ABSTRACT

This article examines the perception and valuation of mineral resources in sixteenth and seventeenth-century European mining regions. It aims to critically review the utilitarian and anthropocentric view of mining and mineral resource production, circulation and consumption that is shaped by a long tradition of economic history and history of technology. To understand human relation to the underground and its resources only in terms of innovation and rationalization means to ignore the many different layers by which resource landscapes affected the miner’s perception of nature and mineral matter. The literary, material and visual culture of sixteenth- and early seventeenth-century central European mining sites proves to be fruitful ground for historicizing the interplay between manual labor, mechanical arts, natural resources and religion in mining landscapes. This paper aims to connect the material and immaterial or the physical and symbolic dimensions of human-nature entanglement in early modern mining and suggests a way to locate human and geological agency within the context of a divine oeconomy.

Keywords: mining, natural resources, economy, environment, Anthropocene

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1. MINING AND THE DEATH OF NATURE?

In the classical study *Technics and Civilization* (1934) Lewis Mumford reflects on humanity’s quest for natural resources as well as the technologies and effects of mining. In the second chapter “Agents of Change”, he juxtaposes the “inorganic” qualities of the underground coal mine with the fertile qualities of agriculture and derives his critique of modern capitalism from it. The mine is characterized as a “... dark, a colorless, a tasteless, a perfumeless, as well as a shapeless world: the leaden landscape of perpetual winter” (Mumford 1934, p. 70). While fields, forests and rivers represent an environment of the living and fertile, the underground is a place of the inanimate and mechanical. Only artificial lighting, ventilation and lifting machines enable miners to penetrate into the depths to bring mineral resources to the surface. Mumford’s underground is a space surrounded by darkness, a space that bears riches but also brings death; it is a place where miners have lived in constant fear and danger. The mine is both materially and metaphorically an image of a fully rationalized and engineered environment that set the path to “carboniferous capitalism” (Mumford 1934, pp. 74–77; 156ff.). The mining industry represents for Mumford not only an economic and technological driving force but also a collective mode of modern making and thinking. In a dramatic tone he describes how the material underground started to dominate modern life, or to put it differently, the extension of the underworld to the surface:

The animus of mining affected the entire economic and social organism: this dominant mode of exploitation became the pattern for subordinate forms of industry. The reckless, get-rich-quick, devil-take-the-hindmost attitude of the mining rushes spread everywhere: the bonanza farms of the Middle West were exploited as if they were mines, and the forests were gutted out and mined in the same fashion as the minerals that lay in their hills. Mankind behaved like a drunken heir on a spree. (Mumford 1934, pp. 157–158).
For Mumford the subterranean and inorganic foundations of modern life implicate a process of rationalization, mechanization and de-naturalization. He locates the origins of this capitalist “devil-takes-the-hindmost attitude” in the sixteenth-century European mining ventures. However, his account of early modern mining is almost entirely based on De re metallica libri XII (1556) by Georg Agricola (1494–1555), which he reads as a purely technical book (see also Hamm 2012, p. 322). Mumford’s teleological story of economic and technological developments in the process of industrialization is part of a larger mainstream narrative of Western culture that has propelled the effort of science, technology, and capitalism to ‘master’ nature; or the destruction of nature by mechanistic science and technology that began in the late sixteenth and early seventeenth century. This narrative builds on the fundamental dichotomy between technology and nature, or culture and environment (see especially Latour 1991; Bennett 2001; Chakrabarty 2009; Pritchard and Zeller 2010; LeCain 2017). The history of early modern mining written from the viewpoint of economic history and history of technology has often emphasized innovation, or development, or both. This research has contributed to considering mining as an essential driving force towards a mechanical and rational understanding of nature that paved the way for capitalism. It most problematically links the rise of a mechanistic world view with the process of carbonization and industrialization. Such frameworks tend to ignore or minimize the multifarious ways in which mining and metallurgical practices came to be ingrained in the societies in which they were carried out. Mining was not just a paradigm of capitalistic exploitative mechanization, rather it was inserted into cultural frameworks that escape this simple derivation. In the following I will show how mining and the underworld in the sixteenth and seventeenth centuries were part of vitalistic, non-reductionistic worldviews, that become visible in the practices of miners but also in their beliefs, expectations and emotions. This perspective not only replaces reductionism to multifariousness but offers a revisionist reading of a historiographical narrative—which is very popular in current Anthropocene scholarship—that evaluates and measures historical societies, practices and events post factum in the light of today’s political, ecological or economic conditions. My investigation of the early modern resource economies of European mining offers a connected examination of mined materials, knowledge, infrastructures, experiences and beliefs.

This perspective builds on Carolyn Merchant’s classical study Death of Nature: Women, Ecology and the Scientific Revolution (1980) while challenging it at the same time. In her remarkable book Merchant analyzes how the representation of nature as female and the naturalization of women were linked to the dominations of women and the earth. Among other practices she comprehends sixteenth-century mining activities as a crucial factor within a slow process of alienation from nature: mining practice and literature comprise a prominent arena, in which the traditional perception of nature as a caring and nurturing mother (magna mater), which had already evolved in antiquity, is challenged and subjugated by a more recent view of nature as a passive object of investigation, experimentation, and fit for capitalist exploitation. People began to experience

[...] nature as altered and manipulated by machine technology. A slow but unidirectional alienation from the immediate daily organic relationship that had formed the basis of human experience from earliest times was occurring. Accompanying these changes were alterations in both the theories and experiential bases of social organization which had formed an integral part of the organic cosmos. (Merchant 1983, p. 68).

