of humanism's acceptance at Leipzig.[51] Agricola departed the university in 1518, henceforth referring to himself as Georgius Agricola.

After having Latinized his name, Agricola embarked on a doctor of medicine degree in Italy.[52] The first stopover on his Italian adventure was Bologna, northern Italy's main center for medieval learning.[53] Agricola would not have stood out as a foreign student. It was quite common for non-Italians to receive doctorates from Italian universities. European universities differed considerably from region to region, and each one had a particular area of focus and expertise.

Northern universities, especially German, and their Italian counterparts were different in two respects: their curriculum and their organization. Northern universities emphasized arts and theology, where Italian ones specialized in law and in medicine. Historian Paul Grendler has observed that in the sixteenth century, the universities of Vienna, Heidelberg, and Leiden "had

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[51] Günther Wartenberg, "Georgius Agricola und die geistigen Auseinandersetzungen seiner Zeit," 65; and Wim François, "Ad divinarum rerum cognitionem. Petrus Mosellanus and Jacobus Latomus on biblical or scholastic theology," *Renaissance and Reformation* 29 (2005): 14. Thomas Brady has argued that the change in university curriculum mirrored a change in leadership. Across Germany, professors replaced college masters as heads of universities. For Brady, the college masters' departure meant "that the medieval university…serve[d] the Church, [whereas] the early modern university…served the State." Thomas A. Brady, *German Histories in the Age of Reformations, 1400-1650* (Cambridge: Cambridge University Press, 2009), 24. See also Davide Cantoni and Noam Yuchtman, "Medieval Universities, Legal Institutions, and the Commercial Revolution," *The Quarterly Journal of Economics* 129 (2014): 840-841.

[52] See Prescher, "Dr. Georgius Agricola 1494-1555: A European Scientist and Humanist from Saxony," 86; and Bocchini Varani, "Agricola and Italy," *GeoJournal* 32 (1994): 151.

[53] Nancy G. Siraisi*, Medieval & Early Renaissance Medicine: An Introduction to Knowledge and Practice* (Chicago: The University of Chicago Press, 1990), 59. The University of Bologna competed with the University of Padua as the leading European institution in law, medicine, and the arts. It was certainly the larger of the two universities in the fifteenth century. In fact, Paul Grendler argued that the university was such a key element to civic identity that the *comune* of Bologna decided to pay the salaries of the medical professors in the 1220s. The practice ceased a decade later, and then resumed in 1280. Presumably, the civic officials recognized how much stability the university provided; thus wanting to guarantee that stability, they decided to support the professors financially. Paul Grendler, "The University of Bologna, the city, and the papacy," *Renaissance Studies* 13 (1999): 475-476.

only three or four professors of both law and medicine…in faculties of twenty or more."[54] From matriculation records, Grendler confirmed that the majority of professors at these three universities taught arts, including logic, philosophy, and the humanities.[55]

Yet the crucial difference between northern and Italian universities was the structure of the institutions themselves. In northern Europe, many universities had "senates empowered to make academic policy. They had professorial rectors or deans who led significant parts of the university, such as the faculty of theology."[56] The senates controlled the curriculum. The governing of an institution by another body was not new to the early modern period. Medieval German universities had their courses authorized and libraries confirmed by both the pope and the emperor. The Church supervised the universities. They were not autonomous; they were subjected to ecclesiastical oversight. What northern and Italian universities shared, however, was that they were sites of innovative research.[57]

Grendler has also noted that Italian universities famously welcomed students who had already completed their bachelor of arts degrees from another European university. In fact, students could complete only doctorate degrees in Italy because the Italian universities had stopped granting bachelor of arts degrees by about 1400.[58] Agricola furthered his education at a moment that historians have come to identify as the peak of student mobility. A zenith of travel for educational pursuits occurred in the latter half of the sixteenth century.[59] In his classrooms in Bologna, Agricola would have presumably encountered members of the German aristocracy.[60]

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[54] Grendler, "The Universities of the Renaissance and Reformation," 6.
[55] Grendler, "The Universities of the Renaissance and Reformation," 7.
[56] Grendler, "The Universities of the Renaissance and Reformation," 10.
[57] Grendler, "The Universities of the Renaissance and Reformation," 1.
[58] Grendler, "The Universities of the Renaissance and Reformation," 9.
[59] Hilde De Ridder-Symoens, "Mobility," in *A History of the Universities in Europe, volume ii: Universities in early modern Europe (1500-1800)*, ed. Hilde De Ridder-Symoens (Cambridge: Cambridge University Press, 1996), 417.
[60] Charles G. Nauert, "The humanist challenge to medieval German culture," *Daphnis: Zeitschrift fur mittlere deutsche Literatur* 15 (1986): 283.

He stepped foot onto a foreign campus, but he took a seat in a familiar pedagogical setting. Agricola and his peers would have all studied the same set of Latin texts.[61] In this way, Italian universities encouraged the formation of networks of peripatetic students who had a command of Latin.

A significant difference between German and Italian universities was pedagogical instruction. Historian Charles Nauert has argued that the Italian professors encouraged their pupils to embark on a specific intellectual program: humanism. Nauert found evidence of Italian instructors encouraging their students to read and analyze ancient texts. Nauert deemed this approach as the embodiment of humanism. He then went on to trace humanist strands of thought across Europe. He contended that Italian-trained Germans were responsible for encouraging humanism's growth in their home country.[62] Nauert concentrated solely on the diffusion of humanist thinking, but he neglected to explain the ways in which those Italian professors fostered a humanist spirit in the classroom. He was not concerned with showing humanism's inception at Italian universities. As a consequence, he portrayed all the faculties in the Italian university system as the same. He did not account for their nuances, nor did he focus on their particularities.

Historians have filled in some of the gaps left by Nauert by studying the pedagogical program in the faculties of medicine. They have found evidence of professors of medicine requiring students to read the works of Aristotle, Galen, and Hippocrates. Those texts arrived in Italy as the Arabic translations of Byzantine scholars, and they quickly became revered.[63] Some

[61] Davide Cantoni and Noam Yuchtman, "Medieval Universities, Legal Institutions, and the Commercial Revolution," 839.
[62] Nauert, "The humanist challenge to medieval German culture," 283.
[63] The introduction of Greek and Roman texts to Italian scholars helped those same scholars at universities challenge the current scholastic reasoning of the Middle Ages. In the Byzantine Empire, classical Greek literature experienced a revival with many scholars translating the works into Arabic. With an increase in trade between Italy and Byzantium, goods silk, purple, and gold embroidery were not the only commodities crossing borders. Without

instructors even esteemed the ancient texts above those written in the Middle Ages. Grendler noted that professors of medicine often "sneered at medieval medical texts and revered the ancient texts of Galen."[64] The Italian faculties of medicine introduced a program of study that trained students to rely on ancient medical works. The goal was to create innovative medical practices. By imitating the ancient writers, the students would have arrived at new medical conclusions and new anatomical studies.[65] It is precisely this education that Agricola would have received in Italy. His was a training that blended humanist traits and medical theories.

Historian of medicine Nancy Siraisi has used the term *medical humanism* to describe the ways in which humanists influenced the study of medicine. She believed that an early modern doctor would have brought a new perspective to the field of medicine because he would have stressed philology. His approach would have differed from his older peers because he would have featured his linguistic skills. According to Siraisi, early modern doctors emphasized the philological elements of ancient Greek when they clarified the medical advice of an ancient author. Those like Agricola who were entrenched in the traditions of *medical humanism* would have edited, translated, and transcribed a relatively small number of texts by Hellenist scholars.

The focus on language would have also served Agricola in his interactions with patients. His humanism instruction would have provided him with the tools to communicate eloquently and succinctly. Speaking well would have certainly secured his patients' confidence. Perhaps they would have been even more inclined to take directions and facilitate cures.[66]

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question, western Europe's introduction to ancient medicine occurred because of the labor of scholars in the East. The twelfth-century translations movement of Byzantine intellectuals gave European physicians access to the Latin versions of classical texts. See Robert Sabatino Lopez, "Silk Industry in the Byzantine Empire," *Speculum* 20 (1945): 1-2; and Paul Oskar Kristeller, "The Philosophy of Man in the Italian Renaissance," *Italica* 24 (1947): 95.

[64] Grendler, "The Universities of the Renaissance and Reformation," 13.

[65] Grendler, "The Universities of the Renaissance and Reformation," 13.

[66] Nancy G. Siraisi, "Oratory and Rhetoric in Renaissance Medicine," *Journal of the History of Ideas* 65 (2004): 191.

Familiarity with philosophers soon became commonplace amongst physicians, who began their academic training in the arts faculty. From its inception, the faculty of medicine required its students to learn both theory and practice. Professors of medicine designed the medical curriculum to include both the reading of ancient literature and the acquisition of technical skills. The conventional career trajectory of a medical student "progressed from logic, through natural philosophy, to medicine."[67] The medical program had a robust curriculum in moral philosophy, mathematics, and Greek and Latin literature; but the stress was on logic, natural philosophy, and medicine. It would be unwise to attribute all the advances of medicine in the fifteenth, sixteenth, and seventeenth centuries to *medical humanism*. But it would also be a mistake to deny its transformative effects. By critiquing these texts, early modern physicians confronted their own realities of the natural world, prompting investigations and case studies.[68] By the sixteenth century, the Italian medical faculties took seriously the philosophical component of their skills.[69] The method of *medical humanism* was at once cerebral and practical. At the University of Bologna, Agricola received an education that included courses resolving both anatomical conundrums and philosophical issues.

That unique approach to biology and philosophy has led some historians to declare that medical humanists redirected the field of natural philosophy. Hiro Hirai identified humanistic-

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[67] Charles B. Schmitt, "Aristotle among the physicians," in *The medical renaissance of the sixteenth century*, eds. A. Wear, R.K. French, and I.M. Lonie (Cambridge: Cambridge University Press, 1985), 4.

[68] Nancy G. Siraisi, *History, Medicine, and the Traditions of Renaissance Learning* (Ann Arbor: The University of Michigan Press, 2007), 263.

[69] Nancy G. Siraisi, *Medieval & Early Renaissance Medicine: An Introduction to Knowledge and Practice*, 66. Because the sixteenth-century physician required knowledge of logic, natural philosophy, and medicine, he was paid more handsomely than his natural philosophy counterparts. According to Charles Schmitt, the career of a medical student progressed equally in social prestige and financial reward. In fact, the University of Bologna awarded its first *laurea* in medicine in 1268. Following that conference, the city granted tax privileges to medical students and professors. It should also be noted that physicians classified themselves beginning in the Middle Ages. At the top of the prestige pyramid were the surgeons, while the apothecaries gathered at the bottom. See Schmitt, "Aristotle among the physicians," 4; and Siraisi, *Medieval & Early Renaissance Medicine*, 60; and Roy Porter, *The Greatest Benefit to Mankind: A Medical History of Humanity from Antiquity to the Present* (London: Harper Collins Publishers, 1997), 11.

trained physicians such as Gerolamo Cardano (1501 – 1576), Marsilio Ficino (1433 – 1499), and Jean Fernel (1497 – 1558) as having all contributed to "redirect[ing] [a] philosophy toward natural questions."[70] Andrea Carlino also qualified the medical humanists' style as singular and "peculiar to the *studia humanitatis* [as] they gaze fixed on the past, yet directed toward a radical recasting of learning."[71] While both Hirai and Carlino conceded that the community of medical humanists was anything but coherent, they did stress the elements that the intellectuals shared. Chief among those characteristics was the importance of reading and rhetoric. More specifically, Hirai acknowledged that medical humanists turned to the works of ancient authors like Galen to provide "the traditional and authoritative explanatory tools of philosophy and medicine."[72] Medical humanists used classical texts to make sense of the human body. The pivot that Hiro and Carlino identified occurred most prominently when the classical authorities did not provide satisfactory answers, such as the problem of generation.[73] The only way, however, to understand the pitfalls of classical theories was to study them closely. Humanistic-trained physicians like Agricola had the opportunity to read classical Greek and Latin texts when they received their medical training as these ancient sources grounded the medical curriculum of Italian universities.[74]

The most significant ancient writer was Galen (129 – 210). Galen had always held prominence within medical faculties across Europe during the Middle Ages. In the thirteenth century, the limited corpus of Galenic writings began to permeate the medical faculty and to form the basis of university training. Perhaps Galen's texts resonated with medieval and early

[70] Hiro Hirai, *Medical Humanism and Natural Philosophy: Renaissance Debates on Matter, Life and the Soul* (Leiden: Brill, 2011), 3.
[71] Andrea Carlino, "Medical Humanism, Rhetoric, and Anatomy at Padua, circa 1540," in *Rhetoric and Medicine in Early Modern Europe*, eds. Stephen Pender and Nancy S. Struever (New York: Routledge, 2012), 114.
[72] Hirai, *Medical Humanism and Natural Philosophy: Renaissance Debates on Matter, Life and the Soul*, 4.
[73] Hirai, *Medical Humanism and Natural Philosophy: Renaissance Debates on Matter, Life and the Soul*, 4.
[74] See Nancy G. Siraisi, *Medicine and The Italian Universities, 1250-1600* (Leiden: Brill, 2001), 24; and Siraisi, *Medieval & Early Renaissance Medicine*, 49.

modern audiences because he stressed a balance between theory and practice. Aligning with other Hippocratic authors, Galen affirmed their theories, but he grounded them in his own experiences. He accepted the existence of "natural causes of disease and recommended non-supernatural cures."[75] According to historian Evan Ragland, Galen contended that "a physician needed more than the rational inferences of the Dogmatists or the reflections on many experiences of the Empirics. All rational inferences from the perceptible signs of diseases and health to their hidden causes had to be confirmed by experience or trial (*peira*). In some cases, especially in the task of discovering the properties of drugs, only well-informed experience or trials could determine their effects."[76] Galen argued that physicians should treat patients only after having determined the underlying causes of illnesses.[77]

Galen inherited certain ideas from Aristotle. In one instance, Galen borrowed from Aristotle the terms and concepts "to expand and systematize trends already present in Hippocratic writings, including the use of artificial means whereby nature is constrained."[78] Both Galen and Aristotle noted that medicine involved a study of particulars. A physician examined a particular patient with a particular ailment in order to provide a particular remedy. Medicine inherently rested with particulars. For this reason, natural philosophers in the Middle Ages and early modern period read Aristotle and Galen and asserted that their versions of medical practice should be defined as *ars*, as opposed to *scientia*. They could not claim medicine as *scientia* because it did not lead to universal truths through syllogistic reasoning.[79] According to philosophers and physicians, *scientia* (science) arrived at universally valid truths through

[75] Mary Lindemann, *Medicine and Society in Early Modern Europe* (Cambridge: Cambridge University Press, 2010), 88.
[76] Evan R. Ragland, "'Making Trials' in Sixteenth- and Early Seventeenth-Century European Academic Medicine," *Isis* 108 (2017): 509.
[77] Glen M. Cooper, "Approaches to the Critical Days in Late Medieval and Renaissance Thinkers," *Early Science and Medicine* 18 (2013): 539.
[78] Ragland, "'Making Trials' in Sixteenth- and Early Seventeenth-Century European Academic Medicine," 509.
[79] Siraisi, *History, Medicine, and the Traditions of Renaissance Learning*, 13.

syllogistic demonstrations. The *ars* (arts) also used logical reasoning, but these disciplines did not arrive at certain, general truths.[80] The demonstrative, "hard" sciences had internal ends—knowledge and understanding. Yet, medicine had an external end—the healing of the sick. "Discovery" within the medical tradition consisted of interpreting symptoms. The medical arts always strove for a desired end—health.

Galen did not devote himself blindly to Aristotle's texts, however. Medieval and early modern physicians noted points of discord between the two classical writers. One discrepancy between them was the function of the heart. Aristotle believed that the heart was the source of heat and life.[81] Galen believed that while special and significant, the heart worked with other organs to maintain a patient's health. The significance of the heart remained a fierce debate in medical circles until the seventeenth century.[82] Medical learning at medieval and early modern Italian universities was deeply indebted to and rooted in Aristotelian and Galenic doctrines.[83]

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[80] Nancy G. Siraisi, "Medicine, physiology and anatomy in early sixteenth-century critiques of the arts and sciences," in *New Perspectives on Renaissance Thought: Essays in the History of Science, Education and Philosophy*, eds. John Henry and Sarah Hutton (London: Gerald Duckworth & Co. Ltd, 1990), 219.

[81] Aristotle wrote, "So also is it as regards natural heat. For the body of every animal, and each of its several parts, possesses a certain innate natural heat, so that during life they are sensibly warm, but become cold when life departs and death ensues. Now, the fountain-head of this heat must in sanguineous animals be of necessity in the heart, and in bloodless animals in the analogous organ; for the elaboration and concoction of the food, though carried on in all parts by the agency of their natural heat, is especially effected in the dominating organ, that is in the earth or its analogue. Thus it is that all the other parts of the body may become cold, and yet life be maintained; but, if this happen to the heart, there is no escape from destruction, inasmuch as the heart, or, in bloodless animals, that which takes the place of a heart, is the primal source of heat and the residence of the soul, which is, so to speak, embodied there in fire. The maintenance, then, of this fire and the maintenance of life are of necessity identical, and its destruction is what is known as death." Aristotle, *Youth & Old Age, Life & Death and Respiration*, trans. W. Ogle (London: Longmans, Green, and Co., 1897), 4.469b6-20.

[82] Siraisi, *Medicine and The Italian Universities, 1250*-1600, 32.

[83] It must be noted that scholars did not accept all of Galen's accounts. One critic of Galen was the Paduan physician, Pietro d'Abano (1257-1316), who spoke to the opacity in the difference between the medical arts and the natural sciences. In his work written in 1310, *Conciliator Differentiarum, quæ inter Philosophos et Medicos Versantur,* D'Abano argued that medicine required extensive training in logic in order to understand the more advanced medical texts. In this sense, he supported the study of formal logic by medical students because it became impossible to comprehend the discipline without dialectic. D'Abano sought to stress how the work of a physician did depend on logic. It was not extraneous. For this reason, D'Abano called natural philosophy and medical arts sisters. He argued that science inferred conclusions from immediate causes—a progression that Galen deemed the *doctrina compositiva*. According to D'Abano, science was demonstrative, and causes were discovered through syllogisms. D'Abano believed that there were two methods of scientific proof: effects through causes and causes through effects. He disagreed with Galen's contention that the action of the planets in the solar system influenced

In *De re metallica*, Agricola reveals his training in Galenic medicine when he concentrated on the specific environmental conditions of the miners. Galen theorized that health occurred when the four humors—black bile, yellow (or red) bile, blood, and phlegm—were balanced. If a humoral imbalance were to happen, then disease would ravage the body. One's environment influenced the state of disequilibrium. Agricola was thus keen to explain the miners' working conditions. He paid attention to the quality of the air and the temperature of the mine. Agricola knew that each mine would have had different conditions that in turn would have uniquely affected each miner. In order to restore a miner's health, he would have needed to understand a miner's activities and his idiosyncrasies.[84] Agricola practiced Galenic medicine on a case-by-case basis.

In *De re metallica*, Agricola's humanist training as a doctor is evident through his attention to the miners' health and his Galenic references. In one instance, he stated how the mines were devoid of water. That dryness in turn would cause the miners great harm, for "the dust [that the miners created by digging] would penetrate their lungs, causing a shortness of breath (*pulvis...penetrans in asperam usque arteriam et pulmones, parit difficultatem anhelitus et vitium)*."[85] Agricola was aware of the effects that mining had on the body. He had clearly witnessed the afflictions of the miners. Agricola's depictions of the miners' suffering suggest

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illnesses. Instead, D'Abano asserted that there were other factors contributing to health. D'Abano urged alternative scholars of medicine to consider causes, other than celestial influences. He made medicine less supernatural and more empirical. D'Abano established a precedent by considering neither Aristotle's nor Galen's ideas as infallible. D'Abano's treatises demonstrated how there was room for interpretation amongst humanist scholars. See Cooper, "Approaches to the Critical Days in Late Medieval and Renaissance Thinkers," 547; Nancy G. Siraisi, *Arts and sciences at Padua: the stadium of Padua before 1350* (Toronto: Pontifical Institute of Mediaeval Studies, 1973), 59; 152; and William A. Wallace, "Circularity and the Paduan Regressus: From Pietro d'Abano to Galileo Galilei," *Vivarium* 33 (1995): 81.

[84] Mary Lindemann made a similar observation in her text *Medicine and Society in Early Modern Europe*. See Mary Lindemann made a similar observation in her text *Medicine and Society in Early Modern Europe* (Cambridge: Cambridge University Press, 2010), 23.

[85] Agricola wrote, "*quae ariditas maius etiam malum daroperariis: siquidem pulvis, qui cietur et agitator sossionibus, penetrans in asperam usque arteriam et pulmones, parit difficultatem anhelitus et vitium…*" Georgius Agricola, *De re metallica* (Basel: Froben Press, 1556), liber sextus, 172.

that he cared for them as a physician. He could have plausibly been the physician of some of the miners. He even mentioned the accumulative effects that mining had on the body. Agricola believed that miners should wear "quite high boots (*satis altos perones*)" when descending into cold, watery shafts.[86] The boots, according to Agricola, would have protected the miners' legs for the "cold was the enemy of the nerves (*frigus est inimicum nervis*)."[87] He advised that all miners wear the boots as to prevent ill-health, "especially as they reached old age (*praesertim cum vixerit ad senectutem*)."[88] Agricola's prescription was specific and detailed. He not only recognized the problem, but he also provided a remedy. Agricola could have easily gathered the information from his discussions with miners. Those discussions could have occurred either in the mines or in his clinic. In any case, Agricola presents himself as well-informed. He understood the accumulative, deadly effects that mining could have on the body. His training certainly made him aware of ailments.

He also revealed his training as a doctor when he used precise medical vocabulary. In the previous example, Agricola stated how cold water could potentially be "the enemy of nerves (*inimicum nervis*)."[89] He inserted the term *nervi* for a reason. He could have written tough, fibrous tissue, but he wanted to be exacting with his terminology. His precision conveys to the reader a specific knowledge-set. By using the term *nervi*, Agricola fashioned himself as a member of the medical community.

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[86] Agricola described, "*Et enim frigus est inimicum nervis…sed fossores ad eam rem satis altos perones sibi comparent, qui crura tuean tur ab aquarum frigore: cui consilio qui non paruerit, is magno afficietur incommodo valetudinis: praesertim cum vixerit ad senectutem*." Agricola, *De re metallica*, liber sextus, 172.
[87] Agricola wrote, "*Aqua in quibus puteis inest multa et frigidio crura vitare solet: et enim frigus est inimicum nervis*." Agricola, *De re metallica*, liber sextus, 172.
[88] Agricola explained, "*Cui consilio qui non paruerit, is magno afficietur incommodo valetudinis: praesertim cum vixerit ad senectutem*." Agricola, *De re metallica*, liber sextus, 172.
[89] Agricola, *De re metallica*, liber sextus, 172.

He also used medical terms when he wrote about diseases and illnesses. When describing the maladies that miners encountered, Agricola offered his reader comparisons. Agricola noted how the miners could encounter a destructive illness, an "evil (*malum*)"; one that brought:

> death to the men who worked in the shafts [or] tunnels where the hard rock is broken by fire. There the air is infected with poison from the veins, since large and small veins and seams in the rocks exhale a subtle virus from the minerals, which is squeezed out by the fire, and this poison itself is raised with the smoke not unlike *pompholyx* and sticks to the walls….the bodies of living creatures who are most infected with this poison immediately swell and lose all movement and sensation and wither away without pain; men even in the act of climbing from the shafts by the steps of ladders fall back into the shafts when the poison grows, because their hands do not perform their faculty, and appear to be round and spherical, and likewise their feet.[90]

> *Sed est aliud malum magis pestiferum, quod que homini mox affert necem: in quibus puteis, vel fossis…vel cuniculis durum saxorum igni frangitur, in his aer inficitur veneno: siquidem venae et veniae conmissurae que saxorum exhalant subtile quoddam virus, ignis vi expressum ex rebus metallicis aliisque fossilibus: quod ipsum cum fumo subleuatur, non aliter ac pompholyx, quae in officinis, in quibus venae metallicae exocquuntur, ad superiorem parietis partem adhaerescit…Corpora autem animantium isto veneno infecta plerunque continuo turgescunt, et omnem motum ac sensum amittunt, sin que dolere intereunt. Homines etiam ex puteis scalarum gradibus ascendentes, ubi virus incrementum sumpserit, rursus in eos decidunt: quia manus non faciunt suum officium [sphaerica] et rotunda ipsis videntur esse,…[etiam] pedes*.[91]

Here Agricola used the term *pompholyx* to describe zinc oxide, which was a furnace deposit. Too much exposure could lead to poisoning. Through his training and experience as a doctor, Agricola knew a disease that he could compare to the one afflicting the miners.

The term would have also resonated with those readers who were familiar with Galen's text. In *Method of Medicine*, Galen cited *pompholyx* as a remedy for ulcers. He deemed

[90] Agricola, *De re metallica*, liber sextus, 172. Agricola made reference to *pompholyx* seven times throughout the text. He reminded the reader that the miners would constantly remove *pompholyx* from the walls of both the shafts and the furnaces.
[91] Agricola, *De re metallica*, liber sextus, 172.

pompholyx as "the least painful and no less efficacious" than others.[92] Galen also prescribed *pompholyx* to treat wounds in the rectum. Galen stated that these types of wounds necessitated:

> medications that are more liquid, and because of this, those that are moderately warm…dry medications are more suitable than the so-called dissolved medications, for they are more readily mixed with the juice of plantain, or some other such thing…medications of this sort are saffron, pompholyx, aloes and the so-called cephalics.[93]

Agricola's reference to *pompholyx* would have served a purpose. It would have indicated to his readers that he was a student of Galenic medicine, thus establishing him as a learned man of medicine.

His Italian professors in Bologna may have introduced Agricola to Galen's texts, but it was in Venice that he developed an intimate familiarity with the ancient writer's works. He encountered the writings of Aristotle and Galen while working in the print shop of Aldo Manuzio (1449/1452 – 1515). After a year of reading humanist treatises and attending humanist lectures, Agricola departed Bologna for an apprenticeship in Venice. In the city, Agricola found himself in an intellectually stimulating workspace. The increase in manuscript production had a profound impact on European cities, especially Venice. During the second half of the fifteenth century, when the city was at its peak as a commercial power, printers began populating the Republic's cityscape. Venice created a hospitable atmosphere for those interested in manuscript production. The city would have competed with Florence to attract prospective publishers. In Florence, printers would have had easier access to texts because a fair number of scholars chose to reside there. Venice, on the other hand, offered "capital resources and typographical expertise."[94] Aldo Manuzio was one printer who decided to forgo close proximity to the scholars

[92] Galen, *Method of Medicine*, eds. and trans. Ian Johnston and G.H.R. Horsley (Cambridge: Harvard University Press, 2011), 117.
[93] Galen, *Method of Medicine*, 49.
[94] Andrew Pettegree, *The Book in the Renaissance* (New Haven: Yale University Press, 2010), 61.

and established his print shop in Venice. Manuzio arrived in the city in 1490 as an already renown intellectual and pedagogue.[95] He found great success in Venice, producing ninety-four editions of classical authors between 1494 and 1515.[96]

Agricola worked in the shop in its heyday, editing and transcribing Greek works. Manuzio's print shop issued specialized editions of Greek and Roman authors.[97] In fact, the shop managed the publishing of texts written by authors that historians have since configured as cornerstones of humanist learning. Those ancient writers included Galen and Hippocrates.[98] Through the sheer number of texts printed, Manuzio and Agricola advocated an approach to Latin scholarship that incorporated Greek. For the two of them, Greek was indispensable.

Participating in the publication of these texts facilitated Agricola's study of classical antiquity. Agricola did not work in solitary conditions. His transcriptions were made in the presence of other intellectuals, particularly those of English extraction. With his colleagues, Agricola immersed himself in the cultural and intellectual heritage of antiquity. He deployed his humanist training to judge, line-by-line, the reliability of the Greek-to-Latin translations in Manuzio's print shop. He read and digested the ancient Greek texts. He analyzed his sources in a philological manner in order to present his interpretation of the ancient author's works. His humanist training in Bologna had certainly prepared him for the linguistic and philological labor of the print shop. For two years, Agricola put his skills as a humanist to work.[99] He left the work

[95] Pettegree, *The Book in the Renaissance*, 60.
[96] Pettegree, *The Book in the Renaissance*, 60.
[97] Douglas F. Bauer, "Problems in the Aldine Pindar," *The Princeton University Library Chronicle* 76 (2015): 420.
[98] Varani, "Agricola and Italy," 153. Aldo Manuzio was a humanist-trained enthusiast of books. He was born Theobaldo Manuzio in 1450 but changed his name to Aldo. He received his university training in Rome and Ferrara, where he studied Latin and Greek respectively. He travelled to Venice in 1490 to solidify his plans to open a Greek press. See Burton Chance, "Early Printing of Medical Books and Some of the Printers who Printed Them." *Bulletin of the History of Medicine* 22 (1948): 653-656.
[99] Prescher, "Dr. Georgius Agricola 1494-1555: A European Scientist and Humanist from Saxony," 86.

of an editor to take up the position of town physician in Joachimsthal (now Jáchymov, Czech Republic).[100]

From 1527 to 1531, Agricola worked in the small mining town. Perhaps it was here that he was first exposed to miners and their practices. Here the Ore Mountains dominated the landscape and divided the region between Saxony and Bohemia. The mountain range was favorable to mining with its steep slopes and pristine forests. Agricola arrived in the district after the discovery of silver deposits in 1511.[101] News of Joachimsthal's abundant silver ore circulated and attracted the attention of banking and trading companies located in Nuremberg and Leipzig.[102] The limited sources regarding Agricola's time in Joachimsthal make it challenging to ascertain if the deposits lured him to relocate to the region, but we can gather from his publication history that the undulating landscape did capture his imagination. While residing in Joachimsthal, Agricola studied local minerals and recognized their medicinal properties. He eventually came to articulate his findings in his first published text, *Bergmannus* (1528).

His exposure to the mining community only increased when he began to provide medical attention to the residents of Chemnitz. He remained in Chemnitz until his death in 1555.[103] While there, Agricola settled into four one-year municipal appointments (1546 – 1547, 1547 – 1548, 1551 – 1552, 1553 – 1554). His tenure in Chemnitz saw disputes between Catholics and

[100] Agricola's position as town physician was not an unusual occupation. Many cities across Europe created these employment opporunties in the aftermath of the Black Death. City councils appointed physicians to look after the poorer inhabitants. The creation of the role also contributed to the legitimacy of the city council. The inhabitants could feel confident that the council was concerned with their welfare. Ruth Schilling, Sabine Schlegelmilch, and Susan Splinter, "Stadtarzt oder Arzt in der Stadt? Drei Ärzte der Frühen Neuzeit und ihr Verständnis des städtischen Amtes," *Medizinhistorisches Journal* (2011): 100.
[101] Jiri Majer, "Georgius Agricola und der böhmische Bergbau seiner Zeit," in *Georgius Agricola, 500 Jahre*, ed. Friedrich Naumann (Basel: Birkhäuser Verlag, 1994), 35.
[102] Jiri Majer, "Georgius Agricola und der böhmische Bergbau seiner Zeit," 36.
[103] Doris Oltrogge, "Writing on Pigments in Natural History and Art Technology in Sixteenth-Century Germany and Switzerland," *Early Science and Medicine* 20 (2015): 338.

Reformers.[104] Historian Helmut Bräuer declared that the religious discord had an effect on Agricola, perhaps even contributing to his reluctance to continue working within municipal politics. In any case, Agricola left politics and focused on his intellectual pursuits.

It was in Chemnitz that Agricola began to compose *De re metallica* (1556). As the town physician, Agricola almost undoubtedly saw miners who were afflicted by ailments associated with their occupations. He witnessed the hazards of the working conditions; he also likewise understood the wealth and security that such a trade provided. Mining, for Agricola, was a profitable trade. Perhaps inspired by his patients, Agricola crafted *De re metallica* and expressed the benefits of mining to his educated Christian audience. The crafts of mining and metallurgy had not captured the attention of scholars in early modern Europe. Agricola wanted to understand the day-to-day methods of miners and metallurgists.

But Agricola could not have penned such a mammoth text without a benefactor.[105] *De re metallica* begins with Agricola's declaration of affinity for his patrons. Agricola identified the Saxon Electors Maurice and Augustus as "the most illustrious and most mighty dukes of Saxony (*Illustriss et potentiss saxoniae du cibus langraviis Toringiae*)."[106] Agricola felt such a debt of gratitude to his patrons that he dedicated most of his works to them. Quite likely, Agricola's self-interest and desire to secure funding prompted him to craft the florid dedication in his work. Or, to the contrary, the declaration of affection served a pragmatic purpose, thanking the men who

[104] Helmut Bräuer, "Georgius Agricola als Chemnitzer Bürgermeister," in *Georgius Agricola, 500 Jahre*, ed. Friedrich Naumann (Basel: Birkhäuser Verlag, 1994), 230.
[105] See Mario Biagioli, *Galileo Courtier: The Practice of Science in the Culture of Absolutism* (Chicago: The University of Chicago Press, 1993).
[106] Agricola, *De re metallica*, Epistola, 1. The electors were members of the princely electoral college that elected the Holy Roman Emperor. The Golden Bull of 1356 stated that an exclusive body of seven members of the political elite would receive special privileges, including the right to elect the King of the Romans, the future Emperor. See Márta Vajnági, "Britain-Hanover and the Imperial Election of 1745," *Hungarian Journal of English and American Studies* 14 (2008): 51; and James Bryce, *The Holy Roman Empire* (London: The MacMillan Company, 1904).

had provided financial support. In any case, Agricola's sycophantic references to his patrons provides evidence of the rituals of patronage in early modern Europe.

Agricola's training as a doctor and an editor in Italy made him uniquely qualified to write about mining practices in *De re metallica*. His exposure to ancient texts guided his transcriptions as an interpreter, influenced his work as a physician, and affected his writings as a scholar. Agricola belongs in the category of humanist-trained physicians whose mastery of classical literature led like-minded scholars to participate in learned communities that extended outside the realm of medicine.

Chapter 2

Reevaluating, Reassessing, and Reconsidering Humanism: An Exploration of Agricola's Humanist Proclivities

Agricola turned to ancient texts in search of an explanation when he could not understand a phenomenon that he witnessed in the mines. At one point, he documented how miners constructed scaffolding to extract minerals from the veins, but he admitted that he did not know how the miners located concealed veins in the first place. The miners told Agricola that they believed that the movement of a twig guided them to the vein. They went on to narrate how a mysterious power controlled the twig's movement and thus determined the vein's discovery.[107] Agricola remained skeptical, until he found evidence of ancient writers making room for the supernatural in their own narratives. He turned to Homer's *Odyssey* and discovered tales such as Minerva turning the aged protagonist Ulysses "suddenly into a youth, and then restor[ing] him back again to old age with a divining rod (*Homerum Minerva senem Ulyssem virgula divina repente in iuvenem convertit, ac rursus restituit in senium*)."[108] Only after having gathered similar citations of magic from ancient Greek literature did Agricola feel comfortable accepting

[107] Georgius Agricola, *De re metallica* (Basel: Froben Press, 1556), liber secundus, 26-29.

[108] Agricola wrote, "*Veteres autem non ea modo quae ad uictum et cultum attinent, virgula divina con qui si veniunt sed rerum etiam formas verterunt: etenim (sic) incantatores Aegyptiorum virgas, ut Hebraeorum literae narrant, in serpentes mutarunt: et apud Homerum Minerva senem Ulyssem virgula divina repente in iuvenem convertit, ac rursus restituit in senium*…" Agricola, *De re metallica*, liber secundus, 27. Agricola identified the goddess as Minerva, who was also known as Athena. Homer wrote, "With this, Athena touched him with her golden wand. A well-washed cloak and tunic she first of all put about his breast, and she increased his stature and his youthful bloom. Once more he grew dark of color, and his cheeks filled out, and dark grew the beard about his chin. When she had done all this, she departed, but Odysseus went into the hut. And his staunch son marveled, and, shaken, turned his eyes aside for fear it was a god. And he spoke, and addressed him with winged words: 'Of different sort you seem to me now, stranger, than a while ago, and the clothes you wear are different, and your color is no longer the same. Truly you are a god, one of those who hold broad heaven. Be gracious, then, that we may offer to you acceptable sacrifices and golden gifts, finely wrought; and spare us.'" Homer, *Odyssey*, ed. Jeffrey Henderson and trans. A.T. Murray (Cambridge: Harvard University Press, 1995), 172-185, 131.

and endorsing the presence of magic in the world. Homer gave the supernatural a role in his narrative, and so too did Agricola.

By quoting Homer, Agricola was following in the footsteps of Petrarch (1304 – 1374), undoubtedly the greatest contributor to humanism.[109] Petrarch devoted his time to his Homer manuscript, despite not making an effort to learn Greek.[110] He found ancient Latin culture more alluring.[111] Historians may debate the meanings of humanism, its chronology, its origins, and its impact, but all agree that Petrarch played a key role in the development of humanism. It was Petrarch whose imitation of Cicero tied Italian humanism to a European rhetorical tradition. Petrarch's works typify a certain version of humanism, one in which rhetoric was linked with eloquence and moral philosophy.[112] Historians have come to view rhetoric, eloquence, and moral philosophy as the distinguishing features of humanistic endeavors. For many scholars, humanism was thus a literary and cultural movement affiliated with classical antiquity where writers, such as Petrarch, Leonardo Bruni (1370 – 1444), and Lorenzo Valla (1406 – 1457), imitated their ancient rhetorical heroes in their own works.

The Characteristics of Humanism

Humanism remains an amorphous category. Historians cannot settle on which intellectuals are deserving of the humanist title. In 1962, Paul Kristeller famously declared that

[109] Ronald Witt even deemed Petrarch to be the father of humanism. See the sixth chapter of *In the Footsteps of the Ancients: The Origins of Humanism from Lovato to Bruni* (Boston: Brill, 2000), 230-291.
[110] Petrarch obtained a Greek manuscript of Homer from Nikolaos Sygeros, who served as a Byzantine ambassador in Italy. Sygeros gave Petrarch the manuscript either at the end of 1353 or at the start of 1354. See Philip Ford, "Homer in the French Renaissance," *Renaissance Quarterly* 59 (2006): 1.
[111] Paul Grendler, *Schooling in Renaissance Italy: Literacy and Learning, 1300-1600* (Baltimore: Johns Hopkins University Press, 1992), 124.
[112] Witt, *In the Footsteps of the Ancients*, 240.

humanism was a "vague and varied (*vago e vario*)" term in French- and English-scholarship.[113] In an attempt to provide clarity, he adhered to a rigid taxonomy.[114] He defined humanists as those early modern Italian writers who wrote in Latin, used classical allusions, employed precise terminology, cultivated philological skills, and outlined proper moral behavior.[115] Kristeller believed that humanists were trained rhetoricians. He answered *what* a humanist was, but he neglected to answer *why* humanists pursued this particular avenue of inquiry.[116] His framework was altogether precise and narrow. Disagreeing with Kristeller's synchronic approach was Ronald Witt. Witt reoriented the scholarship of humanism to consider those participants from the thirteenth century. He expanded the qualifications of a humanist to include writers who had inspired Petrarch. Witt focused on Petrarch's intellectual inheritance. For him, humanism was the stylistic imitation of classical authors. He discarded Kristeller's contention that humanism's origins were located in rhetoric and the medieval *ars*. Instead, Witt argued that grammar served as humanism's genesis.[117]

More recently, Christopher Celenza has applied nuance to further Kristeller's definition of humanism. He followed in the tradition of Witt and examined the literary works of

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[113] Paul Oskar Kristeller, "Umanesimo filosofico e umanesimo lettarario." *Lettere Italiane* 14 (1962): 382.

[114] Kristeller's books include *Renaissance Thought: The Classic, Scholastic, and Humanist Strains* (New York: Harper Torchbooks, 1961); *Renaissance Thought and the Arts* (Princeton: Princeton University Press, 1965); *Renaissance Thought II: Papers on Humanism and the Arts* (New York: Harper Torchbooks, 1965); and *Renaissance Thought and Its Sources* (New York: Columbia University Press, 1979). In a later article, Kristeller wrote, "In my view, it is best defined as a scholarly and literary movement that advocated the study and imitation of classical [A]ntiquity and that came to affect more or less deeply all areas of the Renaissance period, including philosophy, the sciences, the arts, and the religious and political thought of its time." Paul Oskar Kristeller, "Humanism," *Minerva* 16 (1978): 586.

