

Ecological Impacts and Environmental Perceptions of Mining in Europe, 1200–1550: Preliminary Notes

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The proliferation of mines in Europe since the late twelfth century is well documented, but only recently have scholars begun to fathom the scale of the industry's ecological impact, on the one hand, and its role in stimulating environmental thinking and action, on the other. Focusing on the extraction and processing of metal ores, this article begins by illustrating how the nascent sector reshaped different ecosystems, as traced by several palaeo-scientific methods. It then turns to cultural-historical sources to propose that, rather than becoming passive, unwilling, or ignorant victims of a polluting industry, contemporaries criticised what they perceived as extraction's harms and sought to reduce them, but also developed ways to justify their risks. Communities' actions, which mingled with the materiality of mines and their surroundings, wrote a major chapter in Europe's environmental history, one whose ongoing impact remains poorly understood.

I. Introduction

Few industries capture the aggression of modernity, imperialism, and global capitalism more truthfully than mining. Since the sixteenth century, European powers and their private proxies have waged a relentless campaign of extraction across the world's 'new resource frontiers', often involving the excavation and processing of metal ores.¹ Environmental historians thus rightly see mining as ushering in a rampant era of ecological degradation under the auspices of European colonialism and industrialisation.² The latter's documented ruthlessness,

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¹ The literature here is vast. For a recent review see Per Högselius, 'The Historical Dynamics of Resource Frontiers', *N.T.M. Zeitschrift für Geschichte der Wissenschaften, Technik und Medizin*, 28 (2020), 253–66.

² Recent works include: Nick Bainton and Martha Macintyre, *The Lihr Destiny: Cultural Responses to Mining in Melanesia* (Canberra: ANU E Press, 2010); Nicholas A. Robins, *Mercury, Mining, and Empire: The Human and Ecological Costs of Colonial Silver Mining in the Andes* (Bloomington: Indiana University Press, 2011); Kuntala Lahiri-Dutt, ed., *The Coal Nation: Histories, Ecologies and Politics of Coal in India* (London: Routledge, 2016); and Paula Butler, *Colonial Extractions: Race and Canadian Mining in Contemporary Africa* (Toronto: University of Toronto Press, 2019).

however, has inadvertently given earlier mining, including in Europe, a benign ‘preindustrial’ air. For instance, while the authors of a recent global history of pollution stress that ‘every mine—even the smallest—in some way damaged the environment’, they chose to periodise their work into an *ancien régime* and all that followed, showcasing mining as a unique driving force behind modern, that is to say genuinely impactful, pollution.³ This, despite the exponential growth of metal use in military, agriculture, construction, and trade, and the operation of many hundreds if not thousands of extraction sites in Europe since the late twelfth century (Figure 1).⁴ Obscuring the scale and scope of what may be called Europe’s underground cathedrals provides ‘the Middle Ages’ with a rare respite from its unsavoury hygienic reputation, if only as a reflection of the era’s technological ‘deficit’. Before the harnessing of steam, electricity, and the internal combustion engine—indeed, before the introduction in the seventeenth century of industrial explosives—ore extraction and metal production in Europe is easy to imagine as an artisanal and even heroic endeavour with negligible environmental consequences.⁵ In part, this is a question of optics: where local operations continued into the twentieth century and until the present, signs of earlier extractive efforts have mostly been obliterated. And where mining ceased altogether, the relief allowed sites to revegetate or (sub)urbanise. New green mantles in particular allowed heirs of former mining communities to celebrate the bucolic landscapes now framing remnants of an innovative technological past and its unique cultural heritage.⁶ As this article begins to show, however, from both a palaeo-ecological and cultural-historical perspective, the accepted periodisation is worth revisiting, with several implications laid out in the conclusion concerning Europe’s long-term environmental history.

While mining operations never entirely ceased in Europe (including the British Isles and Scandinavia) since late antiquity, relatively low-grade extraction gave way to a marked acceleration in the later twelfth century.⁷ By the early

³ François Jarrige and Thomas Le Roux, *The Contamination of the Earth: A History of Pollutions in the Industrial Age*, trans. by Janice Egan and Michael Egan (Cambridge, MA: MIT Press, 2020), p. 43.

⁴ The literature on preindustrial extraction in Europe is substantial and often region-specific. A major study, focusing on technology, commerce, and economics, is Ian Blanchard, *Mining, Metallurgy and Mining in the Middle Ages*, 3 vols (Stuttgart: Franz Steiner, 2001–05).

⁵ John U. Nef, *The Conquest of the Material World* (Cleveland, OH: Meridian Books, 1967), pp. 3–64; Jeanette Graulau, *The Underground Wealth of Nations: On the Capitalist Origins of Silver Mining, A.D. 1150–1450* (New Haven, CT: Yale University Press, 2019), pp. 33–37.

⁶ For instance, the UNESCO World Heritage site concerning the Ore Mountains linking Germany and the Czech Republic describes it as a ‘cultural landscape’ and boasts the area’s mining as a ‘trigger for technological and scientific innovations transferred worldwide’. All true, yet the text is silent about the industry’s ecological impact locally and in its exported form. See ‘Erzgebirge/Krušnohoří Mining Region’, UNESCO <<https://whc.unesco.org/en/list/1478/>> [accessed 23 July 2022].

⁷ On ancient and early medieval mining, see Oliver Davies, *Roman Mines in Europe* (Oxford: Clarendon Press, 1935); Beno Rothenberg, ed., *Studies in Ancient Mining and*

sixteenth century the region's miners probably numbered well over one hundred thousand, and their work's impact on countless ecosystems, including non/human animals and their health, was substantial.⁸ The darker aspects of the renascent sector have come into sharper relief in recent decades. Chemical analyses of soils, lake sediments, and ice-cores, palaeopathological studies of skeletal remains, and remote-sensing reconstructions of local topographies below and above the ground have begun to provide a finer-grained, if still partial, view of the industry's many footprints, as set against an equally complex ecological background. Mining historians and archaeologists have also begun to trace communities' understanding of these changes and their responses to them, although an integrated regional picture remains a desideratum. The present article is a preliminary attempt to bring both approaches into systematic dialogue, combining some of the era's major mining areas. It distinguishes between present-day (etic, universalist) ecological dynamics and the *variety* of cultural-insider (emic) conceptualisations of the environment, nature, or indeed Creation.⁹ Addressing both aspects in turn, it highlights the value of their respective evidence and methodologies without necessarily seeking to reconcile their findings. Given the field's vast scope, the argument is mostly limited to the extraction and processing of metal ores, which have recognised polluting impacts both then and now, and covers the period from the sector's take-off in the late twelfth century to mining's consolidation as a specialised field of knowledge in the mid sixteenth.

Metallurgy in South-West Spain: Explorations and Excavations in the Province of Huelva (London: Institute of Archaeo-Metallurgical Studies, 1981); Alfred Michael Hirt, *Imperial Mines and Quarries in the Roman World: Organizational Aspects, 27 BC – AD 235* (Oxford: Oxford University Press, 2010); Harald Witthöft, 'Early Medieval Mining and Smelting in the Harz Mountains—Historical Perspectives', in *Aspects of Mining and Smelting in the Upper Harz Mountains (Up to the 13/14th Century) in the Early Times of Developing European Culture and Economy*, ed. by Christiane Segers-Glocke and Harald Witthöft (St Katharinen: Scripta Mercaturae, 2000), pp. 99–118; and Zoltán Batizi, 'Mining in Medieval Hungary', in *The Economy of Medieval Hungary*, ed. by Jozsef Laszlovszky (Leiden: Brill, 2018), pp. 166–81. One qualitative difference between the scale of these activities and those at the focus of this article comes to light in the legal sphere: prior to 1200 no civilisation produced a corpus of mining legislation or anything remotely resembling the scale of ordinances on the matter issued by diverse European landlords and rulers. See Guido Christian Pfeifer, '*Ius Regale Montanorum*': *Ein Beitrag zur spätmittelalterlichen Rezeptionsgeschichte des römischen Rechts in Mitteleuropa* (Ebelsbach: Aktiv, 2002); Roberto Farinelli and Giovanna Santinucci, eds, *I codici minerari nell'Europa preindustriale: archaeologia e storia* (Florence: All'Insegna del Giglio, 2014); and G. Geltner, 'Mine Air Makes Free? Rural Liberty, Materiality, and Agency in Europe's Long Thirteenth Century', *Journal of Social History*, 56 (2023), shac064 <<https://doi.org/10.1093/jsh/shac064>> [accessed 16 January 2023].