In her argument, the Scientific Revolution offers an apt explanation for the emergence of a mechanized worldview altogether with a rationalized understanding of nature, that can be explored, exploited and conquered. However, historians of science have dethroned the Scientific Revolution; the sharp distinction between vitalism and mechanism that structured the grand narrative of the emergence of new science and the process of industrialization has long been criticized for obscuring the various interconnections of vitalist and mechanist thinking and philosophy in the early modern period (Schaffer 1987; Garber 2001; Newman 2006; Keller 2010). Furthermore, there is a
distinction between nature and technology, or between organicist and mechanistic worldviews, that prevents comprehension of how past actors thought about the complex economies of natural resource production. It is thus striking that in current contributions on human geological agency and the Anthropocene, these fine-grained historical studies are overshadowed by generalizing and descriptive claims. Current contributions on the agency of a self-regulating earth system for instance, which are inspired by the works of Lynn Margulis and James Lovelock on the Gaia hypothesis, build on the linear narrative of the enchantment from nature as well while adding a more responsive and revitalized view of the earth to this sequence (Lovelock and Margulis 1974; Latour 2017). Facing the relevance and political weight of these ongoing discussions and the role, effects and responsibilities of human species therein, we should target a more nuanced understanding of the history of life-environment interactions, and the place of humans therein (see also Renn 2020, especially 379 ff.).

In the following I comprehend nature, humans and technology as mutually entangled (see also Pritchard and Keller 2010). This contribution looks at the interconnectedness of vitalist and mechanical concepts of the earth from the perspective of sixteenth and seventeenth century mining practice and literature. It argues for a different, non-teleological history of proto-industrialization and the production and perception of natural resources in the early modern period. Up to the eighteenth century, mining was heavily indebted to religious beliefs, neoplatonic ideas and alchemical thought, which embodied the potential for spiritual and material manipulation and change. As numerous contributions have worked out, particularly from the history of alchemy, it is important to acknowledge that vitalist formulations have always incorporated corpuscular or mechanical elements so characteristic of the ‘New Science’ (Newman 2019; Snobelen 2012; Teeter Dobbs 1975 and 1991; Debus 1977).

2. MINING AS A FACTOR OF CHANGE?

When we approach early modern mining from Mumford’s perspective, highlighting the impact of technology, we are indeed confronted with a fundamentally transformed and engineered landscape: mining in central Europe experienced a considerable boom beginning in the mid-fifteenth century—due to new technologies such as the implementation of new smelting processes (e.g. the process of liqation where silver is separated from copper by using lead as a solvent), complex drainage, hauling and wind machines, or new financial tools such as mining shares that provided the mining entrepreneurs with capital. The production rate of silver increased almost fivefold during that time (Nef 1941, 1987; Bartels and Slotta 2012; Asmussen and Long 2020; for medieval mining see Graulau 2020).

With hard physical labor, machine power and under dangerous working conditions, the miners constructed a complex infrastructure that expanded vertically and horizontally. In the underground, miners were building shafts and galleries for the transportation of materials and people, they installed ventilation technologies and built long adits to solve the problem of ground water. At the surface, the mines were connected to roads and waterways in order to transport the ores to the processing sites or to provide the miners with much needed timber for their constructions. Rivers and streams were redirected to power the machines, and dams were built in many places to create more water pressure. This infrastructure of shafts and galleries, roads and waterways, machines, hammer works, smelters and mints was constructed and maintained by countless workers. As a very general rule for the pre-industrial European silver mining industry one can calculate for every miner working underground about six to ten workers in the subsequent

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2 In a similar manner, Charles Wolfe has argued that a vitalist mechanism was developed out of early modern philosophy of life, therefore the opposition of mechanic and vital is artificial and reductive in many respects (Wolfe 2019).

3 On the grand narrative of the anthropoceneologists see especially Bonneuil (2015); Bonneuil and Fressoz (2016, pp. 69–96), and Kunnas (2017).

4 On the process of liqation see Suhling (1976); for the financial tool of the Kuxe, see Asmussen (2016); Westermann (1997); Mendels (1961).
SPIRITED METALS AND RESOURCE ECONOMIES

production facilities and in the supply area of the mining district (Schirmer 2018, p. 230; Schirmer 2013).