[115] Kristeller wrote, "The nature of this humanist influence is also characteristic: it consists primarily in the introduction of fresh classical sources and in the restatement of their ideas, in the vogue of classical quotations and allusions, in the use of the newly refined methods of historical and philological scholarship, and in an attempt to replace the specialized terminology of the medieval schools, their tight methods of arguing, their elaborate commentaries and disputed questions, by treatises, dialogues, and essays written in a smooth and elegant style. Kristeller, *Renaissance Thought: The Classic, Scholastic, and Humanist Strains*, 26.

[116] Patrick Lewis Baker, "Illustrious Men: Italian Renaissance Humanists on Humanism" (PhD, diss., Harvard University, 2009), 7.

[117] Witt, *In the Footsteps of the Ancients*, 6.

intellectuals who did not necessarily write in Latin. By expanding the source base for historians, Celenza hoped to answer that pesky *why* question. For him, humanists were readers and writers who crafted prose about their thoughts and experiences and mimicked the spirit of ancient authors. As such, Celenza affirmed that historians cannot divorce a humanist's text from his context.[118] In this way, he looked to humanism as a concept capable of bridging the gap between social and intellectual histories.

Because of the conflicting views and definitions of humanists, it is challenging to place Agricola within the category of humanism. *Was* Agricola a humanist and, if so, to what end? *Why* would he have pursued it? Superficially, Agricola looks like a humanist. He used clear and precise language, and he did cite ancient poems as evidence for his claims. In other ways, Agricola does not fall under the rubric of a humanist.[119] He did not use a dialogue form in his writing. Most importantly, *De re metallica* was not a literary critique. Agricola wrote a text about mining, a subject untouched by other humanist writers.

Agricola provides an additional prospective on humanism. Historians have rightly focused their efforts on those intellectuals, like Leonardo Bruni and Lorenzo Valla, who produced a vast output. The more an intellectual wrote, the more evidence the historian has to aid in his assessment of humanist endeavors. In doing so, however, modern scholars have restricted their gazes. They have neglected intellectuals, like Agricola, who were neither Italian nor literary critics. Agricola provides a unique opportunity to study humanism in a social context outside the confines of Italian literary society.

Agricola was an intellectual who demonstrated his training in the *studia humanitatis* in order to construct a trusted, professional identity. He was a humanist to the extent that he was a

[118] Christopher Celenza, *The Lost Italian Renaissance: Humanists, Historians, and Latin's Legacy* (Baltimore: Johns Hopkins University Press, 2004), xviii.
[119] Witt, *In the Footsteps of the Ancients*, 26-27.

student of the *studia humanitatis*. As Celenza notes, the *studia humanitatis* became a "recognized marker of the new culture of humanism."[120] After having received an education in grammar, poetry, rhetoric, history, and moral philosophy, Agricola applied his learned skillset to his argument construction. In order to argue for the benefits of mining and describe the peculiarities of the profession, Agricola confronted his Aristotelian worldview, referenced classical texts, showcased his Greek command, and prescribed appropriate behavior. For Agricola, humanism was a pedagogical program that could facilitate and elevate the art of mining.

Humanism's Effects on Natural Philosophy

The secondary literature on humanism is vast. More specific to our purposes are those texts that investigate humanism's effects on natural philosophy. Scholars have begun to investigate the ways in which humanism affected intellectuals' engagement with nature. Margaret Osler, for one, took a more selective and narrow approach to her exploration for humanism and natural philosophy. In "Renaissance humanism, lingering Aristotelianism and the new natural philosophy: Gassendi on final causes" (2000), Osler confronted Aristotelianism in the seventeenth century. She chose to focus on a single intellectual's contribution, examining Pierre Gassendi's (1592 – 1655) relationship to ancient authority. She concluded that Gassendi had a "deep ambivalence towards his ancient model [Lucretius]" when it came to final causes in

[120] Christopher Celenza, *The Intellectual World of the Italian Renaissance: Language, Philosophy, and the Search for Meaning* (Cambridge: Cambridge University Press, 2018), 129.

physics.[121] Osler noted that Gassendi chose to ignore Lucretius' claims while accepting those of Aristotle. She found that Gassendi selected to include in his treatises those explanations from ancient authors that supported his claims. He jettisoned the rest. Osler believed that Gassendi typified the experiences of natural philosophers. They were not blindly devoted to the ancient corpus. Like Gassendi, Agricola used his own voice to criticize freely ancient authors.

Osler's declaration that a humanist-trained natural philosopher could have held new observations with ancient facts and remain theoretically consistent echoed an earlier argument made by Ann Blair in her article "Humanist Methods in Natural Philosophy: The Commonplace Book" (1992). Blair contended that natural philosophers could have faith in both ancient theories and newer findings without "generating any internal tension."[122] She came to this conclusion after having traced natural philosophers' "quintessentially humanist" method of reading and gathering information in the commonplace book. Blair primarily relied on Jean Bodin's *Universae naturae theatrum* (1596) as evidentiary support. She argued that the method of the commonplace book inspired precepts of Francis Bacon's new science. Blair believed that humanist practices laid the groundwork for Bacon's eventual methodological rupture.

James A.T. Lancaster also explored the reasons for Bacon's rupture in his article "Natural Knowledge as a Propaedeutic to Self-Betterment: Francis Bacon and the Transformation of Natural History" (2012). Lancaster asserted that the humanist agenda of self-betterment inspired Bacon to produce a *historia naturalis* that had "power over nature and, in turn, social betterment."[123] For Lancaster, looking to improve society and the self was a uniquely humanist

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[121] Margaret J. Osler, "Renaissance humanism, lingering Aristotelianism and the new natural philosophy: Gassendi on final causes," in *Humanism and Early Modern Philosophy*, eds. Jill Kraye and M.W.F. Stone (London: Routledge, 2000), 195.
[122] Ann Blair, "Humanist Methods in Natural Philosophy: The Commonplace Book," *Journal of the History of Ideas* 53 (1992): 547.
[123] James A.T. Lancaster, "Natural Knowledge as a Propaedeutic to Self-Betterment: Francis Bacon and the Transformation of Natural History," *Early Science and Medicine* 17 (2012): 190.

endeavor. He believed that Bacon and other humanists, such as Pier Paolo Vergerio (1498 – 1565), Conrad Gessner (1516 – 1565), and Edward Topsell (1572 – 1625), promoted a self-improvement model that was "the result of a transfer of humanist values into the domain of natural history."[124] Lancaster never provided a definition of humanism, but the reader can assume that he believed humanism to be the study of mankind. He ultimately compromised his argument by refusing to define humanism. Historians studying the early modern period always speak about humanists' devotion to antiquity. Kristeller, Witt, and Celenza all identified this gaze to the past as a defining feature of humanism. It is striking, then, that Lancaster refused to incorporate this characteristic into his definition. He never explored the ways in which his intellectuals grounded their theories of self-betterment in ancient texts. Lancaster also failed to show how each intellectual encountered the humanist tradition. Admittedly, he was not focused on how Bacon, Vergerio, Gessner, and Topsell came to demonstrate their humanist proclivities, but the reader is left wondering if he believed that humanist virtues were self-evident. How did the so-called humanists come to embody those humanist ideals of self-betterment? This chapter begins with the assumption that Agricola's humanist education was not a passive endeavor.

Similar to the works of Osler, Blair, and Lancaster, this chapter focuses on the techniques and practices of humanism that Agricola chose to embody in *De re metallica*. His decision to display some and jettison others reveals a unique perspective on the study of nature. His rhetorical strategies were rooted in a humanist tradition. I argue that Agricola deliberately confronted his Aristotelian worldview, referenced classical texts, showcased his Greek command, and prescribed appropriate behavior. These techniques revealed his subjectivity and

[124] Lancaster, "Natural Knowledge as a Propaedeutic to Self-Betterment: Francis Bacon and the Transformation of Natural History," 184.

precision. Those two epistemic virtues thereby encouraged a natural philosophy that was grounded in textual scholarship.

The Devotion to Aristotle

Kristeller, Witt, and Celenza all agree that a humanist's defining attribute was his devotion to classical Greek and Roman authors. Some humanists imitated the ancient texts' style or contents; others chose to merge their own theories with those of the ancients. Kristeller found evidence of humanists regularly challenging the authority of ancient writers. He asserted that Aristotle was one such ancient author whose texts were dissected, imitated, and interpreted by humanists.[125] The historian stated that "in different ways and different reasons," early modern intellectuals pushed against their Aristotelian heritage.[126] Agricola, like other humanists, grounded his theories on natural phenomena within an Aristotelian framework. During the Italian "Renaissance" (1300 to 1600), intellectuals evaluated scientific advancement against classical texts. Here the ancient corpus of philosophy, recovered by medieval grammarians, became the paragon of style. Humanists sought to rehabilitate this ancient rhetorical heritage and regarded the work of Aristotle as the epitome of reason. Better translations of the ancient texts facilitated the development of a spectrum of interpretative techniques.

Commentaries of Aristotle began in antiquity and never ceased. Many of the Greek commentators sought to unify the works of Aristotle and Plato. They wanted to reconcile Plato with other poets and orators. The next major layer of commentary occurred in Arabic—the language of Averroës (1126 – 1198). Averroës relied on Aristotle's texts, like *Poetics* and

[125] Kristeller, *Renaissance Thought: The Classic, Scholastic, and Humanist Strains*, 29.
[126] Kristeller, *Renaissance Thought: The Classic, Scholastic, and Humanist Strains*, 46.

Rhetoric, not only as a source to comprehend philosophical ideas, but also as a means to understand ancient drama. Averroës used the Aristotelian texts to demonstrate how rhetoric, poetics, and dialectic combined to form a universal scheme of knowledge. Thirteenth-century scholastic philosophers then translated into Latin these Greek and Arabic commentaries. Latin translations, which occurred chiefly in Sicily and Southern Italy, introduced medieval western Europe to Aristotle. It was not long until scholars noticed the conflicts and contradictions within the Aristotelian tradition. All these differing versions of Aristotle placed a strain on the lexicon of Latin. In fact, one finding argues that medieval translators recovered more than thirty distinct, Arabic terms to define the Latin verb *esse* (to be). For those Renaissance humanists hoping to purify the dialect, these translations proved irritant and tiresome. Troubles in interpretation grew in intensity with the multiplication of commentaries and debates, which were responses to either the ancient Greek or the Arabic texts. Inconsistencies generated arguments, and scholars searched for solutions. These critical debates over the Aristotelian doctrine created a multilayer system of engagement.

By the time Agricola had begun documenting the techniques of miners, the Aristotelian texts had endured an extensive process of translation and commentary. Contrasting interpretations of the doctrine and conflicting understandings of the natural world emerged. Scholars did not use the *corpus aristotelicum* in a universal manner. A transformed Aristotle surfaced when aspects from the medieval tradition merged with the fruits of humanism.[127]

Agricola's explanation of metal deposits in rivers demonstrates his reliance on and interrogation of Aristotle's theories. He encountered miners who believed that the sun drew out

[127] For more information, see Carol Poster, "Whose Aristotle? Which Aristotelianism? A Historical Prolegomenon to Thomas Farrell's Norms of Rhetorical Culture," *Philosophy and Rhetoric* 41 (2008): 278; Brian P. Copenhaver and Charles B. Schmitt, *Renaissance Philosophy* (Oxford: Oxford University Press, 1992), 8; and Charles B. Schmitt, "Aristotelianism in the Veneto and the Origins of Modern Science: Some Considerations on the Problem of Continuity," in *The Aristotelian Tradition and Renaissance Universities* (London: Variorum Reprints, 1984), 113.

metals from veins and rivers. They believed that the sun's heat could unsettle the metals from where they were embedded. Place, according to Aristotle, had "neither cause nor form…nor as end, nor does it cause the beings to move."[128] According to Aristotle, place, or the natural location of rest, did not possess the four elements: earth, water, air, and fire. Thus, any one of the elements could detach a substance, like a metal, from its natural place. Agricola perhaps recognized that the miners used Aristotle's theory of elements to explain the motion of metals. At the same time, Agricola pointed out that although "the rays of the sun draw up [vapors] from the surface of the ground, they do not penetrate, for the air of a tunnel is cold despite it being covered by solid earth only two-fathoms deep. The earth opposes the force of the sun (*at calores ad sole nequeunt ex eiusmodi venis extrahere materiam metallicam: ut enim est summa terrae cute vapores alliciant in eius viscera usque non penetrant: nam aer cubiculi quem terra ad duos passus solida tegit acuelat, aestate frigidus est: haec enim intermedia terra rapit solis impetum*)."[129] Agricola had observed a counterexample. He reminded the reader that even with its "excessive heat (*nimio solis ardore*)," the sun still could not draw out metallic materials in some spots where trees provided shade (*vestiti arboribus sint et umbrosi*).[130] Agricola did not blindly devote himself to Aristotle's ideas. He tested Aristotle's theories against his own observations.

Agricola's understanding of the concepts of "dryness" and "moisture" reflect his adherence to Aristotelian views. Aristotle posited that the four transmutable elements possessed certain fundamental properties that acted as an "efficient" force upon the elements. These

[128] Aristotle, *Physics*, trans. C.D.C. Reeve (Indianapolis: Hackett Publishing Company, 2018), IV 1, 209a20-23. The discussion of Aristotle's theory on place is needlessly complicated by muddled translations of the ancient Greek author. For a thorough investigation into Aristotle's idea, see Peter K. Machamer, "Aristotle on Natural Place and Natural Motion," *Isis* 69 (1978): 377-387.
[129] Agricola, *De re metallica*, liber tertius, 54.
[130] Agricola wrote, "*quinetiam tantum abest ut sol est profundo terrae materiam metallicam eliciat...ut quidem possit plerosque locos venis abundantes, propterea quod vestiti arboribus sint et umbrosi*." Agricola, *De re metallica*, liber tertius, 54.

properties were dryness, dampness, heat, and cold. Dryness and dampness were passive. Heat and cold were active. The properties operated in pairs. For instance, "earth" was considered dry and cold. Agricola operated within the framework of Aristotle, even acknowledging how the sun could affect the dryness and coldness of the earth. Yet there were limits. The sun could not affect the movement of the earth. That is, the sun could not dislodge metals, or materials of the earth. Agricola's observations and experiences, meanwhile, led him to recognize the limits of the sun's power and with that the limits of Aristotle's theories.[131]

Agricola repeatedly prefaced his positions that contradicted Aristotle's theories with the phrase "not resistant by experience (*experiment non repugnant*)."[132] The statement succinctly distills down Agricola's belief about understanding the natural world: it was not sufficient to use inductive reasoning. Agricola emphasized that in order to comprehend a phenomenon, one should observe it and classify it.[133] Agricola presented and advocated an approach that coupled strict observation with the Aristotelian corpus.

Jacopo Zabarella (1533 – 1589) is another example of an intellectual who refined his interpretation of the Aristotelian doctrine as the times directed. In *De methodis* (1578), Zabarella proposed, on occasion, a strict interpretation of Aristotle's philosophy. Yet at other times his approach was innovative. More specifically, Zabarella's approach to Aristotle, as it pertains to the place of cause-effect relationships and of demonstration in teaching, reinforces the notion that humanism was neither immobile nor divorced from science. For instance, Zabarella used induction to discover known principles. He believed that one must proceed from universals to

[131] Robert Halleux also studied the ways in which Agricola diverged from ancient theories. He noted that Agricola disagreed with classical authors' theories of mineral deposits. He pushed against the notion that a germination occurred. Ancient writers believed that minerals grew in the earth, not unlike semen and embryos. Agricola, Halleux declared, thought that the process was "*physique et inorganique, il n'y a pas de sexe, pas de germe, pas d'insémination*." Robert Halleux, "La nature et la formation des métaux selon Agricola et ses contemporains," *Revue d'histoire des sciences* 27 (1974): 215.
[132] Agricola, *De re metallica*, liber tertius, 54.
[133] David R. Oldroyd, *Thinking about the Earth: A History of Ideas in Geology* (London: Athlone, 1996), 34.

particulars. Aristotle, in contrast, proceeded occasionally from particulars to universals. Aristotle did not go from universals to particulars in all cases. A paradox appeared, until Zabarella reconciled it. Aristotle's analyses ran from particulars to universals in the treatment of living things. The logician insisted that Aristotle did not "incorrectly" assess these entities. Instead, he held the treatment as "rational" because it eased the way of teaching.[134]

The objection that Aristotle placed the particular before the universal was of little consequence to Zabarella. Teaching sometimes demanded the abandonment of precepts. In these rare circumstances when teaching and knowledge would have rendered themselves enigmatic, a change in progression was reasonable. Zabarella's attempts to clarify the place of induction and demonstration, within a scientific method, whittles away at Kristeller's totalizing and synchronic rubric of humanism. *De methodis* provides an opportunity to see the plurality of thought within the humanist tradition. A cursory glance at the works of Zabarella shows that Agricola was not alone in his approach to Aristotle. Aristotle's works prompted discussion and disagreement among scholars. If Aristotle remained the authority on the subject of the scientific method and if all cultures read the texts in a different manner, then it reasons that science and its method remained culturally determined. In the humanist tradition, a single, universal Aristotle did not exist.

The Allusions to Antiquity

[134] Jacopo Zabarella, *Opera logica*, trans. John P. McCaskey (Cologne, 1597), I.13, 79; I.14, 81. For the secondary literature on Zabarella, see Heikki Mikkeli, *An Aristotelian Response to Renaissance Humanism: Jacopo Zabarella on the Nature of Arts and Sciences* (Helsinki: Societas Historica Finlandiae, 1992); Paolo Palmieri, "Science and Authority in Giacomo Zabarella," *History of Science* 45 (2007): 404-427; P.S. Popov, "The Logic of Aristotle and Formal Logic," *Philosophy and Phenomenological Research* 8 (1947): 1-22; Antonino Poppi, "Zabarella, or Aristotelianism as a Rigorous Science," in *The Impact of Aristotelianism on Modern Philosophy*, ed. Riccardo Pozzo (Washington, D.C.: The Catholic University Press, 2004), 35-63.

In addition to references to Aristotle, Agricola sprinkled his text with allusions and quotations from ancient Greek and Roman authors. At times, his references were overt; that is, he identified the writer and the source. Other times, he was less specific and more subtle. In these instances, he relied on the reader's knowledge-set and training to deduce the reference's providence. Although he may have obfuscated his sources, he never concealed his reasons for including them. The classical texts always served as illustrations in support of his crusade for mining.

For instance, when discussing the limits of man's attempts to excavate the earth, Agricola cited the works of Ovid (20 March 43 BC – 17/18 AD). Agricola did not call for miners to exhaust the preserves of nature by exploitation. He believed that there were limits to mining. In his opinion, men should not expend their time, energy, and resources attempting to recover the minerals at the depths of the earth. Those minerals, Agricola declared, "should not be sought (*eruenda ignitur non sunt*)."[135] The men who did extract those riches were "wicked (*scelerati*)."[136] Agricola turned to Ovid to support his claims of wickedness during the Iron Age. Echoing Ovid's words, Agricola reminded the reader that men descended into the earth and dug up "the alluring resources, the bad iron and the even deadlier gold (*effodiuntur opes…iam atque nocens ferrum ferro atque nocentius aurum*)."[137] Agricola presented the ancient Roman author's

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[135] Agricola wrote, "*Terra non occultat et ab oculis removet ea quae hominum generi utilia sunt et necessaria, sed ut benefica benigna atque mater maxima largitate fundit ex sese, et in aspectum lucem que profert herbas, legumina, fruges, fructus, arborum: at fossilia in profundo penitus abstrudit, eruenda ignitur non sunt*." Agricola, *De re metallica*, liber primus, 4.

[136] Agricola, *De re metallica*, liber primus, 4.

[137] Agricola wrote, "*Ovidius eam audaciam merito insequitur his versibus.*

Nec tantum segetes aliment atque debita dives
Poscebatur humus, sed itum est in viscera terrae,
Quasque recondiderat, Stygis atque admoverat undis,
Effodiuntur opes, irritamenta malorum.
Iam atque nocens ferrum ferro atque nocentius aurum
Prodierat, prodit bellum."

Agricola, *De re metallica*, liber primus, 4. Here, Agricola cited Ovid's *Metamorphoses* (8 AD). Ovid wrote, "The affluent earth was not only pressed for the crops and the food that it owed; men also found their way to its very

words as a warning, both to the reader and to the miner. He did not question the veracity of Ovid's thesis. Ovid's arguments were accurate and instructive. For Agricola, Ovid's writings documented the consequences of man's selfish past. The assumption, of course, is that Agricola believed that greed could spur a similar destructiveness in his time. The damage that Ovid described occurred in the Iron Age, and yet the events resonated with our early modern author. The actions of rapacious men created difficulties at an earlier epoch and could, quite plausibly to Agricola, wreak havoc again in the sixteenth century.

Agricola made another less overt attempt to warn his readers about avarice with his reference to Troy. He reiterated how "the products of the mines [were] not themselves the cause of war. For when a tyrant, inflamed with love for a woman of excellent form, makes war…the fault lies in the unbridled lust of the tyrant and not in the face of the woman (*belli etiam causa res fossils non sunt: ut enim cum unus aliquis tyrannus magno amore inflammatus in mulierem egregia forma, facit bellum...istiusmodi belli in effrenata tyranni libidine est culpa, non in facie mulieris*)."[138] Here, Agricola did not name his source. One possibility could have been the story of Helen of Troy. In Greek mythology, Helen's allure piqued the interest of Prince Paris of Troy, who abducted her and started the putative Trojan War. Her tale of romance appeared in Homer's *Iliad* and *Odyssey* and Virgil's *Aeneid*. We can assume that Agricola had some passing familiarity with these ancient Greek epic poems, given his humanist training at university and the recovery of ancient Greek texts in the early modern period. Perhaps the narrative of Helen was

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bowels, and the wealth which the god had hidden away in the home of the ghosts by the Styx was mined and dug out, as a further incitement to wickedness. Not dangerous iron, and gold—more dangerous even than iron—had emerged. Grim War appeared, who uses both in his battles, and brandished his clashing weapons in hands bespattered with slaughter." Ovid, *Metamorphoses*, trans. David Raeburn (London: Penguin Books, 2004), Book I, 137-143.

[138] Agricola, *De re metallica*, liber primus, 12.

ubiquitous during the writing of *De re metallica*, thus rendering redundant any declaration of the source material.

The significance of the reference did not hinge on the reader's familiarity with the source material. Agricola was able to construct and thusly control the reference's meaning. He told the reader what to absorb. Despite not making a reference to the source directly, Agricola left no ambiguity about this particular quotation's substance.

Agricola intended to show how history provided examples of avarice ravaging the world. He culled through the texts of ancient Greek and Roman authors to document the ways in which mining brought great wealth to republics. Yet, he also conceded that mining had devastated other economies.[139] Agricola reminded the reader how the Romans' thirst for gold led to the disintegration of their friendship with the Parthians.[140] He mentioned how Marcus Crassus (115 BC or 112 BC – 53 BC) desired the gold of the Parthians. Crassus' lust became the jest of his enemies, who poured liquid gold down his throat while declaring, "gold you thirst, gold you drink (*aurum sitis, aurum bibis*)."[141] Agricola viewed man's potential to love or to "thirst" for precious metals and minerals as the most serious challenge to the mining profession. By including literary and historical instances of the impact of greed from classical sources, Agricola

[139] Agricola stated, "*Quod autem metallica multos auxerit divitis ex historiis intelligimus, etenim (sic) inter scriptores antiquos constat aliquot respublica florentes, nonnullos reges, plurimos homines privatos ex metallis eorum atque ramentis divites esse factos*." Agricola, *De re metallica*, liber primus, 2.

[140] The Parthians lived in present-day northeastern Iran. When Crassus decided to invade, the Parthians had a good relationship with the Romans. Richard Paul Allen, "Overshadowed by Julius Caesar: The Importance of Marcus Crassus and Pompeius Magnus" (MA, diss., Southeastern Louisiana University, 2013), 31.

[141] Agricola, *De re metallica*, liber primus, 6. Marcus Crassus (115 BC or 112 BC – 53 BC) was a Roman general most remembered for his disastrous campaign against the Parthians. In *Parallel Lives*, Plutarch documented Crassus' military adventures in addition to his financial dealings. Plutarch portrayed Crassus as a wealthy man obsessed with wealth, using it to leverage political capital. In *De re metallica*, Agricola did little to disabuse his audience of Plutarch's rendering of Crassus. For Agricola, Crassus served as an example of a man too in love with money. His vice destroyed him. For more information on Crassus, see Richard Paul Allen, "Overshadowed by Julius Caesar: The Importance of Marcus Crassus and Pompeius Magnus" (MA, diss., Southeastern Louisiana University, 2013); T.J. Cadoux, "Marcus Crassus: A Revaluation," *Greece & Rome* 3 (1956): 153-161; and Keith Roberts, *The Origins of Business, Money, and Markets* (New York: Columbia University Press, 2011).

demonstrated how mining operations tested the mettle of a morally outstanding individual. Metals and minerals only swayed those with unstable footing.

The thirst for gold was a common trope in classical texts. In the *Aeneid*, Virgil described the fate of Polydorus, who was the youngest son of King Priam of Troy. At the outset of the Trojan War, Priam decided to entrust Polymnestor, the king of Thrace, with the care of his son and the protection of the royal Trojan treasury. When Troy fell, Polymnestor murdered Polydorus and cached the Trojan treasure. Virgil wrote:

> This Polydorus, with great weight of gold, luckless Priam had once sent in secret to be reared by the Thracian king, when he now lost hope in the arms of Dardania and saw the city beleaguered. When the power of Troy was crushed and Fortune withdrew, the Thracian, following Agamemnon's cause and triumphant arms, severs every sacred tie, slays Polydorus, and takes the gold perforce. *To what crime do you not drive the hearts of men, accursed hunger for gold?* When fear had fled my soul, I lay the divine portents before the chosen chiefs of the people, my father first, and ask what is their judgement.[142]

Ultimately, Polydorus's mother, Queen Hecuba, seeks revenge, killing Polymnestor for the betrayal. The image of King Polymnestor as the quintessential greedy man has appeared in numerous literary texts and reveals the popularity of the *Aeneid*.

Dante also used Virgil's example of King Polymnestor to embody the sin of avarice in the *Divina Commedia*. While in the fifth circle of Purgatory, Dante and Adrian encounter the hoarders and the wasters.[143] Dante listens as Hugh Capet recites a list of historical figures who were avaricious. With great distress, the King of the Franks includes his descendants in the list, along with King Polymnestor and Marcus Crassus. Capet proclaims:

> We cry Sapphira's and her husband's blame;

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[142] Virgil, *Aeneid*, trans. H. Rushton Fairclough (Cambridge: Harvard University Press, 1999), Book III, 49-59. Emphasis my own.

[143] Dante organized the circles in Purgatory in accordance with the familiar scheme of the Seven Capital Vices. St. Gregory the Great (540-604) first created the tiered system, laying out the sins in a particular order. The sins were pride, envy, anger, sloth, avarice, gluttony, and lechery. See Patrick Boyde, *Human Vices & Human Worth in Dante's Comedy* (Cambridge: Cambridge University Press, 2000), 70.

we praise the hooves that battered Heliodorus;
then round the ledge runs Polymnestor's name,

foul to all time with Polydorus' blood.
Then we conclude the litany crying: 'Crassus,
you supped on gold—tell us, did it taste good?'[144]

It is not shocking that Dante made references to King Polymnestor and Crassus. Dante relied heavily on classical texts, and he drew inspiration for his *Divina Commedia* from the *Aeneid*. Dante mirrored Virgil's text in his narration of the perilous journey of a wayward man to the promised land. Virgil, in many ways, was Dante's *maestro*. Dante emulated Virgil's language, tropes, and themes. Dante was a devoted classicist, echoing Virgil's depiction of the thirst for gold.[145]

Agricola was familiar with the trope, and he included his own reference to Virgil in the first book of *De re metallica*. Agricola wrote that "Virgil, speaking of Polymnestor, [said] that the crime of the murderer occurred because of greed. He breaks the law, murders Polydorus, and obtains gold. (*Virgiulius dicit homicidii culpam in avaritia residere de Polymestore loquens: Fas omne abrumpit, Polydorum obtruncat, et auro*)."[146] He paraphrased the *Aeneid* in order to show that metals did not corrupt men. Avarice corrupted men.

Agricola's reliance on the established recognition of these classical tropes to instruct his audience in moral matters affirms Kristeller's view that these sources serve as a model of moral instruction. Furthermore, the historian contended that humanists considered "classical antiquity

[144] Dante, *The Divine Comedy*, trans. John Ciardi (New York: New American Library, 2003), Canto XX, 112-117. Dante wrote, "*Indi accusiam col marito Saffira;/ lodiam i calci ch'ebbe Eliodoro;/ e in infamia tutto 'l monte gira/ Polinestor ch'ancise Polidoro;/ ultimamente ci si grida: 'Crasso,/ dilci, che 'l sai: di che sapore è l'oro?*'" Dante, *La Divina Commedia*, trans. Henry Wadsworth Longfellow (Oxford: Benediction Classics, 2012), 246.
[145] See Boyde, *Human Vices & Human Worth in Dante's Comedy*, 19; Pier Massimo Forni, "Dante between Antiquity and Modernity," *Dante Studies, with the Annual Report of the Dante Society* 127 (2009): 55; and Jay Rudd, *Critical Companion to Dante: A Literary Reference to His Life and Work* (New York: Facts on File, 2008), 145-146.
[146] Agricola, *De re metallica*, liber primus, 12.

their major guide and model in thought and literature and their moral writings."[147] Ovid's mythological narratives helped Agricola detail man's perennial struggle with greed. Agricola relied on the ideas and theories of ancient Greek and Roman authors to caution against the fractures caused by avarice and to extol the benefits of mining. He selected texts from ancient authors who articulated that the minerals were not themselves evil. Instead, evil men used wicked means to procure minerals and metals. Implicit in the use of these sources was Agricola's confidence in their authority.

Agricola undoubtedly understood that his audience would have accepted the authority of these sources. He taught lessons by appealing to the readers' vulnerabilities. Agricola turned to these ancient Greek and Roman sources in order to express how, throughout history, the love of gold and silver has undermined mankind's fidelity, "bringing forth judicial sentences for innumerable crimes (*emuntur iudicia, infinita scelera eduntur*)."[148] He used a classical allusion that those familiar with classical sources would have understood. Agricola relied on well-known sources that would convey the fragility of man and provoke the emotions of his readers.

The persuasiveness of Agricola's claims was contingent upon the audience's recognition of the sources' significance. He did not need to explain the sources' authority. He assumed that the reader would have accepted their authority. Thus, the sources had to have held some prominence in the minds and experiences of readers for the allusions and lessons to make an impact upon them.

The Emphasis on Greek

[147] Kristeller, *Renaissance Thought: The Classic, Scholastic, and Humanist Strains*, 26.
[148] Agricola, *De re metallica*, liber primus, 6.

It was not enough to display his knowledge of classical literature. Agricola also had to convince the reader of his ability to read and understand ancient Greek. He accomplished such a task by not translating Greek terms into Latin. For instance, in the fifth book, where he discussed the methods of surveying and excavating, Agricola refused to translate the Greek *κ ρ ν π τ α ι*.[149] He explained that this term defined the cross-cuts that miners made in the earth to connect vertical and inclined veins.[150] Similarly, Agricola used Greek terms to describe the angles of the shafts' structure. In that same fifth book, he documented how the miners created a right-angled triangle with the shafts. He used the Greek, *o ρ θ o γ ω ν ι o ν*, to describe this triangle with a right angle.[151] He either did not know the Latin equivalent or refused to translate the terms. It was a demonstration of his knowledge. Employing Greek has us believe that Agricola desired to be exacting with his terminology. The use of Greek also indicated to the reader that Agricola was continuing in a well-established tradition. In these examples, Agricola showed a cultivation and refinement of his linguistic skills.[152]

Humanists like Agricola needed a command of ancient Greek and Latin in order to imitate ancient writers. Imitating classical authors was good writing. But imitation of the classics could only occur if humanists had a philological skillset. Philology, in fact, stood at the center of *studia humanitatis*. According to historian Paul Grendler, the humanists learned these skills at university, where instructors taught them refined methods of philological scholarship. The more experienced humanists went on to publish printed editions of ancient Greek authors, providing commentaries and extending their own antiquarian studies. Greek held a symbolic importance,

[149] Agricola, *De re metallica*, liber quintus, 75.
[150] Agricola, *De re metallica*, liber quintus, 75.
[151] Agricola, *De re metallica*, liber quintus, 88.
[152] John F. Tinkler, "Renaissance Humanism and the genera eloquentiae," *Rhetorica: A Journal of the History of Rhetoric* 5 (1987): 280.

expressing a commitment to the *studia humanitatis*.[153] In the case of Agricola, we see his linguistic training in his classification schema.

The Precision of Terminology

In addition to his use of Greek terms, Agricola also used precise terms when classifying the veins in the mining operations. While discussing the veins and stringers in the third book of *De re metallica*, he detailed the similarities of three varieties of veins: *venae profundae*, *venae dilatatae*, and *venae cumulatae*. Agricola became accustomed to calling *venae profundae* those veins that "descend[ed] from the surface of the earth to its lowest depths (*summon terrae corio descendit in imam eius sedem*)."[154] The veins that "neither ascend[ed] to the earth's nor descend[ed] to earth's depths (*neque profundae instar ascendit versus terrae superficiem, nec descendit versus eius profundum*)" were the *venae dilatatae*.[155] As the name suggests, these veins expanded over a large area. Lastly, the *venae cumulatae* were the rarest type. These formed when pockets of minerals began to accumulate.[156] Agricola assigned precise terms to the veins because each one required unique locating and extracting methods. The rigor of linguistic precision indicated to the reader that Agricola had performed his due diligence. He had taken the time to observe the characteristics of the veins and thereafter classified them.

Agricola's exactness of terms contributed to the elegance of his prose. According to Christopher Celenza, humanists were intellectuals, but "above all they [were] readers and

[153] Grendler, *Schooling in Renaissance Italy: Literacy and Learning, 1300-1600*, 125. See also Kristeller, *Renaissance Thought: The Classic, Scholastic, and Humanist Strains*, 26; and Paul Oskar Kristeller, "Humanism and Scholasticism in the Italian Renaissance," *Byzantion* 17 (1944-1945): 352. Given how much emphasis Kristeller placed on linguistic skills, it is surprising that he did not elaborate on philology. One finds very little in the way of an explanation of philological coursework in Italy, for example.
[154] Agricola, *De re metallica*, liber tertius, 29.
[155] Agricola, *De re metallica*, liber tertius, 30.
[156] Agricola, *De re metallica*, liber tertius, 31.

writers."[157] Humanists, after all, were professional rhetoricians. For Agricola, conveying the details of mining operations meant avoiding the confusion of mining terminology. By using precise, distinguishable words, he attempted to provide clarity to the reader. Agricola's precision of terms provides another example of how he conforms to Kristeller's version of a humanist. Agricola thus made mining techniques more intelligible and useful. In *De re metallica*, we see his approach to eloquence—writing that did not deceive the reader.[158]

The Instruction of Morality

Agricola's prescription of proper attitudes and behaviors about mining operations was an attempt to guide the reader. He identified and documented the problematic traits that he found unappealing in men. The very inclusion of these behaviors in a text about mining places Agricola nicely into Kristeller's outdated humanist category. Admittedly, Kristeller has received criticism for his narrow application of the term *humanism*; so, it is interesting when Agricola affirms one of Kristeller's criteria.[159] Kristeller asserted that humanists wrote moral compositions in order to provide "theoretical and practical instruction to the individual, especially the young."[160] For Kristeller, humanists spent their time crafting not only political and economic tracts but also moral ones. Where readers could easily dismiss "the political and economic realities of the day," they could not reject so readily conduct literature.[161] According to Kristeller, humanists could always locate a reader who was interested in comportment guidance. Humanists endorsed

[157] Celenza, *The Intellectual World of the Italian Renaissance: Language, Philosophy, and the Search for Meaning*, 1.
[158] Hanna H. Gray, "Renaissance Humanism: The Pursuit of Eloquence," *Journal of the History of Ideas* 24 (1963): 498-503.
[159] For a discussion of the criticisms leveled at Kristeller, see Baker, "Illustrious Men: Italian Renaissance Humanists on Humanism," 5-12.
[160] Kristeller, *Renaissance Thought II: Papers on Humanism and the Arts*, 30.
[161] Kristeller, *Renaissance Thought II: Papers on Humanism and the Arts*, 30.

behavior that they found in ancient literature. Humanists sifted through the words of great classical orators in order to find precedents. The first step was identifying the behavior; the second was explaining the ethical truths about the behavior. Thirdly, humanists had to implore the audience to accept those truths.[162]

Agricola illuminated his understandings of the ethical truths of mining in *De re metallica*. At times, he was keen to include clever, thoughtful statements, such as "insane is he who values wealth over virtue. Insane is also he who rejects them, and does nothing, instead of putting them to good use (*insanit enim qui pluris facit divitias, quam virtutes. Insanit etiam qui easdem respuit, ac pro nihilo ducit, cum liceat ipsis bene uti*)."[163] Agricola's remark serves as evidence for Kristeller's belief that humanists "adorn[ed] [their] compositions with pithy statements quoted from the poets or coined by [themselves]."[164] Agricola, like others studied by Kristeller, fashioned himself a moral teacher; and he believed that truisms could help to facilitate his instruction.

Agricola's prescription of behavior rested on the assumption that metals were not inherently evil. Individuals' misuse made metals evil. Agricola declared that "man does not kill another with iron alone, but kills because of poison, starvation, or thirst (*homo hominem non solum ferro interficit, sed necat veneno, inedia, siti*)."[165] Men should not condemn the metals.

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[162] Gray, "Renaissance Humanism: The Pursuit of Eloquence," 506-507. Kristeller listed Niccolò Machiavelli's *The Prince* (1532) as an example of a text belonging to the moral literature genre of humanists. Kristeller wrote, "Aside from the political treatises, the moral literature of the Renaissance addressed itself mainly to the private individual…the purpose of the moral treatise is to give theoretical or practical instruction to the individual, especially the young. The lines between decency and success are not always as clearly drawn as we might wish, and as a result, the word virtue came to have a curious ambiguity. It meant moral virtue, to be sure, but Machiavelli's *virtù* stood more for the strong character that assured political success, and the "virtuoso" was distinguished by intellectual and social skill rather than by moral excellence." Kristeller, *Renaissance Thought II: Papers on Humanism and the Arts*, 30.

[163] Agricola, *De re metallica*, liber primus, 11.

[164] Kristeller, *Renaissance Thought and Its Sources*, 27.

[165] Agricola, *De re metallica*, liber primus, 13.

Instead, they should condemn their own vices. No clearer did Agricola make this point than with his use of wine as an example of the good producing the bad. He wrote:

> Wine, by far the best drink, if drunk in moderation, aids the digestion of food, helps to produce blood, and promotes the juices in all parts of the body… It is good not only for the body, but also for the mind. It throws dark and gloomy thoughts from our mind and delivers us cares and concerns. If drunk without restraint, the body hurts. An intoxicated man has no secrets. He rages and rants and commits many wicked atrocities.
>
> *Vinum, potus longe optimus, si modice bibitur, prodest con coctionis ciborum, ad sanguinis ortum…promovet succis in omnes corporis partes…bono est, nec corpori solum, sed animo etiam utile. Nam tenebras et caliginem mentis nostrae discutit: cura et sollicitudine nos liberat: reddit fidentes rebus. Sin immodice bibitur, corpus laedit, et gravibus morbis opprimit. Vinolentus etiam nihil tacitum tenet: furit et bacchatur, multaque scelera nefaria facit et flagitia*.[166]

Agricola concluded that wine was not the problem but man's profligate consumption of it. He assigned blame to the person. He assigned the person agency. Humans were not passive, unthinking beings to Agricola. They had emotions and vices. Iniquity was one such excess. A moderate drinker rarely got himself into trouble. Whereas an excessive drinker could never circumvent danger. Drinking and mining could evolve into similar vices without constraints, according to Agricola. A greedy miner, like an excessive drinker, succumbs to his vices. Yet a miner who mined moderately harvested the benefits of the natural world and rarely found himself in trouble.

The Lack of Dialogue

Agricola advocated for propriety in mining, yet he did so without relying on dialogue form. He did not engage in conversation with an adjudicator. Using interlocutors as a rhetorical

[166] Agricola, *De re metallica*, liber primus, 14.

device was one means of establishing continuity. Some intellectuals conversed within their texts with interlocutors as a means to illuminate the truth.[167] Those with whom the humanists spoke could have been friends, disciples, or critics. They could have even been imaginary, creations of fiction. By framing their ideas as a dialogue, intellectuals could attach an intimate tone. What mattered was the engagement with the reader. A conversation allowed the audience to become witnesses. A dialogue, as opposed to a treatise, permitted the reader to "see" or "hear" an exchange.[168] The reader became a passive participant, and the author became a more intimate authority. The genre of dialogue was popular among humanists because it not only permitted an imitation of their classical heroes like Plato and Cicero, but also fed their confidence in the persuasive power of their words.[169] In a dialogue, they could delineate the reasons as to why they asserted a position or refused to take one. A dialogue dramatized the process of analysis, argumentation, and exposition.