⁸ The number, which is logical but has never been tested empirically, is based on a letter from Charles V concerning the Habsburg Empire, cited by Nef, p. 43.

⁹ For a recent discussion, see Velichko H. Fetvadjev and Fons J. R. van de Vijver, 'Measures of Personality Across Cultures', in *Measures of Personality and Social Psychological Constructs*, ed. by Gregory Boyle, Donald H. Saklofske, and Gerald Matthews (San Diego, CA: Elsevier Science and Technology, 2015), pp. 752–76.



Figure 1.

Mining sites in Europe, 1200–1550. While each location is grounded in historical and/or archaeological sources, the map remains incomplete, and draws on a continuously updated dataset.

(Map by Léa Hermenault, Sarah May, and G. Geltner)

II. Preindustrial Mining Ecologies

Whether minor or extensive, many of Europe's earlier mining sites eventually vanished under mechanised efforts or else fell into disuse, disappearing behind new vegetation or human construction. Even where mining landscapes remain in full view, the naked eye struggles to detect the sometimes-dramatic changes they underwent, from the deposition of toxins, to the destruction and introduction of species, to the creation of new topographies both above and below the ground. Extraction did not necessarily take place in pristine rural areas, yet several studies concerning what are now France, Italy, Germany, Sweden, and the Czech Republic have unearthed its development and variety.¹⁰ Collectively these works underscore how different admixtures of topography, geology, climate, technology, and of course human behaviours shaped different ecological processes. The present section brings these insights together in a preliminary way; given the still fragmentary state of this field, no comprehensive view is yet possible, although the evidence so far suggests ample possibilities to extrapolate from the available data onto a larger regional picture. As the present section argues, palaeo-scientific

¹⁰ This is not to diminish from the relevance of other mining regions, including the Balkans, Iberia, and the British Isles, but rather reflects the currently available palaeo-environmental studies concerning (former) mining sites.

studies as a whole provide one path to understand, especially from the perspective of bio- and geochemistry, the scale of the sector's impact centuries before industrialisation, and establish mining's role in precipitating a new ecological era earlier than is commonly thought. The role of miners' and mining's *perceptions* as triggering environmental change will be the focus of the next section.

To begin with the least visible agents: mining for metal, and above all the processing of metalliferous ores, released hazardous chemicals into the environment, whatever the scale of the works being carried out. Their poisonous particles impacted humans, fauna, and flora near and far, both immediately and in the longer term, as they embedded themselves into the biosphere and travelled through air and water to further sinks.¹¹ The presence and distribution of such deposits are now being tapped as archives of mining and smelting activities in their own right, enabling scholars to chart their chronologies by supplementing and in some cases compensating for a lack of written evidence.¹² For instance, the earliest written record of activities at the major copper mine at Falun, in central Sweden, dates to 1288, although an uptake in deposits of lead, copper, zinc, cadmium, and sulphur in nearby soils and lakes attests regular extraction from around the year 1000 at the latest and in an accelerated manner from about 1250.¹³ Notable among the mine's ecological impacts, sulphur dioxide and metal deposits heavily and sometimes irreversibly acidified local soils to a depth of between 50–100 centimetres and for up to a twelve-kilometre radius. This was most likely due to roasting the sulphur-rich ores in the open air well outside the mine (see the next section) as a preliminary measure, which was exacerbated by subsequent smelting and secondary reductions involving more oxidation.

Soil deposits attest not only when mining activities initially took place but also their changing pattern over time. While the Falun mine's sulphur dioxide emissions peaked in the seventeenth century at above 35,000 tonnes per year, already by the year 1500 they reached nearly 5000 t/y, that is just higher than their 1990s levels (the mine closed in 1993). In other words, the emissions of this major mine trace a different path from that of a negligible impact followed

¹¹ Maja-Lena Brännvall and others, 'The Medieval Metal Industry Was the Cradle of Modern Large-Scale Atmospheric Lead Pollution in Northern Europe', *Environmental Science and Technology*, 33 (1999), 4391–94.

¹² José-Ignacio Manteca and others, 'Early Metal Pollution in Southwestern Europe: The Former Littoral Lagoon of El Almarjal (Cartagena Mining District, S.E. Spain). A Sedimentary Archive More than 8000 Years Old', *Environmental Science Pollution Research International*, 24 (2017), 10584–603; Joseph R. McConnell and others, 'Pervasive Arctic Leads Pollution Suggests Substantial Growth in Medieval Silver Production Modulated by Plague, Climate, and Conflict', *Proceedings of the National Academy of Sciences of the United States of America*, 116 (2019), 14910–15; Michael Opare Asare and Jerry Owusu Afriyie, 'Ancient Mining and Metallurgy as the Origin of Cu, Ag, Pb, and Zn Contamination in Soils: A Review', *Water, Air and Soil Pollution*, 232 (2021), 240 <<https://doi.org/10.1007/s11270-021-05166-4>> [last accessed 16 January 2023].

¹³ R. Bindler and J. Rydberg, 'Revisiting Key Sedimentary Archives Yields Evidence of a Rapid Onset of Mining in the Mid-13th Century at The Great Copper Mountain, Falun, Sweden', *Archaeometry*, 58 (2016), 642–58.

by sudden and ruinous peak created during the Industrial Revolution. What is more, the emissions' particles settled into the earth in a roughly concentric pattern radiating from the mine outwards, yet also conforming to the northwest–southeast orientation of the valley in which it lies. Finally, they left significantly heavier deposits in forested areas than in non-forested ones, where they were less likely to resist being washed away. Within a radius of around 1.5 kilometres from the mine, such deposits reached a critical load after the thirteenth century, that is, they exceeded the area's assimilative capacity, also known as weathering.¹⁴ Toxicity would have therefore been too high for trees to survive, or rather regrow, given that they were quickly cut down for timber reinforcement in the mine and to produce charcoal for processing ores. However, the area's climate and agricultural land-use meant that, beyond this inner zone, harmful deposits could mostly be weathered before the intense seventeenth-century exploitation, and indeed none of the eight local lakes that were eventually acidified did so before 1600.¹⁵ In sum, while around the year 1550 Falun's major biochemical impacts lay just ahead of it, toxins were amassing throughout the valley apace.

The northern German ore-mining region of the Harz provides another example of ecological change, yet this time in a more typical (for Europe) mountainous region, with intense extraction attested already between the twelfth and fourteenth centuries.¹⁶ Here, geochemical as well as palaeo-botanical studies evince widescale impregnation of soils with metal particles, mostly produced through washing, roasting, and smelting ores. By killing numerous microorganisms the latter processes have prevented the decomposition of plant remains, which in turn allowed them to be preserved until this day and be collected and analysed. Not surprisingly, they exhibit high values of zinc, lead, and copper, and demonstrate how even small-scale manual industries inhibited fundamental biological processes and prevented the regrowth of original flora. Furthermore, emissions likely harmed humans directly through water- and airborne toxins and indirectly via wild and domesticated animals' drinking and grazing on poisoned grounds. Hundreds of small smelting ovens operated along water routes, as still attested today by the numerous visible slagheaps or else the toxic particles they left behind, and these accelerated and extended the pollution of local sinks. For instance, sediments from a lake on the western escarpment of the Harz record a sharp rise, especially of lead content, in the thirteenth and fourteenth centuries, reaching densities 600 times greater than in their natural background.