However, this infrastructure not only channeled and organized the flow of resources it also transmitted communications between the underworld and the surface: for example, the news of newly discovered ore veins spread widely at lightning speed and motivated foreigners to settle in prosperous mining areas. Contemporaries called the news and rumors about new ore findings “Berggeschrey” or “mountain clamor” (Asmussen and Long 2020, pp. 18–21). Scattered settlements grew quickly into remarkable mining towns with many thousand inhabitants: Schwaz in Tyrol, Annaberg in the Erzgebirge (Ore Mountains) and St Joachimsthal (present day Jáchymov) in Bohemia counted among the largest cities in the Holy Roman Empire (Westermann 2015, pp. 211–213; Slotta 2012, pp. 592–599; Kaufhold 2004, pp. vii–xi). In St Joachimsthal for example, the rapid influx of people due to the prospering silver mines, led to the construction of a few houses in 1516. The loose settlement quickly developed into a mining town with a population of 18,200 by 1534 (Bartels 1997). But supplying these mountain areas with food and other goods for everyday use was difficult; the rocky soils, long winters and short summers as well as the high precipitation rates in the Erzgebirge made it impossible for the mining towns to be self-sufficient (Westermann 1997). Uwe Schirmer’s impressive evaluation of trade and consumption has shown that around 50,000 to 70,000 inhabitants in the mountain areas of the Erzgebirge in the sixteenth-century were dependent on the supply of food from the Saxon-Thuringian lowlands and from Bohemia. Yearly about 11,000 tons of grain and 2,000 tons of meat were transported to the mountain regions (Schirmer 1997, pp. 140–143). The expanding quest for mineral resources thus not only changed the surface and subsoil in fundamental ways, but had far reaching effects; it transformed the networks of Central European food logistics and trade, social structures and other forms of sociality. The study of economic and technological impacts of the early mining industry enjoyed a particular standing among historians from the former German Democratic Republic (DDR). Notable mining historians such as Johann Köhler and Adolf Laube discovered the “germs of capitalism” (Köhler 1955) in the Saxon mining industry (Laube 1974). Their remarkable studies still count among the most influential and important works on these early mining industries, which no mining historian should ignore. However, they also shaped an economic determinist argument far beyond Cold War academia. Far from dismissing this line of research, this article offers a complementary view to these earlier approaches while applying a broader comprehension of the early modern industry of mineral resources than one that is driven by technological innovation, human mastery over nature or quantitative extraction rates.

According to the classical study of the resource economist Erich Zimmermann (1933), resources are made through processes of appraisal and human labor. Zimmermann understands resources not simply as fixed and finite, but as constantly in the making. Resources are not, but “they become”, as he puts it (Zimmermann 1933, p. 3). He proposed a functional and relational notion of resources, which depend on people’s wants and their appropriation of their environment. However, understanding resources as entirely social and dependent on human control and human wants neglects the uses and possibilities that matter affords to humans. In a recent article, the anthropologists Tanya Richardson and Gisa Weszkalnys focus their attention on resource making as not only a social but also as a material process. They start from an understanding of resources as “relational phenomena” of resource materialities (Richards and Weszkalnys 2014). The latter involve “the combined examination of the matters, knowledges, infrastructures, and experiences that come together in the appreciation, extraction, processing and consumption of natural resources” (Richards and Weszkalnys 2014, p. 8). In line with these recent conceptual approaches to a broader understanding of resources, I argue for a dynamic and more holistic approach to resources as socio-natural entities consisting of material, symbolic, epistemic, political, and discursive dimensions. It is essential to connect the production rates, the technologies of extraction, the development and expansion of infrastructure or the environmental transformations with local belief systems and the material imaginaries that were attached to the ores and the practices of mining.
Looking closely at the mystical and symbolic qualities of the miners’ practices and the polysemantic meaning of mineral matter sheds light on the ambiguity of technē, material wealth, and belief and knowledge systems. Hence, the world-transformative power of the human agency of mining communities needs to be understood as socio-economic and cultural phenomena in the broadest sense to which nature stands not in opposition, but is tightly entangled.

3. ENVIRONMENTAL TRANSFORMATION, MECHANIZATION AND THE DIVINE OECOLOGY OF MINING

In many studies, both older and more recent, the physician Georg Agricola is regarded as chief witness to the profound changes brought about by the developments in mining in the sixteenth century and their socio-economic consequences. In particular, the 292 woodcuts that are integrated in his renowned book on mining De re metallica give a concrete and vivid expression to these profound changes. The illustrations depict an environment that has been visibly and fundamentally transformed (Figure 1). They show a largely deforested mining landscape, perforated throughout with pits and shafts. The miners are represented as diligent and hard-working, and can be seen operating machines or working in the shafts and tunnels. Agricola’s woodcuts show how nature is converted into a productive resource through mechanical and bodily labor. However, these illustrations are more complex than being reduced to their technical and transforming aspects. Furthermore, an interpretation of Agricola’s book as a key document that vividly expresses human mastery over nature is reductive. De re metallica and also Agricola’s earlier text on mining, a dialogue entitled, Bermannus sive de re metallica, dialogus (Basel 1530), present mining not only as an activity, but much more broadly as a practical and moral undertaking (if not to say a vocation) guided by knowledge and skill, as well as Christian virtues and temperance. In the second book of De re metallica, which deals with the miners’ knowledge and practices, Agricola describes mining as an industry blessed and established by God: it involves human labor, a broad range of mineral, technical and mathematical expertise and manual skills, mechanical powers and a generous nature offering her goods to the idealized figure of the honest, virtuous and pious miner. The latter is named metallicus sapiens or metallicus prudens (Agricola 1556, pp. 19–29, especially p. 21). Human labor, technology, nature and religion form together a divinely ordered and blessed oeconomy: by oeconomy I refer to the classical concept of oikos meaning the management of the household, that also included land, water, plants, animals, minerals, tools, and manufactured goods (Maifreda 2012, pp. 143–185 and 191–199). This perception of mining as spiritual, moral, technological and economic undertaking forms a common ground of Agricola’s mining books, and of sixteenth and seventeenth century mining literature in general.