Historians have often deemed Leonardo Bruni's *Dialogi ad Petrum Histrum* as the quintessential humanist tract.[170] The *Dialogi* embodies many characteristics of humanism, such as emulating classical writers and illustrating civic pride. Written in the early fifteenth century,

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[167] Kristeller believed that dialogues best showcased the humanists' rhetorical considerations. In his seminal texts, Kristeller urged other historians to study the often-overlooked genre of humanists, even though he admitted that these texts represented a small portion of humanists' output. They nonetheless could illuminate their argumentation sensibilities. Kristeller viewed the humanists as innovators of the medieval rhetorical traditions. To his mind, the humanists' great invention was the inclusion of a less authoritative adjudicator. Contrasted with the medieval commentators, humanists gave their interlocutors less authority. Kristeller asserted that historians should use dialogues to trace the continuity and discontinuity between the medieval scholastic tradition and the Renaissance humanist one. See Kristeller, *Renaissance Thought and Its Sources*, 28.

[168] Historian John Tinkler points to Thomas Aquinas' *Summa Theologica* (1265–1274) as evidence of an authoritative speaker. In the humanist dialogues, Tinkler identified "skeptical distance between the author and authority." See John F. Tinkler, "Humanism and Dialogue," *Parergon* 6 (1988): 205.

[169] Luca Bianchi, "From Jacques Lefèvre d'Étaples to Giulio Landi, Uses of the dialogue in Renaissance Aristotelianism," in *Humanism and Early Modern Philosophy*, eds. Jill Kraye and M.W.F. Stone (London: Routledge, 2000), 41.

[170] For years historians have characterized Bruni as the embodiment of humanism. See, for instance, Hans Baron, *The Crisis of the Early Italian Renaissance: Civic Humanism and Republican Liberty in an Age of Classicism and Tyranny* (Princeton: Princeton University Press, 1966); Christopher S. Celenza, "Humanism and the Classical Tradition," *Annali d'Italianistica* 26 (2008): 25-49; Timothy Kircher, "Renaissance Humanism and its Discontents," *The European Legacy* 20 (2015): 435-449; and Carol Quillen, "The Uses of the Past in Quattrocento Florence: A Reading of Leonardo Bruni's Dialogues," *Journal of the History of Ideas* 71 (2010): 363-385.

probably around 1406, the *Dialogi* purportedly records the conversations between Bruni, Coluccio Salutati (1331 – 1406), Niccolò Niccoli (1364 – 1437), and Roberto Rossi (1355 – 1417).

In the *Dialogi*, Bruni created a debate about the primacy of Latin. It is Salutati who urges his younger friends to engage in "disputations," or face-to-face debates.[171] Salutati has each individual argue a point of view. Debating, Salutati contends, will give them all an opportunity to practice their oratorical skills and to showcase their knowledge of antiquity.[172] Salutati explains that such a debate will bring everyone closer to the ancient writers, even if their works have not survived. Not all of the participants agree with Salutati, however. Niccolò Niccoli believes that because they do not have access to the ancient texts, disputation is an impossible exercise. In the same breath, Niccoli criticizes the Aristotelians who marveled at their hero's philosophy, but they refused to learn Latin.[173] In Niccoli's mind, Dante was also at fault for not learning and using Latin. Salutati quickly comes to Dante's defense, proclaiming that Dante would have eclipsed the ancients' talents had he written in Latin. Dante's flaw, according to Salutati, was writing in the vernacular.[174] Niccoli objects to Salutati's praise, pointing out that Dante included literary and historical inaccuracies in the *Divine Comedy*.[175] The *Dialogi* continues in this

[171] Quillen, "The Uses of the Past in Quattrocento Florence: A Reading of Leonardo Bruni's Dialogues," 364.
[172] Quillen, "The Uses of the Past in Quattrocento Florence: A Reading of Leonardo Bruni's Dialogues," 364.
[173] Bruni stated, "*O praeclaros nostril temporis philosophos! Siquidem ea docent quae ipsi nesciunt; quos ego nequeo satis mirari, quo pacto philosophiam didicerint, cum litteras ignorant: nam plures soloecismos quam verba faciunt cum loquuntur: itaque illos stertentes quam loquentes audire mallem*." Leonardo Bruni, *Dialogi ad Petrum Histrum*, ed. Giuseppe Kirner (Livorno: Giusti, 1889), 15.
[174] Bruni wrote, "*Dantem vero, si alio genere scribendi usus esset, non eo contentus forem, ut illum cum antiquis nostris compararem, sed et ipsis et graecis etiam anteponerem. Itaque, Nicolae, sit u sciens prudensque illos praeteristi, afferas rationem oportet, cur Ipsos aspernere: sin autem oblivion aliqua tibi dilapsi sunt, parum mihi gratus videris, qui eos viros memoriae fixos non habeas, qui civitati tuae laudi et gloriae sunt*." Leonardo Bruni, *Dialogi ad Petrum Histrum*, 30.
[175] "*Nam quid est in illis quod aut admirandum aut laudandum cuiquam videri debeat? Ut enim a Dante incipiam, cui tu ne Maronem quidem ipsum anteponis, nonne illum plerumque ita errantem videmus, ut videatur rerum omnium fuisse ignarum? Qui illa Virgilii verba: 'Quid non mortalia pectora cogis, Auri sacra fames,' (quae quidem verba nonquam alicui vel mediocriter quidem docto dubia fuere) quid sentirent apertissime ignoravit. Nam cum in avaritiam dicta essent, is tamquam prodigalitatem detestarentus accepit. M. vero Catonem, eum qui civilibus bellis*

fashion with Niccoli and Salutati debating the literary legacy of the authors from both antiquity and the Trecento.

Bruni's *Dialogi* revived the dialogue form that was famously used by Cicero. In both *De oratore* (55 BC) and *Dialogi*, Cicero and Bruni, respectively, recreated men's conversations about oratory. Both writers also included male interlocutors of different ages and had them express conflicting opinions.[176] The similarities between *De oratore* and *Dialogi* are striking, yet not shocking. Bruni deliberately created a text that emulated Cicero's.[177] Historians have thusly used Bruni's text to illustrate the themes of humanism, like a devotion to antiquity, a stress of eloquence, and a predilection for debate.

Contrasting his contemporaries like Bruni, Agricola did not utilize the dialogue format to present his ideas. He relied on simple, direct exposition. He did give the critics of mining a voice, however. He chose to include his critics' opinions. He acknowledged the ideas of those who believed that mining was neither useful nor safe.[178] Indeed, he stated that there were "some who believed that mining work was dangerous because of the pestilential air that the miners destroyed their lungs (*tum dicunt periculosum esse metallicae operam dare, quod metallorum fossores interimantur modo ad aere pestifero, quem spiritu ducunt, modo haurientes puluerem*

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interfuit, senem admodum barba cana atque prolixa describit, ignorans videlicet tempora: ille enim quadragesimo octavo aetatis suae anno, iuvenis etiam atque aetate integra supremum diem Uticae clausit. Verum hoc leve est; illud autem gravius atque intolerabile, quod M. Brutum, hominem iustitia, modestia, magnitudine animi, omnique denique virtutis laude praestantem, ob Caesarem interfectum libertatemque populi romani ex faucibus latronum evulsam, summon supplicio damnavit; Iunium vero Brutum ob regem exactum, in campis Elysiis posuit. Atqui Tarquinius regnum a maioribus suis acceperat, eoque tempore rex fuit, cum esse regem iura permittebant; Caesar autem vi et armis rempublicam occupaverat, interfextisque bonis civibus, patriae suae libertatem sustulerat. Quamobrem, si sceleratus M., sceleratiorem esse Iunium necesse est; sin autem Iunius laudandus quod regem exegerit, cur non Marcus in caelum tollendus quod tyrannum occiderit? Omitto illud quod medius fidius christianum hominem scripsisse mepudet: quod eadem fere poena eum, qui mundi vexatorem, atque eum, qui mundi salvatorem prodidisset, affciendum putatvit." Leonardo Bruni, *Dialogi ad Petrum Histrum*, 31-32.

[176] Quillen, "The Uses of the Past in Quattrocento Florence: A Reading of Leonardo Bruni's Dialogues," 369.

[177] Jerrold E. Seigel, *Rhetoric and Philosophy in Renaissance Humanism* (Princeton: Princeton University Press, 1968), 103-105.

[178] Agricola, *De re metallica*, liber primus, 5.

pulmones ex ulcerantum macie extabescant)."[179] Agricola neatly, and rather graphically, demonstrated the merits of his critics' opinions. He may have invented those critics, but he did give them space. He did not dismiss their concerns. Miners were not free from danger, Agricola acknowledged. He himself witnessed the atrocities of mining accidents. But he was convinced that the miners could have prevented the accidents with proper instruction and training. Agricola was a fierce advocate of mining education. He set out the risks and demanded solutions. His engagement with his critics did not appear in the form of a dialogue; yet he was still persuasive.

Contributing to the persuasiveness of his argument was the posing of questions. Agricola peppered his exposition with queries to the reader. He asked, on one occasion, "who would not want to live as opposed to having everything, let alone metals? (*Qui enim non potior esset vivendi ratio, quam vel universa possidendi, nedum metalla*)."[180] With this quotation, Agricola placed himself within a moral debate. His rhetorical question was an attempt to engage again with those critics who purported that mining created avarice. Questions like this opened the metaphorical doors to a conversation. Agricola presented questions to the reader and then provided answers. He invited the reader into his thought process. He articulated an internal dialogue through questions and answers.

Agricola's lack of a dialogue form, then, places him outside the confines of historians' paradigms. He demonstrated that he possessed the learned literary skills of a humanist. Nevertheless, Agricola showed us those skills in a nontraditional way. He applied his training to discuss and document mining experiences. He was not composing his thoughts on civic participation like Leonardo Bruni. His intellectual contribution was the documentation of

[179] Agricola, *De re metallica*, liber primus, 3.
[180] Agricola, *De re metallica*, liber primus, 3.

experiences, his own and those of the miners. We could characterize Agricola as a humanist, only if we were to expand the definition of a *humanist*.

Conclusion

Agricola used classical allusions, employed precise terminology, cultivated philological skills, and defined proper behavior. Notwithstanding, he also refused to indulge in the decidedly humanist genre of dialogue. In this instance, Agricola falls outside of Kristeller's taxonomy. Perhaps, however, it is not even historically sound to categorize Agricola's stylistic choices as Agricola himself never identified as a humanist. In fact, the term *humanism* was coined in 1808 by a German educator.[181] Yet, despite being anachronistic, *humanism* remains ubiquitous in early modern histories in part because of its attachment to the *studia humanitatis*.

Agricola was a German intellectual who received his training in the *studia humanitatis* in Bologna. The pedagogical practice of humanism existed in early modern university settings. Students like Agricola did receive linguistic training in ancient Greek and Latin. No historian can deny that aspects of the intellectual tradition appeared across Europe. What historians have come to debate are the movement's origins, chronology, significance, and characteristics. As the literature stands, Agricola does not fall within the humanist category. In *De re metallica*, Agricola embodied a humanist by making references to classical Roman and Greek texts and featuring his philological skills. In other ways, he sheared away humanist attributes by not writing in a dialogue form.

[181] The German educator Friedrich Immanuel Niethammer (1766-1848) coined the term to describe an education system that focused on ancient Greek and Roman classics. See Celenza, "Humanism and the Classical Tradition," 26.

Aiding in the difficulty in categorizing Agricola as a humanist is historians' preoccupation with individuals. Scholars of humanism continue to use individuals' texts as yardsticks. They have judged their assessments of the movement against intellectuals of the period. The spotlight on individuals is not new to the history of humanism. Jacob Burckhardt famously focused on Leon Battista Alberti (1404 – 1472) to provide evidence for his argument that the Renaissance, and humanism along with it, ushered in modernity.[182] Although historians have abandoned Burckhardt's conclusion, they still use intellectuals to prove true their arguments. Hans Baron used Leonardo Bruni (1370 – 1444).[183] Ronald Witt relied on Petrarch (1304 – 1374).[184] Christopher Celenza framed his arguments around Lorenzo Valla (1406 – 1457) and Marisilio Ficino (1433 – 1499).[185] In fact, Celenza's most recent text relies exclusively on individuals to support his notion of humanism. In an episodic manner, Celenza's chapters oscillate between his historical actors.[186] He contends that humanists' texts illuminate not only personality traits, but also societal concerns. Intellectuals can indeed gauge conditions, but they are not the only means by which to arrive at social and cultural norms. A shift away from intellectuals and an emphasis on the actions of historical figures could help to expand historians' understanding of humanism. Historians would hopefully not feel compelled to judge intellectuals against other actors. Modern scholars of humanism do not need to assess an intellectual's humanist credentials; nor do they have to identify the thinker as a humanist. Agricola is a peculiar intellectual. In some ways, he embodied humanist characteristics. In other

[182] Jacob Burckhardt, *The Civilization of the Renaissance in Italy* (New York: Harper and Row, 1958), 106-108.
[183] See the third chapter in Baron's *The Crisis of the Early Italian Renaissance: Civic Humanism and Republican Liberty in an Age of Classicism and Tyranny*.
[184] See the third and sixth chapters in Witt's *In the Footsteps of the Ancients*.
[185] See the fourth chapter in Celenza's *The Lost Italian Renaissance: Humanists, Historians, and Latin's Legacy*.
[186] Celenza, *The Intellectual World of the Italian Renaissance: Language, Philosophy, and the Search for Meaning*, 1.

ways, he rejected them. What is certain is that he used his humanist proclivities to argue for the virtues of mining. He remained faithful to his ancient philosophical forebearers to the point when their ideas clashed with his own observations. He was loyal to their words, but he was not blindly devoted to them.

Chapter 3

Alloys, Alchemy, and Agricola: An Examination of Agricola's Quest to Make Metallurgy Less Secretive

Georgius Agricola elevated the arts of mining and metallurgy in *De re metallica* (1556). He explained to his educated Christian audience that he wrote the comprehensive how-to manual because he wanted to document the skills and the precision necessary to mine the earth and perform related metallurgical practices. Often overlooked, the crafts of mining and metallurgy had not yet captured the attention of writers in early modern Europe. Agricola, however, wanted to understand and share the day-to-day methods and theories of miners and metallurgists at the very moment when western Europe sought to increase the money supply. Agricola demonstrated how the crafts were a worthy source of study. Intentionally or unintentionally, he rebelled against the dark shadow that had enveloped the mechanical arts and rejected the negative connotations of manual labor and coin production.[187]

The present chapter focuses on the ways that Agricola detailed the processes and praised the contributions of metallurgists. His presentation of the metallurgists' skillset was unique because he classified those metallurgists as alchemists. He exposed their skills to the public, making metallurgical and alchemical theory readily available to a broader audience. Where alchemy was once considered secretive and deceptive, Agricola made it more open. He recorded with precision his observations in awe of the smelters and assayers. By noting their techniques and providing his own commentary, Agricola re-characterized alchemy. This chapter discusses

[187] Throughout the sixteenth and seventeenth centuries, the term *mechanical* referred to activities that required manual labor. Although the meaning of the word did come to include an association with machines, *mechanical* still had a connection to labor that one would have completed with one's hands. See Jim Bennett, "The Mechanical Arts," in *The Cambridge History of Science, volume 3*, eds. Katharine Park and Lorraine Daston (Cambridge: Cambridge University Press, 2008), 673-695.

the theme of secrecy in knowledge-making alchemical practices. The techniques were not so secretive that Agricola could not observe and then document them. He presented alchemy in a new way, one that identified metallurgists as alchemists, relied on Paracelsian theory, and promoted the creation of instruments for human utility. He wrote about metallurgical practices in a manner that unified elements of intellectual life, social standing, and gender dynamics. In Agricola's depiction, alchemists still remained secretive. They operated under a thin veil of mystery and concealment. It is crucial, then, to discern the moments when alchemical knowledge was shared or when it was hidden.

Technological Innovation and Craft Secrecy

By detailing the processes of assaying, smelting, burning, and roasting, Agricola destroyed craft secrecy. As an outsider, he was not incentivized to conceal craft practices. He did not possess the desire to protect, through concealment, the technical secrets of mining and metallurgy. Perhaps Agricola did believe that by publishing these "secrets" he was protecting them. His treatise could have been a measure to preserve them. In any case, Agricola falls into the category of primarily male intellectuals transmitting craft productions through written records.[188] In the years prior to Agricola's work, the practices remained ensconced within the particular community of metallurgists, who ostensibly communicated innovative techniques orally among one another.

Agricola's descriptions of alchemic practices made public an otherwise secret knowledge-set. The practice of making alchemy a less secretive endeavor illuminates Agricola's

[188] Karel Davids, "Craft Secrecy in Europe in the Early Modern Period: A Comparative View," *Early Science and Medicine* 10 (2005): 342.

virtues of faithfulness and precision. He wanted to describe metallurgical techniques both faithfully and precisely. Agricola understood that his readers had a disapproving opinion of alchemists, and he hoped to correct and provide an alternative example. He seemingly understood that his audience did not hold alchemists in high regard, believing them to be secretive and duplicitous. The unflattering discourse seemed to work in Agricola's favor as he described the specific techniques and experience needed to complete alchemical practices. The alchemists that he encountered were not secretive. In fact, they openly shared their knowledge-set. Agricola, then, was rewarded for making the claims more public.

Mario Biagioli explored the connection between secrecy, openness, and novelty in *Galileo's Instruments of Credit: Telescopes, Images, Secrecy* (2006). Biagioli contended that early modern individuals, like Agricola, maneuvered and conspired to reveal knowledge only when they could be rewarded. He had Galileo serve as an example of someone who actively conspired to conceal his findings so as not to be deprived of credit. Biagioli claimed that Galileo withheld specifications about his lens in order to impede his competitors' replications.[189] Galileo would go on to reveal his procedures only when he believed that the public would celebrate his openness and reward his novelty. For Biagioli, his lack of disclosure did not destabilize his claims.[190] It led, perhaps, to an even more celebratory reveal.

It is precisely this debate about technological innovation and craft secrecy that has captivated economic historians and historians of science.[191] Although historians disagree about whether secrecy hindered or stimulated knowledge-production, they have all focused on the

[189] Mario Biagioli, *Galileo's Instruments of Credit: Telescopes, Images, Secrecy* (Chicago: The University of Chicago Press, 2006), 81.
[190] Biagioli, *Galileo's Instruments of Credit: Telescopes, Images, Secrecy*, 83.
[191] See Koen Vermeir, "Openness versus secrecy? Historical and historiographical remarks," *The British Journal for the History of Science* 45 (2012): 165-188 and Koen Vermeir and Dániel Margócsy, "States of secrecy: an introduction," *The British Journal for the History of Science* 45 (2012): 153-164.

dissemination of knowledge by a member of that community. Economic historian Carlo M. Cipolla argued that the migration of skilled craftsmen contributed to technological development in the early modern period. His study focused on the arrival of French clockmakers to seventeenth-century London. Cipolla believed that the clockmakers had invaluable skills. They taught the English artisans about clockmaking, and they introduced capital to the London economy. Cipolla found evidence of decrees forbidding the emigration of skilled workers, an act which he contended was not unique to London. Other governments and administrations "knew that the loss of able craftsmen had grave consequences for the economy."[192] Skilled artisans, according to Cipolla, spread innovations and buttressed economies.

Pamela Smith also studied skilled artisan labor in seventeenth-century Europe, but she narrowed her study to one individual, the alchemist Johann Joachim Becher. In *The Business of Alchemy* (1994), Smith claimed that Becher found a hospitable audience at the court in Vienna for his alchemical endeavors. Furthermore, it is Smith's argument that Becher's success was in large part a result of the historical moment when alchemy shed its metaphysical and mystical exterior for a more practical and experiential approach. Agricola lived during the same time period as Becher. He too helped move the metallurgical and alchemical arts to resemble a more "scientific" enterprise. But Agricola, unlike Becher, was not a member of the metallurgical or alchemical communities. He was an outsider. No historian has yet considered the ways in which an outsider would have changed or modified the dissemination of information.[193]

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[192] Carlo M Cipolla, *Before the Industrial Revolution: European Society and Economy, 1000-1700* (New York: W.W. Norton & Company, 1980), 157.

[193] Historian Pamela Long defined secrecy as "intentional concealment." She acknowledged that there were gradations. Secrecy, in Long's mind, lies at one end of the spectrum, while openness occupies the other. See Pamela Long, *Openness, Secrecy, Authorship, Technical Arts and the Culture of Knowledge from Antiquity to the Renaissance* (Baltimore: The Johns Hopkins University Press, 2001).

A study of Agricola's *De re metallica* reveals how craft secrecy crossed social boundaries. Agricola collected and articulated the processes of men who as technicians and artisans were below Agricola's social standing. Agricola, in contrast, was an intellectual. He was not a member of the mining or metallurgy community. Notwithstanding, he saw these men and their practices as noteworthy. He wanted to peel away the layer of secrecy of their occupational practices. No longer would their expertise be hidden from those who lacked an understanding of the craft.[194] Agricola sought to bring that understanding of alchemy to an intellectual audience through his detailed observations.

Alchemy was both a spiritual and a performative endeavor. The alchemist worked to perfect nature. Broadly defined by historian Michela Pereira, *alchemy* in the Middle Ages and early modern period was the "philosophical search for the agent of material perfection of base materials."[195] Alchemists created materials derived from nature that could serve society. Utility, according to historian Pamela Smith, inspired alchemists to discover, create, and transform materials.[196] In this way, the search for perfection combined "representation with performance, spiritual experience with material agency, speculative philosophy with the examination of 'empirical particulars.'"[197] The alterations to natural goods involved processes such as calcination, distillation, coagulation, and tincturing, all of which historians have traced to the ancient Greeks and Egyptians.[198] Indeed, historians have stratified the history of western

[194] Pamela H. Smith, "What is a Secret? Secrets and Craft Knowledge in Early Modern Europe," in *Secrets and Knowledge in Medicine and Science, 1500-1800*, eds. Elaine Leong and Alisha Rankin (London: Routledge, 2011), 49.
[195] Michela Pereira, "Alchemy and the Use of Vernacular Languages in the Late Middle Ages," *Speculum* 74 (1999): 336.
[196] Pamela H. Smith, *The Business of Alchemy: Science and Culture in the Holy Roman Empire* (Princeton: Princeton University Press, 1994), xii.
[197] Bruce T. Moran, "Introduction," *Isis* 102 (2011): 300.
[198] Bruce T. Moran, "Art and Artisanship in Early Modern Alchemy," *Getty Research Journal* 5 (2013): 2.

alchemy into three periods: Greco-Egyptian, Arabic, and Latin European.[199] Some historians of science have also sought to locate the instances when theories of alchemy expanded and contracted.[200]

To speak of alchemy was to discuss theory and practice. Alchemists actively gathered information about the natural world through experimentation and observation. One such example was assaying, the process of analyzing the quality and quantity of ores. Alchemy was both an art and a craft that required the use of one's hands. It also had a cerebral component: theory. Through syllogisms, alchemists proved or disproved their conjectures. Doing alchemy called for access to the "worlds of both…the scholar (through books) and of the artisan (through the laboratory)."[201] Indeed scholars have begun to examine the ways in which alchemists secured patronage, conducted experiments, and communicated findings. Throughout the 1960s and 1970s, historians of science fiercely debated the instances where alchemy served as the preamble to modern, recognizable chemical experiments and conjectures.[202]

Challenging the teleological objective of detecting the modern science's origins, this chapter examines Agricola's representation of alchemists. The novelty of this chapter is the inclusion of metallurgists within the category of alchemists. Agricola saw the metallurgists as alchemists. Historians of alchemy have overlooked metallurgists simply because they were not solely interested in *chrysopoeia*, or the transmutation of gold.[203] Agricola showed that metallurgists too were engaged in the extensive labors of transmutating gold or silver. While creating gold or silver did occupy a fair amount of time in the workspace, they also extracted

[199] Lawrence M. Principe*, The Secrets of Alchemy* (Chicago: The University of Chicago Press, 2013), 4.
[200] See William R. Newman and Lawrence M. Principe, "Alchemy vs Chemistry: The Etymological Origins of a Historiographic Mistake," *Early Science and Medicine* 3 (1998): 38.
[201] Smith*, The Business of Alchemy*, 48.
[202] See Newman and Principe, "Alchemy vs Chemistry: The Etymological Origins of a Historiographic Mistake," 38.
[203] Moran, "Art and Artisanship in Early Modern Alchemy," 1.

other metals and minerals from ores. The metallurgists' methods for removing materials were similar to the experiments of alchemists. Agricola grouped together alchemists and metallurgists and provided evidence that historians should consider metallurgy and alchemy in tandem. Scholars should not divide them into two discrete spheres of activity.

Aristotle, Magnus, and Paracelsus: Agricola's Intellectual Inheritance

Agricola, however, was not the first to write an alchemical and metallurgical text with the hope of lifting the veil of secrecy from the field. Albertus Magnus (1193/1200 – 1280) circulated his own impressive treatise, *De mineralibus* (1260), three centuries prior to the publication of Agricola's *De re metallica*. A Dominican theologian, Magnus was interested in tracking the methods of metal transmutations.[204] In his quest to learn about the changes humans could make to natural elements, Magnus found himself reading the Latin-translated works of Avicenna (970 – 1037), Averroës (1126 – 1198), and other Muslim writers.[205] He visited the alchemists in their workspaces in Cologne and Paris, as well as the miners in their shafts in Goslar and Freiberg. Observing their practices grounded and contextualized the theories that he had come to understand.[206] Reading the treatises and visiting the alchemists provided a more robust comprehension of alchemical practices. It was not enough for Magnus to study the methods; he wanted to bear witness to them. Agricola acknowledged Magnus' contribution to the literature on mining and metallurgy. He wrote:

> Finally the rivers or streams that flow from the eastern sun… or those that flow from the northern parts to the southern parts, they favor those who approach the closest to the lauded ones because they have more gold. But because gold is not

[204] Pearl Kibre, "Alchemical Writings Ascribed to Albertus Magnus," *Speculum* 17 (1942): 499.
[205] E.J. Holmyard, *Alchemy* (Middlesex, England: Penguin Books, 1957), 116.
[206] Kibre, "Alchemical Writings Ascribed to Albertus Magnus," 109.

> generated in rivers and streams as we have discussed in *De Subterraneorum Ortu et Causis*, Book V, against Albertus. Gold is snatched away from the veins and stringers and settled in the sands, in whatever course the rivers or streams flow, that is not resistant to experience. However, we do not deny that gold is generated in veins and stringers which lie under the beds of rivers or streams…
>
> *Postremo fluvii vel rivi, qui ab orientis solis partibus manant... aut qui ad septentrionum partibus manant in meri diei partes, quo propius ad iam laudato accedunt, eo sunt auri feraciores: quod longius ab eis discedunt, eo sunt minus auri feraces. Sic isti sentient de fluviis et rivis. Quia vero aurum non gignitur in fluviis et rivis, ut lib. De subterraneorum ortun et causis disputavimus contra Albertum, sed ad venus et fibris abreptum considit in omnium rivorúmue arenis, quamque tandem cursum tenue rit fluvius aut rivus in eo aurum inveniri posse rationi est consentaneum, cui experiment etiam non repugnant. Attamen aurum in venis et fibris, quae sunt sub alveo fluviis vel rivi, ut in caeteris gigni et inveniri non negamus…*[207]

Agricola appreciated Magnus' approach, even while contradicting his findings. They both observed, collected, and recorded the specialized tasks and communications of miners and alchemists.

Agricola also shaped his ideas after those of another important scholar in the history of alchemy, Paracelsus. Born Philippus Aureolus Theophrastus Bombastus von Hohenheim on 17 December 1493 at Maria-Einsiedeln, a village near Zürich, Paracelsus wrote texts on alchemical thought, such as *The Treasure of Treasures for Alchemists*.[208] He dismissed the notion that alchemy's prestige was derived from efforts to create gold and silver. For him, this was not the primary aim. He claimed that alchemy's true purpose lay in preparing medicines. Paracelsus

[207] Georgius Agricola, *De re metallica* (Basel: Froben Press, 1556), liber tertius, 54.

[208] Holmyard, *Alchemy*, 165; 170. According to historian E.J. Holmyard, he selected the name Paracelsus to indicate that he was superior to Celsus (ca. 25 B.C.-A.D. 45), an ancient Roman author of medicine. See also Allen G. Debus, "The Chemical Philosophers: Chemical Medicine from Paracelsus to van Helmont," in *Chemistry, Alchemy, and the New Philosophy, 1550-1700* (London: Variorum Reprints, 1987), 235-259; Allen G. Debus, "Fire Analysis and the Elements in the Sixteenth and the Seventeenth Centuries," in *Chemistry, Alchemy, and the New Philosophy, 1550-1700* (London: Variorum Reprints, 1987), 127-147; and Allen G. Debus, "The Paracelsians and the Chemists: The Chemical Dilemma in Renaissance Medicine," in *Chemistry, Alchemy, and the New Philosophy, 1550-1700* (London: Variorum Reprints, 1987), 185-199.

therefore argued for the utility of alchemical practices.[209] Alchemists could create therapeutic substances.[210] He believed that nature produced both adverse and advantageous elements. As for the former, he argued that alchemists could isolate those impurities, extract them, and create minerals and metals.[211] For Paracelsus, alchemy was the transformation of substances into a fixed, finished product. When religious conservatives denounced the transmutation of God's natural environment, Paracelsus reconciled his theological beliefs with those of alchemy. He declared, "[f]or God endowed man with reason, in order that he might know what the desire means. But he himself must decide whether to yield to it or not, whether to follow his reason or not. God has placed the seed in man's speculation, in which his reason lies, and in the object which kindles the speculation."[212] Paracelsus advocated engagement; men did not have to watch idly. They could instead engage in their natural environment and develop a product that society could utilize.

Paracelsus used iron to demonstrate further his idea that nature provided the means by which to produce human instruments. He asserted, "God has created iron, but not what can be made from it, namely horseshoes, rods, sickles; He simply gives us iron ore…the iron must be separated from the dross and then whatever is to be made should be forged."[213] This quotation is crucial, not only because it highlights Paracelsus' views that humans could interfere with their natural environments and still remain faithful servants to God, but because it also identifies smelters and smiths as alchemists. For Paracelsus, the men who worked with metals belonged in

[209] Paracelsus' contention that alchemists could produce goods with great utility to humans harkens back to Pamela Smith's observation. Smith, *Business of Alchemy*, xii.
[210] Holmyard, *Alchemy*, 170.
[211] Moran, "Art and Artisanship in Early Modern Alchemy," 2.
[212] Paracelsus, *Das Buch von der Gebärung der Empfindlichen Dinge in der Vernunft* (c. 1520), 3.2. Quoted in Nicholas Goodrick-Clarke, *Paracelsus: Essential Readings* (Berkeley: North Atlantic Books, 1999), 59.
[213] Paracelsus, *Labyrinthus Medicorum Errantium* (1538), 7.3. Quoted in Goodrick-Clarke, *Paracelsus: Essential Readings*, 102-103.

the same category of workers as those who created gold and silver. Agricola borrowed this broader definition of alchemy. For both Paracelsus and Agricola, alchemists included an expansive range of workers who attempted to transform raw materials into goods that could be more useful. Smelters and smiths had a familiar presence in society. Both Paracelsus and Agricola made alchemists more visible and familiar, less hidden and alien.

Paracelsus' thoughts aligned with those of Agricola, who firmly believed that humans should interact with their environment. Agricola encouraged engagement with nature. From observing the mining and metallurgical practices of the laborers, he learned how nature rarely produced one pure metal. Rather workmen had to develop the means by which to siphon and separate them. Agricola wrote, "frequently two metals, rarely more than two, [were] melted out of one ore, because naturally however there [was] some amount of gold in silver and in copper, and some silver in gold, copper, lead, and iron… (*Saepius enim duo metalla, rarius plura ex una eademque vena conflari solent. Naturaliter autem potissimum auri quaedam portio inest in argento et in aere: argenti quaedam in auro, in aere, in plumbo nigro, in ferro: aeris aliqua in auro, in argento, in plumbo nigro, in ferro: plumbi nigri aliqua in argento: ferri denique quaedam in aere…*)"[214] According to Paracelsus, nature produced a variety of elements that interacted to produce ores containing a blend of metals. He expanded upon the Aristotelian theory of nature's principles—air, earth, fire, and water. These elements existed in addition to salt, sulfur, and mercury. The existence of those last three elements formed the basis for Paracelsus' theory.[215] He believed that humans could find salt, sulfur, and mercury in nature; isolate them in an alchemist's workspace; and then utilize them to perfect the imbalances of the

[214] Agricola, *De re metallica*, liber decimus, 354.
[215] Debus, "Fire Analysis and the Elements in the Sixteenth and the Seventeenth Centuries," 129.

human body. For Paracelsus, salt, sulfur, and mercury were powerful poisons that alchemists could develop for physicians to deploy to treat human ailments.[216]

The specificity with which Agricola described the processes of extracting sulfur and distilling salt suggests that he was familiar with Paracelsus' theory. Sulfur was corrosive to metals and could "resolve [them] into ashes (*in cinerem resoluit metallum*)."[217] Sulfur was most harmful, above all, to iron. The smelters all agreed that they had to remove it from the ores. To prepare sulfur, the smelters boiled a mixture of gold, silver, glass, saltpeter, and salammoniac in vinegar.[218] After six hours, the smelters poured the substance into "a vessel and washed [it] with warm water (*effusum in vasculum aqua calida*)."[219] The residue that settled at the bottom of the vessel was dried sulfur, understood by the smelters to be a component of metals.[220] Despite not being a component of metals, salt also proved invaluable to the smelting process. The smelters would use salt in their recipes to extract the impurities from gold.[221] Thus the smelters found a method through which to obtain the ingredient. Smelters knew to refine salt by boiling "river

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[216] "The body is developed from Sulphur, that is, the whole body is one Sulphur, and that a subtle Sulphur which burns and destroys invisibly. Blood is one Sulphur, flesh is another, the major organs another, the marrow another, and so on; and this Sulphur is volatile. But the different bones are also Sulphur, only their Sulphur is fixed: in scientific analysis each Sulphur can be distinguished. Now the stiffening of the body comes from Salt: without the Salt no part of the body could be grasped. From Salt the diamond receives its hard texture, iron its hardness, lead its soft texture, alabaster its softness, and so on. All stiffening or coagulation comes from Salt. There is therefore one Salt in the bones, another in the blood, another in the flesh, another in the brain, and so on. For as many as there are Sulphurs there are also Salts. The third substance of the body is Mercury, which is a fluid. All parts of the body have their own fluid: the blood has one, the flesh has another, the bones, the marrow, each has its own fluid, which is Mercury." Paracelsus, *Opus Paramirum* (1531), 6.11. Quoted in Goodrick-Clarke, *Paracelsus: Essential Readings*, 82-83. See also Debus, "The Chemical Philosophers: Chemical Medicine from Paracelsus to van Helmont," 237.

[217] Agricola, *De re metallica*, liber octavus, 213.

[218] Agricola, *De re metallica*, liber decimus, 367.

[219] Agricola, *De re metallica*, liber decimus, 367.

[220] According to Pamela Smith, the idea that sulfur, in addition to mercury, was a component of metals entered the European knowledge base thanks to the Latin-translated works of Jabir Ibn Hayyan (721-813). See Pamela H. Smith, "Vermilion, Mercury, Blood, and Lizards: Matter and Meaning in Metalworking," in *Materials and Expertise in Early Modern Europe: Between Market and Laboratory*, eds. Ursula Klein and E.C. Spary (Chicago: The University of Chicago Press, 2010), 39-40.

[221] In fact, Agricola listed the recipe that smelters use to create a metal that when melted with an ore containing gold, the gold would get drawn out. The smelter started with one *libra* of the concentrates from washing pyrites, or other stones to which gold adheres. Then he would add half a *libra* of salt, half a *libra* of argol, a third of a *libra* of glass-galls, a sixth of a *libra* of gold or silver slags, and a *sicilicus* of copper. Agricola, *De re metallica*, liber nonus, 324.

water (*aqua fluvialem*)" and waiting for it to evaporate.[222] The smelters understood that nature produced salt; humans simply had to find the means to extract it. Agricola agreed with Paracelsus that humans should take it upon themselves to manipulate nature for their own uses. Learning and exploring the ways to remove elements from nature was neither deceptive nor irreligious.[223]

Paracelsus and Agricola's shared notion that alchemists could mimic, or even perfect, nature was undoubtedly rooted in Aristotle's writings. In the second book of *Physics*, Aristotle stated, "the arts either, on the basis of Nature, carry things further [*epitelei*] than Nature can, or they imitate [*mimeitai*] Nature."[224] Alchemists seized these words to claim that their craft duplicated nature's gifts and also rendered them superior. According to historian William Newman, medieval alchemists used Aristotle's texts to legitimize their theoretical frameworks. More specifically, alchemists believed that Aristotle affirmed the use of experiments to arrive at fundamental truths about nature.[225] Aristotle gave them the toolbox with which to defend their assertions.

Most alchemists working in Agricola's time subscribed to Aristotle's principles concerning the formations of metals and minerals. Aristotle contended in the first three books of *Meteorologica* that there were two "exhalations," vaporous and smoky. The vaporous exhalation occurred when the sun's rays shined on still water.[226] This exhalation was cold and moist, while

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[222] Agricola, *De re metallica*, liber decimus, 367.
[223] According to Elisabeth Berry Drago, alchemists were constantly pushing up against the stereotype of them being cheats and frauds. She wrote, "Gold and greed appear again and again as cornerstones of alchemical satires…the alchemist as a dishonest seller of false goods and false knowledge does more than associate the alchemist with centuries-old moral anxieties around money. Such a treatment positions the fraudulent alchemist as a type of fraudulent merchant in an era of emerging commercial economies." Elisabeth Berry Drago, *Early Modern Artistry and Experiment in the Work of Thomas Wijck* (Amsterdam: Amsterdam University Press, 2019), 51.
[224] Aristotle, *Physics* 2.8.199a.15-17.
[225] William Newman, "What Have We Learned from the Recent Historiography of Alchemy?" *Isis* 102 (2011): 315.
[226] See D.E. Eichholz, "Aristotle's Theory of the Formation of Metals and Minerals," *The Classical Quarterly* 43 (1949): 141. Aristotle stated, "It produce[d] two different kinds of body, being itself twofold just as it is in the upper

the smoky was hot and dry. The smoky exhalation formed when the sun's rays struck torrid land.[227] According to Aristotle, the vaporous and smoky exhalations were responsible for creating metals. The aridity of the land suppressed the vaporous exhalation and converted it into metal. Together the exhalations formed metals.

Centuries after Aristotle formulated his theories of exhalations, assayers measured, developed, and tested the methods by which they could determine and extract specific metals from ores.[228] Assayers, unlike most alchemists, recorded and transmitted their ideas to others outside of the field. Where historians have neatly divided alchemy and assaying into distinct fields of practice, Agricola was keen to combine them. For him, they both fell under the category of metallurgy, as they both involved the techniques for discovering alloy compositions.

Mining, Coining, and Smelting: Agricola's Historical Moment

Coining encouraged the field of assaying because it relied on the recognition of alloy compositions. In the early modern era, a complex relationship between assayers, metallurgists, and governments emerged. Precious metals, such as gold, silver, and on occasion copper, were

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regions. For there [were], we maintain, two exhalations, one vaporous and one smoky; and there [were] two corresponding kinds of body produced within the earth, "fossil[s]" and metals. The dry exhalation by the action of its heat produces all the "fossil[s]," for example, all kinds of stones that [were] infusible—realgar, ochre, ruddle, sulphur and all other substances of this kind. Most "fossil[s]" [were] colored dust or stone formed of a similar composition, for instance cinnabar. Metals [were] the product of the vaporous exhalation, and [were] all fusible or ductile, for example, iron, gold, copper. These [were] all produced by the enclosure of the vaporous exhalation, particularly within stones, whose dryness compress[ed] it together and solidifi[ed] it, just as dew and frost solidify when they have been separated—only metals [were] produced before separation ha[d] taken place." Aristotle, *Meteorologica*, trans. H.D.P. Lee (Cambridge: Harvard University Press, 1952), Book III, 378a26ff.

[227] Holmyard, *Alchemy*, 24.