¹⁴ On the origins of this quintessentially etic term, see Harold W. Streeter and Earle B. Phelps, *A Study of the Pollution and Natural Purification of the Ohio River. III: Factors Concerned in the Phenomena of Oxidation and Reaeration* (Washington, DC: U.S. Department of Health, Education, and Welfare, 1958). For a recent critique, see Max Liboiron, *Pollution Is Colonialism* (Durham, NC: Duke University Press, 2021), esp. 39–80.

¹⁵ Anna S. Ek and others, 'Environmental Effects of One Thousand Years of Copper Production at Falun, Central Sweden', *Ambio*, 30 (2001), 96–103.

¹⁶ Katharina von Kurzynski, ed., *Schätze des Harzes. Archäologische Untersuchungen zum Bergbau- und Hüttenwesen des 3. bis 13. Jahrhunderts nach Christus* (Oldenburg: Isensee, 1994).

High concentrations of lead, zinc, and copper likewise appear in nearby floodplains.¹⁷ And an analysis of peat bog sediments in the region also found strong evidence of mining and smelting activities, with a peak release of lead and copper particles between the later twelfth and mid-thirteenth centuries. This was followed by a sharp decline around the second plague pandemic (aka the Black Death) in the mid-fourteenth century and a brief resumption in the early sixteenth. Such concentrations, according to the study's authors, would have rendered the area hazardous at the time, and have left it 'still remarkably polluted in modern times', that is, centuries after local mining and metal processing ceased, yet in a far more populated region.¹⁸

The proliferation of noxious metal deposits in this period took place in southern European sites as well. For instance, the Metalliferous Hills (*Colline Metallifere*) region of Grosseto, in south-western Tuscany, was home to a bustling extractive industry even before the Continent's thirteenth-century resurgence. Recent analyses such as X-ray fluorescence (XRF) and Field emission scanning electron microscopy (FESEM) have yielded abundant data on local mining's diverse geochemical footprints (Figure 2). In the areas of Serrabottini and Niccioleta, near the town of Massa Marittima, average copper concentrations reached 15,000 ppm (parts per million, or 1.5%), and zinc accumulated at nearly 25,000 ppm (2.5%) due to local silver and lead production in the thirteenth and fourteenth centuries. In nearby Montieri, modestly high rates of lead, copper, and arsenic (400, 140, and 60 ppm, respectively) were detected along waterways at some remove from the original extraction and processing sites, where tailings accumulated. Indeed, testing soils that are currently buried under more recent residential areas strongly suggests that these were the original sites for polluting activities, as lead concentrations there vary between 10,000 and 50,000 ppm (1–5%).¹⁹ These are extremely high rates: not only in present-day terms, but also in comparison with data from Falun, where roasting took place away from

¹⁷ Matthias Deicke, 'Findings Concerning the Environmental History of the Harz Mountains and the Utilisation of Mineral Resources', in *Aspects of Mining and Smelting*, ed. by Segers-Glocke and Witthöft, pp. 66–78; and Ulrich Willerding, 'On the Utilisation of the Plant Resources of the Upper Harz Mountains by the Mining and Smelting Industries during Medieval Times', in *Aspects of Mining and Smelting*, ed. by Segers-Glocke and Witthöft, pp. 79–98.

¹⁸ H. Kempter and B. Frentzel, 'The Impact of Early Mining and Smelting on the Local Tropospheric Aerosol Detected in Ombrotrophic Peat Bogs in the Harz, Germany', *Water, Air, & Soil Pollution*, 121 (2000), 93–108 (p. 105).

¹⁹ Luisa Dallai and others, 'Le analisi fisico-chimiche territoriali ed "intra-sito" nelle Colline Metallifere: aspetti descrittivi, "predittivi" e prima interpretazione storica dei dati', in *VII Congresso nazionale di archeologia medievale*, ed. by Paul Arthur and Marco Leo Imperiale (Florence: All'Insegna del Giglio, 2015), 1, 389–94; Vanessa Volpi, Luisa Dallai, and Alessandro Donati, 'L'uso di tecnologie ad elevate prestazioni, pXRF, per lo studio del distretto minerario delle colline metallifere (Toscana, Italia)', in *Les Métaux précieux en Méditerranée médiévale. Exploitations, transformations, circulations*, ed. by Nicolas Minvielle Larousse, Marie-Christine Bailly-Maître, and Giovanna Bianchi (Aix-en-Provence: Presses universitaires de Provence, 2019), pp. 219–30; and Luisa Dallai, Alessandro Donati, and Vanessa Volpi, 'A Multidisciplinary Project for the Study of Historical Landscapes: New Archaeological and Physicochemical Data from the "Colline Metallifere" District', in *CAA2016: Oceans of Data. Proceedings of the 44th*



Figure 2.

Minimum and maximum concentrations of lead (1), arsenic (2), silver (3), and copper (4) found today south of Massa Marittima, in the Metalliferous Hills region of Tuscany. The analysis posits that the unique chemical profile traces the areas of ore deposits and slag heaps produced by the local mines, which date to the thirteenth century at least. See L. Dallai, L. Chiarantini, S. Iacopini, C. Sergenti, and V. Volpi, 'Il rame e l'argento delle Colline Metallifere (alta val di Pecora) nel XIII secolo. Metodologie multidisciplinari per lo studio dei bacini di approvvigionamento e del ciclo di produzione dei solfuri misti', in Tiziano Mannoni. *Attualità e sviluppi di metodi e idee*, ed. ISCUM (Florence: All'Insegna del Giglio, 2021), II, 207–14, fig. 3.

(Image courtesy of Luisa Dallai)



the mine and town.²⁰ There, soil deposits with different chemical composition dating to around 1245 yielded 445 ppm for copper, 100 for lead, 800 for zinc, and 70 for nickel.²¹

Noxious metal particles impacted soils and vegetation, as well as non/human animals, be it through direct breathing and skin contact or consuming exposed water, plants, and animals. Palaeopathological studies of human skeletal remains from cemeteries strongly associated with mining communities leave no doubt that harmful emissions embedded themselves here too, potentially leading to irreversible conditions ranging from pulmonary disease, to brain damage, to anaemia and hypertension.²² For example, in Brandes-en-Oisans, in the French Alps, preliminary washing and roasting of ores took place on-site, and evident attempts at preventative zoning (see below) offered only partial reprieve. Polarography conducted on bones from the local cemetery, mostly dating to the thirteenth and fourteenth centuries, showed concentrations of up to 5221 ppm for lead and 250 ppm for copper, while soil samples from near the cemetery yielded a concentration of 5630 ppm for lead, 1010 ppm for copper, 422 ppm for zinc, 74 ppm for silver, and 67 ppm for nickel.²³ Even if skeletons absorbed some of these toxins from the earth after burial, the original rates would have been considerable. To take another example, in the former mining area of Sala, Sweden, enamel samples taken from miners' teeth dating between 1470 and 1600 preserved lead concentrations ranging from 2.1 and 88.8 ppm (average ≈ 14 ppm). These figures far exceed prehistoric human samples and, on the higher end, equal lead concentrations found for England during the later Industrial Revolution.²⁴

The chemical processes that mining, breaking ores, washing, roasting, and smelting set in motion had further consequences for local ecosystems. In

Conference on Computer Applications and Quantitative Methods in Archaeology, ed. by Mieko Matsumoto and Espen Uleberg (Oxford: Archaeopress, 2018), pp. 135–46.

²⁰ According to the US Environmental Protection Agency (EPA), a concentration of more than 15 ppm of lead in drinking water is considered dangerous. Natural copper deposits in soil range between 5 and 250 ppm, with an average of 50 ppm in the earth's crust. See the US Center for Disease Control's factsheets; on lead, see: <<https://www.cdc.gov/TSP/substances/ToxSubstance.aspx?toxid=22>>; on copper: <<https://www.cdc.gov/TSP/ToxProfiles/ToxProfiles.aspx?id=206&tid=37#bookmark01>> [both accessed 23 July 2022]. Lead concentration in bones from a large sample of deceased people in three urban areas in Canada ranged from 0.45 to 240 ppm with mean concentrations per city ranging from 8.47 to 11.11 ppm. See E. R. Samuels and others, 'Lead Concentration in Human Bones from the Canadian Population', *Science of the Total Environment*, 89 (1989), 261–69.