In both of Agricola’s mining books, environmental transformations and mechanization are key aspects of this divine oeconomy. His earlier work, Bermannus sive de re metallica, originated during his appointment as town physician of St Joachimsthal. The renowned Bohemian boom town and its mining sites nearby serve as the dialogue’s principal setting. The book’s subject is a conversation between a learned miner, Bermann, and two physicians, Naevius and Ancon, about the nature, properties and benefit of different metals as well as the techniques and economic promises of mining (Norris 2015; Morello 1994). In the opening of the book the three protagonists meet at the market square of St Joachimsthal. As they see the mining shareholder, Colmann, leaving town and heading towards a prosperous silver mine nearby, they start a discussion about the

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5 The woodcuts of Agricola’s book have been frequently analyzed and reproduced in numerous books on mining, mineralogy or mechanics up to the present day. Agricola himself highlighted the huge number of pictures in the title of his work: “The twelve books of Georgius Agricola on Mining. In which the Operations, Instruments, Machines, and everything that pertains to Mining are not only lucidly described, but also set before the eyes [of the reader] in the form of pictures, inserted at the appropriate places with their Latin and German names, so that nothing can be more clearly conveyed.” For the woodcuts see Pieper (1955), Kessler-Slotta (1994), Lefèvre (2010), Hannaway (1997).

6 On Agricola’s life and works see Wilsdorf (1956) and Naumann (1994).
financial fortunes of mining (Agricola 1530, pp. 17–20). Curious about the exact location of the rich silver mines, Naevius and Ancon agree to Bermann’s offer to show them the extraction sites.
As they walk up the mountain and oversee the entire valley and the impressive dimensions of the mining town Ancon marvels:

Good Lord! How many beautiful houses! They cover the valley just as they stick to both hillsides. It looks as if one is lying on top of the other. I almost think I see one of our big cities, like Erfurt or Prague, or the kind Italy has with Bologna or Padua. And now I hear, what surprises me the most, it is said to be only a few years since these mines have become active. (Agricola 1530, p. 24).\(^7\)

The protagonists continue to discuss not only the transformation of the remote landscape into a heavily populated urban center, but also the environmental effects of the mining activities. The environmental impacts of mining were indeed numerous—the demand for wood decimated the forests; channeling rivers and streams as well as draining of groundwater made humid areas dryer; entire mountains collapsed due to extensive mining; landscapes started to sink; the fundamental transformations caused by mining created completely new topographies (Gleitsmann 1984; Bartels 1988; Reith 2011, pp. 52–53; Uekoetter 2012). Likewise, the pollution of soil and air was considerable and ore washing poisoned the streams and rivers. Finally, the environmental effects of mining affected the miners’ health—the hard and dangerous work caused various diseases, lung diseases in particular such as the ‘Bergsucht’ (miner’s sickness) or the ‘Lungensucht’ (disease of smelter workers), but also deformations, such as ‘Krummhälse’ (crooked necks), caused by the crawling posture (Suhling 2005; Rosen 1943, pp. 39–88). Early modern resource exploitation was thus already a process where the bodies of the miners, mineral matter, technologies, infrastructures, and the natural environment were tightly entangled.

Of all these different effects of mining, Bermann only mentions the human-induced climate change, which he understands and praises as technological progress:

Ancon: I think the weather is very clear and pleasant at this time of year. I don’t know how it is in autumn and winter.

Bermann: In the past we, mainly in the seasons you mentioned, had so much and dense fog that they covered the whole valley and sometimes even stole the sight of the sun from us. Back then someone could have rightly said that we lived in the fog and darkness no different than the Cimmerians. Now, however, the forests have been chopped down and also the numerous adits have been driven into the mountains, through which the water runs off. That is why the fog has disappeared, just as the mountains have become drier and the air freer. And so our valley is no longer surrounded and hidden by the fog! (Agricola 1530, pp. 27–28, translated by Tina Asmussen).\(^8\)

Bermann’s appreciation of the miners’ large-scale intervention to local landscapes is based on an understanding of nature as something that could be manipulated and improved by technology and human labor, but which, as we will see, does not stand in opposition to nature.

Agricola’s text and also contemporary writings, for instance on mining diseases (Paracelsus 2013 [1533–1535]), aptly show that pre-industrial societies reflected on human impacts on the natural environment and its various subsequent consequences on several layers, which included religious belief, discourses on nature, emotions, symbols and images.

In the following I’ll expand on these different layers and propose shifting our attention from a quantitative understanding of environmental damage to a more holistic understanding of intervention into the natural world, in which the idea of the divine household plays a central role—

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\(^7\) NAE: Deum immortālē quot & quāta ædifica, que tū vallem tegunt, tū ita montibus ex utraq. ipsius parte herent, ut alterū alteri quasi incumbere videatur: aliqūa ex magnis urbibus nostris Erphurdim puto vel Pragam pene videre mihi videor, aut quātas Italia habet Bononiam & Patavium: & autio, quod magis mirum, perpaucos esse annos ex quo fodinæ hic cultæ sunt.

\(^8\) Aër satis serenus & gratus est in valle hac anni tēpore, qualis vero in autumno & hyeme sit ignoro. BER. Solebant quo fodiæ hic cultæ sunt.
since nature has been distorted by the Fall and needed restoration and cultivation to get back its divine state, techniques of land management and improvement were subjected to divine providence (Mukerji 2002). Art, engineering and more generally the manipulation of material matter were perceived as a noble and virtuous service of God.