[228] Cyril Stanley Smith and R. J. Forbes, "Metallurgy and Assaying," in *A History of Technology: From the Renaissance to the Industrial Revolution, c. 1500-c. 1750*, ed. Charles Singer (Oxford: Oxford University Press, 1957), 59.

the basis of coinage. Yet no single authority stamped the metals into the coins.[229] Coinage had to serve two purposes: to make coins identifiable and to make them uniform. The latter proved challenging because of the prevalence of fraud.[230] That is, the amount of metal in a coin was never a constant; it varied. Multiple authorities stamped indiscriminate amounts of metals into the coins. Evaluating these discrepancies, governments sought to standardize the processes of alloy creation. They found that converting the ores of jewelry or foreign coins into a single alloy allowed for a more predictable measurement.[231] Smelting and refining became imperative to coining operations.

Agricola wrote *De re metallica* at a moment when western European nations were attempting to recover from a decline in gold and silver production. In earlier centuries, the Black Death radically reduced the population of Europe and forever changed the European markets. The severe shortage of labor led to a drastic fall in output.[232] In Germany, miners, smelters, and proprietors were searching for more efficient assaying methods because the mines were becoming less productive and more expensive. At the same time, extracting and refining ores became more arduous tasks because the veins were less abundant. The miners had to work harder

[229] Jotham Parsons, *Making Money in Sixteenth-Century France: Currency, Culture, and the State* (Ithaca: Cornell University Press, 2014), 5. For more sources on coinage, see Louise Buenger Robbert, "Monetary Flows—Venice 1150 to 1400," in *Precious Metals in the Later Medieval and Early Modern Worlds*, ed. J.F. Richards (Durham, North Carolina: Carolina Academic Press, 1983), 53-78; Harry E. Cross, "South American Bullion Production and Export 1550-1750," in *Precious Metals in the Later Medieval and Early Modern Worlds*, ed. J.F. Richards (Durham, North Carolina: Carolina Academic Press, 1983), 397-424; Glyn Davies, *A History of Money* (Cardiff: University of Wales Press, 2016); Harry A. Miskimin, "Money and Money Movements in France and England at the end of the Middle Ages," in *Precious Metals in the Later Medieval and Early Modern Worlds*, ed. J.F. Richards (Durham, North Carolina: Carolina Academic Press, 1983), 79-96; John Munro, "Bullion Flows and Monetary Contraction in late-Medieval England and the Low Countries," in *Precious Metals in the Later Medieval and Early Modern Worlds*, ed. J.F. Richards (Durham, North Carolina: Carolina Academic Press, 1983), 97-158; John J. Tepaske, "New World silver, Castile and the Philippines 1590-1800," in *Precious Metals in the Later Medieval and Early Modern Worlds*, ed. J.F. Richards (Durham, N.C.: Carolina Academic Press, 1983), 425- 445; and Thomas Walker, "The Italian Gold Revolution of 1252: Shifting Currents in the Pan-Mediterranean Flow of Gold," in *Precious Metals in the Later Medieval and Early Modern Worlds*, ed. J.F. Richards (Durham, North Carolina: Carolina Academic Press, 1983), 29-52.

[230] Pamela Long, "The Openness of Knowledge: An Ideal and Its Context in 16th- Century Writings on Mining and Metallurgy," *Technology and Culture* 32 (1991): 342.

[231] Parsons, *Making Money in Sixteenth-Century France: Currency, Culture, and the State*, 7.

[232] Davies, *A History of Money*, 166.

to manipulate and extract the ores, and proprietors had to pay laborers higher salaries. The mines began to drain the German states financially and physically.[233]

Exacerbating this crisis was the influx of precious metals from the Spanish colonies in the Americas.[234] The expanding supply lowered the value of gold and created a moment of economic transformation that historians have since labeled the "price revolution."[235] Despite disagreeing over whether specie (mostly silver) from the New World caused inflation in Europe, scholars all agree that there was an increase of specie supply. On one side of the debate, there are those who believe that the bullion led to an increase in prices across Europe and produced a balance-of-payments deficit. Occupying the other side of the debate are those historians who contend that the specie did not drive up the prices, rather governments did. The scholars all agree that prices across Europe changed; yet they all use different primary sources to arrive at their conclusions. Earl J. Hamilton, for instance, launched the debate after having scrutinized medieval Spanish monetary decrees and mint ordinances.

Carlo Cipolla attributed the increase of Italian prices from 1552 – 1560 to the rebuilding efforts after the Habsburg–Valois War (1551 – 1559) in his article "The so-called 'Price Revolution': Reflections on the 'Italian Situation" (1972).[236] He questioned the timing of the

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[233] John Day, "The Great Bullion Famine of the Fifteenth Century," *Past & Present* (1978): 35; John U. Nef, "Mining and Metallurgy in Medieval Civilisation," in *The Cambridge Economic History of Europe from the Decline of the Roman Empire*, eds. Edward Miller, Cynthia Postan, and M.M. Postan (Cambridge: Cambridge University Press, 1987), 723.

[234] Long, "The Openness of Knowledge: An Ideal and Its Context in 16th- Century Writings on Mining and Metallurgy," 341.

[235] The particularities of this source base introduce one of the three significant problems of this entire dispute. In his book *American Treasure and the Price Revolution in Spain, 1501-1650* (1934), Hamilton looked only at the registry lists recorded in Seville by agents of the House of Trade (*Casa de Contratación*) and the made conclusions about the economic health of all of medieval and early modern Europe. The assumption, no doubt, is that all the European economies were connected. There was a global market. The debate continues to regenerate each time a scholar asserts a conclusion about Europe as a whole after having interpreted sources from one locale. It seems more sensible to evaluate each government and state's economy on its own terms.

[236] See Carlo Cipolla, "The so-called 'Price Revolution': Reflections on the 'Italian Situation,'" in *Economy and Society in Early Modern Europe, Essays from Annales*, ed. Peter Burke (London and New York: Routledge, 1972), 43-46; Douglas Fisher, "The Price Revolution: A Monetary Interpretation," *The Journal of Economic History* 49

price spikes. He looked at eight years of indices and concluded that there was another plausible explanation for the inflation—war. Cipolla's decision to focus only on eight years of economic history allowed him to eliminate distractions. His was a microstudy of sorts that reaffirms how the temporal scope affects the conclusions that the historian reaches. Temporal differences yield conflicting conclusions. Hamilton chose to start his study in the Middle Ages with the Black Death because he believed that the Black Death reduced the population of western Europe at the moment when gold coinage in western Europe was increasing the money supply. The surge in pricing across Europe during the sixteenth and seventeenth centuries has held the attention of historians for decades. Micro and macro historical approaches provide conflicting explanations at times.

Agricola's *De re metallica* can also serve as a source to understand the economy of western Europe. Although he made no mention of inflation, he did compose the text at the presumed apex in the European markets' price rises. Metalworking was evolving into an expensive undertaking. According to economic historian John Nef, the annual output of silver in central Europe was nearly three million ounces between 1460 and 1530.[237] In Saxony, where Agricola focused his interests, the average yearly silver output during the period 1521 to 1544 was 304,320 ounces and during the period 1545 to 1560 was 420,800 ounces.[238] Proprietors had become increasingly agitated at the increasing costs of the coining and assaying businesses. It was at precisely this moment that Agricola sought to record the practices of metalworking.

(1989): 883-902; Earl J. Hamilton, *American Treasure and the Price Revolution in Spain, 1501-1650* (Cambridge, Massachusetts: Harvard University Press, 1934); Earl J. Hamilton, "Prices as a Factor in Business Growth: Prices and Progress," *The Journal of Economic History* 12 (1952): 325-349.

[237] Nef, "Mining and Metallurgy in Medieval Civilisation," 735. Nef argued that this period was the zenith of silver production. In fact, those numbers were not seen again until the nineteenth century.

[238] John U. Nef, "Silver Production in Central Europe, 1450-1618," *Journal of Political Economy* 49 (1941): 579.

Agricola found smelting, the process of extracting metals from ores through heating and melting, fascinating. In fact, he devoted the entire ninth book to it. Smelting helped to frame the ores that would later "obtain their proper color and become pure and may be of great use to mankind in many ways (*ut suus cuique color insideat, ut purum fiat, ut multis in rebus homini magno usui sit*)."[239] He came to understand that the smelters burned or melted the ores because they were too hard. The flames generated a more malleable material.[240] Perhaps he believed that relaying the processes of smelting would make the mines of western Europe more efficient and thus more profitable.

Agricola's Descriptions of Smelting and Assaying

Essential to the process of smelting, then, was the furnace. Agricola observed how the smelters constructed a furnace that resembled an oven and prevented waste. Through trial and error, the smelters had learned to create a furnace that would trap loose particles. For instance, the cupola stopped any contents from flying away with the smoke. Rather than escaping, the fragments would have adhered to the roof.[241] The type of ore also dictated its placement in the furnace. Agricola noted:

> if pyrites or *cadmia*, or any other metallic veins containing metal, possesses sulphur or bitumen, it should be so roasted that neither is lost. For this reason, it is thrown onto an iron plate full of holes and roasted with charcoal placed on top. There are three walls that support the plate, two on the sides and the third at the rear.
>
> *Si vero pyrites vel cadmia, vel alia vena metallic particeps plusculum sulfuris vel bituminis in se contineat, sic vrenda est, ut neutrum pereat: itaque in ferrum*

[239] Agricola, *De re metallica*, liber nonus, 285.
[240] Agricola, *De re metallica*, liber octavus, 213.
[241] Agricola, *De re metallica*, liber octavus, 215.

> *lamina foramina plena coniecta, carbonibus quem superiniectis uritur. Eam lamina sustinent tres muri, duo ad lateribus, tertius ad tergo.*[242]

Under those plates, the smelters placed buckets of water to catch the cascading "sulphurous or bituminous vapor (*vapor sulfurosus vel bituminosus*)."[243] The furnaces melted the ore in order to extract the sulphur and bitumen, both of which the smelters had deemed to be pernicious.

The designs for these melting-type furnaces varied in size and in construction. Agricola devoted considerable time to explaining the construction and design processes.[244] He marveled at the furnaces' colossal sizes, some of which were fifteen feet high. The furnaces were massive and because of their size dominated the smelters' working areas. Curiously, Agricola never saw a workspace with just one furnace. Multiple furnaces were the rule. Agricola noted how on average he saw between two to six furnaces at each site.[245] Despite never having identified the builders of the furnaces, Agricola implied that the smelters, at the very least, played a role. He learned, for instance, that the builders assembled the furnaces' walls with "some natural stones (*nativi quidam lapides*)," like bricks, because they typically "resist[ed] injury…and last[ed] a long time, especially that which [was] soft and devoid of cracks (*iniuriis ignium resistunt, et ad longum tempus durant: maxime vero hi ipsi qui molles sunt et fibrarum expertes*)."[246] What Agricola assumed was that the reader would have known that constructing the foolproof furnace for smelting did not occur miraculously or instantaneously. Trials and errors led to an efficiently designed furnace. The smelters, at the very least, participated in the building of the furnaces. These furnaces had a front wall that was no taller than five feet, "so that the ore [could be] conveniently put into the furnace together with those things which the master need[ed] for his

[242] Agricola, *De re metallica*, liber octavus, 216. In their translation of *De re metallica*, the Hoovers translated *vrenda* as roasted, as opposed to burnt. I have used a similar approach. See Agricola, *De re metallica*, trans. Herbert Clark Hoover and Lou Henry Hoover (Mansfield Centre: Martino Publishing, 2014), 276.
[243] Agricola, *De re metallica*, liber octavus, 216.
[244] Stanley Smith and Forbes, "Metallurgy and Assaying," 51.
[245] Agricola, *De re metallica*, liber nonus, 285.
[246] Agricola, *De re metallica*, liber nonus, 285.

work of smelting (*in fornacem commode vena conici possit una cum his, quibus magistro ad eam ex coquendam opus est*)."[247] The design of the furnace accommodated the needs of the smelters, leading Agricola to believe that the smelters crafted a furnace that best facilitated their processes for extracting the impurities of ores.[248]

Assayers developed ways to maintain the purity of the metals. They learned, for example, that a "golden yellow (*auro insederit*)" hue appeared when heating gold, suggesting that the metal was free of impurities.[249] Detecting the impurities of tin proved more strenuous. In this case, the smelters would strike the tin with a hammer. If the tin cracked, it was too impure to create bars. Those impure ores of tin would not go to waste, however. The smelters would use them to create other materials.[250]

The presence of impurities plagued the smelting process as well. Like assayers, the smelters searched for ways to prevent or extract the impurities before they even roasted the ores. For example, washing the ore and screening the metal, which was tin in Agricola's example, on a perforated iron plate were two methods of removing impurities.[251]

The smelters' much used furnace could also spawn impurities. One issue was the difficulty of working with bismuth, a metal similar to lead or tin. Certain smelters had designed technologies within the furnaces to discourage the pieces of charred wood or charcoal from falling into the bismuth. Agricola observed how some dug "a pit on a sloping place and below it [placed] a forehearth, into which the bismuth continually flowing and remaining pure (*foveam in*

[247] Agricola, *De re metallica*, liber nonus, 286.
[248] Stanley Smith and Forbes, "Metallurgy and Assaying," 49.
[249] Agricola, *De re metallica*, liber decimus, 366.
[250] Agricola, *De re metallica*, liber nonus, 335-336.
[251] Agricola, *De re metallica*, liber nonus, 331.

declivi loco fodiunt, et sub eo catinum, in quem plumbum ex fovea statim effluens manet purum)."[252] At every stage of the smelting process, the laborers analyzed the ores and the metals.

The quality analysis involved sorting and separating the ores. Agricola described how the fortuitous sorters received their ores from "experienced (*imperitus non fecerit*)" miners who separated the metalliferous material from earth, stone, and solidified juices before hauling the loads up the shafts.[253] Most, however, were not so fortunate. They had to cull through the debris to retrieve the valuable metals. To accomplish this task, they broke the ores with hammers, burned them in furnaces, crushed them with stamps, and grounded them into powders.[254] Isolating and extracting the impurities from the ores was arduous. Clearly the sorters and the smelters grew accustomed to the rapidity of their labor because Agricola rather nonchalantly remarked that "nature usually creates metals in an impure state (*natura metalla plerunque procreare soleat impura*)."[255] Removing the impurities prior to the smelting process was essential.

Agricola learned that smelting ore with impurities created waste, and the furnace's flames did not dissolve the impurities. If they were present prior to burning, the impurities would still appear in the melted product. That material would remain unrefined and would have required additional analysis and removal. To decrease the amount of wasted materials and wasted time,

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[252] Agricola, *De re metallica*, liber nonus, 349. In their translation of *De re metallica*, the Hoovers identified the term *catinum* as the forehearth. I have done the same. See Agricola, *De re metallica*, trans. Herbert and Lou Henry Hoover, 433.

[253] Agricola, *De re metallica*, liber octavus, 208.

[254] Agricola, *De re metallica*, liber octavus, 208. Regarding broken stones or rocks, the sorters relied on the method of sieving. Here the men would place the fragments into a large box that was three feet long and nearly a foot and a half wide. Upon further investigation, Agricola discovered that the box had sloping sides and a netted bottom. The netting ensured that broken rock "of the size of a hazelnut [could] not pass as the pieces which [were] too large to pass through [were] removed by the workman…(*Hoc eius fundum foramina habet, per quae glareae nucis avellanae magnitudine penetrare non possunt: quae sunt maiores quam ut penetrant, eas operarius reportat, rursusque pilis subriicit: eas vero quae penetrarunt, et sabulum atque arenas in vas magnum colligit et ad loturam reservat: cum autem laborandi munus exequatur capsam duobus funiculis de trabe suspendit*)." Idem, liber octavus, 222.

[255] Agricola, *De re metallica*, liber octavus, 208.

the sorters and the smelters agreed to continue the sorting and inspecting methods. Quality control was imperative.

The design of the furnaces also ensured a measure of quality control for the smelters, leading Agricola to conclude that the smelters did indeed participate in the building of furnaces. The furnaces had specifically designed mechanisms to control the temperature. Assaying required that the smelter begin melting the ore at a high temperature and cooling it at a lower temperature. Melting metals involved ever-changing temperatures and close observation. Smelters had to check and then pull the metal out of the furnace once the metal had changed colors or crystals had formed.[256] Controlling the heat inside the furnace was essential. Agricola recognized how the smelters released hot air through a tap-hole, which also allowed them to test the alloy. When the men opened the tap-hole for the second or third time, the smelter would have verified that the alloy of "gold or silver ha[d] become richer (*auro vel argento ne sit divitior facta*)," or whether the lead was "too weak and wanting in strength (*debilis et viribus carens*)" to absorb any more gold or silver.[257] The tap-hole allowed the smelters to control the temperature of the furnace. The utility of the aperture suggested to Agricola that the smelters themselves had played a part in creating the design.

The ability to manage the furnace's flames signaled to Agricola that he was witnessing the practices of a talented smelter. A wide range of smelters invited Agricola to bear witness to their techniques. Naturally enough, he saw smelters whose skillsets were weak. The number of inexperienced smelters must have been great enough to encourage him to describe the practices of talented smelters. According to Agricola, the talented smelter determined the placement of the ore in the furnace. First, however, the smelter had to know what type of ore he was handling.

[256] Stanley Smith and Forbes, "Metallurgy and Assaying," 64.
[257] Agricola, *De re metallica*, liber nonus, 311.

Identifying the ores was key. The talented smelter would recognize the type and quality of the ore, and he would need to appreciate if the ore disintegrated quickly. He would have placed the ore that did not melt slowly at the back of the furnace, where the flames were more furious.[258] Knowledge of the ores was also necessary to determine the size of the flames. When melting a small amount of ore, the experienced smelter would have used a "gentle blast (*leni...flatu*)" from the bellows, with the medium-sized a moderate one, with the large size a "violent (*acri*)" blast, and he would have relied on "a much less sharp blast when he smelt[ed] the ores of gold, silver, and copper (*multo tamen minus acri quam cum venas vel auri vel argenti, vel aeris*)."[259] Matching the flames to the metals was not such a simple task. The skillful smelter also maintained the fires, gradually introducing the charcoal and sweeping the walls.[260]

The adept smelter understood how to manage the furnace's fumes as well. Agricola noted that all smelters avoided inhaling the "noxious juices (*succos nociuos*)" of the metals.[261] The fumes were unavoidable, and the smelters learned ways to make them useful. At times, the fumes could serve as a gauge. If the fumes had a "sweet-smelling odor (*dulcedine odoratum*)," for instance, that would have indicated that the "quicksilver [was getting] consumed (*consumi significat*)."[262] The smelters searched for particles in the fumes. In certain circumstances, the miniscule fragments would escape with the flames of the furnaces, and the smelter would need to examine the fumes to make certain that nothing went to waste.[263] Waste, after all, reduced the capital gains that the smelters, miners, and proprietors could earn from their loads. On the connection between waste and skill, Agricola wrote:

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[258] Agricola, *De re metallica*, liber nonus, 314.
[259] Agricola, *De re metallica*, liber nonus, 331.
[260] Agricola, *De re metallica*, liber nonus, 330.
[261] Agricola, *De re metallica*, liber nonus, 340.
[262] Agricola, *De re metallica*, liber nonus, 344.
[263] Agricola, *De re metallica*, liber nonus, 322.

> If anyone is not tested in these matters and has melted at the same time all of the tin-stone…not wasting the owner's tin [because] the small [fragments] have stuck to the walls. The owner of the workshop has the sweepings by right from the owner of the vein. For these reasons, the most experienced smelter melts them down separately.
>
> *Si quis vero harum rerum non satis expertus, lapillus...simul excoverit, domini non exiguam plumbi iacturam facient...non modo ad parietes adhaerescunt, sed etiam in solaria pauimentum decidunt: quos dominus officinae, venarum dominis suo quodam iure abripe: qua de causa experientissimus quisque excoctor alios separatism ab aliis excoquitur*.[264]

These men were in business. Wasted ores meant wasted money. The capacity to reduce waste marked an expert craftsman.

The process of smelting required an immense skillset. Just as he did with mining, Agricola wanted to showcase the precision involved in metalworking.[265] To do so, he documented how the smelters used one quantitative unit of measurements with great frequency: the *libra*. When smelting gold, smelters would gather "a *libra* of the same…strength of the *stibium* (*rudis con minuti libra et stibii item con minuti*)."[266] Similarly, Agricola included the measurements and procedures to create gold: to a *libra* of the powder prepared from the metalliferous concentrates, it "[was] added a *libra* each of salt, of saltpetre, of argol, and of glass-galls, and it [was] cooked until it melts (*salis, halinitri, aridae vini secis, recrementorum vitri singulorum libram, coquitur donec liquescat*)."[267] Agricola was fascinated by the precision involved in metallurgy. As such, he listed these procedures as if they were recipes in a cookbook. Recipe books in the early modern period did not belong exclusively in the domestic sphere. In

[264] Agricola, *De re metallica*, liber nonus, 330-331.
[265] Smith, "Vermilion, Mercury, Blood, and Lizards: Matter and Meaning in Metalworking," 31.
[266] Agricola, *De re metallica*, liber nonus, 324. The *stibi* or *stibium* was no doubt the sulphide, which is the material that got refined to make antimony.
[267] Agricola, *De re metallica*, liber nonus, 324.

fact, *De re metallica* falls perfectly into the well-established category of recipe books, or books of secrets, that contained procedures for assaying and separating metals.[268]

The smelters had a theoretical framework, but that framework only took them so far. They also needed to observe and to experience those principles directly. Agricola concluded that "constant practice (*assiduous rerum usus docuit*)" taught the smelters the methods that could help them obtain "the most metal from any one ore (*maiori sumptu opus est ad unam quam ad aliam*)."[269] In smelting, theory and practice were used in tandem. Smelting was physically-draining and time-consuming, demanding that its participants learn and observe regularly. The younger, less experienced men would have learned from the older, more seasoned smelters. Naturally, a hierarchy of smelters formed.

Men, Secrecy, and Protection: Agricola's Hierarchy of Knowledge

The hierarchy within the mines was clear to Agricola. In smelting, there were masters and assistants. He observed the different roles that the men performed, and he reasoned that experience differentiated them. With smelting, for instance, the masters supervised the flames. The masters made the decisions about the sizes of the fires, given the skillset and experience required.[270] Masters would have had the experience working with and differentiating between the ores. The masters were those who removed the metals from the furnace after they had been sufficiently melted. Knowing when to retrieve them required patience, skill, and experience. The

[268] Long, "The Openness of Knowledge: An Ideal and Its Context in 16th- Century Writings on Mining and Metallurgy," 321. William Newman notes that recipe books often "represent[ed] the final stages of working out known chemical properties and interactions." Newman, "What Have We Learned from the Recent Historiography of Alchemy?" 320. By this reasoning, the metallurgists only allowed Agricola to enter the workspace and record their findings because they had already determined the reactions. Agricola, therefore, did not witness their discoveries or errors. He saw the final results.
[269] Agricola, *De re metallica*, liber nonus, 285.
[270] Agricola, *De re metallica*, liber nonus, 309.

assistants, on the other hand, were responsible for trapping the flames and fumes inside the furnace. They smeared the forehearths with lute.[271] The assistants accompanied the masters, helping with menial tasks when needed. By training the younger, less experienced smelters, the masters ensured that their expertise would be perpetuated and disseminated. The smelting traditions would endure.

[271] Agricola, *De re metallica*, liber nonus, 308. The lute acted as a glue that kept air from entering the furnace and disturbing the flames.

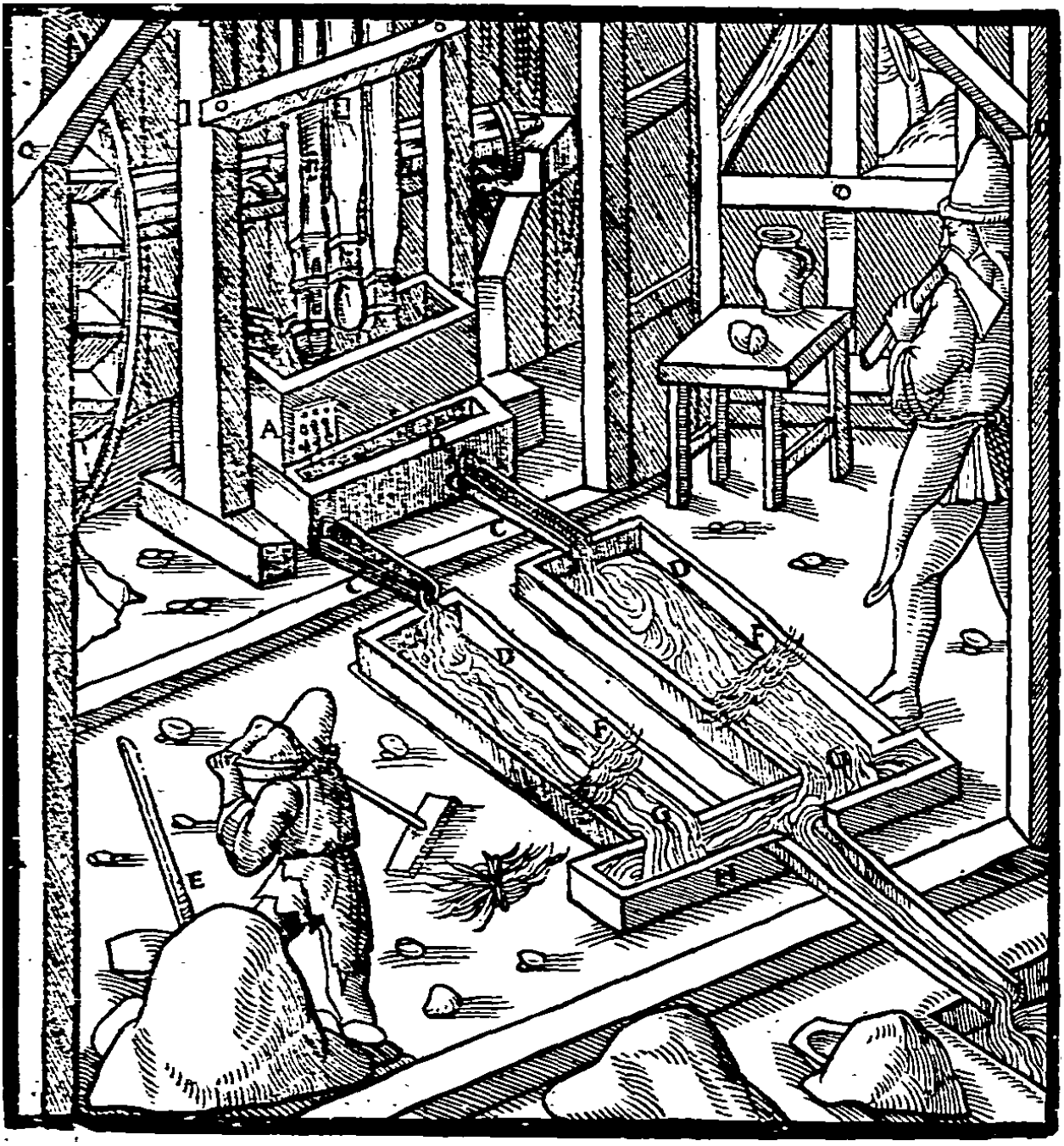

Figure 3.1 [272]

In the image above, Agricola had the engraver depict the typical scene of smelters. Some smelters focused on the furnace's flames, while others broke down the ores with chisels. Each

[272] Agricola, *De re metallica*, liber octavus, 248.

smelter had a different role. Here Agricola decided not to depict the assistants, but they would have followed these master smelters around the workplace.

Agricola's illustrations like Figure 3.1 were prepared by Blasius Weffring in Joachimsthal.[273] Weffring would have completed the drawings for Agricola, and then he would have sent them to the printer, in this case in Basel, where the printer would have transformed them into woodcuts. In charge of Agricola's production of *De re metallica* was Johann Froben (1460 – 1527), who founded the famous Froben print shop in Basel. Froben became a leader in humanist publications.[274]

The inclusion of the woodcuts was a stark departure from ancient models. In the early years of print, most books on nature did not include illustrations, copying the precepts of the classical authors.[275] Historian Andrew Pettegree claimed that the development of woodcuts marked a philosophical and practical change. He argued that illustrations, such as those included in *De re metallica*, "tip[ped] the balance of scholarly investigation towards a science of investigation."[276] The woodcuts' execution was a laborious and expensive undertaking, but one that Agricola felt was necessary and essential to his pedagogic schema.

Agricola was not the first to use illustrations in his text. The anonymous author of the *Bergbüchlein* certainly inspired Agricola. Pictures depicting how to locate veins and how to construct furnaces also appeared in the *Bergbüchlein*. Printed between 1505 and 1510 by Martin Landsberg, the *Bergbüchlein* is also a compilation of mining practices and metallurgical

[273] Pamela Long, "Of Mining, Smelting, and Printing: Agricola's 'De re metallica,'" *Technology and Culture* 44 (2003): 100.
[274] One noteworthy publication from Froben's print shop was Erasmus' "Prince of the Humanists." See Valentina Sebastiani, *Johann Froben, Printer of Basel, A Biographical Profile and Catalogue of His Editions* (Leiden: Brill, 2018), 1. For more on the Froben Press, see also Andrew Pettegree, *The Book in the Renaissance* (New Haven: Yale University Press, 2010), xii-xiv.
[275] Pettegree, *The Book in the Renaissance*, 275-276.
[276] Pettegree, *The Book in the Renaissance*, 276.

recipes.[277] Like in *De re metallica*, the *Bergbüchlein* has pictorial representations of the written text. In one instance, the author of the *Bergbüchlein* drew a visual depiction of how to find veins on sloping mountainous terrain.

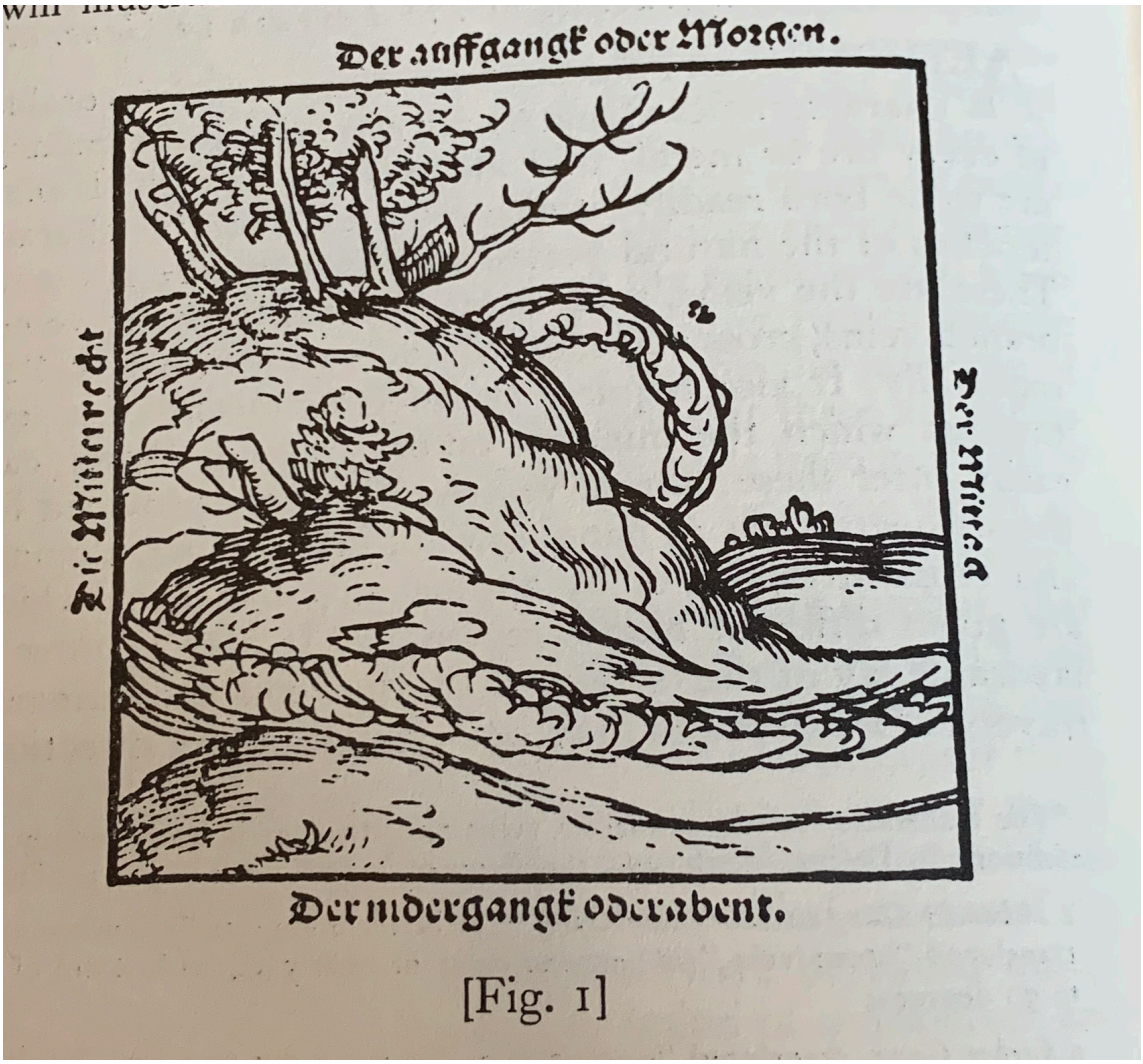

Figure 3.2 [278]

Figure 3.2 is remarkably similar to illustrations in *De re metallica*, such as Figures 3.3 and 3.4.

[277] Anneliese Grünhaldt Sisco and Cyril Stanley Smith, "Introduction," in *Bergwerk-und Probierbüchlein*, trans. Anneliese Grünhaldt Sisco and Cyril Stanley Smith (New York: The American Institute of Mining and Metallurgical Engineers, 1949), 7.
[278] *Bergwerk-und Probierbüchlein*, trans. Anneliese Grünhaldt Sisco and Cyril Stanley Smith (New York: The American Institute of Mining and Metallurgical Engineers, 1949), 22.

Figure 3.3 [279]

[279] Agricola, *De re metallica*, liber tertius, 30.

Figure 3.4 [280]

Both authors assuredly advised their illustrators to use clean lines that draw the readers' eyes to a focal point. Most importantly, the pictures are free of distractions. Perhaps the authors understood how complicated mining practices were; so, they aimed to make the instructions as succinct and comprehensible as possible. The two authors undoubtedly wanted to encourage the reader to perform these tasks for himself.

One noticeable difference between the types of illustrations in both texts is the presence of workers. The miners themselves do not appear in the depictions found in the *Bergbüchlein*.

[280] Agricola, *De re metallica*, liber tertius, 35.

Agricola, however, sought to include the miners as depicted in Figure 3.1. The prominence of the miners speaks to Agricola's desire to showcase the skills required to perform mining tasks.

By including engravings such as these, Agricola lifted the shroud of secrecy associated with alchemical practices and asserted his own authority. In *De re metallica*, Agricola had 270 engravings accompany the written descriptions of mining and metallurgical activities. These visual representations supplemented his words. They were mimetic devices. It is likely that Agricola wanted to encourage the reader to pursue these procedures for himself, and the images served to confirm that the tasks could be performed. These pictorial representations gave the reader a vivid impression of the miners', smelters', and assayers' workspaces. The miners and assayers really did perform the tasks.

Agricola included images of the assayers' workspaces in order to secure a multiplication of witnesses. By positioning the pictorial representations alongside the written descriptions, he encouraged his readers to mimic the procedures. The images were of equal importance to the writing of the experimental proceedings. They allowed Agricola to assert himself as a "reliable purveyor of experimental testimony."[281] Importantly, Agricola stated that he had omitted all those things that he did not "see or had heard about from a trusted person (*nec ipse vidi, neque legi, nec ex hominibus fide dignis cognovi: id profecto quod non vel vidi, vel lectum aut auditum expendi, non est scriptum*)."[282] He emphasized his first-person observation. Agricola wanted to convey his command of the specialized knowledge in order that his audience would refrain from questioning the claims to witnessing and the accuracy of his images. Agricola anticipated that the images would secure his audience's confidence.

[281] Steven Shapin, "Pump and Circumstance: Robert Boyle's Literary Technology," *Social Studies of Science* 14 (1984): 493.
[282] Agricola, *De re metallica*, Epistola, 4.

For Agricola, it is clear that images were a means of recording the curious activities of metalworkers. His use of pictorial representations supports the idea that the production and the communication of knowledge were not distinct activities.[283] According to historian Steven Shapin, "speech about natural reality [was] a means of generating knowledge about reality, of securing assent to that knowledge, and of bounding domains of certain knowledge from areas of less certain standing."[284] Agricola collaborated with artists to create representations of the natural world in the expectation that the images would enhance the communicative value of his text.[285] The reader became an active participant in the knowledge that Agricola described.[286] Coupled with linguistic resources, the images served to facilitate actual replications of the experiments and, at the very least, would "trigger in the reader's mind a naturalistic image of the experimental scene."[287] Agricola, therefore, invited readers into the assayers' workspace.

Agricola did not hide the experimental scene from the reader, but the interactions between the smelters involved a measure of secrecy. That is, the lexicon that the smelters used to describe their tasks was specific. For example, they used the term *pyrites* to identify any ore that contained remnants of gold.[288] Inasmuch as gold was the most valuable metal, it stands to reason that they would employ a term to identify specifically those ores with gold fragments. Using the term *pyrites* would have signaled immediately to the smelters that they were working with a treasured material. A simple word would have elevated the stakes. Such technical language served to include some workers and to exclude others. Not everyone could participate; some lacked the lexiconic skills to communicate. Technical language then was a mechanism of

[283] Shapin, "Pump and Circumstance: Robert Boyle's Literary Technology," 481.
[284] Shapin, "Pump and Circumstance: Robert Boyle's Literary Technology," 481.
[285] Pamela H. Smith, "Art, Science, and Visual Culture in Early Modern Europe," *Isis* 97 (2006): 87.
[286] Richard Cunningham, "Virtual Witnessing and the Role of the Reader in a New Natural Philosophy," *Philosophy & Rhetoric* 34 (2001): 210.
[287] Shapin, "Pump and Circumstance: Robert Boyle's Literary Technology," 491.
[288] Agricola, *De re metallica*, liber nonus, 325.

protection, secrecy, and exclusion. Agricola was fortunate to have been given the opportunity to learn the vocabulary.

A hierarchy emerged in Agricola's representations that was male-dominated. Men assessed other men's abilities and sorted them accordingly. Agricola only ever used the male subject pronoun to describe the workers. He wrote how the "experienced (*non satis expertus*)" smelter would be diligent, having brooms to sweep the walls above the furnace.[289] Agricola only made a record of the men and their pursuits. Even the masters' assistants were men. The menial tasks of refueling the furnace's fire with charcoal were completed by male assistants. Agricola observed how, the smelter prepared "*his* portion (*eius parti*)" for the furnace by throwing a wicker basket full of charcoal into the flames."[290] In his presentation of mining and metallurgical endeavors, Agricola focused exclusively on the male participants.

Men outnumbered women in the mines and workspaces, but women were present. Women also played a part. He did mention that women, along with boys, did appear on occasion to address the mistakes of sorters. "Either through ignorance or carelessness (*vel ignari, vel incauti*)," those men mixed the ore with earth or broken rock, demanding the arrival of "boys and women (*pueri vel mulieres*)" to sort through the crude metal.[291] In this quotation, Agricola implied that women were a secondary—yet at times vital—labor force. He acknowledged their presence, but they were still rather invisible. Agricola rarely recognized the contributions of women in the tasks that he described.

His representation, or lack thereof, of women seemingly contradicts historian Meredith K. Ray's assessment of female participation in early modern science. In *Daughters of Alchemy* (2015), she argued that women not only participated and collaborated amongst themselves, but

[289] Agricola, *De re metallica*, liber nonus, 330.
[290] Agricola, *De re metallica*, liber nonus, 308. Emphasis my own.
[291] Agricola, *De re metallica*, liber octavus, 208.

they also shared and discussed their theories with men.[292] By examining the recipes for medical remedies, Ray traced the activities of women at homes and at courts, where they engaged with the medical communities of sixteenth- and seventeenth-century Italy. Their involvement occurred within the private and public arenas. Agricola's presentation of women's roles in alchemy throughout early modern Europe, on the surface, appears to belie Ray's findings. Women did have a part to play within metallurgy throughout Europe, but Agricola—as a man—was not granted access to those feminine spaces where women would have conducted their experiments. What is clear from Agricola's perspective is that men and women did not interact much in the metallurgical workspaces of early modern Saxony.