²¹ Bindler and Rydberg, fig. 6. The last three elements are my approximation from the chart, since they are not made explicit.

²² 'Lead poisoning', World Health Organization <<https://www.who.int/news-room/factsheets/detail/lead-poisoning-and-health>> [accessed 16 July 2022].

²³ Marie-Christine Bailly-Maître and Joëlle Bruno-Dupraz, *Brandes-en-Oisans: La Mine d'argent des Dauphins (XIII^e–XIV^e siècles)*, Isère (Lyon: Alpara, 1994), p. 189.

²⁴ T. Douglas Price and others, 'Origins of Inhabitants from the 16th Century Sala Silver Mine Cemetery—A Lead Isotope Perspective', *Journal of Archaeological Science*, 80 (2017), 1–13 (pp. 7–8).

Falun, as mentioned, toxin loads prevented forest revegetation, at least in the main site's immediate surroundings, by the early fourteenth century. This meant that woodlands, which supplied both timber to reinforce tunnels and charcoal for roasting and smelting, never fully regenerated, instigating a vicious cycle of deforestation, erosion, and flooding.²⁵ In the upper Harz region of Germany, the forests that miners encountered were likewise soon cut down for mine construction and smelting, and deciduous species such as beech and maple were either severely depleted or never fully replaced. Already in the thirteenth and fourteenth centuries local forests were revegetated, at least in part by humans, with a dominance of pioneer species such as spruce, birch, rowan, hazel, and poplar, as can be determined from the study of local soils and charcoal remains.²⁶ As Christoph Bartels, among the foremost scholars of the era's mining, concluded, by 1540 mining and metallurgy 'burdened the forest beyond the limits of its permanent regenerative capacity'.²⁷ Such critical loads could be reached quickly. A study from Germany's Black Forest region detected deforestation, erosion, and water and air pollution within decades of miners' arrival, and the soil's radically altered mineralogy meant that crops cannot grow on it even today, centuries after the abandonment of local mining.²⁸ Changes in vegetation resulted from another type of human response to the remoteness of mining and local soils' qualities, namely the introduction of cattle to meet miners' dietary needs, which could lead to overgrazing and erosion.²⁹ As we shall see in the next section, however, mining communities could also adapt their habitats more gently to suit their diets.

Miners may well have occasionally settled in non-pristine landscapes. Yet alongside the revegetation, deforestation, erosion, and disease their labour induced, the diversion of water courses and removal of hundreds of tonnes of earth and rock irreversibly altered numerous sites across Europe. In Falun, labourers tunnelled through the copper-rich ground for centuries until the underground network collapsed in 1687, and the area became a massive open pit. In mountainous silver-mining sites further south, an average of 2000 tonnes of ore and 300 tonnes of wood were required to make one tonne of silver—amounts that should be considered from a longer-term perspective as well. For instance, in their peak production eras, centres such as Kutná Hora in Bohemia and Freiberg in Saxony

²⁵ A similar type of unsustainable mining effort has now been postulated for a major iron-age site. See Mark Cavanagh, Erez Ben-Yosef, and Dafna Langgut, 'Fuel Exploitation and Environmental Degradation at the Iron-Age Copper Industry of the Timna Valley, Southern Israel', *Scientific Reports*, 12 (2022), 15434 <<https://doi.org/10.1038/s41598-022-18940-z>> [accessed 17 January 2023].

²⁶ Willerding, p. 85.

²⁷ Christoph Bartels, 'Montani und Silvani im Harz. Mittelalterlicher und frühneuzeitlicher Bergbau und seine Einflüsse auf die Umwelt', in *Bergbau, Verhüttung und Waldnutzung im Mittelalter: Auswirkungen auf Mensch und Umwelt*, ed. by Albrecht Jockenhövel (Stuttgart: Franz Steiner, 1996), pp. 112–27 (pp. 121–22).

²⁸ Gerd Goldenberg, 'Umweltbeeinflussung durch das frühe Montanwesen. Beispiele aus dem Schwarzwald', in *Bergbau, Verhüttung und Waldnutzung*, ed. by Jockenhövel, pp. 230–46.

²⁹ Willerding, pp. 91–93.

churned out some twenty tonnes of silver annually.³⁰ And between the eleventh and thirteenth centuries miners in the small iron-producing area hemmed by the Lahn and Diel estuaries of the Rhine, in central-western Germany, consumed 175–250 hectares of woodland and 15,000–20,000 tonnes of raw ore in order to produce between 1250–3750 tonnes of iron.³¹

These and hundreds of other mining sites were eventually abandoned, prompting some revegetation and allowing local tourist boards to promote an illusion of mildly impacted landscapes. The unwitting hiker, enjoying the seemingly pristine forest of the Carpathians, Dolomites, Alps, or Saxony, is in fact quite often traversing recent anthropogenic grounds. These are sometimes alluded to in local placenames, such as Rudabánya (ore mine), Monte Argentario (silver mountain or mine), Brandes (flames), and Zinnwald (tin forest). Later developments, including agriculture and urbanisation, have likewise masked extensive mining activities and their impacts. The Metalliferous Hills area of Tuscany, for instance, with its abundant forests, olive groves, and other forms of agriculture, not to mention residences, sometimes covers over toxic land. And dense vineyards sloping down the Dolomites in the former silver-mining area near Trent, in northern Italy, obscure numerous slagheaps, pits, and entrances to mining shafts. Some of the latter can now be revealed through remote sensing and ground truthing (Figures 3–5), but they have also been encountered accidentally during residential construction or agricultural labour.³² Mapping mining's preindustrial impact on European landscapes, then and now, is in its infancy, although new technologies are making it a safe and feasible endeavour. Digital imaging of tunnels and local hydrology can likewise augment geological studies to help calculate the amount of rock excavated from the earth in different locations and its dispersal, and chemical testing and vegetation studies can indicate the ubiquity of slag heaps, the proximity of earlier furnaces, and their impact over time, not to mention the scale of lead emissions involved in metal production.³³ Research into the environmental impact of the era's mining and metallurgy, which in some places has lasted for a millennium or more, will certainly shed light on the deep history and ongoing relevance of environmental hazards. Even as we await the results of such efforts, however, it is already clear that ecological change was

³⁰ Richard C. Hoffmann, *An Environmental History of Medieval Europe* (Cambridge: Cambridge University Press, 2014), p. 221.

³¹ Albrecht Jockenhövel, 'Untersuchungen zue mittelaltrichen Eisengewinnung an Lahn und Dill: Das Dietzhölztal-Projekt (DHT)', in *Bergbau, Verhüttung und Walddnutzung*, ed. by Jockenhövel, pp. 12–29 (p. 25).

³² Interview with family members and workers along the Strada ai Masi Saraceni, en route to the Via alle canope, near Trent, Italy. Personal field notes, July 2020.

³³ *Les Métaux précieux en Méditerranée médiévale*, ed. by Minvielle Larousse, Bailly-Maître, and Bianchi.