A crucial text that is often mentioned in the context of the early environmental impacts of mining and which is used as reference for the clashing of the organic and mechanistic world views, is the late fifteenth-century dialogue entitled *Judicium Iovis* [Jupiter’s Judgement] (around 1490), written by the Bohemian humanist Paulus Niavis’ or Schneevogel. Niavis’ text deals with a mythological court case, where Mother Earth with Mercury as her lawyer sues a miner before the judge Jupiter. The plot takes place in a remote landscape in the Erzgebirge near Schneeberg, a hotspot of the late fifteenth-century European silver rush. In the *Judicium Iovis* the personified Earth is introduced as a chaste and generous woman with a pale face and dressed in a green garment. Tears are streaming from her eyes and her head shows injuries. Her dress is torn and her body is punctured in many places. Mercurius accuses the miner of having committed ‘matricide’ (*parricidi accusatus*) and speaks to Jupiter:

> The earth bears fruit year after year, which nourishes and sustains all living things. In the end, all of this is for one: for the sake of man alone, she brings all this forth. But not satisfied with this goodness, man penetrates into the entrails of his mother (*matriis aperit viscera*), he ransacks her womb (*perforat ventrem*), injuring and damaging all the inner parts (*offendit singula intestina*). And finally rips the entire body apart and paralyses its power completely (*corporis et membrorum debilitat*). (Niavis 1953, p. 16).

After having discussed the greedy practices of the plundering ores by the miners, he addresses Earth’s body once again:

> May Your Majesty [i.e. Jupiter] recognize how severe the maltreatment is, if you look at her once from top to toe, her body is full of wounds (*confossam*) and splattered with blood (*sanguine conspersam*); her whole body is covered with blood and looks awful (*totum corpus cruore tectum est*). There is no trace of grace and beauty anymore, her appearance has completely changed from before (*vetus eius ymago mutata est*). (Niavis 1953, p. 17).

The miner replies in his defense with reference to Pliny the Elder that Earth has no end in itself, but was created solely for the sake of humans. He accuses Earth of hiding out of resentment what the gods have generously given and behaving no better than a miserly “stepmother”: “I feel nothing of a mother’s love in you, but I do feel the attitude of a stepmother (*noverca*), who effectively has no love or affection for the children she has to raise.” (Niavis 1953, p. 33). In the seventh book of the *naturalis historia* Pliny states that man has to pay a “cruel price” for his existence—he had been thrown naked into the world and first had to laboriously earn his ability to prove himself in nature (Pliny 1961, p. 507). He thus leaves it open if nature is a benevolent mother or a malicious stepmother.

Interestingly enough, Niavis’ Jupiter abstains from judgement. He hands this task over to the fickle goddess of fortune (*Fortuna*) and she submits her judgement in favor of humans in a letter which is proclaimed by Jupiter:

> It is humans’ destiny to ransack mountains (*hominen debere montes transfodere*); they have to dig pits (*metallifodinas perficere*), they have to cultivate lands (*agros colere*), and do trading business. By doing this they have to offend nature (*terram offendere*), they have to reject the sciences (*scientiam abiecere*), disturbing Pluto (*Plutonem inquietare*) and even search in waterways for ores. But their

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9 For an excellent recent interpretation of the *Judicium Iovis* see Usher (2019, pp. 24–40); the most substantial interpretation of the *Judicium Iovis* is provided by Bredekamp (1984). See also Bredekamp (1981) and Böhme (1988).

10 I have translated the following passages into English from the German translation by Paul Krenkel. Important terms from the Latin version (Niavis, n.d. [*circa* 1590]) are added in brackets.
body will be devoured by the Earth (a terra conglutiri), suffocated by poisonous airs (vapores suffocari); it gets drunk from wine (vino inebriare) and suffers hunger (fame subici) – but, there is a good thing about it: no one knows all dangers of any kind that simply cannot be separated from human beings. Good bye. (Niavis 1953, p. 38)

Fortuna depicts humans as being pushed by labor into the inner parts of the Earth, where they brutally extract resources and cause environmental damage. However, while doing this their own bodies are put at risk. The judgement of the goddess Fortuna and her emphasis on the burden of work—which enables the preservation of human life, but which also leads to corruption and decay—makes sense from a biblical perspective: work only became a pressing reality after the fall of humans (Gen. 3, 17–19; 23). Ansgar Stöcklein elaborated in his thoughtful study on the visions of technical progress. He showed how sixteenth and seventeenth century machine books build on the biblical narrative of the origins of work, while emphasizing that men should facilitate the divine punishment through art and craftsmanship. The authors stress regularly that the benefits from the mechanical arts are neither self-evident nor descend from human nature and intellect, but are far more a gift of God. From God’s revelations and enlightenment come all the new inventions that secure and facilitate human life outside of Paradise (Stöcklein 1969, especially pp. 36–52). The mechanical arts, thus, offer the fallen man the tools to exist but on the other hand caused new working conditions and new risks.

Ironically, Niavis assigns Mercury, the god of commerce, trade, communication and theft, to defend the position of Earth, and most curiously the latter argues in favor of a rural subsistence economy. Turning Mercury into an advocate of a pre-industrial peasant economy, although mining was an arena in which the transition from agrarian to market economies was striking, is puzzling and needs further research.