Conclusion

Although the publication of his text contradicted the generally accepted historical view of alchemy as secretive, Agricola did articulate a hierarchy of knowledge-ownership. Not everyone could participate or possess alchemical knowledge. He did, surely, make the metallurgists' knowledge-set more public by increasing the number of people learning about metallurgical and alchemical theory. To ensure protection and preservation, the metallurgists established a hierarchy of systems. Alchemy was after all still a craft in which its techniques and practices needed protection. In his presentation of metallurgical and alchemical theory and practice, Agricola valued precision. He carefully recorded the measurements needs to perform the tasks. By noting their techniques and providing his own commentary, Agricola re-characterized

[292] Meredith K. Ray, *Daughters of Alchemy, Women and Scientific Culture in Early Modern Italy* (Cambridge: Harvard University Press, 2015), 43.

alchemy. For him, alchemy was a worthwhile intellectual pursuit. It required precision. In this way, he presented a study of nature that included alchemy.

Chapter 4

Power, Providence, and Prosperity: An Analysis of Agricola's Religious Convictions

Agricola completed *De re metallica* at a moment of intense religious turmoil in Europe. As a resident of Saxony, he lived in the center of the European Reformation. It was here on 31 October 1517 that Martin Luther voiced his objections to the practices of the Roman Catholic Church. Luther's protest reverberated throughout the western German countryside, and Agricola was almost undoubtedly affected by the vicissitudes of ecclesiastical structure and doctrinal debates.[293] He made few overt references to his faith, but *De re metallica* contains evidence of a religious man reconciling human behavior, financial woes, and mining profits.

For historians of the Reformation, Saxony is a rich site for inquiry. Because of its centrality to the history of Reformation ideas, Saxony has become a popular locale for historians to examine Luther's role in stimulating anti-clerical fervor. In particular, scholars have used Saxon records to gauge how German princes and their estates stabilized or destabilized clerical sentiment. They have assessed the ways in which German principalities protected their own commercial interests in a period of religious uncertainty. That is, historians have assessed how Saxon dukes encouraged and discouraged Roman Catholic piety in an effort to protect their economic stature.[294] By focusing solely on the official and prescribed religious doctrines of the religious and political elite, they have crafted a top-down history. In these studies, the laity was neglected.

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[293] Davide Cantoni, "Adopting a New Religion: The Case of Protestantism in 16th Century Germany," *The Economic Journal* 122 (2012): 505.

[294] See W. G. Tillmans, "The Lotthers: Forgotten Printers of the Reformation," *Concordia Theological Monthly* 22 (1951): 260-264; Richard G. Cole, "Reformation Printers: Unsung Heroes," *The Sixteenth Century Journal* 15 (1984): 327-339; and Ralph Keen, "Defending the Pious: Melanchthon and the Reformation in Albertine Saxony, 1539," *Church History* 60 (1991): 180-195.

Social historians studying the Reformation have taken up the call to concentrate on the everyday practices of Saxon parishioners. Susan Karant-Nunn, for one, filled in the gaps of these older histories with the perspectives of the laity. She dissolved the sharp boundaries between the clergy, rulers, and laity in her article, "Neoclericalism and Anticlericalism in Saxony, 1555 – 1675" (1994).[295] She argued that as the pastorate gained more social prestige within their local communities, they lost their effectiveness to communicate with their congregations. She used the visitor logs in Saxon churches from the sixteenth and seventeenth centuries to connect the major trends in Reformation historiography: confessionalization, neoclericalism, anti-clericalism, and social discipline.[296] Karant-Nunn argued that parish inspectors noted the growing disdain "for the practice and personnel of religion."[297] The Saxon officials also recognized the anti-clerical fervor and took it upon themselves to purge it, which led to a consolidation of their power. As such, a wedge formed between the pulpit and the pews.[298]

De re metallica offers an opportunity to investigate how Agricola experienced and voiced his religious beliefs in the Reformation era. Inspired by Karant-Nunn's examination of individuals, this chapter explores the lived experience of a lay person. Furthermore, from the instances when Agricola invokes God's name, we can sort out how he practiced his religion. His beliefs worked their way, quietly, into the pages of this seemingly secular text. Agricola is a product of the Reformation era. He studied a problematic topic with respect to God and connected his ideas to the scholastic and humanist traditions. What is more is that Agricola presented a natural philosophy that was compatible with piety.

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[295] Susan C. Karant-Nunn, "Neoclericalism and Anticlericalism in Saxony, 1555-1675," *The Journal of Interdisciplinary History* 24 (1994): 615-637.
[296] Historians of the Reformation define *confessionalization* as the "exploitation of religious beliefs and ecclesiastical structures as a means of achieving the uniform docility of all subjects." Karant-Nunn, "Neoclericalism and Anticlericalism in Saxony, 1555-1675," 615.
[297] Karant-Nunn, "Neoclericalism and Anticlericalism in Saxony, 1555-1675," 619.
[298] See also Jay Goodale, "Pastors, Privation, and the 6Process of Reformation in Saxony," *The Sixteenth Century Journal* 33 (2002): 71-92.

Historians have studied how intellectuals integrated piety and natural philosophies. Ann Blair, in particular, studied how sixteenth- and seventeenth-century natural philosophers attempted to either undermine Aristotle's beliefs or incorporate them into their theologies in her article "Mosaic Physics and the Search for a Pious Natural Philosophy in the Late Renaissance" (2000). Natural philosophers like Johann Amos Comenius (1592 – 1670) developed and promoted a genre of philosophy that connected evidence of "sense, reason, and Scripture."[299] The task of Comenius was to foster and resolve religious and philosophical diversity by "grounding it in the most indisputable authority—that of the Bible."[300] Blair concluded that many natural philosophers chose to accept reason into their study of nature, while at the same time acknowledging human error. God remained the ultimate final authority who could help humankind overcome those limitations.

The rejection and acceptance of Aristotelian ideas by early modern natural philosophers is also the subject of Craig Martin's book *Subverting Aristotle: Religion, History, and Philosophy in Early Modern Science* (2014). Martin began with the assumption that "natural philosophy did not become secularized, instead laymen began to speculate on theology."[301] He examined the ways in which seventeenth-century natural philosophers "subverted" Aristotle in order to promote "the ascent of modern science."[302] Martin traced natural philosophers' focus on Aristotle's paganism and impiety as a means to discredit an Aristotelian approach to scholarship. Polemics in England, for instance, saw Aristotle's impiety as a justification for dispensing with his authority.[303] Martin focused on the perceived impiety of Aristotle, rather than on the rejection

[299] Ann Blair, "Mosaic Physics and the Search for a Pious Natural Philosophy in the Late Renaissance," *Isis* 91 (2000): 40.
[300] Blair, "Mosaic Physics and the Search for a Pious Natural Philosophy in the Late Renaissance," 35.
[301] Craig Martin, *Subverting Aristotle: Religion, History, and Philosophy in Early Modern Science* (Baltimore: The Johns Hopkins University Press, 2014), 3.
[302] Martin, *Subverting Aristotle: Religion, History, and Philosophy in Early Modern Science*, 10.
[303] Martin, *Subverting Aristotle: Religion, History, and Philosophy in Early Modern Science*, 150-151.

of any particular Aristotelian theory. By not examining the theories, Martin leaves the reader wondering what frustrated the natural philosophers. Martin's focus on derision does not make any room for compatibility.

In *De re metallica*, Agricola took a more subtle approach to the reconciliation of religion and natural philosophy. Agricola did not subvert Aristotle's ideas. He conceptualized nature as rational and law-abiding. These two characteristics affirmed Agricola's belief that nature was evidence of a divine creation. In a rational and just manner, God created nature. He devoted pages of *De re metallica* to sorting out how God implemented His design and imparted His purposes into His creation. His religious devotion seeps into the pages of *De re metallica*. He did not divorce himself from God. His desire to explore and understand God's creation rooted his approach to natural philosophy. In Agricola's natural philosophy, there was no disassociation between God, miner, and creation. He was not making room for mining within his theology. Mining already belonged under the rubric as it too dealt with God's creation. His convictions appear most prominently in the discussions of how metals could introduce societal betterment. Those sensibilities propelled him to find justifications for mining. He chose to use religious claims to justify mining. His approach was subjective. He infused his philosophy with his own religious convictions. He did not attempt to hide his beliefs. In fact, the subjective approach made him appear more transparent, surely encouraging the confidence of his readership.

Reconciling Mining's Destruction and God's Creation

Because Agricola received his education, practiced his craft, and produced his manuscript at a moment of religious change in Germany, we should note the instances where he invoked the

name of God. Although he mentioned God sparsely, he seems to attribute all good things in the world to God's benevolence. As demonstrated in the quotation below, Agricola asserted that God wanted humans to use his creation for good. He wrote:

> a young man who devotes himself to learning and cultivates skills, uses his ability rightly. But he who lies, cheats, and deceives by fraud and betrayal, misuses his abilities. Now, the man who, because they are abused, denies that wine, strength, beauty, or genius are good things, is unjust and blasphemous towards the *Most High God, Creator of the World*; so he who would remove metals from the class of blessings also acts unjustly and blasphemously against Him. Therefore, absolutely correct are the words which certain Greek poets have written as Pindar
>
> *Pari ratione adolescens qui doctrinae sese dat, et artes ingenuas colit, recte utitur ingenio. Qui fingit, mentitur, capit, fraude et perfidia fallit, eius celeritate abutitur. Ut autem is qui vinum, robur, formam, ingenui, propter peiorem usum in bonorum numero non habet, in summum illum rerum opificem Deum iniuriosus et contumeliosus est, ita qui res sossiles eximit ex bonorum coetu, in eumdem iniuriam et contumeliam iacit. Rectissime igitur quidam Graeci poetae scripserunt, ut Pindarus*.[304]

He did not create the world for humans to be poor custodians. The refusal of humanity to use skills to improve God's creation would have caused God chagrin, according to Agricola. He believed that if people spoke ill of the metals, they were also "accusing and condemning God as wicked (*se Deum ipsum accusare et scelerum damnare*)."[305] Agricola stated that if God created metals, they could not be evil because God would not have created and introduced evil.

While Agricola believed that mining was not inherently evil, he did recognize that mining had the potential to cause destruction to God's creation. Mining practices, for instance, could ruin nature. In order to gather the metals from veins in the earth, miners had to prepare an

[304] Georgius Agricola, *De re metallica* (Basel: Froben Press, 1556), liber primus, 14. Emphasis my own. Associating truth with Pindar had sense. Pindar (518-438 BC) was an ancient Greek lyric poet whose poems often begin with truth claims, or gnomic statements. In one instance, Pindar proclaimed that "water is the best of things, and gold like fire flaming in the night outshines all other kinds of noble wealth by far." Perhaps Agricola wanted to connect his own ideas with those of Pindar with the hope that his audience would have accepted his statements as true. Agricola was constantly oscillating between informing the reader of mining practices and convincing the reader of mining's good. He wanted to share mining information, but also analog universal human experiences. Quoted first in Mark Payne, "On Being Vatic: Pindar, Pragmatism, and Historicism," *The American Journal of Philology* 127 (2006): 160.

[305] Agricola, *De re metallica*, liber primus, 8.

opening in the fields. Miners cut timber to make a clearing and harvested timber for smelting machines. Agricola noted that the Italians were so disgusted by these mining practices that they introduced a law that "no one should cause the earth to leak (*ne quis metallorum causa terram foderent*)" in their quest for metals because it injured both "fertile fields (*agros uberrimos*)" and "olive groves (*vineta oliveta*)."[306] The clearing was necessary to procure wood, and it left the natural environment devastated.

Agricola acknowledged that mining contributed to the destruction of many creatures' natural habitats. He knew that such efforts left some "birds and beasts (*volucres et bestiae*)," which furnished "food for man (*homini cibus*)," without habitats.[307] In addition to birds, aquatic life was also affected. According to Agricola, the miners understood that the washing of ores deposited poisons into brooks and killed the fish.[308] He believed, on the other hand, that God endowed humans with free will, making them capable of doing good or doing evil. God provided humans with the miraculous gift of nature, and it was left to humans to decide how they were to act—properly or improperly. He placed the emphasis on humans. He pontificated:

> Usury is odious, while the game is cruelly taken from the possessions of the innocent people is wicked in the sight of God and man…as the calling of the miner excels in honor and dignity that of the merchant trading for lucre, while it is not less good, though far more profitable, than agriculture, who can fail to realize that mining is a calling of dignity?
>
> *autem sit odiosum, praeda crudeliter capta ex fortunis plebis, non culpa calamitosae, impia, quaestus metallicihonestate ac decore praestet mercatoris lucro: non minus sit bonus quam agricolae, multo uberior. Quis non intelligit metallicam inprimis esse honestam*?[309]

Mining as a profession was not in itself wicked. Miners with selfish proclivities made the profession appear evil to some. For Agricola, the miners had the power to erase the stain of

[306] Agricola, *De re metallica*, liber primus, 5.
[307] Agricola, *De re metallica*, liber primus, 5.
[308] Agricola, *De re metallica*, liber primus, 5.
[309] Agricola, *De re metallica*, liber primus, 18.

wickedness from the public's view. They had the agency to make mining an honorable profession. The implicit assumption, then, was that providence rewarded reasonable men who worked hard to produce good from the prosperity of nature.

Agricola stressed that the reasonable individual would prosper in the mines. In particular, a miner should use his intellect to judge where to dig the veins. Knowing resources were scarce, a reasonable miner would not want to deplete them by digging all the veins. The reasonable miner would not dig for metals in veins that ran "east through the slope of a mountain (*orientis per deuexum montis*)" or that "incline[d] to the south (*meridie est*)" whose "heads rise to the north (*caput profert in septentriones*)."[310] The reasonable, experienced miner would not simply dig because he noticed "bright specks of pure metal adhering to the stones (*luceant scintillae metallic puri adhaerescentis ad lapides*)."[311] These were red herrings. Experience made miners more sensible. They knew the veins that would yield the metal deposits. Flickers of metals in the water did not determine the prosperity of the vein. Experience and judgment worked in tandem for a miner to prosper. Agricola laid his trust in human reason to discover a moral order.

It is also noteworthy the ways in which Agricola made room for chance in his religious schema. He used *chance* to describe the random, unexpected occurrences of the natural environment. At one point, he described how, "After the miner has chosen a suitable place adapted by nature for mining, he pays attention to the veins. They are either hidden or concealed. (*Metallicus postquam elegit ex multis locis unum aliquem natura aptum ad fossiones, in venis opera cura neque point: se nobis ostendunt et latentes arte: hoc evenire vulgo solet, illud raro: quorum ut runique explicandum est*)."[312] Agricola does not appear eager to claim that the cleverness of the miner produced a good mining location. Instead, Agricola wanted to convey the

[310] Agricola, *De re metallica*, liber tertius, 53.
[311] Agricola, *De re metallica*, liber tertius, 53.
[312] Agricola, *De re metallica*, liber secundus, 24-25.

luck involved in securing a location. Curiously he did not assign God as the architect of that luck. Perhaps Agricola wanted to convey a distance between God and the miner, where God intervened through the will of divine providence but only in certain instances. For the most part, He was largely ambivalent about the daily experiences of laborers.

It was only with chance encounters of prosperity that the miners recognized God's presence in their professional lives. Furthermore, Agricola claimed that another force by chance must have disclosed the veins, "for a horse, if this tale can be believed (*etenim (sic) equus, si huic narration fides habenda est*)," revealed the "veins of Goslar (*Goselariae venam*)" through its hoof.[313] *Chance* described inexplicable events at the behest of fortune. Agricola assigned agency to fortune and chance, acting as providential markers of God's will. Fortune rewarded the good, intelligent, and diligent man. Agricola believed that fortune responded to the hopes of the man who had given his money to several mines in a region renowned for its wealth and "abundant metals (*abundantem metallis*)."[314] The wise man would disperse his resources across multiple mines. He would not focus all of his energy, attention, and means to the gains of one prosperous mine. Only God could determine the success of a given mine, and He could choose not to reward a miner.

Agricola acknowledged that some owners of mines preferred to buy shares in mines, rather than "worrying themselves to search for the veins (*esse solliciti de venuis quaerendis*)."[315] If this were the case, they should not buy too many shares in neighboring mines where they have yet to discover metals lest, "should fortune not respond (*ne si opta tis fortuna non*

[313] Agricola, *De re metallica*, liber secundus, 25. Goslar was, and still is, a town in Lower Saxony.
[314] Agricola, *De re metallica*, liber secundus, 20. In *Natural History*, Pliny describes chance as the one who "takes the place of God [as] another set of people banishes fortune also, and attributes events to its star and to the laws of birth, holding that for all men that ever are to be God's decree has been enacted once for all, while for the rest of time leisure has been vouchsafed to Him." Pliny, *Natural History*, trans. H. Rackham (Cambridge: Harvard University Press, 1938), Book 2, Chapter 5, 185.
[315] Agricola, *De re metallica*, liber secundus 20-21.

responderit)."[316] They may be "exhausted (*exhausti*)" by their losses and have nothing with which they may meet their expenses or "buy other shares which may replace their losses (*faciant et emant alias partes, quae damnum factum resarcire possint*)."[317] He observed how it was more prudent to scatter one's assets in the pursuit of wealth because there was no guarantee that fortune, i.e. God, would reward an owner. No one understood when or how God would have chosen to bestow success on a miner or an owner. Fortune was as unpredictable as nature.

Agricola frequently alluded to the unpredictability of nature when describing the miners' encounters with demons and pests. For him, the "demons (*daemones*)" were "ferocious (*truci*)" and "pernicious pests (*pestis et pernicies*)" that interfered in the miners' daily tasks.[318] He described how these pests caused the miners to abandon some of the pits, and he suggested that they only disappeared because of "prayer and fasting (*precibus et ieiuniis*)."[319] These creatures wreaked havoc on the miners, disrupting water and air supplies.[320] These pests were determined to injure the miners. Agricola went into considerable detail about the annoying pests' effects on the miners; yet he did not detail the demons' physicality or appearance. He made no gesture to discern what these creatures were. Agricola clarified that these pests were not the venomous ants "like [the] spiders (*simile que araneis*)" of Sardinia.[321] His "fierce and murderous demons (*daemon truculentus et homicida*)" remain largely undefined.[322] Quite possibly, Agricola included his encounters with the nondescript demons to articulate to the reader that he and the miners confronted the supernatural in their craft. Or, he could have included the encounters to illustrate how mining drew the practitioners closer to God.

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[316] Agricola, *De re metallica*, liber secundus 21.
[317] Agricola, *De re metallica*, liber secundus 21.
[318] Agricola, *De re metallica*, liber sextus, 173.
[319] Agricola, *De re metallica*, liber sextus, 173.
[320] Agricola, *De re metallica*, liber sextus, 173-174.
[321] Agricola, *De re metallica*, liber sextus, 173.
[322] Agricola, *De re metallica*, liber sextus, 174.

Agricola could have conceivably included the references to pests and demons in order to illustrate God's power of instruction. God could have used the pests to guide humans on how to behave, using the pests to punish the selfish and pretentious miners. Agricola could have used the anecdote of pests to demonstrate the pitfalls of man's arrogance. The pests checked man's narcissistic proclivities. The pests were a reminder that miners specifically, and humans generally, were powerless to God and His creation. In Agricola's description, the pests did not overturn the natural order. The miners could continue their practices. Agricola described the creatures as vexing to the workmen, but powerless to God. For him, only God could direct nature. The pests did, however, preserve and honor the hierarchy of nature, one where humans were inferior to God.[323]

Some scholars have heralded the Reformation as the catalytic event that propelled phenomena out of the "supernatural" category and into Aquinas' designations of "preternatural" and "natural." Alexandra Walsham, for instance, asserted that the reformed thinkers did not wish to question God's providential framework with the new configuration; instead, they wished to agitate and displace the power of demonology and its relation to supernatural forces.[324] Walsham identified the repeal of a 1736–legislation on witchcraft in England as evidence of a "declining belief in this diabolical crime than of disintegration of demonology's symbolic role as an expression of the sacral state and its aspirations."[325] Historians agree that the thinkers of the

[323] For more on pests and *monstra* in the medieval and early modern periods, see John Block Friedman, *The Monstrous Races in Medieval Art and Thought* (Syracuse: Syracuse University Press, 2000), 121-122.
[324] Alexandra Walsham, "The Reformation and 'The Disenchantment of the World' Reassessed," *The Historical Journal* 51 (2008): 524.
[325] Walsham, "The Reformation and 'The Disenchantment of the World' Reassessed," 522. Walsham's perspective subscribes to Max Weber's argument that Protestantism led to the rejection of the Roman Catholic Church's views on sacramental magic as a method for salvation. Weber wrote, "This, the complete elimination of salvation through the Church and the sacraments (which was in Lutheranism by no means developed to its final conclusions), was what formed the absolutely decisive difference from Catholicism. That great historic process in the development of religions, the elimination of magic from the world which had begun with the old Hebrew prophets and, in conjunction with Hellenistic scientific thought, had repudiated all magical means to salvation as superstition and sin,

Reformation challenged the doctrines of the Church, but they disagree about the connection between Protestantism and the supernatural. Agricola shows how an intellectual still managed to maintain theories of the supernatural with both intellectual and religious confidence.

Opposing Scholastic Theologians and Humanist Intellectuals

Agricola's humanist training at universities across Europe facilitated his intellectual tenacity. In his quest to reconcile the meddling in the natural world and the prosperity doctrines of God, Agricola found justification in many texts by ancient authors. One such text was Pliny's *Natural History* (77 AD). Agricola appreciated the ways in which Pliny forthrightly addressed the conflict between human intervention and religious beliefs. Pliny questioned whether the gods were concerned with human affairs at all; and if that were the case, then perhaps the gods were too busy "to punish all crimes promptly."[326] With this quotation, Pliny acknowledged the negative consequences that came with human interference with the natural world. Yet it was necessary to allow humans to prosper. In any case, Agricola turned to an ancient writer to justify mining obstruction in the natural world. He declared that man was "insane (*insanit*)" for both worshipping the riches of mines and considering the metals worthless.[327] He believed that Pliny

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came here to its logical conclusion." Max Weber, *The Protestant Ethic and the Spirit of Capitalism*, trans. Talcott Parsons (London: Routledge, 1992), 61.

[326] Pliny wrote, "For this reason I deem it a mark of human weakness to seek to discover the shape and form of God. Whoever God is—provided there is a God—and in whatever region he is, he consists wholly of sense, sight and hearing, wholly of soul, wholly of mind, wholly of himself." Pliny, *Natural History*, Book 2, Chapter 5, 179. He continued, saying, "But it agrees with life's experience to believe that in these matters the gods exercise an interest in human affairs; and that punishment for wickedness, though sometimes tardy, as God is occupied in so vast a mass of things, yet is never frustrated…" Pliny, *Natural History*, Book 2, Chapter 5, 179-185. For analysis of Pliny's *Natural History*, see also Lynn Thorndike, *A History of Magic and Experimental Science During the First Thirteen Centuries of Our Era* (New York: The MacMillan Company, 1929), 42-47.

[327] Agricola, *De re metallica*, liber primus, 11.

had the recognized authority to resolve two seemingly incompatible issues: human affairs and divine decorum. For Agricola, humanistic study and religious devotion were not irreconcilable.

Agricola's use of Pliny to provide justification within his own religious schema makes an interesting contribution to the debate between humanists and scholastics. Historians have traditionally seen scholasticism and humanism as competing modes of thought and instruction. Scholasticism was the study of the classics with a Christian bent. Scholastics used the works of Aristotle to understand their own faith.[328] Humanism was the type of learning organized around *studia humanitatis*, a group of scholarly disciplines including grammar, rhetoric, history, poetry, and moral philosophy.[329] Humanists of the Renaissance supplanted the scholastics of the Middle Ages, or so some scholars believed.[330]

Historians generally agree that there was conflict between the scholastics and the humanists. The scholastics defended the orthodox doctrines, while the humanists aimed to dismantle them. According to historian Charles Nauert, the antagonism produced "an increasingly poisonous atmosphere."[331] At stake in the disagreements was their opponents' intellectual methods, either dialectical or philological.[332] Broadly speaking, scholastically-trained thinkers relied on the dialectical method proposed by Aristotle, who was not, of course, unmodified.[333] These men focused on the accuracy of an opinion. The humanists, on the other

[328] William Caferro, *Contesting the Renaissance* (Oxford: Wiley-Blackwell, 2011), 100.
[329] Alan Perreiah, "Humanistic Critiques of Scholastic Dialectic," *The Sixteenth Century Journal* 13 (1982): 3.
[330] Alex J. Novikoff, "Toward a Cultural History of Scholastic Disputation," *The American Historical Review* 117 (2012): 332. It should be noted that confusion remains surrounding the origins and development of scholasticism in the medieval period.
[331] Charles G. Nauert, "Humanism as Method: Roots of Conflict with the Scholastics," *The Sixteenth Century Journal* 29 (1998): 431.
[332] Nauert, "Humanism as Method: Roots of Conflict with the Scholastics," 431.
[333] Euan Cameron, *Enchanted Europe: Superstition, Reason, and Religion, 1250-1750* (Oxford: Oxford University Press, 2010), 91. As discussed in the second chapter, "Reevaluating, Reassessing, and Reconsidering Humanism," Aristotelian texts entered medieval Europe as translations from Byzantine intellectuals. The Aristotle that triumphed among medieval theologians was a modified, translated Aristotle.

hand, measured an argument's validity based on the interrogator's linguistic skills.[334] The differences in argumentation become clear in their approaches to interpreting the Bible. The scholastic and humanist thinkers disagreed over the analyses of the Bible because neither found validity in the other's method.

A portion of the hostility was a defense of academic and professional turf. The conservative theologians trained as scholastics and watched as humanists began to encroach upon their faculty. In response to mounting criticism, the humanists attacked and ridiculed the conservatives' teaching and writing, deeming it "trite and inelegant."[335] Their criticisms of the scholastics only resulted in reinvigorating their opponents. These conservative theologians asserted that their traditional method of argumentation—dialectical argumentation—guaranteed "orthodoxy in doctrine and catholicity in religious practice."[336] Scholastics resisted the humanists' pedagogical reforms and took measures to limit the circulation of nontraditional textbooks hoping to discourage philological study.[337]

The humanists did not remain quiet. They charged that the scholastics lacked the necessary linguistic skills to understand the ancients and their form of argument in the first instance. They believed that university students wasted time and energy studying the commentaries of medieval men who did not know Greek. In their minds, a scholar who could not read Greek could not adequately study the Bible, as the entire New Testament was written originally in Greek. Their lack of the necessary linguistic skills prohibited them from appreciating the Bible. The result, the humanists contended, was the cherry-picking of biblical

[334] Nauert, "Humanism as Method: Roots of Conflict with the Scholastics," 431. Two figures that the conservatives admonished were Jacques Lefevre d'Etaples and Desiderius Erasmus.
[335] Nauert, "Humanism as Method: Roots of Conflict with the Scholastics," 430. Nauert uses these adjectives to generalize the thoughts of Northern humanists. He does not attribute the words to any one intellectual.
[336] Nauert, "Humanism as Method: Roots of Conflict with the Scholastics," 431.
[337] Nauert, "Humanism as Method: Roots of Conflict with the Scholastics," 430.

passages. The scholastic theologians only extracted what they could digest. For this reason, the humanists identified the scholastics as ignorant and disingenuous intellectuals, challenging the very enterprises of theology and philosophy. As Agricola's accommodation of Aquinas' texts into his own belief system shows, scholasticism and humanism were not two competing intellectual regimes.

Applying Aquinas' Ideas and Augustine's Beliefs

Historians have identified Aquinas as the scholastics' most famous thinker. His works circulated throughout learned circles in the fourteenth and fifteenth centuries.[338] His works also received attention outside the Dominican establishment. Historian Paul Kristeller detected evidence of Aquinas' ideas and teachings in three distinct groups: theologians connected to religious orders, philosophers attached to Platonic and Aristotelian revivals, and humanists engaged in rhetorical studies.[339] Interest in Aquinas' texts grew because scholars presumably viewed him as a competent interpreter of Aristotle. Aquinas used the works of Aristotle to form a clear argument of how bodies, souls, and spiritual beings relate to each other and to God. Humanists and scholastics alike esteemed the writings of Aquinas. It was not unusual then that Aquinas would have inspired Agricola's beliefs.[340] Although raised in the humanist tradition,

[338] Marcia L. Colish, *Medieval Foundations of the Western Intellectual Tradition, 400-1400* (New Haven: Yale University Press, 1997), 295.
[339] Marcia L. Colish, "St. Thomas Aquinas in Historical Perspective: The Modern Period," *Church History* 44 (1975): 439; and Paul Oskar Kristeller, "Il Tomismo e il Pensiero Italiano del Rinascimento," *Rivista di Filosofia Neo-Scolastica* 66 (1974): 847-858.
[340] Agostino Nifo (1473-1538/1545) is as an example of a lay person, much like Agricola, who was influenced by Aquinas. Nifo was a professor of philosophy and medicine at the University of Padua. He appreciated and praised Aquinas' clear and succinct commentary on Aristotle, despite Aquinas not having a command of ancient Greek. See Jozef Matula, "Agostino Nifo's Reading of Thomas Aquinas," *Divus Thomas* 120 (2017): 65 and Paul Richard Blum, "Introduction," *Divus Thomas* 120 (2017): 18. Marcia Colish believes that Aquinas received such a warm

Agricola found significance in Aquinas' work. Agricola demonstrates how the two schools of thought were not as incompatible as previously believed.

Aquinas addressed miracles in both *Summa contra Gentiles* (1259 – 1265) and *Summa Theologica* (1265 – 1274). These two works served different purposes. In *Summa contra Gentiles*, or *Summa against the Pagans*, he argued from first principles and philosophical maxims. References to Scripture appeared only at the conclusion of chapters as mere "flourishes."[341] The paucity of his Scriptural quotations has encouraged some historians to presume that Aquinas directed the texts at nonbelievers.

Aquinas approached *Summa Theologica* in a different manner. In this text, he sought to resolve conflicting authorities through inferential logic. He famously declared that miracles did not contradict nature. God recognized nature's independence and worked beside the order planted in nature.[342] For Aquinas, nature was orderly and autonomous. God did the miraculous in tandem with nature to produce the extraordinary.[343] Aquinas crafted distinct principles to explain the relationship between God and nature. There existed the supernatural which Aquinas identified as the unmediated actions of God; then there was the natural, which described events that happen regularly and predictably; and lastly there was preternatural, which chronicled those

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welcome from humanists because he used a better translation of Aristotle. See Colish, *Medieval Foundations of the Western Intellectual Tradition, 400-1400*, 295.

[341] Cameron, *Enchanted Europe: Superstition, Reason, and Religion, 1250-1750*, 92.

[342] Aquinas believed, "However, it seems that we should keep in mind that, though God at times does something apart from the order implanted in things, He does nothing contrary to nature. In fact, since God is pure act, whereas all other things have some ad-mixture of potency, God much be related to all else as a mover is to what is moved, and as the active is to what is in potency…So, whatever is done by God in created things is not contrary to nature, even though it may seem to be opposed to the proper order of a particular nature." Saint Thomas Aquinas, *Summa Contra Gentiles*, trans. James F. Anderson (Notre Dame: Notre Dame Press, 1956), Volume 3, part I1, chapter 100, "That Things which God Does Apart from the Order of Nature are not Contrary to Nature," 1-2. See also Peter Harrison, "Miracles, Early Modern Science, and Rational Religion," *Church History* 75 (2006): 497.

[343] Lorraine Daston, "Marvelous Facts and Miraculous Evidence in Early Modern Europe," *Critical Inquiry* 18 (1991): 96.

rare events caused by human interference.[344] In *Summa contra Gentiles*, Aquinas affirmed these three categories of miracles: those that absolutely contradicted the order of nature, as when the sun sets in the east; those that occur out of the range of the normal order, as when the dead are resurrected or when a blind person can suddenly see; and those that occur within the normal order without a natural cause, as when a child's fever is reduced.[345] Aquinas largely agreed with other doctors of the Church in his contention that there was not a sharp distinction between the marvelous and the miraculous, for all the supernatural events sprang from God.[346]

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[344] Aquinas contended, "From each cause there results a certain order to its effects, since every cause is a principle; and so, according to the multiplicity of causes, there results a multiplicity of orders, subjected one to the other, as cause is subjected to cause…If therefore we consider the order of things depending on the first cause, God cannot do anything against this order; for, if He did so, He would act against His foreknowledge, or His will, or His goodness. But if we consider the order of things depending on any secondary cause, thus God can do something outside such order; for He is not subject to the order of secondary causes." Saint Thomas Aquinas, *Summa Theologica*, trans. Fathers of the English Dominican Province (New York: Benziger Borthers, 1948), volume 1, question 105, "Of the Change of Creatures by God," sixth article, "Whether God can Do Anything outside the Established Order of Nature?", 519. He continued by saying, "Now a miracle is so called as being full of wonder; as having a cause absolutely hidden from all: and this cause is God. Wherefore those things which God does outside those causes which we know, are called miracles." Idem, volume 1, question 105, "Of the Change of Creatures by God," seventh article, "Whether Whatever God Does outside the Natural Order is Miraculous?", 520. In fact, many scholars believe that Aquinas borrowed his definition of miracles from Aristotle's words on the intrinsic qualities of nature. See Peter Harrison, "Newtonian Science, Miracles, and the Laws of Nature," *Journal of the History of Ideas* 56 (1995): 533, and Daston, "Marvelous Facts and Miraculous Evidence in Early Modern Europe," 96-97.

[345] Aquinas wrote, "The highest rank among miracles is held by those events in which something is done by God which nature never could do. For example, that two bodies should be coincident; that the sun reverse its course, or stand still…For the greater the things that God does are, and the more they are removed from the capacity of nature, the greater the miracle is. Thus it is more miraculous for the sun to reverse its course than for the sea to be divided. Then, the second degree among miracles is held by those events in which God does something which nature can do, but not in this order. It is a work of nature for an animal to live, to see, and to walk; but for it to live after death, to see after becoming blind, to walk after paralysis of the limbs, this nature cannot do—but God at times does such works miraculously…Now, the third degree of miracles occurs when God does what is usually done by the working of nature, but without the operation of the principles of nature. For example, a person may be cured by divine power from a fever which could be cured naturally, and it may rain independently of the working of the principles of nature." Aquinas, *Summa Contra Gentiles*, Volume 3, part II, chapter 101, "On Miracles," 2-4.

[346] Aquinas noted, "Now, from the fact that God rules thing by His providence it follows that He preserves them in being." He continues by explaining, "Besides, no particular univocal agent can be the unqualified cause of its species; for instance, this individual man cannot be the cause of the human species, for he would then be the cause of every man, and, consequently, of himself—which is impossible…Now this man exists because human nature is present in this matter, which is the principle of individuation. So, this man is not the cause of a man, except in the sense that he is the cause of a human for coming to be in this matter…. Now, there must be some proper agent cause of the human species itself; its composition shows this, and also the orderings of its parts, which is uniform in all cases unless it be accidentally impeded. And the same reasoning applies to all the other species of natural things…Therefore, all the species of things would also cease as soon as the divine operation ceased. So, He preserves things in being through His operation." Aquinas, *Summa Contra Gentiles*, Volume 3, part I, chapter 65, "That God preserves Things in Being," 1; 4. In addition, see Daston, "Marvelous Facts and Miraculous Evidence in Early Modern Europe," 97.

For Aquinas, miracles were a manifestation and representation of God's power. He emphasized that it was "not enough for a miracle if something is done outside the order of any particular nature" but "that it be against the entire order of the whole created nature."[347] Miracles, that is, could only occur in nature under the will of God, who created nature itself. Aquinas placed God outside the order of God's created universe. God did not need to avail himself to nature's principles. Only God, who had created and understood the order of nature, could manifest something new, something miraculous. God, therefore, influenced and continues to influence providentially the course of nature with will and reason.[348]

Agricola agreed with Aquinas' positioning of God, nature, and order. Agricola believed in the power of divine providence. For him, providence was a powerful force that had control over God's creation. He affirmed that "from all these examples are evident the benefits and advantages derived from metals…so who does not understand how highly profitable they are, nay rather, how necessary to the human race? In a word, man could not do without the mining industry, nor did Divine Providence will that he should. (*Ex quibus omnibus perspicuum est, qui*

[347] Aquinas wrote, "A miracle properly so called is when something is done outside the order of nature. But it is not enough for a miracle if something is done outside the order of any particular nature; for otherwise anyone would perform a miracle by throwing a stone upwards, as such a thing is outside the order of the stone's nature. So for a miracle is required that it be against the order of the whole created nature. But God alone can do this, because, whatever an angel or any other creature does by its own power, is according to the order of created nature; and thus it is not a miracle. Hence God alone can work miracles." Aquinas, *Summa Theologica*, volume 1, question 110, "How Angels Act on Bodies," fourth article, "Whether Angles Can Work Miracles," 542. Quoted first in Anselm Ramelow, "Miracles: Finite and Infinite Agents: How Aquinas Would Distinguish Divine Revelation from Deception," *Angelicum* 92 (2015): 71.

[348] Aquinas asserted, "It has already been shown that the operation of providence, whereby God works in things, does not exclude secondary causes, but, rather, is fulfilled by them, in so far as they act by God's power. Now, certain effects are called necessary or contingent in regard to proximate causes, but not in regard to remote causes. Indeed, the fact that a plant bears fruit is a fact contingent on a proximate cause, which is the germinative power which can be impeded and can fail, even though the remote cause, the sun, be a cause acting from necessity. So, since there are many things among proximate causes that may be defective, not all effects subject to providence will be necessary, but a good many are contingent." Aquinas, *Summa Contra Gentiles*, Volume 3, part 1, chapter 72, "That Divine Providence Does not Exclude Contingency from Things," 2. Aquinas instructed that God's providential activity fell into two camps: the planning and the execution. The planning, or rather the ordering, corresponds to God's intelligence. The execution complements God's will. For more commentary on Aquinas' views on divine providence, see Ignacio Silva, "Revisiting Aquinas on Providence and Rising to the Challenge of Divine Action in Nature," *The Journal of Religion* 94 (2014): 287.

fructus quaeque commoditates percipiantur ex metallis...Quis igitur non intelligit eam esse maxime utilem, imo potius necessariam humano generi ne plura: Homo metallica career non potuit, nec ipsum ea career voluit divina benignitas)."[349] Divine providence dictated the success of humans' interaction with nature. God, through divine providence, rewarded humans in their endeavors. In this way, Agricola's thoughts align with another church father, Augustine of Hippo (354 – 430).

Aquinas was not the first doctor of the church to attempt an account of miracles. Saint Augustine asserted in *The City of God* that the entire natural world was a miracle. He asked:

> For again we must not give ear to those who say that no invisible God works visible miracles, since even in their view he himself created the universe, which they surely must admit is visible. Now any marvelous thing that is wrought in this universe is assuredly less than this whole universe, that is, heaven and earth and all things that in them are, which God assuredly created. But the means by which he created it are as hidden and incomprehensible to man as he is himself who created it. No matter then how cheap the natural marvels, that we can see, have come to be held because they are always before us, yet whenever we contemplate them with the eye of wisdom, we see that they are greater marvels than the least familiar and rarest of miracles; for man is greater even than any miracle performed by any man's agency.[350]

The point to be observed is that Augustine placed the miraculous nature of Earth in relation to the observer. An event was miraculous in that it impacted the beholder. Someone had to acknowledge the wonder of God. A miracle was an unusual or unexpected event of nature from the onlooker's point of view. It appeared suddenly. From God's perspective, a miracle was natural. For Augustine, all nature was a miracle, as it was the will of God realized and actualized. The difference between a "miracle" and a natural event occurred only in the way in which God manifested the "miracle."[351] Miracles did not contradict nature, "for how can anything done by

[349] Agricola, *De re metallica*, liber primus, 15.
[350] Saint Augustine, *The City of God against the Pagans*, ed. Jeffrey Henderson (Cambridge: Harvard University Press, 1972), Book X, Chapter 12, 309.
[351] Cameron, *Enchanted Europe: Superstition, Reason, and Religion, 1250-1750*, 92.

the will of God be contrary to nature, when the will of so great a creator constitutes the nature of each created thing?"[352] Augustine elided nature, man, and God. Nature was a testament of the power of God that exceeded human understanding.[353] In fact, Agricola acknowledged that the sweetest food of the soul "is the contemplation of nature (*est contemplation naturae*)," a knowledge of the finest arts and sciences, "a perception of virtue (*perception virtutum*)."[354] Agricola agreed with Augustine that miracles were demonstrations of God's power; humans had merely to recognize them.