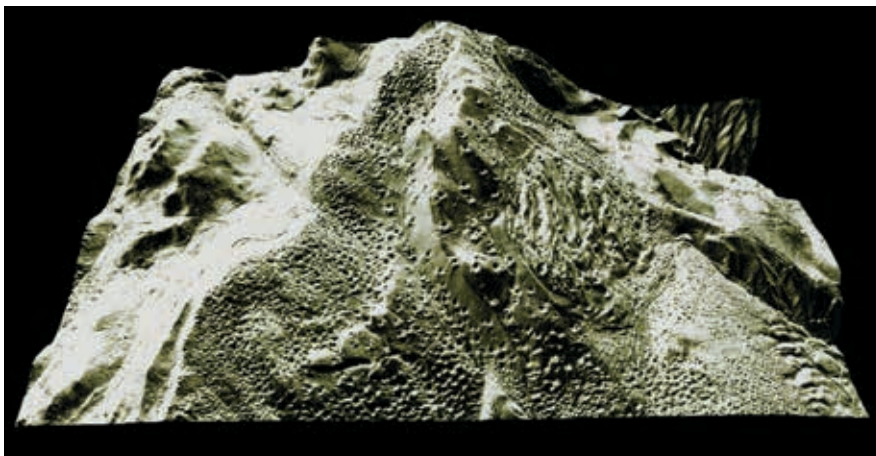


Figure 3.

LiDAR elevation of Monte Corno in the Monte Calisio area. The technology penetrates existing vegetation to expose the dramatic changes caused by local mining since the later twelfth century.

(Image courtesy of Lara Casagrande)



Figure 4.

A former mine entrance, Monte Calisio. Still visible, a cross carved above the entrance may have acted as a spiritual preventative measure.

(Image c. July 2020 by the author)



Figure 5.

Interior of an underground mine, Monte Calisio. While the support columns are likely more recent, the darkened ceiling attests the common use of fire-setting.

(Image c. July 2020 by the author)

widespread and even profound well before the Industrial Revolution, and that it occurred in complex ecosystems and with long-lasting results.³⁴

III. Perceptions and Responses

Soon after the intensification of copper mining at Falun, the residents of the eponymous town, located about 1.5 kilometres away, noticed the deterioration of local vegetation and, at least implicitly, rising risks to their own health. They apparently attributed the change to the open-air roasting of metal ores and responded by banning the practice ‘in the countryside outside the mining areas except during the winter season’,³⁵ presumably to protect the cycle of summer crops and its attendant non/human labourers. Although the solution meant that toxins would be deposited even further from the mine, the action nonetheless attests people’s vigilance and an awareness of certain spatial and therefore environmental dynamics binding the industry and health. Contemporaries certainly understood the mechanism by which roasting impacted the environment

³⁴ See, for instance, the Ecomuseo Civezzano’s reconstructions at <<https://arcteam.github.io/virtualArch.github.io/>> [accessed 22 July 2022].

³⁵ Ek and others, p. 96.

differently from explanations provided by present-day biochemistry. The era's prevalent, if by no means exclusive, natural-philosophical paradigm was Galenism or humoralism, which hearkened back to Hippocrates and Aristotle via a rich Judeo-Islamic, Roman, and Greek tradition.³⁶ The Galenic pursuit of health can be framed as the preservation of a dynamic balance between the four humours of the human body (black bile, yellow bile, blood, and phlegm) and its constantly changing surroundings. There were many ways in which such a balance could be disrupted, including improper diet, sleep, exercise, and emotionality; but the main *environmental* risk for the unbounded bodies postulated by this system was exposure to miasma, that is 'vapour' polluted by decomposing matter, foul air, or stagnant water, and often recognisable by its stench.³⁷ Even if people's common sense was only partly informed by this theory, it is a small leap to posit that roasting ores rich with sulphur dioxide, which smells like nitric acid and can lead to fainting among non/human animals, may have prompted them to want to minimise their (and their animals' and crops') exposure to it.³⁸

Miners and their contemporary observers may well have viewed themselves as entitled beneficiaries of nature or indeed Creation. Yet even they readily admitted that extraction was as taxing as agricultural labour, if not more so.³⁹ The preventative measures miners developed to address the environmental hazards their work involved were therefore common, both below and above the ground. Pictorial, documentary, and archaeological evidence shore up a range of strategies that miners employed to combat falling rocks and heavy tools, humidity, darkness, flooding, suffocation, miasmas, and hard surfaces. Subterranean measures included the use of protective gear (gloves, boots, leather aprons, knee- and buttocks

³⁶ On the humoral tradition in this period, see Petros Bouras-Vallianatos and Barbara Zipser, eds, *Brill's Guide to the Reception of Galen* (Leiden: Brill, 2019); on aetiology, see Vivian Nutton, 'The Seeds of Disease: An Explanation of Contagion and Infection from the Greeks to the Renaissance', *Medical History*, 27.1 (1983), 1–34.

³⁷ The centrality of scent, itself a fluid category, to Galenic forensics is at the core of refuting modernist assumptions about 'the Middle Ages' as one thousand years without a bath. See Mark S. R. Jenner, 'Follow Your Nose? Smell, Smelling and their Histories', *American Historical Review*, 116.2 (2011), 335–51 (pp. 339–40). Londoners' negative responses to the rising use of coal from the late thirteenth century focused on the scent of its smoke. See Carole Rawcliffe, *Urban Bodies: Communal Health in Late Medieval English Towns and Cities* (Woodbridge: Boydell, 2013), pp. 165–67.

³⁸ The common perception of the forge as a main vehicle for propagating dangerous odours both in cities and the countryside was exploited in the era's literature. See Deborah Thorpe, 'Heated Words: The Politics and Poetics of Work in "A Complaint against Blacksmiths"', *Parergon*, 32.1 (2015), 77–101. Moreover, medical writers at the time raised concerns about mines' dangerous fumes. See Angelika Westermann, 'Bergstadt und Montankultur 1350–1850', in *Geschichte des deutschen Bergbaus*, II: *Salze, Erze und Kohlen: Der Aufbruch in die Moderne im 18. und frühen 19. Jahrhundert*, ed. by Wolfhard Weber (Münster: Aschendorff, 2015), pp. 423–24; and G. Geltner, 'Preventative Healthcare among Miners in Europe, 1200–1550', in *Dynamic Balances: Public Health in the Premodern World*, ed. by G. Geltner, Janna Coomans, and Ronit Yoeli-Tlalim (forthcoming).

³⁹ Rainer Slotta, 'Der (Silber-)Bergbau als Kunst-Katalysator', in *Der Alteuropäische Bergbau. Von den Anfängen bis zur Mitte des 18. Jahrhunderts*, ed. by Christoph Bartels and Rainer Slotta (Münster: Aschendorff, 2021), pp. 591–618.

padding, helmets, long-sleeve tunics, leggings, and mouth covers to prevent the inhalation of harmful fumes); bells and harnesses attached to guiding ropes along shafts and tunnels for orientation and rescue; safety protocols concerning fire-setting to weaken the rock around a seam; shaft covers, tunnel gates, and timber reinforcements; mobile and area lighting; drainage channels and overflow sinks; internal zoning; and ventilation. Miners also practised religious piety (Figure 4), cultivated relations with patron saints such as St Barbara and St Anne, and sought to please underground demons and other supernatural entities they commonly believed kept them company. Digging in shifts of six or eight hours followed by mandatory rest periods was standard, and workers avoided carrying arms and developed procedures to resolve disputes, for instance about how to proceed if two digging parties unexpectedly met.⁴⁰ Even this elaborate ensemble of measures, however, hardly guaranteed miners' health and safety below the earth's surface. Tunnels collapsed and killed them, as did fires and floods, noxious gases impacted their lungs, falling tools and rock fractured their bones, and crouching for hours on end in cold and wet places stressed their ligaments and bones substantially. Many such injuries are revealed by skeletal remains from several mining cemeteries.⁴¹

While subterranean risks were known to be high, above-ground environments posed no less of a challenge to miners and their families. Occupational hazards piled onto living in remote and often inhospitable locations and dealing with the fallout of ore processing. Miners' perceptions of and responses to such circumstances could vary greatly between groups, sites, seasons, and labour regimes. Yet collectively they too attest the complex ways people thought about their habitats and evince an understanding that human well-being was inseparable from a broader dynamic balance with the lived environment. That is not to argue that miners' efforts were always successful, of course, let alone that they conformed to present-day paradigms of biodegradation, resilience, or sustainability, which are themselves constantly being debated. In fact, the pressure on local resources, accompanied by the heavy release of toxins, at best reduced

⁴⁰ G. Geltner, 'Kinetic Health: Ecologies and Mobilities of Prevention in Europe, c. 1100–1600', *Mobilities*, 16 (2021), 553–68; G. Geltner and Claire Weeda, 'Underground and Over the Sea: More Community Prophylactics in Europe, 1100–1600', *Journal of the History of Medicine and Allied Sciences*, 76.2 (2021), 123–46.