Fortuna’s last vote makes clear that the Iudicium Iovis is not just an early text that criticizes the exploitation of nature and the environmental impacts of resource extraction. More generally it addresses the challenges of new working conditions in an expanding economic and mercantile industry to nature and humans. Mechanized extraction technologies, division of labor, official administration and wage labor were characteristic of the mining industry since the sixteenth century. Family businesses, small-scale technology and cooperative associations were replaced by models with decidedly capitalist features: the practice of silent partners became a dominant business model, necessary due to the high investment costs involved in opening up new mines and in pumping, extracting and smelting facilities. Moreover, the machines became increasingly complex and expensive, enabling the expansion into deeper layers of rock. Going deeper underground made mining not only more expensive, but also more dangerous for the miners. Therefore, even if Fortuna judges in favor of humans there are no clear winners in this story. She describes a complex economic cycle motivated by God that affects both bodies: the body of Earth and the human body in a micro-macrocosmic relationship. The divine economy of mining proclaimed by Fortuna resembles a metabolic cycle: the cyclical course of the year, in which landscapes flourish, bear fruits and vanish again in winter, corresponds to the natural cycle of humans, their birth, life and death. As miners descend into the inner parts of the Earth and extract resources, their own bodies risk being devoured. The human body and the Earth are equally affected by the practices of resource extraction. The Iudicium Iovis does not depict a human domination of nature, which has been degraded into a passive container of natural riches. Rather it depicts nature as a divine household that humans maintain and in which they themselves are brutally caught and kept as laboring beings. Nature appears to be entirely connected to humans and to technology by chains of dependence and reciprocities.

A few decades later Paracelsus made a similar point in his medical treatise Von der Bergsucht und anderen Bergkrankheiten [On miners’ sickness and other miners’ diseases], which was probably written around 1533–1535 and published posthumously in 1567. Paracelsus reflected on the rise of occupational diseases among miners as a concomitant result of industrial development: “we must also have gold and silver, also other metals, iron, tin, copper, lead, and mercury. If we wish to have these, we must risk both life and body in a struggle with many enemies.
that oppose us.” (Müller 2013, p. 44; translation by Rosen 1943, p. 75).

In Agricola’s De re metallica the brutality of human labor and its destructive effects are transformed into a more conciliatory exchange: he describes a bountiful nature that generously offers her riches to virtuous miners; however, the physical and moral dangers and risks of mining still have a prominent place. Agricola refers to the dangerous and risky mining practices, which is dedicated to the miners’ work.¹² In book VI, he describes and illustrates mining tools and machines in great detail and expands on how working underground endangers the miners’ lives and health, particularly with regards to the problems of air supply or poisonous vapors and accidents in the dark mines.¹³

As we see from these examples, the vision of an entirely connected nature was not at all restricted to a mechanistic view of material exchanges, nor was the process of mechanization and environmental transformation ever detached from the organic or bodily context. As Pamela Smith has shown, the entanglement of the miners’ bodies with matter was particularly evident. The miners’ specific manual labor influenced their musculature and posture, and the matter on which they worked also marked their bodies with distinctive diseases (Smith 2015, 2017 and also 2004). All interventions to nature led to numerous consequences or side effects and formed an ongoing cycle of production and decay. Humans not only produced, manufactured, exchanged or consumed resources and transformed landscapes they also became increasingly entangled with and dependent on them through their bodily and mechanical work and maintenance.¹⁴ This new form of human-technology-nature entanglement in the context of the proto-industrial mining economy has been reflected and addressed by authors such as Niavis, Paracelsus and Agricola.

4. CULTIVATING RESOURCES ABOVE AND BELOW THE GROUND AS A FORM OF UNDERSTANDING GOD’S CREATION

The entanglement of the bodies of humans and of the earth in both spiritual and material regards becomes even more evident when the domain of resource extraction is analyzed from the perspective of natural philosophical theories of mineral generation.

I do not wish to dive into the complex theories of mineral generation at this point, since Francesco Luzzini’s article in this special issue discusses them in detail. I rather would like to stress the widely shared notion of generation and growth of minerals and metals in analogy to human and animal bodies and their work. The comparison between the veins of the earth and of the body had been used to explain weather since Aristotle (King 2012, p. 13). Perceiving the metals in analogy to plants made sense for those people who frequently visited the mines, had direct contact to miners or who actually went down with hammers and picks: native silver indeed looks like a small tree or a ramified twig and native copper can also produce branching formations.

¹¹ “Darbee auch gold vnd silber mussen wir haben, auch andere metallen, eisen, zinn, kupffer, bley, quecksilber, so wir dasselbigen haben wollen, so mussen wir darbay wagen leib vnd leben, mit fienden so gegen vns standen, also auch so wir ander dingen haben wollen, das wir zu nutz vnsers gesondes lebens gezwungen werden zugebrauchen, so ist nichts, das nit vnsern feind mit ihm trage.” (Paracelsus 2013, p. 44).
¹² “I will now speak first of all, of the iron tools with which veins and rocks are broken, then of the buckets into which the lumps of earth, rock, metal, and other excavated materials are thrown, in order that they may be drawn, conveyed, or carried out. Also, I will speak of the water vessels and drains, then of the machines of different kinds, and lastly of the maladies of miners. And while all these matters are being described accurately, many methods of work will be explained.” (Agricola 1950, p. 149).
¹³ “[...] some metalliferous localities, though such are rare, spontaneously produce poison and exhale pestilential vapor, as is also the case with some openings in the ore, though these more often contain noxious fumes. In the towns of the plains of Bohemia there are some caverns which, at certain seasons of the year, emit pungent vapors which put out lights and kill the miners if they linger too long in them [...] Further, sometimes workmen slipping from the ladders into the shafts break their arms, legs, or necks, or fall into the sumps and are drowned [...]. Mountains, too, slide down and men are crushed in their fall and perish. In fact, when in olden days Rammelsberg, in Goslar [central Germany], sank down, so many men were crushed in the ruins that in one day, the records tell us, about 400 women were robbed of their husbands. And eleven years ago, part of the mountain of Altenberg [in Saxony], which had been excavated, became loose and sank, suddenly crushed six miners; it also swallowed up a hut and one mother and her little boy.” (Agricola 1950, p. 216).
¹⁴ On the aspect of human-thing entanglement see Hodder (2012).
The Italian metallurgist Vannoccio Biringuccio (1480–1539) used the analogy between the animal, vegetable and the mineral realms when discussing the location of ores. For him the things in the underground were mutually connected to the surface by various signs:

They [the ores] show themselves almost like the veins of blood in the bodies of animals, or the branches of trees spread out in different directions. Indeed, careful investigators of minerals, wishing to show by analogy how ores are located in mountains, have drawn a large tree with many branches, planted in the middle of the base of a mountain. From its principal trunk extend various branches, some thick, some slender, exactly like real trees in mature forests. They think that these grow and enlarge continually and draw themselves toward the sky, ever converting into their own nature the most disposed adjacent materials so that finally the tips arrive at the summit of the mountain and emerge with clear sign, sending forth, in place of leaves and blossoms, blue or green fumosities, marcasites with small veins of heavy mineral, or other composition of tinctures.¹⁵ (Biringuccio [1540] 1966, p. 13).

Agricola used a vocabulary of generation and growth when discussing the occurrence of silver in the mining area of St Joachimstal:

This silver ore can also be found in very different forms. There are surprisingly large masses in the side cords of the ore veins. It is, so to speak, found as in formal nests. Moreover, it can be found like buds sprouting from flowers.¹⁶ (Agricola 1530, p. 73).

Agricola’s theory of mineral generation, which he formulated elaborately in his later works De ortu et causis subterraneorum libri V (Basel, 1544) and De natura fossilium (Basel, 1546) was based on mineral juices that he sees in analogy to the humors of ancient physiology: various types of water and juices in the Earth are generated by their innate warmth just like the humors are generated in the bodies of animals (Hirai 2005, p. 119–120; Norris 2007).¹⁷ This makes clear that also for Agricola the mineral realm was not a separate domain. Rather it is connected to animal and vegetable bodies through the principle of humors. This perception also becomes visible in terms of utility: in the first book of De re metallica (1556, pp. 1–18) Agricola defends mining against its critics, who consider it as the downside—in a literal and moral sense—of praiseworthy, noble and fertile agriculture: as with the soil, the underground has to be cultivated in order to bring rewards. Cultivating God’s creation above and below ground was not only a metaphor, it was also an empirically founded understanding of nature shared by practitioners and learned humanists alike.

The idea of perceiving the mineral realm in analogy to the animal and the vegetable was discussed by Pliny, Strabo and Albert the Great and received much interest among neoplatonist thinkers such as Henricus C. Agrippa von Nettesheim, Paracelsus, Girolamo Cardano, Bernardino Telesio, Francesco Patrizi and Giordano Bruno to Tomasso Campanella, the Rosicrucians and Robert Fludd (Merchant 1983, pp. 99–126; Oldroyd 1974). Among practitioners, miners and alchemists, the writings and ideas of Paracelsus (1493/1494–1541) gained a considerable influence

¹⁵ Interdum ut gemmæ ex arboribus pullulascent...

¹⁶ ‘Invenitur & hoc varia ratione. Interdum enim massa magnitudinis cannalibus venarum, tanquam in nido quodam reperientur. Interdum ut gemmae ex arboribus pullulascent...’

¹⁷ He explicitly distanced himself from Albertus, who wrote in his De mineralibus that the growth of different minerals is to be attributed to the power of the stars (Agricola 1546, pp. 133, 180). Further he opposed theories that perceived sulfur and mercurius as compositional principles of all metals, which is most prominently articulated in the work of Paracelsus (Agricola 1546, pp. 166–169; Norris 2007, pp. 73–76).
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(Smith 2004, pp. 82–94 and 155ff). On his numerous journeys Paracelsus visited all the important mining regions in Saxony, Bohemia, Slovakia, Transylvania and Slovenia. In these places he received a broad range of knowledge about minerals and metals from miners, ore tasters, smelters, alchemists, mint masters and other practitioners. Especially during his stay in Schwatz in 1522–1523 he learned about the effects of chemical substances on the health of the people (Soukup 2004, pp. 195–248). His philosophy of nature was based on the correspondence between the world (macrocosm), and the human being (microcosm) (Gantenbein 2000). Paracelsus adopted the concepts of “seeds” that was developed in Renaissance neoplatonism and alchemy and placed it at the core of his natural philosophy and theology, seeing God as the primordial seed of everything (Hirai 2005, pp. 179–215; Hirai 2020). For Paracelsus, only experience and manual labor enable knowledge of nature. Understanding and experiencing nature was for him a “form of worship, giving humans an understanding of God’s creation” (Smith 2004, p. 84). In accordance with other authors of mining books such as Ulrich Rülein von Calw (1465–1523), he promoted an organic conceptualization of ores that becomes visible in terms of procreation and giving birth.18 The Bohemian metallurgist Nicolaus Solea (n.d.), heavily indebted to Paracelsus’ ideas, gives detailed information about the entire lifecycle of metals: in his Büchlein von dem Bergwerk [Booklet on mining, 1600] he describes the generation or “semen” of metals (pp. 4–8), their food (pp. 8–11), or their inhalation (pp. 26–29) and exhalation i.e. dying (pp. 29–33). Within this organic perception of the mineral domain the process of growth and refinement of metals is described as a workplace that resembles a church in which the metallic spirits eat, rest and work (“De officina metallorum”, pp. 11–14). This chapter makes particularly clear that hard work was the basic principle of all life on earth on every level of creation.