Describing God's Miracles and Nature's Signs

Agricola made a note of difference between the miracles of God and the signs of nature, however. He believed that if a skilled miner paid close attention to his surroundings, nature would "reveal (*patefecit*)" signs that could allow the miner to prosper. These signs included locating veins and digging trenches.[355] Unlike miracles of God, signs of nature seemed to be daily, ordinary revelations. There was a predictability. Nature did not intend to conceal the signs; and learned skills could easily allow a miner to reveal what nature had chosen to conceal. One could even become "responsible (*prudentem*)" and skilled in the "natural signs (*naturalia venarum signa*)."[356] The mysterious aspect of nature eroded with experience in the mines and

[352] Saint Augustine, *The City of God against the Pagans*, Book XXI, Chapter 8, 51. Quoted first in Daston, "Marvelous Facts and Miraculous Evidence in Early Modern Europe," 95.
[353] Augustine also elaborated on the miracles that demons performed. He contended that those events were nothing more than manipulations of potentialities. God had invested powers in nature, and the demons had seized and manipulated that power. For Augustine, demons were entirely evil creatures. His descriptions of demons as beings in opposition to God speaks to his thoughts on the cosmos. He viewed the world in terms of binaries: God and the devil, the city of God and the city of Satan, and truth and falsehood. See Cameron, *Enchanted Europe: Superstition, Reason, and Religion, 1250-1750*, 180.
[354] Agricola, *De re metallica*, liber primus, 4.
[355] Agricola, *De re metallica*, liber secundus, 28.
[356] Agricola, *De re metallica*, liber secundus, 28. These "signs" were not celestial motions, however.

exposure to rocks. Where miracles were mysterious, "signs" were discoverable. Training and studying could help miners to concentrate on these signs. In one instance, Agricola described how he witnessed experienced miners search for a specific type of rock that was good for smelting tin. These rocks were a positive "sign":

> In it there are scattered the tiniest black gravel from which tin is smelted…Very often indeed, this good kind of rock in connection with valuable stringers contains within its folds the *canales* of mineral bearing veins, if it descends vertically into the depths of the earth, the benefit belongs to the mine in which it is seen first and foremost.
>
> *Sed venae argenti bonum indicium est alterius patris saxum, cui minutissimi lapilli nigri, ex quibus plumbum candidum conflatur... Plerunque profecto saxum otia, cum fibra precisosa coniunctum, canales venae, metallicis faecundae, conplexu suo continet. Quod si recta in profundum terrae descenderit, illa bonitas ei fodinae est, in qua ipsum dolor statim videtur*.[357]

Unlike miracles, signs were not mysterious but predictable. What was more, the miners could teach other miners about these signs.

In teaching the signs to others, the miners developed a ranking system. Agricola observed how the miners identified some indications of nature as "good (*bonum*)" and others as "special (*singulare*)."[358] For instance, Agricola detailed how varieties of stone easily melt when introduced to fire, and an excellent test for their melting capability was the stones' translucency. Translucency could be regarded as a "medium sign (*mediis signis*)" if other "good indications (*signa bona*)" were there; however, if there were no other "good indications (*signa bona*)," then translucency had no significance.[359] Among the components of rocks, color helped the miners determine the quality of the materials. Color was a "special (*singular*)" indication when it came to precious metals.[360] That is, Agricola noted how "the special indication of gold is orpiment; of

[357] Agricola, *De re metallica*, liber quintus, 78.
[358] Agricola, *De re metallica*, liber quintus, 77;78
[359] Agricola, *De re metallica*, liber quintus, 78.
[360] Agricola, *De re metallica*, liber quintus, 78.

silver is bismuth and *stibium*; of copper is verdigris, *melanteria* (*auri singulare indicium est auri pigment, argenti, plumbum cinereum et stibium, aeris, aerugo, melanteria*)."[361] Indications and signs were phenomena in the natural environment that miners could spot and identify. These characteristics of God's creation could be revealed through experience. Miners relied on their colleagues' expertise to reveal the bounty of God's creation. In this way, Agricola proposed that miners had a degree of mastery of God's creation. He and the miners could feel God's presence not only in His providential design of nature, but also in the way He preserved nature.[362] They could understand, identify, and articulate the ordinary course of nature.

Agricola argued in favor of the religious significance of the miners' activities. They performed crucial functions that led to a better understanding of God's creation. By recording the instances in which Agricola saw miners teach their colleagues about the pigments in stones and rocks, Agricola shows how he operated under the assumption that nature existed in a habitual custom. Nature was predictable. Although awe-inspiring, nature was not so mysterious that its understanding was beyond human capacity. Agricola demonstrated the miner's ability to comprehend nature.[363]

Agricola's depiction of order within nature supports Peter Harrison's belief that the early modern period saw a shift in the relationship between science and religion. Harrison asserted that natural philosophers contributed to a reorientation of membership in the Church. Religion had "less to do with membership of the Church, with inner virtue, or with specific ritual practices, and more to do with subscription to a set of rationally justifiable propositions."[364] Harrison argued further that natural philosophers' claim that they knew the order of nature shattered the

[361] Agricola, *De re metallica*, liber quintus, 78.
[362] Rienk Vermij, "A Science of Signs. Aristotelian Meteorology in Reformation Germany," *Early Science and Medicine* 15 (2010): 673.
[363] Daston, "Marvelous Facts and Miraculous Evidence in Early Modern Europe," 99.
[364] Harrison, "Miracles, Early Modern Science, and Rational Religion," 494.

previously held belief that nature, and thereby God, was mysterious. Agricola honored the hierarchy of nature, relegating man to the bottom of that hierarchy.

Conclusion

His scrutiny of miners and their techniques provides insight into how Agricola internalized and practiced his religious beliefs. His work contains only a few references to God. However, he did note the presence of providence, chance, fortune, and demons, all of which hint at a Christian proclivity. In a delicate and skillful manner, Agricola asserted his views. For him, God remained the Creator of the natural world, and man ought to hold nature in reverence to Him.

Agricola did not agree with those critics who contended that mining was inherently antagonistic to religion. Mining had the potential to destroy wildlife and spawn avarice, but it could also draw its participants closer to God. Agricola argued that miners had to confront the supernatural realm, while recognizing their own mortality and God's timing.

Agricola was not the first to adjust his theology to fit his circumstances. Philip Melanchthon (1497 – 1560) was another Reformation figure who saw the natural world as evidence of God's goodwill. Unlike other reforming leaders, Melanchthon was a philosopher, historian, and literary scholar. He was largely responsible for accommodating Aristotelian philosophy to Lutheran principles.[365] Melanchthon was a professor of Greek at the University of

[365] One of Luther's primary concerns was that Aristotle's natural philosophy did not account for immediate acts of God. Sachiko Kusukawa argued that Melanchthon saw natural philosophy as a means to respond to critiques levelled against Luther. By reinterpreting classical and contemporary works, he consolidated Luther's message. See Sachiko Kusukawa, *The Transformation of Natural Philosophy, The Case of Philip Melanchthon* (Cambridge: Cambridge University Press, 1995), 4-5; and Vermij, "A Science of Signs. Aristotelian Meteorology in Reformation Germany," 649; 667.

Wittenberg, and he is best known for cataloguing Lutheran theology in *Confessio Augustana* (1530) and *Loci communes* (1521). Yet it is in *Orations on Philosophy and Education* that he clarified his views on the relationship between the natural world and divine intervention. In his *Orations on Philosophy and Education*, Melanchthon aimed to ensure that universities taught Luther's message of the Gospel correctly.[366]

Like Agricola, Melanchthon believed that God created nature because "He is moved by concern for humankind."[367] In his oration "On the role of the schools" (1543), Melanchthon contended that the variety of the natural world was evidence for God's altruism. That variety of plant life and animal life made life "suitable" for humans.[368] At the same time, God did not want humans to take advantage of His generosity. According to Melanchthon, humans had to act as stewards of God's creation. Melanchthon reminded his audience in "Preface to On the Sphere" (1531) that God had commanded humankind "to pamper and support [nature] with food, drink, and other things made for protecting life."[369] Humans' involvement in God's creation did not negate the power of divine providence, however.[370] Melanchthon and Agricola both agreed that human interference and divine providence were compatible. Both men characterized humankind as rational, free-thinking individuals who were called by God to protect the natural environment. God would act directly in the interests of His believers and anointed.

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[366] Historian Charlotte Methuen also contended that Melanchthon saw philosophy as a basis to determine right and wrong behavior. Melanchthon wanted to respond to Martin Luther's problematic theology. As Luther denied the efficacy of good works, some had started to believe that he was suggesting that no authority existed to gauge civic behavior. Melanchthon sought to resolve this pressing issue. Philosophy could act as the authority. See Sachiko Kusukawa, "Introduction," in *Orations on Philosophy and Education*, ed. Sachiko Kusukawa and trans. Christine F. Salazar (Cambridge: Cambridge University Press, 1999), xi; Charlotte Methuen, "The Role of the Heavens in the Thought of Philip Melanchthon," *Journal of the History of Ideas* 57 (1996): 385-386; 391; Jonathan Regier, "Kepler's Theory of Force and His Medical Sources," *Early Science and Medicine* 19 (2014): 1-27.
[367] Philip Melanchthon, *Orations on Philosophy and Education*, ed. Sachiko Kusukawa and trans. Christine F. Salazar (Cambridge: Cambridge University Press, 1999), 11.
[368] Melanchthon, *Orations on Philosophy and Education*, 11.
[369] Melanchthon, *Orations on Philosophy and Education*, 109.
[370] Melanchthon, *Orations on Philosophy and Education*, 109.

Agricola sought justification for his religious sensitivities in the texts of Pliny and aligned his views with the works of Aquinas and Augustine. Ultimately, however, the most persuasive arguments came from his observations of the miners themselves. Agricola wrote a seemingly irreligious text on mining in the heart of Reformation Germany. Yet, in truth, man's devotion and relationship to God emerge clearly from the pages of Agricola's work.

Chapter 5

Readers, Reactions, and Rehabilitations: A Study of How Agricola Tailored His Text to His Audience

In *De re metallica* (1556), Georgius Agricola provided an explanation for undertaking the composition of a comprehensive how-to manual on the subject of mining. In his desire to raise the status of natural philosophy and elevate the art of mining, Agricola represented mining in a particular way. He presented his descriptions so as to appeal to the logic and ethics of his educated Christian audience. Agricola had an informed idea of who his readership was. His text did not pass to an undifferentiated mass public. As such, he used specific tools of argumentation. He compared the labors of farmers and miners, addressed his critics directly, and referenced ancient writers. He exerted all this energy in order to explain the virtues of mining and the integrity of its participants.

With the communication of the practical, empirical, and theoretical knowledge of mining, Agricola's *De re metallica* fits well into the category of how-to manuals and books of secrets. The publication of Agricola's treatise exposed mining techniques and theories to an audience of non-specialists. He made public the tasks that would have traditionally belonged to expert craftsmen, who would have ostensibly shared their skills orally. Agricola provided access to the secrets of nature. Nature, according to William Eamon, could now become a "repository of occult forces that might be manipulated by using the right techniques."[371] An awareness of nature's secrets did not belong to a reserved few. Certainly, Agricola's references to Aristotelian

[371] William Eamon, "Books of Secrets in Medieval and Early Modern Science," *Sudhoffs Archiv* 69 (1985): 27. Historian Meredith Ray believes that the practice of alchemy economically supported the genre of books of secrets. Many in the early modern period associated the procedures and experiments outlined in the books of secrets. Alchemy and books of secrets were inextricably linked, according to Ray. See Meredith K. Ray, *Daughters of Alchemy, Women and Scientific Culture in Early Modern Italy* (Cambridge: Harvard University Press, 2015), 49.

logic and Christian ethics make it clear that his target audience was educated, European, and Christian. His text would not have appealed to an illiterate Venetian woman, for instance. Although directed to a cultured readership, Agricola's text nonetheless made public a previously undisclosed knowledge-set. In fact, Agricola's appreciation for his readers' sensibilities fits into a larger historiography on the manner in which audiences shaped and participated in discursive knowledge-production.[372]

Scholars placed advice manuals, courtesy texts, and conduct books within the genre of conduct literature. These didactic treatises fluctuated between prescriptions and descriptions of quotidian life, for their authors transmitted the ideal precepts for social behavior and promoted modes of social interaction.[373] In medieval and early modern Europe, these works helped to construct and preserve the rules for good living. Three famous examples of conduct books are Erasmus' *De civilitate morum puerilium* (1530), Castiglione's *Il Cortegiano* (1528), and Giovanni della Casa's *Il Galateo* (1558).[374] By commenting on religious devotion, female chastity, table manners, and social etiquette, writers endorsed good habits. The very proliferation of these texts affirms the idea that reading about good habits could have had a salutary effect on an individual's conduct of life. The performance of those good habits could have also served as

[372] See Mario Biagioli, *Galileo Courtier: The Practice of Science in the Culture of Absolutism* (Chicago: The University of Chicago Press, 1993); Paula Findlen, *Possessing Nature: Museums, Collecting, and Scientific Culture in Early Modern Italy* (Berkeley: University of California Text, 1994); Steven Shapin, "The House of Experiment in Seventeenth-Century England," *Isis* 79 (1988): 373-404; Steven Shapin and Simon Schaffer, *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life* (Princeton: Princeton University Press, 1985).
[373] Helena Sanson and Francesco Lucioli, "Introduction: Women and Conduct in the Italian Tradition, 1470-1900," in *Conduct Literature for and about Women in Italy 1470-1900*, eds. Helena Sanson and Francesco Lucioli (Paris: Classiques Garnier, 2016), 12; Roberta L. Krueger, "Introduction: Teach Your Children Well: Medieval Conduct Guides for Youths," in *Medieval Conduct Literature: An Anthology of Vernacular Guides to Behavior for Youths*, ed. Mark D. Johnston (Toronto: University of Toronto Press, 2009), ix.
[374] William Caferro, *Contesting the Renaissance* (Oxford: Wiley-Blackwell, 2011), 36.

an indicator of one's social standing. Refinement marked class distinctions, and these texts promoted the modes of social life that individuals could use to earn cultural capital.[375]

The literature on conduct books is tied to the history of the "civilizing process." For Norbert Elias, conduct literature constituted an instrument for the regulation of the lower classes' social norms by the elites. Exploring his thesis in *The Civilizing Process* (1939), Elias used advice manuals to trace the transformation of social etiquette in early modern Europe. He contended that there existed a connection between social and psychological processes.[376] For Elias, the upper classes exercised domination through their prescriptions of social behavior. These modalities of change signaled a change in human sensibility, which thus indicated a change in civilization. According to Elias, the making of civilization was a taming process. Through conduct literature, a socially-disciplined and emotionally-constrained man displaced his earlier medieval counterpart.

For the historian, conduct manuals become a tool to examine the changing socio-historical realities of the medieval and early modern period. These works developed conservatively, as one historian articulated, "absorbing and transmitting traditional teachings, rather than breaking with the past."[377] Whereas most research pertaining to early print and literacy focused on an erudite audience, vernacular conduct manuals got at the mentalities of the laity. The manuals had a decidedly broad audience, encompassing both men and women.[378]

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[375] See Pierre Bourdieu, "The Forms of Capital," in *Handbook of Theory and Research for the Sociology of Education*, ed. John G. Richardson (Westport, CT: Greenwood, 1986), 241-258.
[376] Patrick H. Hutton, "The History of Mentalities: The New Map of Cultural History," *History and Theory* 20 (1981): 247.
[377] Krueger, "Introduction: Teach Your Children Well: Medieval Conduct Guides for Youths," xii.
[378] Rudolph Bell, *How to do it guides to good living for Renaissance Italians* (Chicago: University of Chicago Press, 1999), 11. The seemingly universal appeal of these works has some scholars identifying the works as "popular books." See also Paul Grendler, "Form and Function in Italian Renaissance Popular Books," *Renaissance Quarterly* 46 (1993): 453.

A conduct literature aimed specifically at women did exist. Many of these texts emphasized women's roles in the home, laying out their duties and behaviors within the domestic sphere. The works helped to construct an image of femininity.[379] While diverse in format, style, and content, the works all had a common goal—instructing women how to behave as daughters, wives, and widows.

Many of the authors offered education as a path for women to refine themselves. Leonardo Bruni, for instance, addressed his manifesto *De studiis et litteris* (1423 – 1426) to Battista Malatesta, a noblewoman. In this text, Bruni described how a girl should expand her mind through the study of grammar, rhetoric, poetry, history, and moral philosophy. These were the disciplines that formed the cornerstone of *studia humanitatis*, a humanist education; an education that belonged traditionally to men.[380] Bruni suggested that women should stimulate their minds in a similar way to men. The goal, presumably, was that women could improve their intellectual capacity in order to understand Christian commentators and thus become more virtuous. For Bruni and many other authors of conduct books, understanding the role of humans in society and in the natural world transcended gender barriers.

Similar to conduct manuals, books of secrets also captured the attention of a popular audience and promoted a model of courtly behavior. The historian of science William Eamon has done significant work to establish how "professors of secrets" imitated the courtly values

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[379] Sanson and Lucioli, "Introduction: Women and Conduct in the Italian Tradition, 1470-1900," 9. There was a robust genre of conduct literature written by and for women. Women writers provided advice to others regarding each stage of life. Women were consumers. They were readers. The conduct literature for a female audience remains the source base for historians of both intellectual and gender histories. Scholars interested in the intersection of these two histories inevitably confront the secondary literature on the *querelle*. From the 1400s to the 1700s, the debate on the nature of women was commonly referred as the *querelle des femmes*, or the woman question. At stake in these discussions was the advancement of women. Could women advance intellectually and socially as men? For more information, see Virginia Cox, *Women's Writing in Italy, 1400-1650* (Baltimore: The Johns Hopkins University Press, 2008).

[380] Paul Oskar Kristeller, *Renaissance Thought: The Classic, Scholastic, and Humanist Strains* (New York: Harper Torchbooks, 1961), 10.

represented in Castiglione's *Il Cortegiano*. Characterizing their attitude towards the arts as "virtuosity," Eamon contended that these "professors of secrets" broke with tradition by publishing their experiments.[381] They reduced the inexplicable, natural marvels to ordinary technical procedures. Eamon erred when he gave too much agency to the printing press and exaggerates the significance of Baconian science; yet, he did present a compelling argument about the spatial shift of science. According to Eamon, the advent of the printing press contributed to the "breakdown of medieval attitudes" and "opened up new opportunities to publish secrets."[382] Printing and publishing pushed science out of the universities and into courts and homes. For Eamon, these books of secrets were not theoretical, esoteric works. They appealed to a popular audience, and they transformed science into a public activity.

Continuing the scholarship on conduct manuals, Katherine Leong has examined how recipe books shaped local knowledge. Household recipe books are not the traditional primary sources for historians of early modern science. Yet Leong has argued that the seemingly peculiar source base guides the history of science into the realm of local knowledge. She argued that her sources, two hundred printed recipe books and two hundred sixty manuscript ones, were not just repositories of knowledge, but also networks of knowledge. These texts were crafted by a household, that is, by a collective. In *Recipes and Everyday Knowledge: Medicine, Science, and the Household in Early Modern England* (2018), Leong located evidence of parents, children, servants, and even gardeners contributing to the production of these texts. She contended that creating how-to manuals was a local, tacit, and collective experience.[383] The instructional texts

[381] William Eamon, "Science and Popular Culture in Sixteenth Century Italy: The 'Professors of Secrets' and Their Books," *Sixteenth Century Journal* 16 (1985): 480.
[382] Eamon, "Science and Popular Culture in Sixteenth Century Italy: The 'Professors of Secrets' and Their Books," 473.
[383] Elaine Leong, *Recipes and Everyday Knowledge: Medicine, Science, and the Household in Early Modern England* (Chicago: The University of Chicago Press, 2018), 7.

relied on local knowledge. Leong's historical actors tested recipes against others to make certain that theirs was the most accurate recipe of a skill.[384] This chapter takes up Leong's call to study knowledge in a multifaceted system and extend the traditional sites for making knowledge in the early modern period.

Agricola's text on mining falls into the category of "books of secrets" because it explored man's place in the natural world in an approachable manner. Agricola may have assumed that his audience was educated, but he knew that a direct approach would contribute forcefully to his goal. That is, he could not argue for the virtues of mining if he confused his reader. His rhetorical strategies were deliberate.

Agricola was not the first to write on the art of mining, but he elevated the topic so readers could understand. Those earlier texts were unsatisfactory. As a response, he sought to create a text that neither concealed nor befuddled his audience. He wanted to distance himself from those writers, whom he identified as alchemists. Agricola claimed that alchemists wrote those treatises to obfuscate matters with their obscure language.[385] In contrast, Agricola produced a text that used clear and concise terminology.[386] Undoubtedly, Agricola's direct, uncluttered prose reflected his desire to make mining, and a text about it, more accessible. In order to eradicate the ambiguities left by the vague alchemic texts, Agricola standardized his own word choice. He sought never to invent a term. He proposed using the nomenclature employed by the ancient writers, such as Aristotle. This decision gave *De re metallica* coherence and prestige, two qualities that he found to be missing within alchemy. His rhetoric was precise and exacting.

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[384] Leong, *Recipes and Everyday Knowledge: Medicine, Science, and the Household in Early Modern England*, 175.
[385] Georgius Agricola, *De re metallica* (Basel: Froben Press, 1556), Epistola, 2-3.
[386] According to Zweder von Martels, Augurello wrote his poem *Chrysopoeia* (1515) in a classical fashion. See Zweder von Martels, "Augurello's 'Chrysopoeia' (1515) – A Turning Point in the Literary Tradition of Alchemical Texts," *Early Science and Medicine* 5 (2000): 179-180.

Agricola doubted the alchemists' ability to transmit knowledge. He found it curious that these writers would not provide "the names of the masters (*nomina magistrorum*)" who had acquired "great wealth through the occupation (*opificio magnam pecuniam consecuti sunt*)" of alchemy.[387] According to Agricola, detailing the names of the master alchemists would have invested a measure of professionalization and thereby thwarted accusations of fraud. The notion that alchemists were not learning from masters implied that they lacked a tradition of scholastic engagement. As such Agricola proposed that alchemists deceived people because folks did not "read of any of [the alchemists] ever having become rich by this art (*quia nullos ex ha carte quondam divites esse factos scriptum legimus*)," nor did they see them growing rich as other "nations have done (*tot ubivis gentium fuerint*)."[388] Agricola contended that the alchemists' choice to remain silent about the sources of their masters' knowledge made them imposters.[389] Agricola wished to trace the theories behind the alchemic practices, but the absence of names turned his scholarship into a guessing game and detracted from the legitimacy of mining.

The Similar Pursuits of Farmers and Miners

Agricola's work, moreover, was a response to those Christian critics who believed that the pursuit of wealth through commercial activity occupied a morally dubious position. Within a western Christian framework, many believed that increasing one's wealth would corrupt the

[387] Agricola, *De re metallica*, Epistola, 2-3.
[388] Agricola, *De re metallica*, Epistola, 3.
[389] The profits that mining could have generated seemed to concern Agricola on an ethical level. Wealth from mining preoccupied Agricola so much so that he turned to the ancient writers to underscore its place in society. He agreed neither with the Peripatetics, whom he insisted "regarded all wealth as a good thing (*universas quidem divitatias Peripatetici in bonorum numero duxerunt*)" nor with the Stoics, who did not place wealth in the category of good things, but also not count it amongst the evil ones. Because the alchemists failed to share with other intellectual communities, Agricola believed that they should not consider themselves belonging to an "art." See Agricola, *De re metallica*, liber primus, 13.

soul.[390] Repudiating such a belief would place the writer in direct opposition to the Scriptures. In the first book of the Gospels, Matthew wrote, "lay not up for yourselves treasures upon earth, where moth and rust doth corrupt, and where thieves break through and steal. But lay up for yourselves treasures in heaven, where neither moth nor rust doth corrupt […] For where your treasure is, there will your heart be also […] No man can serve two masters."[391] Although many would have read and interpreted the Scriptures differently, the inclusion of such a statement in the Gospels suggests that there was a concern; a concern that the Christian would focus to the point of obsession on generating wealth, and that obsession would ultimately engross his life.

The Scriptures did not disparage all labor, however. Scattered throughout the Bible are positive references to agriculture. In the book of Isaiah, the prophet described how God would reward those who farmed by "send[ing] you rain for the seed you sow in the ground, and the food that comes from the land will be rich and plentiful. In that day your cattle will graze in broad meadows."[392] Agricola seemingly grasped the favorable presentation of agriculture in the Scriptures. He knew to compare the miners' labor to that of farmers in his quest to elevate the art. By making reference to agriculture, he operated under the assumption that his audience would have recognized the nuances of his comparison as well. He assumed that his audience would have interpreted the Scriptures in the same way that he did. Agricola addressed the

[390] Russell Nieli, "Commercial Society and Christian Virtue: The Mandeville-Law Dispute," *The Review of Politics* 51 (1989): 582.
[391] Matthew, 6:19-21.
[392] Isaiah, 30:23. See also Deuteronomy, 28:12: "The Lord will open the heavens, the storehouse of his bounty, to send rain on your land in season and to bless all the work of your hands. You will lend to many nations but will borrow from none;" Proverbs, 27:34-35: "Be sure you know the conditions of your flocks, give careful attention to your herds; for riches do not endure forever, and a crown is not secure for all generations;" Hebrews, 6:7: "Land that drinks in the rain often falling on it and that produces a crop useful to those for whom it is farmed receives the blessing of God;" and Genesis, 27:28: "May God give you of heaven's dew and of earth's richness—and abundance of grain and new wine."

similarities between agriculture and mining and pushed against the vitriolic denunciations of riches and the rich in the Bible. [393]

To Agricola, mining was certainly as noble an occupation as agriculture because they both harvested the bounty of the Earth. As a farmer sowed "his seed in his fields (*in agris suis sementem facit*)" and "injure[d] no one (*nemini tamen facit iniuriam*)," however profitable they may have proven to him; so the miner "dug for his metals (*ille cum suum fodit metallum*)," and he drew forth "great heaps of gold or silver, but hurt no mortal man (*etiamsi magnos acervos auri argenti ne eruat, nulli tamen mortalium dat damnum*)."[394] For Agricola, the two endeavors were sufficiently similar that if critics were to treat farming as socially acceptable, they should also view mining in the same manner. Extracting metals from the ground was no more wicked than taking fish from the seas.[395] Despite the profits that mining enterprises generated, Agricola found dignity in the trade.[396] He commended the "singular honesty, innocence, and goodness (*singularem illorum integritatem et innocentiam bonitatem*)" of miners and strove "to remove completely (*ac funditus tollatur*)" from the critics' minds that the metals were "most profitable to mankind (*humano generi perutilis*)."[397] Agricola's rebuff of the claims of impropriety followed this syllogism:

Metals are evil.
Metals come from the Earth.
The Creator created the Earth.
Then the Creator was evil. [398]

[393] Nieli, "Commercial Society and Christian Virtue: The Mandeville-Law Dispute," 583.
[394] Agricola, *De re metallica*, liber primus, 15.
[395] Bern Dibner, *Agricola on Metals* (Norwalk: Burndy Library, 1958), 30.
[396] Agricola, *De re metallica*, liber primus, 18.
[397] Agricola, *De re metallica*, liber primus, 8.
[398] Dibner, *Agricola on Metals*, 30.

His line of reasoning helped to identify the nonsense in the critique. No morally, self-righteous Christian reader would dare to consider an argument in which the Creator was reasoned to be evil. In this way, Agricola employed logic to support his arguments.

Agricola did not ignore the association of metals with coin. He recognized that his Christian audience would have found mining problematic. It was not new to consider mining an illicit profession. The medieval Church was responsible for creating the hostility for manual labor like mining, according to historian Jacques Le Goff.[399] Mining, after all, created coinage that became instruments of sin such as avarice. Agricola sought to dispel the attitude.

The Singular Importance of Metals

Agricola sought to convince his readers that mining was not an immoral activity by listing all the trades that required metal implements. In declaring the importance of mining and the utility of metals, Agricola specified many occupations within the aesthetic and commercial arts that all required metals. In the first instance, artists used metals, such as "iron and brass to make the tools necessary (*utitur instrumentis ex ferro vel ex aere factis*)" to create "elegant and perfect (*elegans et perfectum*)" decorative works.[400] He also mentioned how painters used metals to yield certain pigments which were "less harmful (*caeteris nocet*)" than others.[401] If one were to classify mining as evil, other crafts, such as ceramics, were likewise evil.

[399] See the fifth chapter titled "Licit and Illicit Trades in the Medieval West" in Jacques Le Goff, *Time, Work, and Culture in the Middle Ages*, trans. Arthur Goldhammer (Chicago: The University of Chicago Press, 1980), 58-70. See also Elspeth Whitney, "Paradise Restored. The Mechanical Arts from Antiquity through the Thirteenth Century," *Transactions of the American Philosophical Society* 80 (1990): 13-16.
[400] Agricola, *De re metallica*, liber primus, 15.
[401] Agricola, *De re metallica*, liber primus, 14-15.

Agricola perhaps recognized that his audience would appreciate that seemingly honorable trades, such as agriculture, could not be seen as evil. He took the time to itemize the ways in which farming, hunting, and fishing all required metal tools. Agricola reminded his reader that farmers made "rustic instruments…of iron (*instrumenta autem rustica…ferrea*)," such as "ploughshares (*vomer*)," "sharebeams (*dentale*)," and "the prongs (*dentes*)" of "hoes (*sarculum*)," "hay-forks (*falx foenaria*)," "straw cutters (*stramentaria*)," "lances (*scalpellum*)," and "forks (*furcae*)."[402] Hunters also required metals in order to catch prey; similarly fishermen needed metals to craft their fish-hooks.[403] Agricola stressed the importance of metals to a number of trades. He wisely selected the trades. They were not random. He chose those crafts that sustained human society. A critic would have found it difficult to minimize the significance of farming, hunting, and fishing. Agricola linked the seemingly sinful metals with human survival.

Agricola sought to rehabilitate the status of mining, by rejecting the presumption that it encouraged a clamoring for wealth. He did not believe that mining fostered vice. While he did recognize that humans had a propensity toward becoming obsessed with the acquisition of metals (i.e., gold), he made it clear that the metals themselves could not explain avaricious tendencies. The Creator did not endow metals with intrinsic natural value. Over time metals assumed value as humans used stones and minerals as a means to exchange goods and services. According to Agricola, identifying metals as a reflection of wealth had encouraged licentious behavior. Thus those individuals who had classified mining as a dishonest form of labor had erroneously correlated mining with the egregious "abuse of gold and silver (*maledicunt auro et argento*)."[404] These critics of mining condemned metals, calling them "deadly (*funestas*)" and blaming them for the "destruction and ruin (*interitus et exiti*)" of the human race "because those who possess

[402] Agricola, *De re metallica*, liber primus, 9.
[403] Agricola, *De re metallica*, liber primus, 9.
[404] Agricola, *De re metallica*, liber primus, 6.

[metals] [were] in the greatest peril (*nam ea qui possident maximo in periculo sunt*)."[405] Agricola did not disagree that lusting after metals could devastate lives, but he challenged the belief that the metals themselves and the workmen extracting them were responsible for the actions of a few esurient men.

In his efforts to separate mining from greed, Agricola considered the example of tyranny. When a tyrant, "inflamed with love for a woman of excellent form (*magno amore inflammatus in mulierem egregia forma*)" declared war on the inhabitants of her city, the "fault lay in the unbridled lust of the tyrant and not in the beauty of the woman (*istiusmodi belli in effrenata tyranni libidine est culpa, non in facie mulieris*)."[406] For Agricola, the problem of greed was that of the coveter, and not the coveted. He refused to settle for the passivity of men as an explanation for halting mining enterprises. Again, he did not disagree that the lust for gold was shameful; certainly, Agricola understood that throughout history men have accurately continued to characterize such accusations as "criminal (*crimini*)."[407] He pained to dismantle the prejudice that the "metals question (*quaeritur metallica*)," or to work in metals, was "degrading and dishonorable (*pudenda et inhonesta*)."[408] He would not concede that mining encouraged moral impropriety. Perhaps a few "dishonorable (*inhonesta*)" men had given mining a poor reputation; yet in Agricola's mind, mining remained an honorable occupation.

Agricola's position on the subject of riches finds resonance within a larger literature on Protestant reform in early modern Europe. John Calvin (1509 – 1564), for example, chose not to spew vitriol at those participating in a mercantile economy. Perhaps he understood the realities

[405] Agricola, *De re metallica*, liber primus, 6.
[406] Agricola, *De re metallica*, liber primus, 12.
[407] Agricola, *De re metallica*, liber primus, 12.
[408] Agricola, *De re metallica*, liber primus, 15.

of urban living.[409] In fact, he proclaimed that it was blasphemous "against God to disapprove of riches, implying that a man who possesses them is thereby wholly corrupted. For where do riches come, if not from God."[410] According to historian Charles Trinkaus, Calvin believed that "the course of human events, as well as of nature, was predetermined in accordance with divine wisdom."[411] Prosperity and tribulations were both signs of divine benediction. Humans had to take responsibility for both their successes and failures.

The Deliberate Reference to Horace

To amplify his point that the preoccupation with greed laid in the value that humans have placed on money, Agricola turned to the works of Horace. Agricola paraphrased how Horace (65 BC – 8 BC) "very rightly (*rectissime*)" said in *Satires* (35 BC – 33 BC), "do you not know the value of money; and what uses it serves? It buys bread, vegetables, and a pint of wine (*Nescis quid valeat nummus, quem praebeat usum/Panis ematur, olus, vini sextarius*)."[412] Agricola used the ancient Roman poet to sharpen his belief that money and the exchange of money was not necessarily the root of all evil in the world.[413] Agricola employed Horace's words to make it clear that money served a societal purpose. He stressed how Horace described the manner in which "wealth commanded its possessor as a slave (*imperat aut servit collecta pecunia*);" rather it should "follow rather than lead the twisted rope (*tortum digna sequi potius quam ducere*

[409] William J. Bouwsma, *John Calvin: A Sixteenth-Century Portrait* (New York: Oxford University Press, 1988), 196.
[410] John Calvin, *Commentaries*, Ex. 11:2. Quoted in Bouwsma, *John Calvin: A Sixteenth-Century Portrait*, 196.
[411] Charles Trinkaus, "Renaissance Problems in Calvin's Theology," *Studies in the Renaissance* 1 (1954): 73.
[412] Agricola, *De re metallica*, liber primus, 12.
[413] W.S. Anderson, "The Roman Socrates: Horace and His Satires," in *Critical Essays on Roman Literature*, ed. JP Sullivan (New York: Routledge, 1963), 1.

funem)."[414] Agricola recognized that simply stating in his own words how metals and minerals did not solely exacerbate the human condition would prove insufficient. He needed the words of a hegemonic figure to advance his argument. By deploying Horace's text, Agricola assumed that his audience would have recognized not only Horace's corpus, but also the ancient poet's authority.

By making references to Horace, Agricola clearly sought to appeal to a large, educated audience. It should not go unnoticed that Agricola wrote his text in Latin. He did not want to restrict his audience by writing in German. Composing the text in Latin broadened his readership.

It was not unreasonable to assume that a Latin-reading audience would be familiar with Horace's *Satires*. Amongst early modern Latinists, Horace received praise for his rhetorical finesse; his skillset was even legendary amongst his Roman contemporaries, who applauded him for his brevity and precision.[415] In sixteenth- and seventeenth-century European universities, the study of Horace played a major role in the curriculum of Latin studies.[416] According to Paul Grendler, early modern commentators avoided Virgil's allegories in favor of Horace's rhetoric. Ludovico Ariosto (1474 – 1533) and Pietro Bembo (1470 – 1547) both imitated his poetry. For sixteenth-century pedagogues, Horace's writing became the paragon of style.[417]

During the early modern period, Latin continued to maintain its privileged position in universities. Students learned to read and write in Latin before receiving instruction in their vernacular tongues.[418] Many encouraged the cultivation of Latin in order to absorb ancient

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[414] Agricola, *De re metallica*, liber primus, 12.
[415] Anderson, "The Roman Socrates: Horace and His Satires," 1.
[416] Horace was Erasmus' favorite satirist. Margaret A. Sullivan, "Bosch, Bruegel, Everyman and the Northern Renaissance," *Oud Holland* 121 (2008): 118.
[417] Paul Grendler, *Schooling in Renaissance Italy: Literacy and Learning, 1300-1600* (Baltimore: Johns Hopkins University Press, 1992), 252-254.
[418] Keith Percival, "Grammar, Humanism, and Renaissance Italy," *Mediterranean Studies* 16 (2007): 94.

literature, against which intellectuals evaluated scientific advancement. Humanists sought to rehabilitate this ancient rhetorical heritage and regarded the work of Aristotle as the apex of reason. At the university level, this emphasis evolved into *studia humanitatis*, which encompassed several disciplines: grammar, rhetoric, history, poetry, and moral philosophy. Study included the "reading and interpretation of its standard ancient writers in Latin and, to a lesser extent, in Greek."[419] Better translations of the ancient texts led to a spectrum of interpretative techniques.

With the nod to Horace, Agricola revealed his humanist education. He studied in the Italian humanist tradition at Bologna and Padua, after having been graduated from Leipzig University at the age of twenty.[420] In such a way, the presence of these Horatian texts found in *De re metallica* shows how humanism was a "constant accompaniment to the movement referred to by the term Renaissance."[421] Agricola composed this text in a moment when "the act of rediscovery based on the conscious decision to reclaim and cultivate all the extant literature of antiquity."[422] The inclusion of Horace's texts not only would have resonated with the reader, but also would have given authority to Agricola and legitimacy to mining.

The Lauded Skillset of Miners

Agricola also legitimized mining enterprises by observing and recording the skills and the expertise needed to mine properly. He rejected the prevailing view that miners were unskilled,

[419] Kristeller, *Renaissance Thought: The Classic, Scholastic, and Humanist Strains*, 10.
[420] Pamela Long, *Openness, Secrecy, Authorship, Technical Arts and the Culture of Knowledge from Antiquity to the Renaissance* (Baltimore: The Johns Hopkins University Press, 2001), 184; and Bocchini Varani, "Agricola and Italy," *GeoJournal* 32 (1994): 1494-1555.
[421] Percival, "Grammar, Humanism, and Renaissance Italy," 96.
[422] Percival, "Grammar, Humanism, and Renaissance Italy," 112.

lazy laborers. For a miner to become successful, a miner had to understand a variety of disciplines: philosophy (to discern the origin, cause, and nature of subterranean things), medicine (to attend to other diggers), astronomy (to judge the direction of the veins from knowing the divisions of the heavens), surveying (to estimate how deep a shaft should be sunk to reach the tunnel), arithmetical science (to calculate the cost to be incurred in the machinery and the working of the mine), architecture (to construct the various machines and timber work required underground), drawing (to draw plans of his machine), and law (to claim his own rights).[423]

When selecting a suitable place to mine, the miner had to consider seven elements: the situation, the conditions, the water, the roads, the climate, the ownership rights, and the neighbors.[424] Agricola acknowledged that mining required an exhaustive store of resources. In order to avoid wasting time and money, the wise miner had to evaluate quickly which terrain would prove the most productive. For instance, Agricola observed how miners did not mine mountains that were situated on open "plains (*campi*);" neither did they dig in the summits of mountainous regions, unless the veins in those mountains had been found and thus were abounding in metals and other products.[425] Agricola also noted how miners should consider mining in a forested locale. Although open space would appear less laborious for the miners, a sylvan area would provide "an abundant supply of woods (*suppeditet ipsi lignorum copiam*)" for the underground "timbering (*substructiones*)," the "machinery (*machinas*)," "building (*aedificia*)," "smelting (*excoctiones*)," and "other necessities (*aliaque necessariam*)."[426] Agricola, in fact, did not underestimate the complexity of the miners' intellectual toolkit.

[423] Agricola, *De re metallica*, liber primus, 1.
[424] Agricola, *De re metallica*, liber secundus, 21.
[425] Agricola, *De re metallica*, liber secundus, 21.
[426] Agricola, *De re metallica*, liber secundus, 22.

In this attempt to persuade his audience of the advantages of mining, Agricola acknowledged the opinions of mining critics. As articulated by Agricola, many individuals believed that mining was unnecessarily perilous. These critics pointed to the "pestilential air (*aere pestifero*)" that miners breathed and the "masses of rock (*metallorum sossores*)" that crushed workers as evidence of the danger.[427] But it was not solely environmental concerns that critics expressed. They also argued that workmen in the mines lacked the skills to function safely underground. These critics, for instance, noted that certain workmen broke "their arms, legs, [or] necks (*brachia, crura, cervices*)" after having fallen "from the ladders into the shafts (*scalis in puteos delapsi*)."[428] Agricola did not deny that these events occurred, but he did stress their rarity.

