Rachel Carson Center

Perspectives

Mining in Central Europe

Perspectives from Environmental History

Edited by
FRANK UEKOETTER

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RCC Perspectives

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Frank Uekoetter

Introduction: Mining and the Environment

The mining exhibit is one of the most acclaimed parts of the Deutsches Museum. It sends visitors on a long, winding underground route that for the most part looks and feels like an actual mine. The exhibit casts a wide net: early modern mining, coal mining, lignite open-pit mining, and mining for ores and salt are all part of the tour, with ore processing and refining making for the grand finale. It is not an exhibit for the claustrophobic, as the path is rather narrow at times, and visitors are expected to complete the entire tour—there are only emergency exits between entrance and finish. However, most visitors enjoy the exhibit, and employees of the Deutsches Museum are accustomed to inquiries as to when they last took the tour. It is also a very German exhibit: the only room dedicated to a foreign mine deals with the Wieliczka Salt Mine near Kraków, Poland, a type of mine without an equivalent in Germany.

It is helpful to evoke this experience here, and not only because the workshop "History Underground: Environmental Perspectives on Mining," where most of these papers were first discussed, started with a tour of this exhibit. Mining shows little respect for national boundaries: the quest for underground resources was a global endeavor even before the dawn of modernity, and minerals crossed borders just as easily as the people who brought them up from the depths of the earth. Much of the silver from the Bolivian mine Potosí ended up in China, while the turn-of-the-century Ruhr region in Germany was full of Polish-speaking miners. Because engineering challenges are similar all over the world, mining technology has long emerged as transnational. During our Deutsches Museum tour, one speaker found an exhibit which showed the type of square-set timbering that played a huge role in his paper about Nevada's Comstock: hollow rectangular frames made of wood that met the peculiar geological conditions of the famous silver mines.

This issue assembles only those conference papers that dealt with central Europe, but it does not claim that European mining is homogenous or unique. Quite the contrary, the issue highlights the many faces of mining even within a limited geographic area. The following papers deal with copper and silver in Tirol, mercury in Slovenia, lead and zinc in Westphalia, lime in the Rhineland, and uranium in East and West Germany.

The aspects of mining they explore are equally diverse: pollution and health hazards, spatial patterns, arrangements between the mining and agriculture industries, and even the reconstruction of the vegetation of the past through detailed pollen, micro-charcoal, and geochemical analyses of a Tirolean fen. This issue brings together the classic documents-oriented approach of the historian with approaches from the natural sciences, and it is not just for the sake of chronology that we begin with the latter. The paper by Elisabeth Breitenlechner and her colleagues, part of the large HiMAT (History of Mining Activities in the Tyrol and Adjacent Areas) special research area at the University of Innsbruck, provides a glimpse of scientific approaches that mining historians, and not only those of an environmental stripe, will henceforth ignore at their peril. In fact, we might read Laura Hollsten's remarks on the mobility of mercury as a cue that the line between the natural sciences and the humanities may be less clear than commonly assumed.

Needless to say, this collection of essays is nowhere close to being comprehensive. It ignores entire mining regions like Germany's Harz mountains, nowadays home to two mining-related world heritage sites, as well as resources like salt and coal, key commodities of early modern and industrial times respectively. Readers will also search in vain for a discussion of the sixteenth-century scholar Georgius Agricola and his *De Re Metallica*, whose introductory chapter on the legitimacy of mining and its inherent environmental toll inspired a scholarly debate that continues to this day. The perspectives offered in the present volume are not those that one would normally expect in a collection of this kind.

However, that is precisely the rationale for this issue. Taken together, these papers demonstrate that the environmental history of mining is richer than commonly assumed, and certainly deserving of more attention among researchers of different backgrounds. Furthermore, these essays provide insights into different ways of doing environmental history, and that is all the more worthwhile for a theme like mining, where the environmental impact seems so obvious at first glance. At the RCC workshop, the conveners choose to close with a session entitled "All The Same? Towards a Global Environmental History of Mining," born out of a discomforting feeling that stories might end up sounding repetitive. As it turned out, we should not have worried: an exploration of the full range of environmental perspectives on mining is still underway.