Nevertheless, human labor in the mine and nature’s labor underground was engaged with vital matter: in contrast to our modern belief, metals were perceived as animated, changeable, renewable, and some even thought they were able to regenerate when the mines were abandoned by the miners (see Luzzini’s article in this special issue with further literature). The latter was formulated by Johannes Mathesius (1504–1565), the Lutheran priest and pastor of the mining town of St Joachimsthal in his printed collection of mining sermons Sarepta oder Bergpostilla (1562, especially the Third Sermon, pp. XXXVIII–LVII).19 He further stated that metals would develop very slowly from base metals to precious metals:

So arises the common occurrence among our miners that when they strike a nice bismuth, they say they came too early; by which they mean that if the ore had only sat longer in the mountain fire, it would have become silver. (Mathesius 1562, p. L).

In all these texts from authors with medical, alchemical or theological backgrounds, mining is characterized as an economic, empirical and spiritual undertaking: Solea described the mine as a workplace and underground church (Solea 1600, p.12), Mathesius depicted it as God’s metallurgical laboratory (Mathesius 1562, p. XLI), and Paracelsus regularly drew analogies from his medical or metallurgical practice to the Christian doctrine of salvation, for example, when the distillation and the removal of slag during the refining of metals is seen as a metaphor for the resurrection of Christ (Gantenbein 2000, p. 20). A significant image illustrating the divine agency is found in the manuscript Speculum metallorum [Mirror of the metals], which contains alchemical sections by Martin Stürz, a descendant of a Saxon mining family (Stürzt, Basel Codex 1597, p. 5r–8r; Kirnbauer 1961). The visualization of the generation of metals connects metallurgical knowledge with theological interpretation (Figure 2).

18 “Hierher gehört nun das gemeine zugnuß unser Bergkleut/ wenn sie einen schönen Wißmat erschlagen/ pflegen sie zu reden/ wir sind zu früh kommen/ damit sie bekennen/ wenn diese bergart linger im bergfewer gestanden/ so were gut silber drauß worden.” (Mathesius 1562, p. 50).
19 "Item in der vermisschungader vereynigung deß quecksilbers und schwefels im ertz helt sich der schwefel als der menlych som und daß quecksilber als der weiblich sam in der geberung oder entpfähung eynes kindes.” (Rülein, 1518 [1500], p.n.)
Behind a crucified Christ seven ribbons are depicted that represent the seven metals with their corresponding planetary sign and colors: lead (Saturn, black), tin (Jupiter, blue), iron (Mars, red/brown), gold (Sun, gold), copper (Venus, green), mercury (Mercury, red) and silver (Moon,
silver/grey). In this illustration an analogy is created between the suffering, death and salvation of Christ and the generation of mineral matter (Vienna Codex 1575, fol. 20r.; Kirnbauer 1961, p. 22). These examples underscore Horst Bredekamp’s argument, that a mine run by virtuous miners was not only a form of work which appealed to God, but also became a symbol of the redemption of matter and humans at the same time (Bredekamp 1981, p. 17). Therefore, not only with regards to the practices (and consequences) and benefits of mining but also with regards to the theories of metallogenesis (generation of metals) we see that labor is considered as an essential factor, which determines and enables natural and human forms of resource production. We thus should not restrict labor solely to the domains of economy, industry and production. For a broader understanding of the early modern resource economies of mining it is essential to connect the economic implications of labor with its natural philosophical and spiritual meanings.

5. CONCLUDING REMARKS

The disruption of the forest ecosystem by the rise of early modern (mining) industry, combined with a careless use of resources, bears striking parallels to modern environmental problems. Carolyn Merchant, for instance, argued that our present environmental crisis differs only quantitatively and not qualitatively from the past (Merchant 1983, p. 67). In current Anthropocene research, the scale and intensity of the human footprint in the history of the earth is measured by means of quantitative data and models which are compared to pre-industrial values and end up in exponential graphs (see for instance, Steffen, Crutzen and McNeill 2011). The Anthropocene is understood as a qualitative leap caused by the quantitative increase and extension of human transformative actions. Despite the alarming evidence for this argument today, it is in danger of returning to scientism, i.e. claiming natural objectivism without historical subjectivity. 20

It is the task of historians to approach the subject of human agency on earth not just as an objective effect of mechanistic factors, but as the interaction of choices, beliefs, worldviews and passions.

In the divine oeconomy of mining, mineral ores appear as materials interwoven with bodily labor, technological inventions and challenges, financial promises, ideas of divine providence and redemption, as well as with expectations of discovery. The material history of natural resources, which can be quantified in terms of extraction rates, price and weight and which is based on work and technology, must therefore be expanded to include the material imaginaries, which entangle early modern practitioners with the materials and the environment.

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20 See Bonneuil and Fressoz (2016, especially pp. 69–83), for a sharp critique on the grand narrative of the 'anthropocenologists'.
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