In any case, the perils of one workman would not have prevented that workman's colleagues from the pursuit of mining. Indeed, Agricola compared the trades of miners and carpenters to prove further the ridiculousness of his critics' opinions. He wrote that although "accidents occurred rarely (*raro eiusmodi accidant*)," they could happen when workmen were negligent.[429] But even then, an accident would not hinder the workflow. He pointed to carpenters, who would not stop working even when one workman acted "carelessly (*incavte*)," "fell from a high building [and] lost his life (*ab alto aedificio delapsus animam efflavit*)."[430] Agricola professed that while these somber events did occur, the blame laid squarely with the negligent workmen.

Yet it was not only the topographical conditions that the miners had to evaluate; they also had to test the conditions at the subterranean level. Agricola noted that if a miner were to

[427] Agricola, *De re metallica*, liber primus, 3.
[428] Agricola, *De re metallica*, liber primus, 3.
[429] Agricola, *De re metallica*, liber primus, 3.
[430] Agricola, *De re metallica*, liber primus, 3.

discover other "dry lands (*terra sicca*)" that contained "pure or *rudis* metal (*metallum purum vel rusem*)," he had encountered a "good sign (*bonum signum*)."[431] It was also not a "bad sign if he were to see yellow, red, black, or some other extraordinary earth (*si lutea, vel rubra, vel nigra, vel alia quaedam insignia, quae caret metallo, non malum*)."[432] According to Agricola, the rocks and veins provided clues to the miners as to whether an area would produce a bountiful yield of metals.[433]

It was not, at the same time, the job of every miner to locate the viable places to mine; there was a division of labor within the mining operation that corresponded to technical specialization. Agricola suggested that the majority of workmen could be categorized as follows: miners, shovelers, windlass men, carriers, sorters, washers, and smelters.[434] There were also foremen, who were responsible for making and mapping the drains in the tunnels. The collection and distribution of water from the "veins, stringers, and seams in the collected rocks (*venis, fibris, commissuris saxorum collecta*)" required a talent in the foreman that impressed Agricola.[435] The foreman had to have knowledge of carpentry to design the tunnels' timber "shafts (*columnas*)" that supported mining operations and prevented rocks from becoming detached, thusly "oppressing the workers with destruction (*ruinis que opprimant operarios*)."[436] Agricola failed to address where and from whom these workmen and foremen were receiving instruction. Did they learn skills on the job? Did the mine operate as if it were a guild with a hierarchy of apprentices and masters? Agricola appeared eager to draw, albeit never explicitly, parallels between trade guilds and the mining operation in sixteenth-century Saxony.

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[431] Agricola, *De re metallica*, liber quintus, 77.
[432] Agricola, *De re metallica*, liber quintus, 77.
[433] Agricola, *De re metallica*, liber quintus, 78.
[434] Agricola, *De re metallica*, liber quartus, 70.
[435] Agricola, *De re metallica*, liber quartus, 69.
[436] Agricola, *De re metallica*, liber quartus, 69.

The Hierarchical Organization of the Mine

Moreover, Agricola established the legitimacy of mining by detailing the hierarchy within the enterprise. He devoted six pages to descriptions of the duties of the Mining Prefect (*praefectus metallorum*), the *Bergmeister* (*magister metallicorum*), the Jurors (*jurati*), the Mining Clerk (*scriba fodinarum*), the Share Clerk (*scriba partium*), the manager of the mine or tunnel (*praefectus fodinae vel cuniculi*), the foreman of the mine or tunnel (*praeses fodinae vel cuniculi*), and the workmen (*operariorum*).[437] In charge of the entire mining process was the Mining Prefect, whom the king or prince appointed as his "deputy (*vicarium*)."[438] The Mining Prefect acted as the king's lieutenant and regulated all operations. The Prefect's immediate subordinate was the *Bergmeister* (*magister metallicorum*), whose responsibility it was to decide the punishments of "fraudulent, negligent, or dissolute men (*homines fraudolentos vel negligentes et dissolutos*)."[439] The *Bergmeister* (*magister metallicorum*) kept order throughout the entire Principality with his threats of imprisonment and fines.[440] While each mine would have had at least one judge, there was a single *Bergmeister* (*magister metallicorum*) to whom all the judges reported. At the local level, there were two jurors whom the *Bergmeister* (*magister metallicorum*) tasked with deliberating on issues related to the "underground workings, machinery, [and] timbering (*consultant de fossionibus, de machinis, de substructionibus*)" of the mine.[441] These men "of good faith (*bonae fidei*)" reported to the *Bergmeister* (*magister metallicorum*), who could not make any decisions involving rights or boundaries of mines

[437] Agricola, *De re metallica*, liber quartus, 65-70.
[438] Agricola, *De re metallica*, liber quartus, 65.
[439] Agricola, *De re metallica*, liber quartus, 66.
[440] Agricola, *De re metallica*, liber quartus, 66.
[441] Agricola, *De re metallica*, liber quartus, 67.

without first consulting with the jurors.[442] Continuing at this local level of power was the Share Clerk (*scribae partium*), who catalogued the names of both the sellers and buyers of the mining shares.[443] Working in close proximity to the Share Clerk (*scribae partium*) was the mine manager (*praefecti fodinae*), who announced "to the proprietors their contributions in a document which [was] affixed to the doors (*symbola dominis scheda in foribus publici aedificii fixa indicit magna vel parua*)" of the town hall.[444] He, however, did not decide the amount of those contributions, as that duty would have fallen to the *Bergmeister* (*magister metallicorum*) and the two jurors. The mine manager simply announced the information. He received his weekly salary and those of the miners from the tithe-gathers. The daily supervision of the actual mining procedures fell to the mine's business manager, who oversaw the manner in which the foremen dug the ore.[445]

Across central Europe, the *Bergmeister* (*magister metallicorum*) was the lord's principal officer to whom finders of ore would have gone to process a claim. The *Bergmeister* (*magister metallicorum*) or his representative would have granted a miner a concession to exploit a section of land. Ordinarily the *Bergmeister*'s office (*officio magistri metallicorum*) would have divided the seam into smaller sections called meers. The size of a given meer varied from district to district, but the *Bergmeister* (*magister metallicorum*) would always reserve a section for the lord. The lord would always have at least one meer. In most cases, the lord then became the employer

[442] Agricola, *De re metallica*, liber quartus, 66.
[443] Agricola, *De re metallica*, liber quartus, 67.
[444] Agricola, *De re metallica*, liber quartus, 68.
[445] Agricola, *De re metallica*, liber quartus, 68-69. Agricola portrayed the mine as a masculine space, but historian Pamela Long found evidence of women working above the mines, sorting ores, carrying supplies, and preparing charcoal. Long describes in her article, "Of Mining, Smelting, and Printing: Agricola's 'De re metallica,'" that women in early modern Saxon mines worked alongside their husbands and sons. Perhaps because Agricola was focused solely on the processes and methods of mining operations, he neglected to disclose the identity of the miners themselves, let alone address the familial relations between them. In his lack of descriptions, Agricola showed the limits of his custodianship of mining practices. See Pamela Long, "Of Mining, Smelting, and Printing: Agricola's 'De re metallica,'" *Technology and Culture* 44 (2003): 100.

of miners who worked directly for him.[446] Those miners who did not work for the lord received their wages from wealthy investors, or *Gewerken*. *Gewerkschaften* were "large, absentee-owned mining companies that began replacing the small, owner-worked operations of the Middle Ages."[447] The *Gewerkschaften* allowed investors, like foreign nobility and Saxon churchmen, to profit from the mining boon without ever visiting a single mine.[448] Investors bought shares, or *Kuxen*, in the mines.[449] Mining was a costly venture, and the practice of purchasing *Kuxe* guaranteed a flow of capital.[450]

The acquisition of *Kuxen* was a gamble, however. The price of one share, a single *Kux*, did not depend on the mine's yields. Demand dictated the price of a *Kux*. It was not until the district published the mine's returns that the investor would know if he had made a profit. The investor had to assume all the financial burden. The unpredictability of mining returns therefore encouraged investors to purchase *Kuxen* in multiple mines.[451] The investors became imperative to mining operations.[452]

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[446] John U. Nef, "Mining and Metallurgy in Medieval Civilisation," in *The Cambridge Economic History of Europe from the Decline of the Roman Empire*, eds. Edward Miller, Cynthia Postan, and M.M. Postan (Cambridge: Cambridge University Press, 1987), 712-713.
[447] George H. Waring, "The Silver Miners of the Erzgebirge and the Peasants' War of 1525 in the Light of Recent Research," *The Sixteenth Century Journal* 18 (1987): 232.
[448] Waring, "The Silver Miners of the Erzgebirge and the Peasants' War of 1525 in the Light of Recent Research," 232.
[449] For more information about the mining investment strategy, see Long, "Of Mining, Smelting, and Printing: Agricola's 'De re metallica,'" 100; and Andre Wakefield, "Leibniz and the Wind Machines," *Osiris* 25 (2010): 176.
[450] Tina Asmussen, "The *Kux* as a Site of Mediation: Economic Practices and Material Desires in the Early Modern German Mining Industry," in *Sites of Mediation: Connected Histories of Places, Processes, and Objects in Europe and Beyond, 1450-1650*, eds. Susanna Burchartz, Lucas Burkart, and Christine Göttler (Leiden: Brill, 2016), 160-161.
[451] Asmussen, "The *Kux* as a Site of Mediation: Economic Practices and Material Desires in the Early Modern German Mining Industry," 160-161.
[452] When the mining operations expanded geographically, the miners formed a brotherhood. The *Knappschaften* arrived to minimize the exploitation of miners. They came "aggressively, if not successfully, to represent the miners' interests." Susan C. Karant-Nunn, "Between Two Worlds: The Social Position of the Silver Miners of the Erzgebirge, c. 1460-1575," *Social History* 14 (1989): 314. Originally a religious confraternity, the *Knappschaften* acted as a guild, encouraging miners who lived in both the city and the countryside to participate. Historian Susan Karant-Nunn has argued that the *Knappschaften* did little to discourage the separation between city- and country-dwelling miners. See Susan C. Karant-Nunn, "Between Two Worlds: The Social Position of the Silver Miners of the Erzgebirge, c. 1460-1575," 315.

Agricola perhaps recognized the key role that investors played, and he wanted to participate in the courting of investors. He understood that some men were too eager to accumulate wealth, and they purchased shares in haste that were too expensive. To Agricola, the scramble for wealth was a disaster, leaving them poorer than they were before.[453] Agricola believed that the lord should have implemented a "limit of expenditure (*emptione partium impendendi*)" that he argued would have curbed the "blinded by the desire for excessive wealth (*divitiarum con gerendarum libidine obcaecati*)."[454] A "prudent owner (*prudentes domini*)," according to Agricola, would carefully examine the mines before purchasing the shares.[455] He stressed that shareholders should evaluate the mines for themselves. His documentation of the Saxon mines, then, could have easily served as a marketing endeavor. *De re metallica* invited the reader to witness the success of the Saxon mines. The favorable descriptions of the mines were conceivably Agricola's contribution to the financial security of Saxon mines.

He attributed the success of the mines to the stewardship of his patrons, the "most illustrious dukes (*illustriss…saxoniae ducibus*)."[456] Agricola described how the dukes continued in the tradition of their ancestors by generating revenues from mines through taxation. Yet Agricola also asserted that the dukes were paving a new way. He declared that other towns, such as "Freiberg, Annaberg, Marienberg, Schneeberg, Geyer, and Altenberg (*Fribergum…, Annebergum, Mariebergum, Snebergum, Gairum, Aldebergum*)," had "risen up (*orta sunt*)" because of Saxon leadership.[457] The mines of Saxony had created wealth for the miners, the investors, the dukes, and the surrounding towns. As Agricola saw it, the mines of Saxony buttressed the entire district's economy.

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[453] Agricola, *De re metallica*, liber secundus, 21.
[454] Agricola, *De re metallica*, liber secundus, 21.
[455] Agricola, *De re metallica*, liber secundus, 21.
[456] Agricola, *De re metallica*, Epistola, 1.
[457] Agricola, *De re metallica*, Epistola, 4.

Agricola spent time describing the details of quotidian life at the mines because he wanted to establish the collectivity and expansive nature of the operation. The process did not involve a few licentious men digging for gold. Instead, Agricola portrayed mining as a broad, multi-membered, sophisticated enterprise. With the simple mention of the monarch, Agricola gave mining even more legitimacy. If critics questioned the moral implications of mining, they were also questioning the character of their king who had endorsed it.

A miner, according to Agricola, had to possess knowledge of geology and meteorology in order to understand "the veins, stringers, and seams in the rocks (*venae, fibrae, commissura eque saxorum*)," and he had to be thoroughly familiar with the "variety of species of earths, juices, gems, stones, marbles, rocks, metals, and compounds (*variasque species terrarum, succorum, gemmarum, lapidum, marmorum, saxorum, metallorum, mistorum*)."[458] For Agricola, mining was not just brute, technical labor. The miner had to acquaint himself with multiple disciplines in order to consider the best places to mine the veins.[459] Agricola understood that the profits of mining could not produce a steady income. To combat this instability, the miner had to be judicious when selecting a spot to mine.[460]

Indeed, Agricola encouraged the workmen to reap all the benefits of the land. He even urged them to consider mining in already harvested plots of land because the workmen could live and sustain themselves off the area's agricultural produce, as opposed to importing the necessities. Such importation would have caused trouble with porters and caused "a rise in prices

[458] Agricola, *De re metallica*, liber primus, 1.
[459] Agricola, *De re metallica*, liber primus, 1.
[460] Agricola noted how in comparison to agriculture, mining yielded fluctuating profits because eventually the veins stop yielding metals, but the fields always grow fruit each year. "*Verum mihi non est in animo derogare aliquid de dignitate agriculturae, minusque stabilem quaestum metalicorum esse, non libenter modo, sed etiam semper fatebor, quod venae tandem desinant effundere metalla, cum agri in perpetuum efferre fruges soleant*." Agricola, *De re metallica*, liber primus, 3.

(*auget impensas rerum invectarum*)."[461] Agricola was aware of the resources that mining exhausted, and he sought to make his readers aware that the miners attempted not to damage the natural environment.

To support his argument that miners were judicious stewards of the earth, Agricola anthropomorphized nature as a nurturing, disciplined woman. This image of nature was nothing new to a European audience. Such metaphors and connotations existed in both ancient Greek and early Christian thought.[462] What was novel about Agricola's presentation was that nature was neither passive nor subordinate. For instance, he documented how miners had to create artificially a "constant supply of water (*aquae iugiter fluentes*)" seeing as "nature had denied access to it (*ad natura denegatae augent impensas*)."[463] With this language, Agricola clearly dictated the success of a mining enterprise as dependent on the desires of nature. Nature, then, was not powerless. In another example, Agricola described how nature concealed metals far "within the depths of the earth (*in profundo terra*)."[464] He ascribed agency to the natural world. For him, the earth was not indifferent. The environment manipulated the miners' plans. Agricola's gendered description of the Earth belies Carolyn Merchant's argument that the Scientific Revolution (1500 – 1700) saw the creation of an image of nature as a passive woman to be subdued supplanted by the depiction of nature as a nurturing mother to be revered.[465] For Merchant, the enterprise of science was a masculine endeavor. The participants were primarily men who searched for ways to exploit nature. The personification of nature as female and the genders of its participants only served to highlight the misogyny inherent within scientific

[461] Agricola, *De re metallica*, liber secundus, 23.
[462] Carolyn Merchant, *The Death of Nature: Women, Ecology, and the Scientific Revolution* (New York: Harper Collins, 1980), 196.
[463] Agricola, *De re metallica*, liber secundus, 22-23.
[464] Agricola, *De re metallica*, liber primus, 8.
[465] Merchant, *The Death of Nature: Women, Ecology, and the Scientific Revolution*, 2.

practices and circles.[466] Instead, *De re metallica* contains evidence for an image of nature as an active, controlling woman.

Agricola's description of the natural world as active and responsive did not mean that man's desires were left unsatisfied, however. The natural world elected to "conceal (*recondit*)" metals within the depths not because she wished that men not dig them out, but because "nature with providing skills (*provida solers que natura*)" has given each thing "its own place (*in vasis propriis*)."[467] That is, despite its attempts to hide resources, nature still succumbed to the will of man. Miners had to work cleverly to reap the benefit, but they did eventually succeed at controlling the uncontrollable, natural world.

Conclusion

Agricola's how-to manual on mining belonged to a well-established literary genre of conduct literature because it made public a specialized knowledge-set. He understood that the readers would have had a passing familiarity with mining, but he presented his text as if they were ignorant of mining's intricacies. He cited examples of miners' safety procedures, thereby presenting them as expertly cautious laborers. He represented these miners as skillful because he was arguing against the critics who had previously identified them as lazy. Addressing his opponents directly was one of his styles of argumentation. He also included a rebuttal to the critics who believed that mining encouraged avarice. Agricola showed that mining did not create or spur greed; instead, mining served a societal good. Agricola reminded his audience that fishermen, hunters, and farmers relied on metals to craft their instruments and perform their

[466] Dorinda Outram, "Gender," in *The Cambridge History of Science, volume 3*, eds. Katharine Park and Lorraine Daston (Cambridge: Cambridge University Press, 2008), 798.
[467] Agricola, *De re metallica*, liber primus, 8.

tasks. Agricola selected these laborers for a specific purpose. Fishing, hunting, and agriculture were all recognized as virtuous in the Scriptures. Agricola assumed that his audience was Christian, and that assumption informed his approach to argument. He customized his descriptions in order to appeal to the sensibilities of a certain reader population. No doubt his goal was to rehabilitate the image of the miner in the eyes of his educated, privileged, and Christian reader.

Chapter 6

Artisans, Aristotle, and Accuracy: An Evaluation of Agricola's Relationship with the Miners

De re metallica represents Agricola's attempt to convince his educated, elite audience that the mechanical arts — i.e., craftsmanship — should be scrutinized in the same manner as natural philosophy. In early modern Europe, natural philosophy and its subfield natural history favored certain forms of knowledge, "usually the knowledge of the privileged."[468] Natural historians, for instance, sought to describe and investigate the natural world. As practitioners of a particular knowledge-production, these (mostly) men granted meaning to natural occurrences. Natural philosophy was exclusive. It excluded practitioners; it excluded discourses. Agricola saw the similarities between the knowledge-making procedures of natural philosophers and miners. After having interacted with the mining community, Agricola sought to bring mining practices to the attention of natural philosophers. He demonstrated that miners used techniques and practices that the natural philosophers may have recognized as their own.

He described his interactions between the skilled miners and himself as a learned man. The miners taught Agricola their techniques, such as measuring and surveying. Agricola appreciated and valued the miners' technical knowledge, which is reflected by his devotion to articulating the miners' knowledge. He understood the miners' practical skills as a particular form of knowledge. Agricola made mining practices more attainable for the non-specialized literate public. In a precise, elegant, and interrogative manner, Agricola communicated to his

[468] Brian W. Ogilvie, *The Science of Describing: Natural History in Renaissance Europe* (Chicago and London: University of Chicago Press, 2006), x.

educated, elite audience how the mining community of sixteenth-century Saxony investigated the natural world through hands-on experience, accurate measurement, and empirical techniques.

Artisans as Theoretical Contributors

Historians have only just started to examine the ways in which the miners that Agricola so esteemed contributed to technical, scientific knowledge. Recovering and reconsidering the contributions of artisans and craftsmen has become the task of historians of science. Scholars such as Pamela Smith and Brian Ogilvie have sought to acknowledge, at the least, and to elevate, at the most, the theoretical contributions of these tradesmen.[469] For too long, historians of early modern Europe have dismissed artisans and craftsmen from the historical narrative in favor of historical actors who advanced Baconian science. Smith and Ogilvie, along with Simon Schaffer, have urged historians to abandon their teleological presumptions and reassess the artisanal methods. In fact, these artisans and craftsmen participated within a regime of knowledge-production that depended upon experience, investigation, and community.[470] These men observed techniques, investigated approaches, and gained experience. They participated in a community of learning. Artisans and craftsmen did not exist in isolation. Theirs was not a solitary trade. They gained knowledge through conversation and socialization with other tradesmen. According to Smith, craftsmen shared their experiences with others. They observed the natural world together; they practiced new techniques together. Experience, then, encompassed repeatable practices. Some historians have even identified those repetitive activities, such as experiments, as the foundation of modern Baconian science.

[469] Pamela H. Smith, *The Body of the Artisan: Art and Experience in the Scientific Revolution* (Chicago and London: University of Chicago Press, 2004); Ogilvie, *The Science of Describing: Natural History in Renaissance Europe*.
[470] Arthur Clegg, "Craftsmen and the Origin of Science," *Science & Society* 43 (1979): 188-191.

Agricola's *De re metallica* arrived at a moment of change, when the study of nature bifurcated into two distinct endeavors. On the one hand, there was natural philosophy, a contemplative enterprise. The other concerned knowledge-making of practical effects, such as improving agricultural techniques.[471] For centuries these two discourses remained discrete analytic ventures, until Francis Bacon combined them. Bacon's approach to the study of the natural world created a discursive hybrid, one that rearticulated natural philosophy in terms of instrumentality. He blended the contemplative efforts of an Aristotelian schema with the practical dimensions of artisanal instruments. Bacon's method did not deliberately endorse the kinds of practices that Aristotelians would have identified as an artform, or Aristotle's *technē*. Aristotle's natural philosophy was not supposed to be about creating physical effects or craft production. It also did not have a theoretical component.[472] Historians have argued that it was Bacon who first supported a curiosity that created an alliance between the contemplative and the practical. Yet Agricola showed that the miners' techniques also collapsed Aristotle's rigid boundaries.

Artisans as Manual Laborers

By delineating the intellectual components of the art of mining, Agricola contradicted Aristotle, who saw the mechanical arts as inferior to the intellectual endeavors of natural philosophy.[473] Aristotle distinguished between natural philosophy and the mechanical arts, or

[471] Peter Dear, "What is the History of Science the History of?: Early Modern Roots of the Ideology of Modern Science," *Isis* 96 (2005): 397.
[472] Dear, "What is the History of Science the History of?: Early Modern Roots of the Ideology of Modern Science," 394. Here *theoria* is juxtaposed with *technē*. Dear is making a distinction between the knowing and the know-how. The role of observation in both these discrete intellectual categories is unclear, however.
[473] The place of technical skill within Renaissance Aristotelianism has preoccupied intellectual historians. In *Aristotle and the Renaissance* (1983), Charles Schmitt underscores the importance of the technical skills required to

those activities that were practical and manual.[474] For Aristotle, natural philosophers aimed to discover causes. They were not focused on singular events. They were focused on generalizations. Natural philosophers used deductive reasoning to arrive at general causes. Aristotle's praise of natural philosophy contrasted starkly with his assessment of the mechanical arts, which he believed was devoid of reasoning.

Aristotle did not think highly of the mechanical arts because they required manual labor. The mechanical arts did not have a cerebral component. Instead, those participating in the mechanical arts used their hands to perform tasks and be productive. Aristotle believed that only enslaved people used their hands.[475] Manual labor was synonymous with slave labor. He wrote in *Politics*:

> For them it is better to be ruled in accordance with this sort of rule, if such is the case for the other things mentioned. For he is a slave by nature who is capable of belonging to another—which is also why he belongs to another—and who participates in reason only to the extent of perceiving it, but does not have it…Moreover, the need for them differs only slightly: bodily assistance in the necessary things is forthcoming from both, from slaves and from tame animals alike.[476]

Aristotle asserted that nature created people unequally. Some were stronger than others. The physically weaker individuals enslaved those who were more capable physically. Manual labor required physical prowess, but it did not require rational thinking. A rational man could perform laborious tasks on a farm, for instance. The labor would exhaust him physically, but not

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operate within the humanist tradition. He seeks to dispel the belief that Renaissance Classicism had only to do with such matters as sculpture, painting, poetry, and rhetoric. See Charles B. Schmitt, *Aristotle and the Renaissance* (Cambridge, MA: Harvard University Press, 1983).

[474] Jim Bennett, "The Mechanical Arts," in *The Cambridge History of Science, volume 3*, eds. Katharine Park and Lorraine Daston (Cambridge: Cambridge University Press, 2008), 673.

[475] Aristotle firmly believed that the Greeks should enslave only the "barbarians," rather the non-Greeks. Barbarians were "more slavish in their characters than Greeks." He even went so far as to create a hierarchy of barbaric civilizations. The barbarians of Asia were more "slavish" than those in Europe. Aristotle, *Politics*, trans. Carnes Lord (Chicago: The University of Chicago Press, 2013), 3.14, 1285a20-23. For a secondary source on Aristotle's views on slavery, see Malcolm Heath, "Aristotle on Natural Slavery," *Phronesis* 53 (2008): 243-270.

[476] Aristotle, *Politics*, 1.5, 1254b 20-26.

mentally. The ones who were weaker physically, were stronger mentally. Enslaved men and women required a master to rule them.[477] Rationality, then, had no place within the domain of manual labor. Aristotle contended that enslaved men and women were not rational, free-thinking individuals.[478] Aristotle's belief in the inferiority of slave labor solidified the low epistemological status of manual labor in antiquity. Manual labor, and therefore the mechanical arts, could never arrive at theoretical truths.[479]

Aristotle ignited a debate between theory and practice that was still on-going by the time Agricola wrote *De re metallica*. Agricola's determination to elevate the mining craft contradicted the Aristotelian schema of knowledge. Even in the sixteenth century, Aristotle's ideas informed attitudes.[480] Aristotle had created a hierarchy of knowledge-making procedures. There was theory; and there was practice. Theory involved abstract speculation in search for causes. Practice (*praxis*) was either those things done or those things made. Disciplines such as history belonged under the "things done" rubric. Historians studied particulars through experience.[481] They did not use deductive reasoning, which became the hallmark of Aristotle's theoretical arts category. Miners would have belonged to the "things made" domain. These artisans practiced *technē*. Theirs did not require a cerebral component. It was precisely that label that Agricola

[477] In the fourth chapter of the third book of *Politics*, Aristotle wrote, "There is rule of a master, by which we mean connected with the necessary things. It is not necessary for the ruler to know how to perform these, but only to use those who do; the other [sort of knowledge] is servile (by the other I mean the capacity to perform the subordinate tasks of a servant). Now we speak of several forms of slave; for the sorts of work are several. One sort is that done by menials: as the term itself indicates, these are persons who live by their hands; the manufacturing artisan belongs among them. Hence among some peoples the craftsmen did not partake in offices in former times, prior to the emergence of rule of the people in its extreme form. Aristotle, *Politics*, 3.4, 1277a 33-38 – 1277b 1-3.
[478] See George Boas, "Some Assumptions of Aristotle," *Transactions of the American Philosophical Society* 49 (1959): 21; 59-60; and Julia Annas, "Aristotle's 'Politics': A Symposium: Aristotle on Human Nature and Political Virtue," *The Review of Metaphysics* 49 (1996): 739.
[479] Pamela H. Smith, "Laboratories," in *The Cambridge History of Science, volume 3*, eds. Katharine Park and Lorraine Daston (Cambridge: Cambridge University Press, 2008), 293.
[480] Smith, "Laboratories," 293.
[481] Lorraine Daston, "Marvelous Facts and Miraculous Evidence in Early Modern Europe," *Critical Inquiry* 18 (1991): 110.

wanted to jettison. The mining profession not only involved manual labor, but also required substantial intelligence.

Early modern craftsmen's techniques of investigation and methods of observation have gone unnoticed by historians because of the distinction drawn between the theoretical and the practical. Learned men participated in theoretical knowledge-production, where craftsmen and artisans belonged to the group producing practical knowledge. That distinction between the two knowledge-sets was, and continues to be, valid. Learned knowledge occurred within a university and was facilitated by books. Artisanal knowledge was neither taught in universities nor written in texts.[482] Yet both groups engaged in a probe of the natural world.

Miners as Precise Artisans

In the hope of demonstrating to his learned audience that craftsmen and educated men had similar quests for knowledge, Agricola devoted portions of *De re metallica* to explaining the precision involved in the miners' investigation of the natural world. Shaft-digging served as representative of that intellectual rigor. He described how the miners sought to dig accurate shafts to facilitate mining operations. These shafts descended vertically into the ground and connected the tunnels that the miners had already hollowed out of a hill. Miners also built shafts to intersect in a perpendicular fashion with the main veins. Shafts, then, increased the points of access to the veins. The more access points to a vein correlated to a larger number of men working and thus expedited the excavation of minerals and metals.[483] Constructing a shaft proved an essential component to the art of mining. Agricola had observed so many shaft-

[482] Smith, *The Body of the Artisan: Art and Experience in the Scientific Revolution*, 7-8.
[483] Georgius Agricola, *De re metallica* (Basel: Froben Press, 1556), liber quintus, 75.

diggings that by the time he wrote *De re metallica*, he felt comfortable enough to speculate about the measurements. Agricola concluded that shafts were usually "two fathoms long (*longa duos passus*)," "two-thirds of a fathom wide (*lata duas tertias passus partes*)," and "thirteen fathoms deep (*alta tredecim passus*)."[484] He observed how the miners made meticulous measurements because a single error in calculation could result in the collapse of the entire tunnel structure and endanger the workmen.

Agricola did not hesitate to describe mining as a dangerous occupation. He observed how exhaustion could cause harm to the miners. In one instance, he chronicled how miners could easily grow dangerously weary if they were to descend to a deep shaft. The sheer depth of the shaft required the men to take breaks while they descended. The dead weight of the men could prevent the ladders from remaining stable, however. To avoid the dangers of using an unstable ladder, the men would lay timbers alongside the ladder to maintain its structural integrity as the miners sat and relaxed.[485]

Agricola took notice of the safety precautions. The mining officials would not allow a miner to work two shifts in succession for fear that the miner would become too "exhausted (*defatigatus*)" and fall asleep.[486] A fatigued miner was a liability. A fatigued miner would have created an unsafe environment for his colleagues. He could potentially maneuver the hauling machine too aggressively, or he could wield a pick too erratically. While doing excavations, the miners had to remain mentally sharp. To mitigate harm and to improve efficiency, the officials would permit the miners to work only one seven-hour shift in succession.[487] Agricola repeatedly articulated the skills and experiences necessary to do mining both safely and effectively.

[484] Agricola, *De re metallica*, liber quintus, 71.
[485] Agricola, *De re metallica*, liber quintus, 83.
[486] Agricola, *De re metallica*, liber quartus, 69.
[487] Agricola, *De re metallica*, liber quartus, 69.

Agricola was also struck by the miners' understanding of air quality. The miners showed Agricola that they were concerned about the air's dryness and toxicity. Some mines were entirely devoid of water, creating an arid atmosphere that caused dust to stir. That dust had harmful effects on the miners' lungs, impeding breathing and causing diseases.[488] Air quality remained a constant source of anxiety. Agricola commented how "poisonous smoke (*fumi virosi*)" flared up when the miners began burning piles of wood to carve out the stringers.[489] In his opinion, the prudent and skilled individuals understood the dangers of the fumes and thus decided to incinerate the piles of wood on Friday evenings, a time when they neither descended the shafts nor entered the tunnels. By the time they returned to the tunnels on Monday, the miners would have noticed that the air would have cleared.[490] At times, skill alone could not prevent the spread of pernicious air. In those moments, the miners drew from their skillset to assess the air quality and arrive at a decision to abandon the mines.[491] Agricola continued to reiterate the moments when a miner recognized his limitations. For him, that ability distinguished the capable miners from the inexperienced ones.

Adapting to the changes in environment provided a measure for Agricola to assess a miner's experience. The seasoned miners knew how to accomplish their professional tasks, while combatting the unpredictability of the natural world. Miners had to be cognizant of the rain, for instance. Those with experience understood that rainfall and the pooling of water in a shaft could potentially disrupt the excavation process. As such, miners would build a shed or covering over the shaft to prevent water from trickling into it.[492] Rainfall could cause the miners to lose sensation and become numb by the colder temperatures, while too little rain could encourage

[488] Agricola, *De re metallica*, liber sextus, 172.
[489] The stringers were filaments that ran subparallel in a rock. See Agricola, *De re metallica*, liber sextus, 173.
[490] Agricola, *De re metallica*, liber sextus, 172-173.
[491] Agricola, *De re metallica*, liber sextus, 174.
[492] Agricola, *De re metallica*, liber quintus, 71.

dust buildup.[493] Miners had to consider carefully the physical conditions of a location before constructing a shaft.[494] The discovery of a *vena profunda* did not necessarily spur the creation of a shaft. Expert miners knew when to build and when to vacate a mine.

Agricola observed the miners throughout the seasons and therefore saw how the changing conditions dictated the ways in which the men modified their approaches. In the warmer months, miners had to schlep or roll the ore down the mountains.[495] Yet in the winter months, the miners could use sleds and dogs to transport their materials. The snow, then, did not hinder the men; instead, the wintry conditions eased their work.

Agricola's observations about miners' abilities to change their tactics based on weather conditions supports Pamela Smith's contention that artisanal knowledge was inherently particularistic. Artisans in early modern Europe had to account for the weather, employing "the particularities of materials" in their crafts.[496] Scholars should push against the assumption that craftsmen and artisans did not develop skills of abstraction and generalization.[497] For Smith, artisanal knowledge was inherently experimental, but that did not mean that it was not also cerebral.

Miners as Experienced Inventors

In fact, an examination of the instruments used by miners reveals some of the cerebral aspects of artisanal knowledge. Agricola devoted pages to descriptions of the tools utilized by

[493] Agricola, *De re metallica*, liber quintus, 71.
[494] Agricola, *De re metallica*, liber secundus, 22.
[495] Agricola, *De re metallica*, liber sextus, 125.
[496] Pamela Smith, "In a sixteenth-century goldsmith's workshop," in *The Mindful Hand: Inquiry and Invention from the Late Renaissance to Early Industrialization*, eds. Lissa Roberts, Simon Schaffer, and Peter Dear (Amsterdam: Royal Netherlands Academy of Sorts and Sciences, 2007), 43.
[497] Smith, "In a sixteenth-century goldsmith's workshop," 43.

surveyors and miners, presumably because he wanted to convey the meticulous nature of the art. He noticed that the miners all used particular tools to accomplish the "varied and many (*varia et multiplex*)" mining tasks.[498] The variety of instruments that the miners and smelters used so impressed Agricola that he included an image, Figure 6.1, of all the equipment.

[498] Agricola, *De re metallica*, liber quintus, 78.

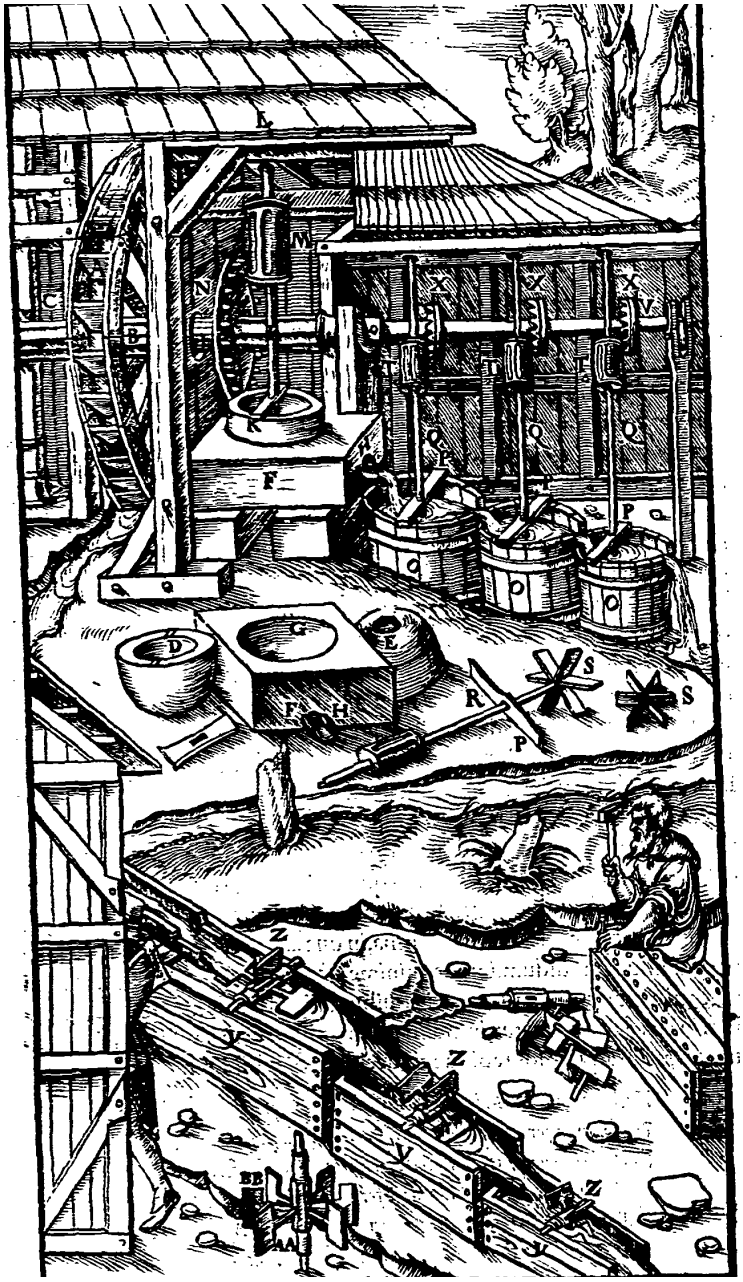

Figure 6.1 [499]

[499] Agricola, *De re metallica*, liber octavus, 234.

All the instruments had specific purposes. He took notice of miners grabbing the same tools to perform the same tasks. Knowledge of the environment went hand in hand with knowledge of the tool. Agricola was struck by the miners' knowledge and experience.

His fascination with mining instruments is evident in his discussion of "crumbling ore (*saxum molle et fragile*)."[500] After having reminded the reader that he had already classified the three different varieties of ores, the crumbling ore, the hard ore, and the hardest ore, he proceeded to describe the different tools required to excavate them. The miners used a hammer to uncover the hard ore.[501] The crumbling ore, which was a mixture of earth and soft solidified juices, required a more delicate approach.[502] In order to retrieve the crumbling ore, the miners needed a pick.

These picks were not the ones that "a peasant (*rustico*)" would have used, however.[503] Agricola made note of the differences between the two picks. Where the peasant's pick was "wide at the bottom and pointed (*ima parte latus et acutus*)," the miner's pick was "sharp (*cuspidatus*)."[504] That point would have given a more precise blow. Agricola implied that the peasant's pick did not necessarily require precision. Peasants "swept up earth and gravel (*converrunt terras et glareas*)."[505] The miners, on the other hand, had to be exacting with their instruments as they wanted to avoid damaging the ore. Such a mistake would have been punishing.

[500] Agricola, *De re metallica*, liber quintus, 78.
[501] Agricola, *De re metallica*, liber quintus, 79.
[502] Agricola, *De re metallica*, liber quintus, 78.
[503] Agricola, *De re metallica*, liber sextus, 109.
[504] Agricola, *De re metallica*, liber sextus, 109.
[505] Agricola, *De re metallica*, liber sextus, 110.

Agricola included illustrations of the picks in order to have the reader visualize the discrepancies. He did not want to rely solely on his words to convey the precision that the miners required in their excavations.