Elisabeth Breitenlechner, Marina Hilber, Joachim Lutz, Yvonne Kathrein, Alois Unterkircher, and Klaus Oeggl

Reconstructing the History of Copper and Silver Mining in Schwaz, Tirol

Introduction

The Eastern Alps have been an important source of raw materials such as metal and salt for the past 5,000 years. In particular, the landscape of the Tirolean Inn valley was shaped by the impact of ore mining and agricultural activities like livestock farming and tillage. Archaeological evidence for the beginnings of ore mining in central Europe has been found as far back as the fourth millennium BCE in northern Italy (Monte Loreto[1]) and the second and third millennium BCE in the Western Alps (St. Véran[2]), suggesting that the availability and the usage of copper may have been a development stimulus for European societies.

At present scientists still lack evidence about the beginnings of copper mining and metallurgy in the Eastern Alps, but there are indirect indications of early metallurgic activities. The confirmation of small-scale metallurgy in settlements like the Mariahilfbergl (Brixlegg, Tirol) from the fifth millennium BCE onwards,[3] and the geochemical signature of archaeological finds like *Ösenringe* and metallurgical slags from various early Bronze Age sites in central Europe offer hints about where and when Tirolean copper production may have begun. These artifacts consist of fahlore-derived copper, characterized by high amounts of antimony as well as minor concentrations of arsenic, silver, and zinc.[4] Copper ore with this geochemical signature is found in the deposits of the lower Inn valley in Tirol.

Acknowledgement: This study was conducted in the framework of the special research program HiMAT (The History of Mining Activities in the Tyrol and Adjacent Areas—Impact on Environment & Human Societies) and financially supported by the Austrian Science Fund (FWF) (grant no.: F3111-G02) as well as the municipality of Schwaz.

1 Roberto Maggi and Mark Pearce, "Mid Fourth-Millennium Copper Mining in Liguria, North-West Italy: The Earliest Known Copper Mines in Western Europe," *Antiquity* 79 (2005): 66–77.

2 Hélène Barge, *Saint-Véran, la montagne, le cuivre, et l'homme,* vol. 1, *Mine et métallurgie préhistoriques dans les Hautes-Alpes* (Theix: Actilia Multimédia, 2003).

3 Martin Bartelheim et al., "Kupferzeitliche Metallgewinnung in Brixlegg, Österreich," in *Die Anfänge der Metallurgie in der Alten Welt*, ed. Martin Bartelheim, Ernst Pernicka, and Rüdiger Krause. (Rahden, Westfalia: Verlag Marie Leidorf, 2002), 33–82; Bernd Höppner et al., "Prehistoric Copper Production in the Inn Valley (Austria), and the Earliest Copper in Central Europe," *Archaeometry* 47, no. 2 (2005): 293–315.

4 Höppner et al., "Prehistoric Copper Production."

However, archaeological finds are not the only evidence available. Methodological advances in pollen analysis over the last decade have enabled detailed reconstructions of past vegetation and its use in agriculture. These same methodological approaches may be applied to reconstructing the history of mining, as well. Mining activities impact the regional vegetation in various ways: there is high demand for wood for different purposes (construction, fuel), and local and regional agriculture is intensified in response to subsistence needs of the miners. Additionally ore-processing procedures release metals (e.g., lead, copper, arsenic, antimony) into the environment, as is seen in the local deposits.

Human-environment interactions in a mining territory may be reconstructed based on the information stored in wetlands regarding vegetation history, anthropogenic activities, and atmospheric metal deposition.[5] At the same time, the challenge is to separate the signals from mining activities and those from agricultural activities, which are quite similar. The palaeoecology of mining has not yet been investigated in depth. Several multi-proxy studies of combining palynological (pollen and microcharcoal) and geochemical data from wetlands in mining districts display promising results and show coeval changes in vegetation and heavy metal deposition.[6] However, the correlation of the vegetation changes in the pollen diagram with mining activities is a crucial step.