⁴¹ Estelle Herrscher, R. Colardelle, and F. Valentin, 'Meulières et pathologies humaines: un rapport effectif? Analyse d'une documentation bucco-dentaire entre le xiii^e et le xviii^e siècle à Grenoble', in *Les Meulières. Recherche, protection et mise en valeur d'un patrimoine industriel européen (Antiquité–xx^e siècle)*, ed. by Alain Belmont and Fritz Mangartz (Mayence: RGZM, 2006), pp. 99–108; Riccardo Francovich and Kathy Gruspier, 'Relating Cemetery Studies to Regional Survey Rocca San Silvestro: A Case Study', in *Reconstructing Past Population Trends in Mediterranean Europe (3000 BC – AD 1800)*, ed. by John Bintliff and Kostas Sbonias (Oxford: Oxbow, 1999), pp. 249–57; Ylva Bäckström and T. Douglas Price, 'Social Identity and Mobility at a Pre-Industrial Mining Complex, Sweden', *Journal of Archaeological Science*, 66 (2016), 154–68; and by implication Auxane de Lépinau and others, 'Entre peste et famine: caractérisation d'une crise de mortalité par l'étude des trois sépultures multiples du site de Kutná Hora—Sedlec (République tchèque, xiv^e siècle)', *Bulletins et mémoires de la Société d'Anthropologie de Paris*, 33.2 (2021) <<https://doi.org/10.4000/bmsap.7664>> [last accessed 17 January 2023].

biodiversity temporarily, at worst amounted to biocide. However, miners could also engage in relatively light interventions, including bringing cattle into highland settlements for their meat, milk, wool, skin, and manure. This improved miners' diets and expanded their autonomy, although cattle's presence could also lead to overgrazing and erosion. To augment their diets further, miners regularly foraged and hunted as well as planted trees and crops, albeit in suboptimal and increasingly acidic terrains, whose toxins were then absorbed by plants, animals, and eventually human bodies.⁴² Another documented response to the difficulties of life in mining communities was woodland management. For instance, a 1462 contract signed for nine years between the papacy and alum miners in Tolfa, in central Italy, obligated the leaseholders to annually replenish the area's woodlands, which they were otherwise free to use.⁴³ And sediments from the Niederpöbel Valley in the German Ore Mountains suggests that local miners deliberately reduced competition for species they preferred for timber (*Abies alba*) and charcoal production (*Fagus sylvatica*).⁴⁴ Such practices may well have curbed biodiversity, yet suggest both awareness and skill in regenerating local resources.

Provided a mining region had sufficient supplies of wood (which was not always the case), it made sense to conduct at least initial ore processing as close as possible to excavation sites.⁴⁵ The enforcement of minimal distances for roasting in summer months at Falun thus seems untypical of the industry and reflects the affordances of a low-lying area. Another atypical approach emerges from Rocca San Silvestro, in southwestern Tuscany, where ores were probably tested locally for quality and then carried away for processing. It remains unclear whether this separation of tasks was a deliberate preventative health measure, the result of insufficient woodlands, the attraction of pre-existing infrastructures nearby, or a combination of these factors. At any rate, the mine's tunnels opening onto the flat bottom of the valley made it relatively easy to transport heavy ores west towards the coast. The role of geology and topography is likewise apparent in truly mountainous and forested terrains, such as Brandes in the French Alps. Here, both remoteness and an obstructive terrain rendered it cost-efficient to carry out at least

⁴² Marie-Christine Bailly-Maître and others, 'Travail et milieu. Incidences sur une population au Moyen Âge', in *L'Identité des populations archéologiques*, XVIe Rencontres internationales d'Archéologie et d'Histoire d'Antibes (Sophia Antipolis: Éditions APDCA, 1996), pp. 211–43.

⁴³ G. Zippel, 'L'allume di Tolfa e il suo commercio', *Archivio della R. Società Romana di Storia Patria*, 30 (1907), 5–52, 389–462 (p. 443 [no. 18]). The papacy had to contribute towards reforestation as well.

⁴⁴ Johann Friedrich Tolksdorf and others, 'Forest Exploitation for Charcoal Production and Timber since the 12th Century in an Intact Medieval Mining Site in the Niederpöbel Valley (Erzgebirge, Eastern Germany)', *Journal of Archaeological Science: Reports*, 4 (2015), 487–500 (p. 496).

⁴⁵ Here and elsewhere, I am alluding to the importance of understanding the role played by mines' and mining areas' materiality and spatiality in regulating all life around them, a theme explored in greater depth in Geltner, 'Mine Air Makes Free?'. For a broader discussion of what they term 'geopower' (as distinct from biopower), see Margaret Davies, *EcoLaw: Legality, Life, and the Normativity of Nature* (London: Routledge, 2022).

some processing locally, such as breaking, washing, and preliminary roasting. The risks were hardly lost on miners, whose preventative solutions in this context involved zoning: washing and roasting facilities were located away and downwind from water sources and residential areas, although (as noted in the previous section) toxins impacted them nonetheless.⁴⁶ In other regions, as earlier examples from the Harz region, Saxony's Ore Mountains, and Montieri have suggested, short-term pragmatism in rough terrain could discourage preventative zoning and lead to locating ovens quite close to excavation sites, domiciles, and along waterways. From an ecological perspective these had the additional disadvantage of accelerating the delivery of toxins further into local water systems. And in the longer run, the remaining slag heaps continued to leach hazardous chemicals into the earth and water, limiting the type of vegetation that could grow there, poisoning grazing animals, and harming their non/human consumers.

The specific impacts of mining and metallurgy on a given ecosystem depended on numerous physical factors as well as complex human decision-making. Yet, whatever their shape and pace, such transformations in the landscape struck contemporary observers, whether they were insiders of or outsiders to the renascent sector, and in whatever terms they understood these changes and their own place in nature (Figure 6). In 1361, for instance, John de Treeures, a Cornish landlord, complained to Edward, the Black Prince, that

fully sixty tanners have entered upon his demesne and soil, which bears wheat, barley, oats, hay and peas, and is as good and fair as any soil in Cornewaille, and have led streams of water from divers places to Treeures over part of his said demesne and soil, so that, by reason of the great current of water they have obtained and the steep slope of the land there, all the land where they come will go back to open moor, and nothing will remain of all that good land except great stones and gravel.⁴⁷

Unlike the invisible and possibly Galenic chain of causality surmised by Falun's residents, de Treeures directly observed that his crops' deterioration was owing to the area's altered hydrology, which in turn resulted from the recent proliferation of tin mining. He also stressed—landlord to landlord—that the threatened soil was painstakingly drained for cultivation. Direct flooding of arable land may have been a smaller concern in higher altitudes, where more visible and palpable impacts included the creation of numerous pits, shafts, entrances, slag heaps, and other debris; deforestation and its accompanying erosion; and air and water pollution. All these observable changes could manifest within a few years of works' commencement, and their eventual impact on lower-lying crops, animals, and humans would have been easily noticed by local villagers and farmers.

⁴⁶ Marie-Christine Bailly-Maître and Paul Benoit, 'L'Habitat des mineurs: Brandes-en-Oisans et Pampailly', in *Cadre de vie et manières d'habiter (XII^e–XVI^e siècle)*, ed. by Danièle Alexandre-Bidon, Françoise Piponnier, and Jean-Michel Poisson (Caen: Publications du CRAHM, 2006), pp. 259–65.

⁴⁷ Quoted in John Hatcher, *English Tin Production and Trade before 1550* (Oxford: Clarendon Press, 1973), p. 45.