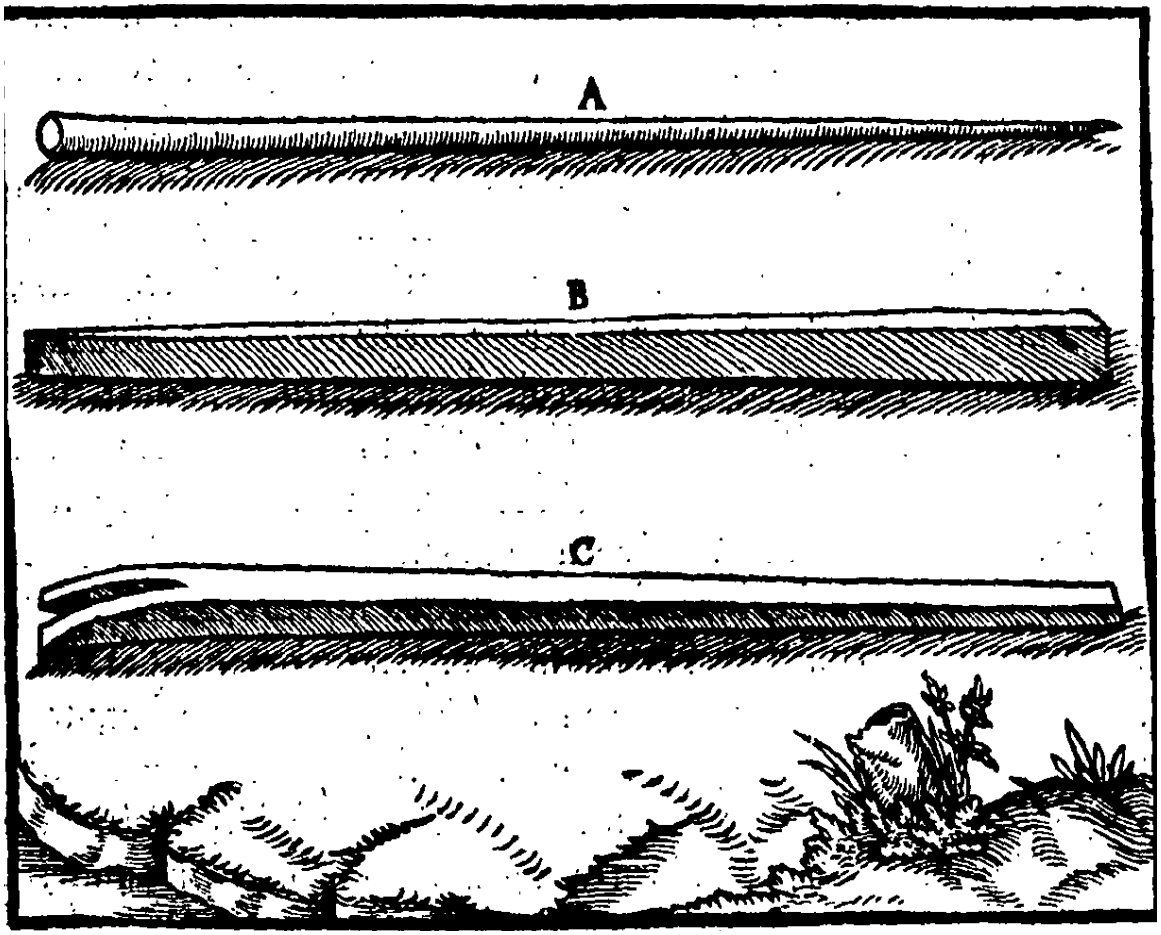

Figure 6.2 [506]

[506] Agricola, *De re metallica*, liber sextus, 109.

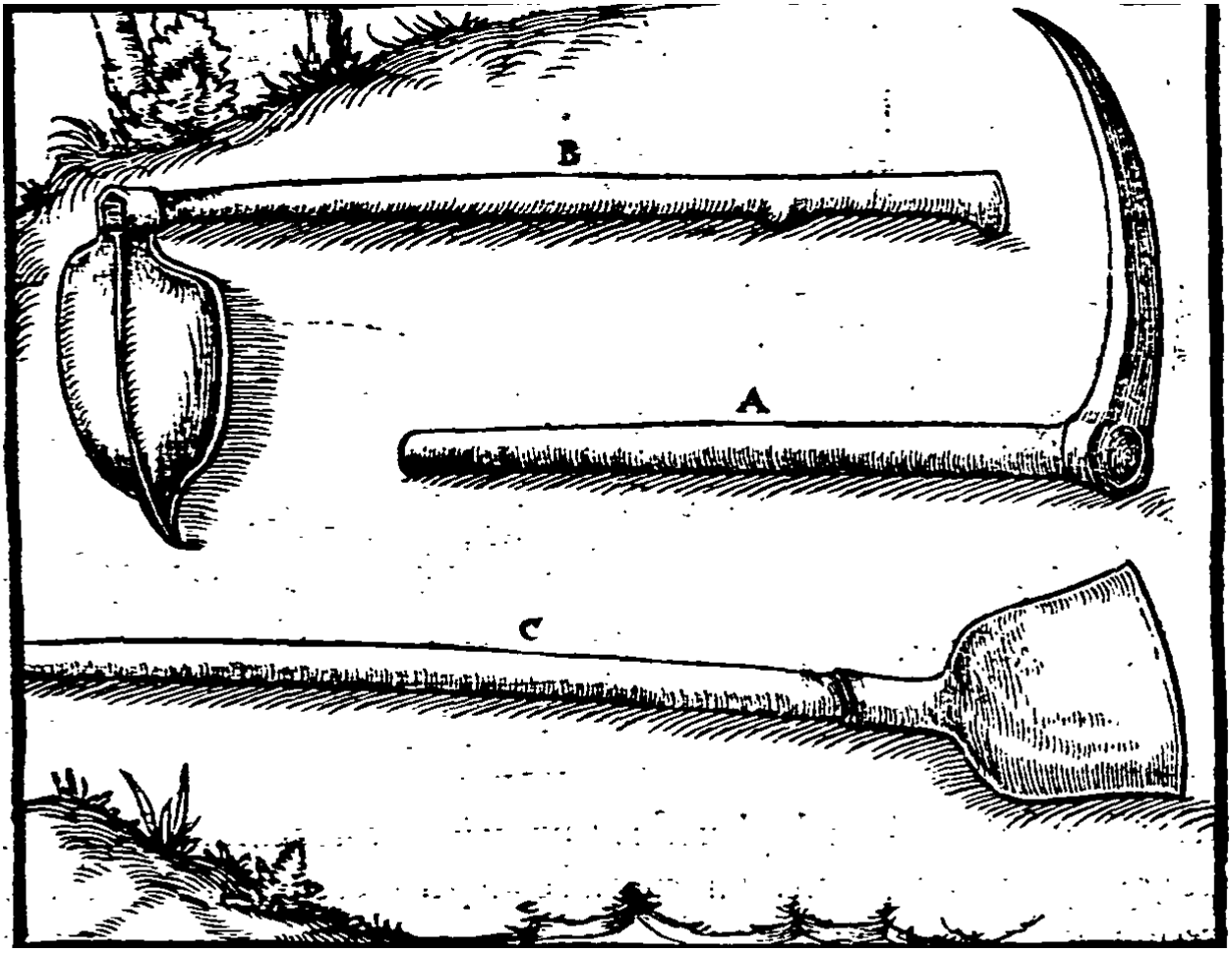

Figure 6.3 [507]

Providing an image of the instruments underscored the two tools' disparities. In order for the illustration to have been germane, Agricola would have had to assume that the reader had some familiarity with agriculture. Using agriculture as a benchmark was not new to Agricola. He had, of course, measured mining labor against that of agriculture in his assertion of mining's virtues. In that instance, mining and agriculture were similar enough to make a cogent argument. Yet regarding the tools required to perform tasks, mining and agriculture were different.

For Agricola, the innovation of mining tools was a marked difference. He was particularly impressed with the hauling machines. The miners had invented the machines and

[507] Agricola, *De re metallica*, liber sextus, 110.

made them with great skill, designing them to draw both water and ore from the deep shafts.[508] Agricola made note of the varieties of hauling machines. The variety of shafts' depths necessitated a variety of hauling machines. After having selected the correct machine for a given shaft, the miners then had to consider which machine to use based on the hauling load. If, for instance, the miners were hauling a dry load, they had five distinct machines from which to choose. One such machine required two logs and stakes to anchor it to the ground.[509] After having verified that the timbers remained stationary, the miners would then connect the ends of two cross-timbers with another set of timbers.[510] The miners positioned the two cross-timbers such that they could still place ladders.[511] They would fix and secure the posts in the middle of the cross-timbers with iron keys. The miners used the posts to then attach the barrel. The miners then soldered each end of the barrel with a piece of wood that was exactly "a foot and a half long (*longi sesquipedem*), a palm wide (*lati palmum*), and three digits thick (*tres digitos*)."[512] After connecting the wood, the miners would fasten a "windlass rope (*suculam funis*)" around the barrel and affix it to the middle part.[513] The miners had designed a machine that could bring a bucket up from the shaft, while "an empty one was being sent down (*ex puteo extrahitur in eundem demittitur vacuum*)."[514] The efficiency of the machinery was striking. He had his illustrator create a sketch, Figure 6.4. Agricola was so impressed with the technology, even asserting that it went "unknown to the Ancients (*veterinus incognitae*)."[515]

[508] Agricola, *De re metallica*, liber sextus, 117.
[509] Agricola, *De re metallica*, liber sextus, 117.
[510] Agricola, *De re metallica*, liber sextus, 117.
[511] Agricola, *De re metallica*, liber sextus, 117.
[512] Agricola, *De re metallica*, liber sextus, 117.
[513] Agricola, *De re metallica*, liber sextus, 118.
[514] Agricola, *De re metallica*, liber sextus, 118.
[515] Agricola, *De re metallica*, liber sextus, 117.

Figure 6.4 [516]

In this figure, the illustrator depicted the machine in the center. It was front and center, along with the miners. The rendering does not depict the technology in isolation. The inclusion of the

[516] Agricola, *De re metallica*, liber sextus, 118.

miners was a deliberate choice. Agricola perhaps wanted to show the miners' mastery over nature. They used their skills of abstractions to create a machine to help them with their excavations of the earth. Agricola did not dismiss the physicality required to operate the machinery and perform the tasks, but he also wanted to stress the intellectual rigor needed to accomplish the activities. Mining was both intellectually and physically demanding.

Historians have taken note of the technologies described by Agricola, but they seem to dismiss the miners in their studies.[517] Historian Pamela Long, for instance, described how Agricola struggled to explain the complexities of the technologies that he saw because he lacked a technical vocabulary in Latin.[518] What gets lost in Long's analysis is that Agricola still managed to convey the miners' innovation. Perhaps because of the linguistic challenges, Agricola relied on both descriptions and illustrations to showcase the miners' ingenuity. He appreciated the miners' ability to adapt and to perfect their craft through technology. As such, he wanted to understand and relay the purposes behind each and every technological component. The miners were not invisible to Agricola. He saw them and admired their intellectual and physical strengths. He sought to record and reconstruct the artisans' work.[519]

Mining did not occur haphazardly. Every miner followed a method of discovery. First, surveyors scoured the mountains for *vena profunda*. Once the surveyors agreed about the potential abundance of the vein, the laborers began to dig the tunnel. However, the tunnels did

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[517] See, for instance, Ernst Hamm, "Mining History: People, Knowledge, Power," *Earth Sciences History* 31 (2012): 321-326; and Owen Hannaway, "Georgius Agricola as Humanist," *Journal of the History of Ideas* 53 (1992): 553-560.

[518] Pamela Long, "Of Mining, Smelting, and Printing: Agricola's 'De re metallica,'" *Technology and Culture* 44 (2003): 99.

[519] In this way, Agricola appears to contradict Steven Shapin's assessment of the invisible technician. In his influential article, Shapin described how Robert Boyle's technicians went unnoticed by Boyle himself and by historians. Their contributions have been erased from history. Unlike Boyle, however, Agricola saw the technicians and their laborious tasks. He featured them prominently within his text. Perhaps the difference between Agricola and Boyle was the making of science. Boyle was conducting experiments. Agricola did not want to understand experiential claims. Up for debate is whether Agricola was participating in the same type of scientific knowledge-production as Boyle. Steven Shapin, "The Invisible Technician," *American Scientist* 77 (1989): 554-556.

not always descend vertically nor perpendicularly to the ground into the earth. The veins dictated the direction of the tunnel, and the surveyors had to calculate adjustments. To aid them in their construction, surveyors relied on cords and orbs. Some surveyors used an instrument similar to a compass to determine the direction of the veins. Agricola made certain to clarify that the Swiss surveyors whom he observed did not use the same waxed circles as the Germans. They, instead, used "an instrument peculiar to them (*utuntur instrumento, cui index est, ipsis peculiari enim ceratis caret*)," which demonstrated the direction.[520] Those surveyors had to be precise in their calculations.

In his elucidation of surveying, Agricola stressed precision in the measuring of the triangles. Agricola saw how surveyors entered a mine construction once the "owners (*domini fodinarum*)" of the mine wanted "to know how many fathoms of the intervening ground required (*cupiunt quot passuum intervallum effodiendum restet*)" digging.[521] The surveyors relied on triangulation to ensure correct measurements. Although the surveyors agreed about the importance of precision, they disagreed over other matters. They lacked consensus about the most effective and accurate way to determine the length of a tunnel, for example. Some believed that three cords could govern a shaft's depths; others contended that such calibration was not sufficient. After having established the length of the mine with the three cords, these surveyors postulated that it was also necessary to re-evaluate the cords on a level part of the "mountain or in a valley, or in flat fields (*montis, vel vallis, vel campi planicie*)."[522] The controversy centered upon the necessity of measuring the cords for a second time. Agricola did not shy away from discussing the debates among surveyors because he wanted to stress to the reader how integrated

[520] Agricola, *De re metallica*, liber quintus, 104-105.
[521] Agricola, *De re metallica*, liber quintus, 88-89.
[522] Agricola, *De re metallica*, liber quintus, 95.

he was into the mining community. He had come to know the mines and surveyors so well that they felt comfortable sharing their debates with him. Surveying was not free of discord.

The debates echo the importance of community to the miners and surveyors. The workmen depended on the expert opinions of their community members to arrive at new techniques. They practiced the artisanal knowledge as defined by Pamela Smith. Their craft "was empirical, employing observation, precision, and investigative experimentation."[523] All of these conditions occurred in the presence of a group; all of these techniques required a performance.

To underscore the importance of community and to highlight the skills of the miners, Agricola analyzed mining jargon. One such term that he described to his reader was the *vena profunda*. Agricola defined the veins as those that "descended from the surface of the earth to its lowest depths (*summon terrae descendit in imam eius sedem*)."[524] They would have varied in size, but these were the deepest "veins." Miners often described them in contrast to the *vena dilatata*, which did not cascade into the earth. Instead, these veins laid flat on the surface. To extract minerals and metals from the *vena dilatata*, miners did not need to construct tunnels and descend into the earth. For Agricola, extractions from these veins were not as laborious as those for the *vena profunda*.

Miners as Trading-Zone Participants

Agricola had learned enough about mining practices and surveying techniques that he felt compelled to use the specialized language of the mining community. Historians of science have come to label Agricola's exchange with the miners as a "trading zone." Peter Galison first

[523] Smith, "In a sixteenth-century goldsmith's workshop," 42.
[524] Agricola, *De re metallica*, liber tertius, 29.

introduced the concept of a "trading zone" to historians in 1997. He had borrowed it from anthropologist Michael T. Taussig.[525] In his investigation of twentieth-century microphysics, Galison identified a particular arena in which two distinct groups came to an understanding about microphysics through an exchange of information. The mechanisms of those exchanges among specialists occurred within a trading zone. Historians of technology have used Galison's concept, but they have used it to understand encounters in the modern age.[526]

Not until Pamela Long did scholars consider how a trading zone existed in the premodern world. In both *Artisan/Practitioners and the Rise of the New Sciences* (2011) and "Trading Zones in Early Modern Europe" (2015), Long explored how artisans and other trained, skilled men engaged in conversation with learned men. Those dialogues afforded the artisans the opportunity to share their expertise.[527] Long focused her research on Europe in the sixteenth century, an era ripe for investigation because of the paucity of hyperspecialization. Where Galison concentrated his attention on the aspects of knowledge-exchange that occurred thanks to professionalization, Long examined the ways in which that lack of licensure created unique systems of exchange. Both scholars used different historical actors. Galison followed specialists; Long tracked artisans and learned men.

Despite their differences in approach, both scholars arrived at similar conclusions. Galison and Long showed how the social context affected knowledge-production and knowledge-exchange. Both revealed how experts trained within specific social structures created "pockets of meaning systems."[528] Those "meanings systems" thrived because aspects of a given

[525] Peter Galison, *Image and Logic: A Material Culture of Microphysics* (Chicago: The University of Chicago Press, 1997).
[526] Harry Collins, Robert Evans, and Mike Gorman, "Trading zones and interactional expertise," *Studies in History and Philosophy of Science* 38 (2007): 657-666.
[527] See Pamela Long, *Artisan/Practitioners and the Rise of the New Sciences, 1400-1600* (Corvallis: Oregon State University Press, 2011) and Pamela Long, "Trading Zones in Early Modern Europe," *Isis* 106 (2015): 842.
[528] Pamela Long, "Trading Zones in Early Modern Europe," *Isis* 106 (2015): 916.

organizational structure, such as hierarchy or specialization, "cloaked activities."[529] Although Long broadly defined "trading zones" to encompass the exchanges between artisans and learned men, both she and Galison have located the particular locales in which a hierarchy of expertise existed. The skilled taught the unskilled. It was precisely in these arenas that people (such as scientists or artisans) negotiated and debated their knowledge-sets.

De re metallica provides evidence that Agricola participated in a trading zone through his use of mining vocabulary. When conveying their processes, materials, tools, and techniques to inquisitors, artisans would also share their technical vocabulary.[530] At one time, members of an artisanal community would have exchanged these terms orally between themselves. Eventually, according to Long, these artisans, like the miners described by Agricola, shared their terms with outsiders, like Agricola, who integrated them into their own Latin or vernacular languages.[531] Historians should not lose sight of the fact that the artisans' terms represented a specific, technical knowledge-set. Within a trading zone, the exchange of language signaled both a transfer and a translation of ideas.

In *De re metallica*, this aspect of a trading zone appears with Agricola's discussion of nomenclature. Agricola blended these learned, new terms such as *vena profunda* and *vena dilatata* with those concepts identified by Pliny. The Roman author had written on well formations and aluminous vapors. Agricola, having become familiar with Pliny's work at university, used Pliny's terms to augment his own technical nomenclature.[532] In one instance, Agricola brought together his terms from Pliny and his vocabulary from the miners in his

[529] Long, "Trading Zones in Early Modern Europe," 916.
[530] Long, "Trading Zones in Early Modern Europe," 846.
[531] Long, "Trading Zones in Early Modern Europe," 846.
[532] Agricola, *De re metallica*, liber sextus, 173. Paul Grendler has concluded that a study of Pliny's *Natural History* occurred only after students had progressed through the advanced stages of *studia humanitatis*. Paul Grendler, *Schooling in Renaissance Italy: Literacy and Learning, 1300-1600* (Baltimore: Johns Hopkins University Press, 1992), 203.

synthesis on fluxes. Agricola wrote, "I have now decided to explain (*nunc explicare decrevi*)" those things which miners usually called "fluxes (*additamenta*)" because they "were added to ores, not only for assaying, but also for smelting (*adiiciantur ad venas non modo experiendas, sed etiam excoquendas*);" in the "first category belongs lead (*in primo genere sunt plumbum*)," whether it be reduced to little granules or "resolved into ash (*in cinerem resolute*)."[533] Here Agricola produced a description of the natural world, while demonstrating his humanist background along with the miners' technical knowledge.

The miners' specialized vocabulary also extended to measurements. A "meer (*area fodinarum*)," for instance, was the first section of the *venae profundae* that was discovered and mined (*respicientes metallici vel hodie latitudinem cuiusque areae quae est fodinis venae profundae*)."[534] At times, meers became visible to the miners after a strong force of nature so that it "appear[ed] either on the slope of a mountain or hills or on a plain (*deuexo montis, aut collis, aut campi appareat*)."[535] The characteristics of the meers depended on the varieties of veins that contained them. As the veins varied, so too did the meers. Measuring these meers could prove to be challenging. Agricola explained, "if the vein [were] a *vena profunda*, the head meer [was] composed of three double measures[.] [T]hat is, it [was] forty-two fathoms in length and seven in width, which numbers multiplied together [gave] two hundred and ninety-four square fathoms (*Si igitur vena profunda fuerit, area capitis fodinarum constat ex tribus deminsis duplicatis, id est, passus complectitur longitudinis XLII latitudinis VII quibus numeris in se multiplicatis fiunt passus CCXCIIII*)."[536] Precision in measuring these fathoms proved essential because of the

[533] Agricola, *De re metallica*, liber septimus, 184.
[534] Agricola, *De re metallica*, liber quartus, 57.
[535] Agricola, *De re metallica*, liber quartus, 58.
[536] Agricola, *De re metallica*, liber quartus, 56.

demarcation of the boundaries of the owner's head meer.[537] The legal system in early modern Saxony recognized head meers as the standard method of marking the confines of a mine. The miners would have measured the meers and then delivered those measurements to the *Bergmeister* (*magister metallicorum*), who would in turn fix the boundaries.[538]

For Agricola, the competent miners arrived at those fixed boundaries through experience. The more experience a miner had, the more capable he was. Agricola observed how the miners relied on their senses to exercise their craft. Regarding sight, the miners would see if the location yielded an abundant, quality mineral. For as soon as a miner discovered rich and "metallic materials (*materia metallica*)," he would plant a shaft on the spot without any hesitation.[539] Taste also proved a useful guide to productive mining practice. The miners would drink the spring water. From those samplings, they could, according to Agricola, determine the type of mineral submerged beneath them. The miners informed Agricola that there were "six kinds of these (*sex earum genera*)" that were "very different in taste (*multum different in sapore*)": the salty, the nitrous, the aluminous, the vitroline, the sulphurous, and the bituminous kind.[540] Agricola took the time to explain how mining was a full-sensory activity. It required physicality to drop the shafts into the earth and construct tunnels, but the miners also had to have the acumen to determine the location that would yield the most minerals.

His descriptions of the miners' physical strengths were not limited to ore retrieval. Agricola also discussed how the crushers needed brute strength to extract the metals from the ores. When he chronicled the stamping and sifting process of extraction in the eighth book,

[537] Agricola, *De re metallica*, liber quartus, 56.
[538] As discussed in the previous chapter, the *Bergmeister* was a mine manager of sorts. He was responsible for maintaining order and deciding punishments.
[539] Agricola, *De re metallica*, liber quintus, 76.
[540] Agricola, *De re metallica*, liber secundus, 24.

Agricola acknowledged the tasks as laborious.[541] A workman would have collected the broken rock or stones from a fellow artisan, and he would begin the arduous undertaking of separating the small fragments and the larger pieces.[542] He would, Agricola observed, rely on a suspended box fitted with a net to perform his work, but the technology could not complete it for him. The process still involved the shoveling of the loads of broken rocks and stones, and then gathering the pieces that passed through the net and washing them. Agricola made note of the physical demand that the craft required. Although he did not share how many times a day the workman would have performed the strenuous task, Agricola implied that the man would have repeated the sifting and hauling process many times throughout his shift.

[541] Agricola, *De re metallica*, liber octavus, 222.
[542] Agricola, *De re metallica*, liber octavus, 222.

Figure 6.5 [543]

Agricola included an illustration of the "laborious task" perhaps in an attempt to convey the workmen's strength and to depict the workmen's technology. In Figure 6.5, he instructed his

[543] Agricola, *De re metallica*, liber octavus, 223.

illustrator to add the image of a workman shoveling stone and rock into the suspended box. There is also another workman who is schlepping materials. As depicted in the illustration, the artisan's workspace was busy. It even appears congested. The workmen took up space, but so too did the technology. The point to be observed is that Agricola wanted to show the reader the physical stamina needed to execute the extraction process. Technology eased some of the labor, but it did not do everything. The miners still had to participate. As a consequence of experience, some miners had developed and designed ways to conserve their energy.

For instance, Agricola made note of how the waterwheel eased the burden of the miners. The miners used the wheel to provide power for their machines. They had erected waterwheels that drove not only the pumping systems that drained the mines, but also the crushing mechanisms that powered the hammers. Agricola explained to the reader how precious the waterwheel was to the miners. They even constructed a shelter for it, so that weather patterns did not destroy it. The "deep snows or ice in the winter, or storms (*hyeme vel altae nives vel glacies, vel tempestas*)" could potentially "impede (*impediant*)" the wheel's functions.[544] The wheel's shelter is depicted in Figure 6.6.

[544] Agricola, *De re metallica*, liber octavus, 221.

Figure 6.6 [545]

The waterwheel provided the power to the stamps, or the machines that would crush both the dry and the wet ores.[546] The crushing of ores was physically draining. With the wheel performing the

[545] Agricola, *De re metallica*, liber octavus, 222.

[546] Agricola, *De re metallica*, liber octavus, 221-222. Agricola did not describe the way in which the wheels created the centralized power. The wheel would have converted the circular and reciprocal motion. For more analysis on the

task for them, the workmen were able to devote their time and their strength to other activities. Agricola was certainly impressed with the miners' invention. They had created a machine that helped to alleviate the burden. Time and labor were limited and finite. They could not afford to waste their energy. The miners discovered how to maximize efficiency in performing their craft.

Miners with experience could make a path for the "solid veins (*solidas venas*)" when they demonstrated "clear indication of being of good quality (*clara bonitatis indicia*)."[547] They hewed out drusy veins when the miners saw that there were few cavities. Competent miners understood the most effective ways of excavating. Agricola noted how experienced miners knew not to dig barren veins through the streams of water, if they did not spot metallic particles.[548] Experience elevated the skillset of a miner, but it did not make him infallible or omniscient. Agricola cautioned against readers concluding that the experienced miners were always correct. To establish the fallibility of the miners, Agricola listed a few stringers that some miners had dismissed but later had "proven good (*bonitatem probarem*)" after further investigation.[549] Agricola failed to reveal the miner's identity who decided that the stringer was "proven good (*bonitatem probarem*)."[550] It should not go unnoticed that Agricola did not identify by name his subjects of observation.

Indeed, Agricola made it clear that mining was not an art free of disputes. One point of contention was the forked twig. Some miners believed that it was absolutely necessary in order to discover veins; others rejected it as mere superstition. Crafting the twig required miners to cut a fork from a hazel bush with a knife. Although even the type of bush was ripe for debate. Some

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"ingenious systems of power transmission" found in *De re metallica*, see Hamm, "Mining History: People, Knowledge, Power," 321-326.

[547] Agricola, *De re metallica*, liber quintus, 76.

[548] Agricola, *De re metallica*, liber quintus, 76.

[549] Agricola, *De re metallica*, liber quintus, 75. Again, the stringers were filaments that ran subparallel in a rock.

[550] Agricola, *De re metallica*, liber quintus, 75.

argued that miners should use hazel twigs for "veins of silver; ash twigs for copper; pitch pine for lead and especially tin (*venas argenti, fraxini, ad aeris, piceastri, ad plumbi maxime candidi*)."[551] Despite the quarrels regarding the efficiency of the twig, the miners all grasped "the forks of the twig with their hands, making blows (*virgulae cornua minibus prehendentes pugnos faciunt*)."[552] Agricola observed that most miners believed that twigs could transmit the power of the veins or the skill of the miners. Some thought that the veins deflected all the branches of trees close to them; others contended that the veins moved because of the skill of the miners.[553] Miners relied on the existence of a community of experts to discuss and debate their techniques.

Agricola emphasized the collaborative and demonstrative nature of mining. Mining, like all craft knowledge, had a marked public component.[554] Miners showcased their knowledge in public. They had to prove to each other that they were masters of their craft. The community, then, would debate the precision and viability of their techniques and approaches. The judgments of the mining community progressed mining; the opinions of the community allowed the craft to endure.

Agricola attempted to ingratiate himself to this community of mining experts. The German writer's use of the first-person plural exemplifies this trend. He described how "*we* scrutiniz[ed] for veins by observing the snow (*venas scrutamur observantes pruinas*)," which "whiten every herbage except that growing over the veins (*omnes herbae candicant: his exceptis quae crescunt supra venas*)," because the veins "emit[ted] a warm and dry exhalation (*emittunt exhalationem calidam et siccam*)" which "impede[d] the freezing of the moisture (*humidae concretionem impedit*)," for which reason such "plants appear[ed] rather wet (*herbae magis*

[551] Agricola, *De re metallica*, liber secundus, 26.
[552] Agricola, *De re metallica*, liber secundus, 26.
[553] Agricola, *De re metallica*, liber secundus, 26.
[554] Smith, "In a sixteenth-century goldsmith's workshop," 40.

aquis madent)."[555] Self-inclusion into inquiries of the natural world continues with Agricola's declaration that through "the art *we* can scrutinize the secret and hidden veins, observing first the waters of the springs (*arte autem occultas et recondites scrutamur, observantes primo scaturigines fontium*)."[556] In another example, Agricola stated how "*we* follow veins of marble by mining in the same way as is done with rock or building stones when *we* spot them (*marmorum vero venas, cum se sua sponte ostenderint, fodiendo persequimus: idem facimus cum saxa vel caementa nobis occurrerint*)."[557] Presumably Agricola used the collective verb to convey his experience, and thus his authority, to his audience. He did not simply read or listen to descriptions of mining techniques. Instead, he observed and participated in the craft of mining. The miners taught Agricola about their craft, and Agricola dutifully received the knowledge.

The particularities of that knowledge-set appear when Agricola, still relying on the first-person plural verb, discussed the identification and classification of veins. For instance, Agricola told the reader how "*we* call that part of the vein which [was] first discovered, the head-meer (*verum venae partem, quae primo inventa foditur, caput fodinarum appellamus*)" because from that all other meers run.[558] Here Agricola demonstrates how he worked his way into the community to such a degree that he felt comfortable using the miners' own jargon and claiming it as his own.

Agricola's transition into that community of miners extended into his description of surveying. When articulating the importance of correct measurements, Agricola noted how "each system depend[ed] on the measuring of triangles (*utraque ratio versatur in dimensione*

[555] Agricola, *De re metallica*, liber secundus, 26. Emphasis my own.
[556] Agricola, *De re metallica*, liber secundus, 35. Emphasis my own.
[557] Agricola, *De re metallica*, liber quintus, 77. Emphasis my own.
[558] Agricola, *De re metallica*, liber quartus, 56. Emphasis my own.

trianguli)."[559] A small triangle was outlined, and from those calculations, a larger triangle was laid out. Maximum caution was taken so that "*we* did not error (*maxime vero cavendum ne ad vera mensura quic piam aberremus*)."[560] Almost undoubtedly, Agricola was not performing these measurements. But he insisted on presenting himself as someone who completed these mining tasks. Perhaps he wished to stress to the reader how he not only witnessed but also performed the craft. Most importantly, Agricola's use of the first-person plural demonstrates the collaborative aspects of mining. Mining had a public component, one that encouraged the sharing of techniques. The miners exchanged their knowledge with Agricola, and by writing *De re metallica*, Agricola imparted that knowledge to his educated, elite audience.

The skilled miners taught the unskilled Agricola; and, as such, they participated in a trading zone. It is essential to note that the trading zone differed from a gift-exchange. As purported by anthropologist Marcel Mauss, a gift-exchange was a debt economy. One gave a gift, and then he accepted a gift in return. This network of gift-giving occurred in pre-capitalist societies as the fabric of social life.[561] A trading zone, however, did not require the recipient of a gift to reciprocate. After the miners gave Agricola the gift of their knowledge, he did not feel obligated to bestow something in return to the men.

Agricola even distanced himself from the miners and their interactions through his use of verbs. His use of the first-person singular lies in contrast to that of the first-person plural. When he described tasks, Agricola dispenses with "we." When he discussed the writing process, he employed "I." For instance, he wrote, "*I* have released one part of this book, now come to the other, in which *I* treat the art of surveying (*absolui unam huius libri partem, venio ad altera, in*

[559] Agricola, *De re metallica*, liber quintus, 88. Emphasis my own.
[560] Agricola, *De re metallica*, liber quintus, 88. Emphasis my own.
[561] Marcel Mauss, *The Gift: The forms and reason for exchange in archaic societies*, trans. Mary Douglas (London: Routledge Classics, 1990), 105.

qua tractabo artem mensorum)."[562] The switch between the verb conjugations, gliding from the plural to the singular, is noteworthy. "I" signaled to the reader that the writing process differed from those tasks that he had observed. Crafting this text was a solitary, intellectual endeavor. The miners who had shown Agricola their artform did not participate in the writing process. The use of "I" places distance between Agricola and those workmen. Although challenging to discern whether Agricola had any malicious intent with his linguistic choice, it was deliberate. The use of the first-person singular eliminates the miners' contributions to knowledge-production.

Agricola likely alternated between the verbs as a means to reclaim the knowledge that he had accumulated. In one example, Agricola dedicated pages to the classification of rock that the miners dug. He noted how in some places "the hanging wall rock [was] soft and fragile in others hard, in others harder, and in others of the hardest kind. *I* call that ore 'crumbling' which [was] composed of earth and of solidified juices (*saxum tecti molle et fragile, aliter durum, aliter durius, aut durissimum. Venam aut putrem eam voco quae constat ex terris, atque etiam succis concretis mollibus*)."[563] Here, Agricola made it clear that he devised his own system of classification. Agricola and the miners agreed about the differences between the "hard" and "soft" properties of the rocks. Yet the adoption of "I" represents Agricola's own intellectual prowess. With the first-person singular verb, he seized ownership of the miners' knowledge-sets.

The use of the singular verb is particularly striking because Agricola described mining as a group-oriented craft. He had described how miners, as a collective, came to a consensus about the optimal location of a mine, dug the tunnels for extraction, and relied on the strength of the group to expel the rocks from the earth. Miners mastered and transmitted knowledge through observation and through practice. They performed their skills and demonstrated their faculties to

[562] Agricola, *De re metallica*, liber quintus, 88. Emphasis my own.
[563] Agricola, *De re metallica*, liber quintus, 75. Emphasis my own.

an audience of miners.[564] The first-person singular underlines the hermitical nature of writing. There was the doing of knowledge, and then there was the explicating of that knowledge. For Agricola, the two exercises were distinct.

Conclusion

Agricola described the techniques of miners and surveyors in such a way that contradicted Aristotle's rigid boundaries between natural philosophy and the mechanical arts. He aimed to elevate the art of mining by showing the reader how much skill mining required. Agricola was struck by the mathematical precision that mining demanded. The miners had to be exacting in their calculations and measurements. His assessment of the miners' skillset has historiographical significance. Agricola constructed an image of the early modern Saxon miner who was not solely a manual laborer. In Agricola's presentation, the miner had to abstract and calibrate measurements. *De re metallica* presents another opportunity for historians to consider the theoretical contributions of a group of artisans. Agricola came to recognize the extent of the miners' physical and intellectual prowess because they first invited him to participate in their community.

The miners' willingness to share their knowledge calls into question their proprietary attitudes towards craft knowledge. As expressed by Agricola, his interactions with the miners appears public, free, and open. That is, the miners were amenable, even enthusiastic, to share their knowledge with Agricola. In his descriptions of their techniques, practices, and dialogues, Agricola did not communicate to his audience that the miners believed themselves to be the sole

[564] Smith, "In a sixteenth-century goldsmith's workshop," 40.

owners of their mining knowledge.[565] On the other hand, the miners could have been apprehensive to share their expertise with a man outside of their community, who might in turn disseminate specialized skills to competitors. In any case, the miners trusted Agricola sufficiently to share their knowledge. Trust, then, stood at the nexus of the trading zone. Agricola's presence as an observer, a participant, and ultimately as a chronicler of mining practices prompts a reflection on the synergy of experience, trust, and secrecy.

[565] Karel Davids, "Craft Secrecy in Europe in the Early Modern Period: A Comparative View," *Early Science and Medicine* 10 (2005): 342.

Conclusion

This dissertation has examined the rhetoric and scholarly practices that Georgius Agricola used to construct authority in *De re metallica* (1556). Agricola's style of presentation was tactful, and his lens was unique. He framed his views on natural philosophy within the context of mining. *De re metallica* was not a treatise on natural philosophy. It was a comprehensive mining manual. Yet Agricola believed that the two were linked. For him, natural philosophy served a practical role to miners. He made deliberate choices in his presentation of the relationship between nature, man, and the mine. At a moment when natural philosophy was untidy and incoherent, he sought to convince his readers that his thoughts were valid.

Agricola's epistemic virtues of precision, faithfulness, and subjectivity were not in competition. These three epistemic virtues shaped the collection and presentation of mining knowledge in *De re metallica*. Agricola's range of epistemic virtues affected the content of his view on nature. This dissertation focuses on the epistemic virtues found in Agricola's practices and rhetoric, arguing that the specific combination increased his authority. That is, he established his credibility through an appeal to his personability, thus producing and advocating an approach to the study of nature that was uniquely his own

Historians who have studied Agricola's text have focused on its innovative features.[566] For years, many scholars have heralded Agricola's work as the preeminent mining text of the early modern period.[567] By concentrating on the text's singularity, scholars have missed the

[566] Pan Jixing, "The Spread of Georgius Agricola's 'De Re Metallica' in Late Ming China," *T'oung Pao* 77 (1991): 108-118; Pamela Long, "Trading Zones in Early Modern Europe," *Isis* 106 (2015): 840-847; and Thomas Morel, "De Re Geometrica: Writing, Drawing, and Preaching Mathematics in Early Modern Mines," *Isis* 111 (2020): 22-45.

[567] Eric Ash described *De re metallica* as "the most important single work on mining operations published during the early modern period." Eric H. Ash, *Power, Knowledge, and Expertise in Elizabethan England* (Baltimore: The Johns Hopkins Press, 2004), 23. See also Annette Bouheiry, "The Iron Library and its Agricola Collection," *GeoJournal* 32 (1994): 161-167.

opportunity to evaluate how representative of the circumstances the text, in fact, is. Agricola wrote *De re metallica* in a moment of religious and economic upheaval. As a consequence, his text is representative of that precise historical moment.

An examination of *De re metallica* is a step toward providing an alternative perspective on the confluence of intellectual thought, economic history, and the history of science. Agricola's representation of how artisans extracted and analyzed ore collapsed the boundaries between politics, economics, and science. The circulation of mining practices had social and economic value to certain parties, such as merchants and bankers, while those very same practices had economic and intellectual value to artisans and alchemists. Agricola wrote the text because he recognized that many individuals had a stake in mineral trade.

The chapters of the dissertation have each focused on a particular context that affected Agricola's perspective on and descriptions of mining and metallurgical practices. These different contexts reveal the extent to which Agricola straddled period labels in his quest to elevate the art of mining. By devoting equal attention to each context, this study has gauged the ways in which his milieu shaped his interactions with miners, his understanding of theories, and his explanations of practices. An examination of his education, religiosity, and audience helps to explain why he chose to characterize mining practices in a particular manner. The chapters conveniently focus on a thematic perspective, but in reality, the contexts did not fracture so neatly. Agricola's production of *De re metallica* was a messy business.

Agricola appealed to the reader's sensibilities by making subtle references to Aristotle, Galen, Pliny, and Aquinas. He presumed that his reader would have been well-informed enough to understand the significance of those references. Agricola did not care to divide his text based on context. He undoubtedly hoped that his audience would simultaneously accept the authority

of Virgil, for instance, and appreciate the association of mining with piety. In the first book of *De re metallica*, Agricola discussed how the products of mines were not themselves the cause of war. Instead, the lust of metals incited conflict. He turned to the *Aeneid* to provide an example of how, "the products of the mines [were] not themselves the cause of war. For when a tyrant, inflamed with love for a woman of excellent form, makes war…the fault lies in the unbridled lust of the tyrant and not in the face of the woman (*belli etiam causa res fossils non sunt: ut enim cum unus aliquis tyrannus magno amore inflammatus in mulierem egregia forma, facit bellum...istiusmodi belli in effrenata tyranni libidine est culpa, non in facie mulieris*)."[568] In Agricola's rendering of Virgil's take of the murder of Polydorus, Polymnestor's avarice destroyed his kingdom. Metals were not to blame; men were to blame. Agricola's education at universities across Europe afforded him exposure to Virgil and other writers, and he similarly culled examples from classical literature in order to argue for the merits of mining. To his mind, mining practices and religious devotion were not incompatible, and he looked to ancient texts to support this presupposition.

Agricola also communicated the virtues of mining by focusing on the skills of the miners. The hardworking and poorly educated miners were the *dramatis personae* of the text; and Agricola held them in high regard. He communicated to his elite, erudite audience how the mining community of sixteenth-century Saxony investigated the natural world through hands-on experience, accurate measurement, and empirical techniques. The miners taught Agricola how to measure and smelt the ore. They shared their knowledge with him. Theirs was a technical craft, and Agricola appreciated the miners' precision. Out of respect for that precision, he even went so far as to be exacting with his own word choice.

[568] Georgius Agricola, *De re metallica* (Basel: Froben Press, 1556), liber primus, 12.

Yet the miners themselves did not construct the text. The miners permitted Agricola to witness their activities and learn their techniques. But they did not participate in the documenting of their knowledge. *De re metallica* was written by an outsider. This dissertation has attempted to demonstrate how the vista of an outsider affected a text's content.

The next task involves a reconsideration of that gaze. Agricola wrote *De re metallica* for a specific purpose and for an intended audience. His perspective and motivation were uniquely his. Agricola's perception was myopic. This dissertation commenced with the assumption that he neglected to include all participants and practices. Agricola invariably silenced individuals and excluded information. He cherry-picked which techniques and which technicians he included in his text. The exclusion may have been unintentional, but he had an agenda. He wrote *De re metallica* to celebrate the virtues of mining; and if individuals did not contribute to that goal, he ignored them. Future studies will consider how a member of the mining community, or of any community, would have crafted a different text in the relaying of his own knowledge-set. At stake in these discussions are questions of ownership: specialized knowledge belonged to whom and circulated for whom?

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