This study corrects this research gap by using current knowledge about the palaeoecology of mining as a calibration set to evaluate mining activities in Tirol displayed in pollen diagrams. The data from the palaeoecological record is supplemented by historical data for the area studied concerning settlement, agricultural development, and ore mining and smelting operations. Archaeological evidence of past metallurgical activities and their dendrochronological age determination completes the picture. We thus present an interdisciplinary survey by palynologists, geochemists, historians, and linguists that reconstructs the early history of mining in the Tirolean district Schwaz by showing the connections between mining activities and changes in the vegetation.

5 Tim Mighall et al., "Geochemical Evidence for Atmospheric Pollution Derived from Prehistoric Copper Mining at Copa Hill, Cwmystwyth, Mid-Wales, U.K.," *Science of the Total Environment* 292 (2002): 69–80.

6 William Shotyk et al., "History of Atmospheric Lead Deposition Since 12,370 14C yr BP from Peat Bog, Jura Mountains, Switzerland," *Science* 281 (1998): 1635–40; Mighall et al., "Geochemical Evidence for Atmospheric Pollution"; Fabrice Monna et al., "Environmental Impact of Early Basque Mining and Smelting Recorded in a High Ash Minerogenic Peat Deposit," *Science of the Total Environment* 327 (2004): 197–214; Sandrine Baron et al., "Records of Metal Workshops in Peat Deposits: History and Environmental Impact on the Mount Lozère Massif, France," *Environmental Science and Technology* 39 (2005): 5131–40; Isabelle Jouffroy-Bapicot et al., "Environmental Impact of Early Palaeometallurgy: Pollen and Geochemical Analyses," *Vegetation History and Archaeobotany* 16 (2007): 251–58.

Context and Sampling Site

Because the Eastern Alps contain large amounts of profitable ore deposits, they have been an important mining region over the last millennia.[7] One of the most prominent Tirolean mining areas (after the Kelchalpe near Kitzbühel) is located in the lower Inn valley between Schwaz and Brixlegg. The use of artifacts made from copper from local deposits is documented to no later than the beginning of the fourth millennium BCE.[8] According to research by Goldenberg and his colleagues, humans have been extracting copper ores from the bedrock in the lower Inn valley since at least the Early to Middle Bronze Age.[9] Several archaeological findings as well as historical references confirm metallurgic activities involving copper and silver processing in the mining district of Falkenstein near Schwaz in prehistoric and post-Roman times.[10] The reconstruction of successive periods of mining activity in past mining sites in particular may be improved by the combination of pollen and geochemical analysis of mires.[11]

The investigated area is located near Schwaz in the lower Inn valley (Tirol, Austria). The sampling site is situated in the Falkenstein district (the main mining district of the prominent mining area of Schwaz) in the Inn valley on the northwestern slope of the Mehrerkopf. The northern Austroalpine Greywacke Zone around the former mining center of Schwaz consists of dolomites, schists, and porphyric gneisses. The ore exploited at the Falkenstein mining district is found in the Devonian Schwaz Dolomite and contains mainly fahlore of the tennantite-tetrahedrite series ($Cu_{12}As_4S_{13}$ - $Cu_{12}Sb_4S_{13}$).[12] As indicated by the formula, the main components of the fahlore are copper, antimony, arsenic, and sulfur.

7 Clemens Eibner, "Der Kupferbergbau in den Österreichischen Alpen in der Urzeit," *Archäologie Österreichs* 3 (1992): 12–16; Höppner et al., "Prehistoric Copper Production."

8 Irenäus Matuschik, "Der neue Werkstoff—Metall," In "Goldene Jahrhunderte: Die Bronzezeit in Südwestdeutschland," ed. Dieter Planck, *ALManach* 2 (1997): 16–25; Melitta Huijsmans et al.,"Prähistorischer Fahlerzbergbau in der Grauwackenzone—Neolithische und bronzezeitliche Besiedlungsgeschichte und Kupfermetallurgie im Raum Brixlegg (Nordtirol)," in "Alpenkupfer = Rame delle Alpi," ed. Gerd Weisgerber and Gert Goldenberg, *Der Anschnitt* Supplement 17 (2004): 53–62.