Last but not least, mining could involve cultural clashes with the seasonal or permanent arrival of new laborers and their families, often foreigners to the area and increasingly financed by remote owners.⁴⁸

Many early miners and their later successors recorded the visible expansion of extractive industries in a triumphant key, not least thanks to the political and economic privileges the process bestowed. The latter in particular was an achievement that few contemporary rural labourers could boast. Alongside the ephemeral tales, placenames, songs, rituals, and traditions forged in such contexts, church altars, stained-glass windows, manuscript illuminations, murals, sculptures, and town seals preserve the enthusiasm of these new and rejuvenated communities.⁴⁹ Yet miners' pride in their achievement hardly amounts to a dismissal of their labour's environmental impact, which, as illustrated above, would have been at least in part evident to themselves and others.⁵⁰ Indeed, the most famous proponent of the era's mining industry, the Saxon physician, mayor, and scholar Georgius Agricola, acknowledged its harms and depicted them in meticulous etchings that accompanied his hugely influential mining and metallurgical guide, *De re metallica* (1556).⁵¹ Nevertheless, he defended the injurious impact of metal mining on the landscape as serving society's greater good:

If we remove metals from the service of man, all methods of protecting and sustaining health and more carefully preserving the course of life are done away with. If there were no metals, men would pass a horrible and wretched existence in the midst of wild beasts; they would return

⁴⁸ Wolfgang Schwabenicky, *...war einst eine reiche Bergstadt. Archäologische Forschungen zum hochmittelalterlichen Montanwesen im Erzgebirge und Erzgebirgsvorland* (Mittweida: Hainichen, 1991), pp. 36–37; Lena Asrih, 'Untersuchung von Migration in der europäischen Bergbaugeschichte des Mittelalters und im Übergang zur Frühen Neuzeit—Einige Bemerkungen zu Herangehenweisen, Schriftquellen und zum Forschungsstand', in *Bergbau und Mobilität im Mittelalter: Hornictvi a mobilita ve stredovrku*, ed. by Christiane Hemker (Dresden: LfA Sachsen, 2020), pp. 35–43; Gabriele Marcon, 'The Movements of Mining: German Miners in Renaissance Italy (1450s–1560s)' (unpublished doctoral dissertation, European University Institute, Florence, 2022).

⁴⁹ E. Treptow, *Deutsche Meisterwerke bergmännischer Kunst*, Abhandlungen und Berichte des Deutschen Museums, 1.3 (Berlin: VDI-Verlag, 1929); Václav Husa, Josef Petrán, and Alena Šubrtová, *Traditional Crafts and Skills. Life and Work in Mediaeval and Renaissance Times*, trans. by Iris Urwin (London: Paul Hamlyn, 1967), pp. 162–206; Rainer Slotta and Christoph Bartels, eds, *Meisterwerke bergbaulicher Kunst vom 13.–19. Jahrhundert* (Bochum: Selbstverlag des Deutschen Bergbau-Museums, 1990); Katalin Szenda, 'The Mine is Mine! The Visual Assertion of Royal Authority in the Mining Towns of the Medieval Kingdom of Hungary', in *Istoria ca interogație: Mariei Crăciun, la o aniversare*, ed. by Carmen Florea and Greta-Monica Miron (Cluj-Napoca: Argonaut/Mega, 2020), pp. 231–52.

⁵⁰ Tina Asmussen, 'Wild Men in Braunschweig: Economies of Hope and Fear in Early Modern Mining', in 'The Cultural and Material Worlds of Mining in Early Modern Europe', ed. by Tina Asmussen, special issue of *Renaissance Studies*, 34.1 (2020), 31–56; Tina Asmussen, 'Spirited Metals and the Oeconomy of Early Modern European Mining', in 'Early Modern Geological Agency', ed. by Tina Asmussen and Pietro D. Omodeo, special issue of *Earth Sciences History*, 39.2 (2020), 371–88 (pp. 378–79).

⁵¹ The most complete study of the work's illuminations is Marie-Claude Déprez-Masson, *Technique, mot et image. Le 'De re metallica' d'Agricola* (Turnholt: Brepols, 2006).



Figure 6.

A mining landscape from Agricola's *De re metallica* (1556). The woodcut deliberately conveys the deforestation, erosion, digging, and burning that accompanied the era's rural mining.

(Image from Wikimedia commons)

to the acorns and fruits and berries of the forest. [...] They would dig out caves in which to lie down at night, and by day they would rove in the woods and plains at random like beasts, and inasmuch as this condition is utterly unworthy of humanity, with its splendid and glorious natural endowment, will anyone be so foolish or obstinate as not to allow that metals are necessary for food and clothing and that they tend to preserve life?⁵²

Tensions over the consequences of mining found literary expression decades earlier. Around 1495, an otherwise obscure Bohemia-based author by the name of Paulus Nivis composed a vision narrative in which he put miners ('Man') on trial as parricidal destroyers of Earth (*Terra*). His *Judicium Jovis* is a complex and

⁵² Georgius Agricola, *De re metallica*, Book 1, trans. by Herbert Clark Hoover and Lou Henry Hoover (1912; repr. New York: Dover, 1950), p. 14.

ultimately ambiguous text when it comes to the morality of resource extraction, but it certainly gives voice to both critiques of the sector and its defence. The text personifies Earth as a noble, despondent lady, clothed in a torn green gown meant to reveal that she has been, in the pointed words of her (ironic?) champion Mercury, ‘injured, bloodstained, wounded, and pierced’. Miners themselves are depicted as toiling dangerously and unnaturally day and night, blinded by greed, harming agriculture, oblivious to the seasons, perforating the earth, disrupting water flows, poisoning the air, and generally spurning both human and divine laws. By contrast, mining’s advocates, headed by Fortune, describe extraction as an act of kindness, charity, and in the service of piety, and list its contributions to expanding human habitation, communities’ wealth, and service to medicine. Its defenders also explain that mining affords an important correction in the physical distribution of wealth, which is spread unevenly above the ground, and reject allegations that digging disrupts agriculture, since one effectively excludes the other. In this sense, Earth’s resistance to extraction exposes her as discharging ‘the role of a stepmother [meant here as a slur] rather than that of a true parent’.⁵³

Scholars of early mining are familiar with both authors and texts, especially Agricola, who was directly involved in the industry around Saxony for decades. Recently, Phillip John Usher used their writings convincingly to distil early forms of environmental (but decidedly not ecological) thinking, reflecting a new impulse or betraying a higher anxiety about extraction than is usually attributed to the activity in those ‘naïve’ days.⁵⁴ Yet what Usher sees as an under-studied aspect of a humanist turn in the late fifteenth and sixteenth centuries, which hearkens back to classical letters, can also be seen as part of a cultural process rekindled by and rooted in mining experiences since their proliferation across Europe in the later twelfth century. Much of the evidence for this extended chronology will, however, scarcely be found in learned treatises or vision literature, but rather in a combination of landscape-, bio-, zoo-, and other types of archaeology, chronicles, sermons, contracts, financial registers, and remote-sensing and digital landscape reconstructions.

This conceptual and methodological proposal echoes two recent historiographical developments. The first is the growing appreciation among historians of science and technology of Agricola and other early humanists as *codifiers* of bodies of knowledge rather than their creators, and whose practitioners toiled, developed, and transmitted complex insights, including through mining

⁵³ Paulus Nivis, *Judicium Jovis ad quod mortalis homo a terra tractus parricidii accusatus est* (Leipzig: Landsberg, c. 1495), no foliation. Translations here from Frank Dawson Adams’s manuscript (c. 1930), available through the McGill University Library: <<https://mcgill.on.worldcat.org/oclc/61735885>> [last accessed 17 January 2023]. Key discussions include Horst Bredekamp, ‘Der Mensch als Mörder der Natur. Das ‘Judicium Iovis’ von Paulus Nivis und die Leibmetaphorik’, *Vestigia bibliae*, 6 (1984), 261–83; Asmussen, ‘Spirited Metals’; and Phillip John Usher, *Exterranean: Extraction in the Humanist Anthropocene* (New York: Fordham University Press, 2019), ch. 5.