9 Gert Goldenberg, "L'exploitation du cuivre dans les Alpes Autrichiennes à l'âge du Bronze," in *L'Atelier du bronzier en Europe du XXe au VIIIe siècle avant notre ère: Actes du colloque international Bronze '96,* vol. 2, ed. Claude Mordant, Michel Pernot, and Valentin Rychner (Paris: CTHS, 1998), 9–24; Gert Goldenberg and Brigitte Rieser, "Die Fahlerzlagerstätten von Schwaz/Brixlegg (Nordtirol): Ein weiteres Zentrum urgeschichtlicher Kupferproduktion in den österreichischen Alpen," in Weisgerber and Goldenberg, "Alpenkupfer = Rame delle Alpi," 37–52.

10 Christoph Bartels and Andreas Bingener, *Der Bergbau bei Schwaz in Tirol im mittleren 16. Jahrhundert, Das Schwazer Bergbuch*, vol. 3 (Bochum: Deutsches Bergbau-Museum, 2006).

11 Monna et al., "Environmental Impact of Early Basque Mining."

12 Peter Gstrein, "Geologie, Mineralogie und Bergbau des Gebietes um Brixlegg," in *Brixlegg: Eine Tiroler Gemeinde im Wandel der Zeiten*, ed. Sepp Landmann (Brixlegg, 1988), 11–31.

Additionally, the copper in the fahlore crystals is supplemented by minor components like silver, mercury, iron, zinc, and bismuth. Scarce chalcopyrite and galena deposits are also present in the ore. During the Bronze Age, copper was the main target of the miners in the region around Schwaz. Due to the low lead concentrations of the fahlore, prehistoric ore smelting and copper production caused only negligible lead pollution in the Inn valley. Later improvements in the smelting process made it possible to extract the fractional amounts of silver in the ore, which lead to a blossoming of mining in medieval and (early) modern times. Because the methods used—the Saigerhütten process and cupellation—required large quantities of lead to extract silver from the silver-bearing copper, the lead pollution in the Inn valley was much higher at that time. These industrial procedures could be seen as the main cause of lead pollution in medieval and (early) modern times.

In this study, the peat of the fen of Kogelmoos was used to reconstruct the history of vegetation and pollution of the formerly prominent Tirolean mining district of Falkenstein. The mire in the copper- and silver-ore-bearing region near Schwaz was selected after detailed surveys of the north-facing slope of the Mehrerkopf. At 1,120 m above sea level, near the farmsteads of Kogelmoos, the 0.2 ha fen is located between coniferous forest and intensively used meadows. A spruce forest with larch (*Larix*) and fir (*Abies*) is situated to the southwest of the mire. This area is characterized by various mining waste heaps from early modern times, which are still in part bare of vegetation cover even today. In the higher altitudes the spruce forest (*Picea*) is mixed with pine (*Pinus*) and larch (*Larix*) and in the lower areas with fir (*Abies*) and beech (*Fagus*).

Archaeological and Historical Background

The current state of research holds that mining activities in the region around Schwaz in the Tirolian Inn valley were initiated during the first half of the Middle Bronze Age.[13] Archaeological findings[14] and radiocarbon analyses[15] in the Falkenstein area suggest that some galleries date back to prehistoric times. Several remains of prehistoric mining activities in that area can be dated to sometime between the Late Bronze Age (Urnfield culture) and the first half of the Iron Age (Hallstatt culture).[16]

13 Goldenberg, "L'exploitation du cuivre."
14 See Brigitte Rieser and Hanspeter Schrattenthaler, "Urgeschichtlicher Kupferbergbau im Raum Schwaz-Brixlegg," *Archaeologica Austriaca* 82/83 (1998–99): 135–79.
15 Goldenberg and Rieser, "Die Fahlerzlagerstätten von Schwaz/Brixlegg."
16 Rieser and Schrattenthaler, "Urgeschichtlicher Kupferbergbau."

Written evidence for mining activities around Schwaz first occurs much later, at the end of the fourteenth century CE. In a rent-roll of the monastery of St. Georgenberg-Fiecht, which dates back to the years between 1361 and 1370,[17] the first written mention of a farm settlement at the "Hohenchogel" (today the hamlet of Kogelmoos) is found. In 1409, according to legend, a bull revealed a vein of ore by pawing the ground with its hooves in the hamlet of Kogelmoos. The existence of mining activities in the mountains of Schwaz as early as 1400 has been demonstrated through an onomastic analysis of mining-related family and occupational names taken from early tax lists and subject registers.[18] The *Schwazer Bergbuch* ("Schwaz Mining Book") states that the first ores were extracted some 110 years before 1556.[19] Mining activities in and around Schwaz are also documented in clerical, sovereign, and municipal sources from the 1440s onward.[20] The first "Bergordnung" (mining ordinance) concerning the mining district of Schwaz dates back to the year 1449.[21]

By the beginning of the sixteenth century, the rise of Schwaz from a small marketplace on the shores of the river Inn to the center of European copper and silver mining had begun. From that time on, Schwaz left other European silver-producing centers such as the districts in Mansfeld (today: Thuringia in Germany), Oberungarn (today: Slovakia), as well as the towns in the Saxon and Bohemian Erzgebirge (Ore Mountains) far behind. Between 1470 and 1525 more than half of the silver produced in the abovementioned European districts was mined in the various subdistricts of Schwaz.[22] As Westermann has demonstrated, lists of the production of refined silver in the subdistrict of Falkenstein show that the quantity of ore mined in the Schwaz mining district peaked in the 1520s.[23] In the second half of the sixteenth century, mining activities in Schwaz began to decline again. In 1657 the mine holdings were sold to the sovereign by the Fugger family, who owned the last private "Gewerken" (mining operation); the state-operated silver and copper production was ultimately abandoned in 1827.[24]

17 Hanns Bachmann, *Die Mittelalterlichen Stiftsurbare des Bistums Brixen 4: Das Älteste Urbar der Benediktinerabtei St. Georgenberg zu Fiecht von 1361/70 und das Weinzinsregister von 1420 und 1422* (Innsbruck: Universitätsverlag Wagner, 1981).

18 Yvonne Kathrein, "Bei- und Familiennamengeographie im 14. und 15. Jahrhundert in Tirol: Ein onomastischer Beitrag zur Beginnphase des Schwazer Bergbaus," *Innsbrucker Beiträge zur Onomastik* 7 (2009): 53–76.

19 Bartels and Bingener, *Der Bergbau bei Schwaz.*

20 Wolfgang Tschan and Gerd Hofmann, *Das Schwazer Bergrecht der frühen Neuzeit: Eine Quellenedition* (Reutte: Ehrenberg-Verlag, 2008).

21 Wolfgang Tschan, "Das Schwazer Berglehenbuch und die Anfänge des Schwazer Bergbaues," *Der Anschnitt* 5/6 (2008): 202–13.

22 Thomas Sokoll, *Bergbau im Übergang der Neuzeit* (Idstein: Schulz-Kirchner, 1994).

23 Ekkehard Westermann, *Die Listen der Brandsilberproduktion des Falkenstein bei Schwaz von 1470 bis 1623* (Vienna: Verband der wissenschaftlichen Gesellschaften Österreichs, 1988).

24 Georg Mutschlechner, "Vom alten Bergbau am Falkenstein (Schwaz): Nach gedruckten und ungedruckten Quellen," in *Schwazer Buch: Beiträge zur Heimatkunde von Schwaz und Umgebung*, ed. Raimund von Klebelsberg (Innsbruck: Wagner, 1951), 113–25.