⁵⁴ Usher, chs 4–5.

and metallurgy.⁵⁵ Secondly, challenging a common periodisation in the history of science, medicine, and technology also dovetails with the bustling field of preindustrial public health history and archaeology. Scholars working across and beyond Europe have now traced numerous legal, physical, institutional, and behavioural interventions among urban, rural, and mobile communities designed to improve health outcomes (however differently they define health) and capturing an environmental awareness seldom recognised by earlier studies.⁵⁶ Both developments acknowledge earlier societies' emphasis on balancing the unbounded bodies postulated by the era's Galenic medicine, and how that task required thinking deeply and constantly about the connections between people's immediate and more distant surroundings.⁵⁷

IV. Conclusions

Small communities can have major ecological impacts, even over a short period of time.⁵⁸ This could also transpire through the use of simple manual techniques, as the mining sector's new chapter since the late twelfth century illustrates. Unaided by engines, explosives, slavery, national infrastructures, or (for the most part) massive capital investment, the excavation of Europe's underground cathedrals led to considerable changes in ecosystems. Even as contemporary peasants slowly uprooted ancient, low-lying forests, and recovered cultivable land piecemeal from the sea, miners consumed and reconfigured large swathes of woodland in higher altitudes; moved thousands of tonnes of rock; created countless leaching slag heaps; diverted waterways; exposed fresh soils, flora, fauna, and themselves to harmful toxins; accelerated erosion; increased the risk of flooding; and contaminated crops. No site remained unaltered when settled at length by humans, but in the case of mining and metalworking the decline of biodiversity and biota's overall degradation could be swift and sometimes permanent well before mass urbanisation in Europe, and colonialism and the arrival of motorised technologies

⁵⁵ Asmussen, 'The Cultural and Material Worlds of Mining'; Pamela H. Smith, *From Lived Experience to the Written Word: Reconstructing Practical Knowledge in the Early Modern World* (Chicago: University of Chicago Press, 2022). These in turn dovetail with the insights of Traditional Ecological Knowledge (TEK). See M. Juga and others, 'Rural Communities and Traditional Ecological Knowledge', in *Issues and Concepts in Historical Ecology*, ed. by C. Crumley and others (Cambridge: Cambridge University Press, 2017), pp. 84–111.

⁵⁶ A major portal for this field is Premodern Healthscaping: <<https://premodernhealthscaping.hcommons.org>>.

⁵⁷ Rawcliffe; G. Geltner, *Roads to Health: Infrastructure and Urban Wellbeing in Late Medieval Italy* (Philadelphia: University of Pennsylvania Press, 2019); Janna Coomans, *Community, Urban Health and Environment in the Late Medieval Low Countries* (Cambridge: Cambridge University Press, 2021); Abigail Agresta, *The Keys to Bread and Wine: Faith, Nature, and Infrastructure in Late Medieval Valencia* (Ithaca, NY: Cornell University Press, 2022). And see Maurizio Meloni, 'The Politics of Environments before the Environment: Biopolitics in the *longue durée*', *Studies in History and Philosophy of Science*, 88 (2020), 334–44.

⁵⁸ Dorte Herzke and others, 'Microplastic Fiber Emissions from Wastewater Effluents: Abundance, Transport Behavior and Exposure Risk for Biota in an Arctic Fjord', *Frontiers in Environmental Science*, 9 (7 June 2021) <<https://doi.org/10.3389/fenvs.2021.662168>>.

abroad. The ubiquity of such processes, including their ongoing local and regional impact, make this under-studied phenomenon all the more remarkable and worth exploring further by developing models for extrapolating from site-specific data.

Biological and geochemical analyses, alongside digital-computational methods, can support a broader, systematic evaluation of such long-term processes. Yet by themselves they provide a limited account of human agency, risk management, and decision making when it came to preindustrial extraction. As this article has begun to show, cultural-historical and palaeo-scientific methods offer unique and occasionally reinforcing perspectives. Even without attempting to reconcile the two approaches, however, collectively they reveal choices that present-day earth scientists would dub myopic as well as deliberate interventions to improve health outcomes among miners and protect local resources in and around their habitats. Miners may not have been thinking ecologically in a present-day sense, but they certainly witnessed how their labour led to changes in the land, and in certain respects responded to this, including in ways that may reflect a shift in their self-situation as agents in nature or Creation. Decades and often centuries of ore extraction, however, took their toll, especially in regions of continuous exploitation, leading first to the creation or reshaping of anthropogenic landscapes, and later to devastated ones. In the process, miners began to develop a strong cultural identity and their contemporary observers formed a distinct notion of what mining landscapes look like, and at what (and whose) cost they came. The ambiguity of extraction's success is another aspect of a mining culture captured, if by no means invented, by Niavis, Agricola, and other writers associated with humanism and early modernity.

Finally, although it falls beyond this article's scope, it is worth considering whether the landscape legacies of mining played a more important role than is often recognised in shaping European encounters with other places and civilisations. Europeans' knowledge about the human and environmental cost of resource extraction clearly developed out of mining experiences as well as the era's urbanisation and farming. If so, it would have taught labourers, prospectors, and their public and private investors, not only how to identify underground wealth, but also what risks and damage its removal involved, and to whom, well before the emergence of pollution science.⁵⁹ Searching for such insights may thus enrich historical approaches to the design and management of past mining projects, be it on free, leased, or (de)colonised lands, and whether they were forcibly executed by subject indigenous populations or by willing lower-class migrants.⁶⁰ Lastly,

⁵⁹ For instance, while Liboiron, p. 42, stresses that not all pollution (let alone contamination) amounts to colonialism, they present colonialism as creating the imperative, and not merely the capacity, to pollute. But even an expansive interpretation of internal colonisation, which has been meaningfully applied to earlier eras, cannot uphold the implied periodisation when it comes to pollution. Some precolonial communities (including miners outside of Europe) decided to defend and manage what they perceived as pollution in their own, long-held territories, driven by the promise of profit and class mobility. See also Geltner, 'Mine Air Makes Free?'

⁶⁰ Renate Pieper, 'Anwerbung sächsischer Bergleute für den ersten Bergbau in Hispanoamerika. Der Vertrag von Svilla vom 31. Dezember 1528', in *Montangeschichte lehren*.

and at the risk of stating the obvious, mining and metallurgy were hardly limited to Europe or Europeans, including before imperialism.⁶¹ Tracing local histories can therefore shed new light on different cultures' paths to the Anthropocene.⁶² All these suggest that the recovery of 'preindustrial' mining practices, impacts, and perceptions broadens the scope of environmental history.

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Quellen und Analysen zur frühen Neuzeit, ed. by Hans-Joachim Kraschewski and Ekkehard Westermann (Husum: Mathiessen, 2015), pp. 169–73; Allison Margaret Bigelow, *Mining Language: Racial Thinking, Indigenous Knowledge, and Colonial Metallurgy in the Early Modern Iberian World* (Williamsburg, VA: Omohundro Institute of Early American History and Culture and University of North Carolina Press, 2020).

⁶¹ Key studies include: Arun Kumar Biswas, *Minerals and Metals in Pre-Modern India* (New Delhi: D. K. Printworld, 2001); Audrey Peli and Florian Téreygeol, 'Al-Raḍrād (al-Jabalī): A Yemeni Silver Mine, First Results of the French Mission (2006)', *Proceedings of the Seminar for Arabian Studies*, 37 (2007), 187–200; and Erez Ben-Yosef and others, 'Ancient Technology and Punctuated Change: Detecting the Emergence of the Edomite Kingdom in the Southern Levant', *PLoS One* (2019) <<https://doi.org/10.1371/journal.pone.0221967>> [last accessed 17 January 2023].

⁶² Kathleen D. Morrison, 'Provincializing the Anthropocene', *Seminar*, 673 (2015), 75–80.