Material and Methods

Lake and bog sediments are great archives of the vegetation history of former landscapes. The plant remains in the wetlands provide information about the spectra of plant species and their changing proportions in the past.[25] The information stored in the plant remains is preserved in the sediment and is influenced by how and where they were deposited.[26] Additional palaeoecological data can be obtained by geochemical analyses of the deposits.

Pollen grains of flowering plants as well as spores of ferns and mosses are archived in peat bogs for millennia. These 10–100 μm particles can only be recognized with a microscope, but it is nevertheless possible to identify families, genera, and sometimes even species due to the variety of their morphology.[27] Pollen and spores of vascular plants, which are often produced in large quantities, spread through the atmosphere and settle in the vicinity of their source. Because of their high sporopollenin content, pollen and spores are resistant to decomposition if they are hermetically sealed in wetlands and may be preserved for thousands of years.[28] By counting pollen grains in the samples, researchers can draw conclusions about the occurrence and frequency of various species. The palynological data gained in this manner enables a reconstruction of the vegetation history of the area surrounding the wetland.

As mentioned above, humans have changed the landscape mainly through settlement activities and agriculture, but mining and metallurgic workings have also had enormous consequences for the environment. The heavy metal emissions, which originate from ore extraction and particularly from smelting activities, were deposited in sediment basins in much the same manner as pollen and spores. Some of these heavy metals are bound to the sediment and remain in the layer where they were deposited. The combination of palynological and geochemical data with methods of age determination like radiocarbon dating enables the identification of mining phases in the areas surrounding the sediment basin. By this multi-proxy approach, wetlands could be used as archives of the mining history of the last millennia.[29]

25 Gerhard Lang, *Quartäre Vegetationsgeschichte Europas* (Jena: Gustav Fischer Verlag, 1994), 33–51.
26 Peter D. Moore, J. A. Webb, and Margaret E. Collison, *Pollen Analysis,* 2nd ed. (Oxford: Blackwell, 1991), 216.
27 Lang, *Quartäre Vegetationsgeschichte Europas*.
28 Moore, Webb, and Collison, *Pollen Analysis*.
29 Shotyk et al., "History of Atmospheric Lead Deposition"; Monna et al., "Environmental Impact of Early Basque Mining."

Field Sampling

The Kogelmoos fen was surveyed using an avalanche probe, after which a core sample of the peat was taken with a Geonor piston corer from the deepest part in the middle of the bog (fig. 1). The resulting core is 2 m long and has a diameter of 52 mm. Additionally, the uppermost layers were excavated and a peat column of 1 m was collected in metal boxes pressed into the wall of the core site. This method was used in place of boring in order to minimize the compression of the more recent deposits.

Figure 1: Coring (Geonor piston corer) at the Kogelmoos fen (Courtesy of the author)

Pollen Analysis

The sample material was wrapped with cling film before being stored in a cooling chamber until sample preparation. For pollen preparation, subsamples were taken of a constant volume of 1 cm^3 in standardized intervals. The chemical treatment of the peat samples followed the standard procedure used at the Botanical Institute of Innbruck University according to Erdtman[30] and Seiwald[31] (including treatment by hydrochloric acid, chlorination, acetolysis, and, if necessary, hydrofluoric acid). Afterwards the samples were colored with fuchsine and mounted in glycerin jelly. Pollen grains were counted at 400x magnification (for critical determinations at 1,000x magnification)

30 G. Erdtman, "The Acetolysis Method: A Revised Description," *Svensk Botanistik Tidskrift* 54 (1960): 561–69.
31 Alois Seiwald, "Beiträge zur Vegetationsgeschichte Tirols IV: Natzer Plateau—Villanderer Alm," *Berichte des Naturwissenschaftlich-Medizinischen Vereins Innsbruck* 67 (1980): 31–72.

and were identified by using the standard identification keys of the central European pollen flora[32] as well as the reference collection of the Botanical Institute of Innsbruck University. At least 1,000 tree pollen were counted for each pollen spectrum. Furthermore, non-pollen palynomorphs (NPPs), such as fungal hyphae, spores of coprophile fungi, zoological residues, and microcharcoal, were specified and quantified.

The pollen sum consists of the arboreal and non-arboreal pollen counted, but marshland taxa such as alder (*Alnus*), sedges (Cyperaceae), and water plants, as well as spores and NPPs, were excluded from the pollen sum because they would interfere with the data for the area being studied.[33] The calculation of the pollen diagrams was carried out by the program FAGUS,[34] which was developed at the Botanical Institute of Innsbruck University. The graphical representation was performed by the program C2.[35]

Geochemical Analysis

The peat subsamples were homogenized and digested. The received solutions underwent trace element and lead isotope analyses at the Curt Engelhorn Center for Archaeometry in Mannheim. Total concentrations of lead (Pb) and scandium (Sc) were determined using a quadrupole inductively coupled plasma mass spectrometer (Thermo Scientific XS 2). While lead is an indicator of mining activities, scandium concentrations remain largely unaffected. By comparing the ratio of lead to scandium in the samples, it was possible to determine whether increases in lead were due to anthropogenic sources. Lead isotope ratios ($^{208}Pb/^{206}Pb$, $^{207}Pb/^{206}Pb$, $^{206}Pb/^{204}Pb$) of the peat samples were measured with a double-focusing magnetic-sector-based multi-collector inductively coupled plasma mass spectrometer (AXIOM, VG Elemental).[36]

32 Hans-Jürgen Beug, *Leitfaden der Pollenbestimmung für Mitteleuropa und angrenzende Gebiete* (Stuttgart: G. Fischer, 1961); William Punt, ed., *The Northwest European Pollen Flora,* vol 1, vols. 2–4 ed. with G. C. S. Clarke, vol. 5 ed. with Stephen Blackmore and G. C. S. Clarke (Amsterdam: Elsevier, 1976–88); Moore, Webb, and Collison, *Pollen Analysis*; Maurice Reille, *Pollen et spores d'Europe et d'Afrique du nord* (Marseille: Laboratoire de Botanique historique et Palynologie, 1992, supplement 1 published 1995); Knut Faegri and Johannes Iversen, *Bestimmungsschlüssel für die nordwesteuropäische Pollenflora* (Jena: Gustav Fischer Verlag, 1993).

33 P. E. J. Wiltshire and K. J. Edwards, "Mesolithic, Early Neolithic and Later Prehistoric Impacts on Vegetation at a Riverine Site in Derbyshire," in *Climate Change and Human Impact on the Landscape: Studies in Palaeoecology and Environmental Archaeology*, ed. F. M. Chambers (London: Chapman & Hall, 1994), 157–68.

34 Gernot Gelmini, "Programm zur grafischen Darstellung von Pollenzähldaten," Diplomarbeit, Universität Innsbruck, 1997.

35 Stephen Juggins, "C2 Version 1.5 User Guide: Software for Ecological and Palaeoecological Data Analysis and Visualisation," (Newcastle upon Tyne: University of Newcastle, 2007).

36 For a more detailed description of the method used see Elisabeth Breitenlechner et al., "The Impact of Mining Activities on the Environment Reflected by Pollen, Charcoal and Geochemical Analyses," *Journal of Archaeological Science* 37 (2010): 1458–67.

Radiocarbon Dating

The AMS radiocarbon-dating measurements were conducted at the Vienna Environmental Research Accelerator of the Faculty of Physics Isotope Research Group, University of Vienna. The achieved radiocarbon dates were calibrated using the OxCal Version 3.10.[37] Using the calibrated radiocarbon dates (fig. 2) an age-depth model of the samples was calculated. The timescale in the diagram is shown in calendar years in BCE/CE.

Laboratory no.	Depth (cm)	Material	Uncalibrated date BP	Calibrated age range (2 sigma)	Calibrated calendar year BCE/CE
VERA-4290HS	30	Sedge peat	230±30	Cal CE 1640–1946	1659 CE
VERA-4291HS	50	Sedge peat	465±35	Cal CE 1409–1477	1438 CE
VERA-4461	65	Sedge peat	1655±35	Cal CE 261–527	410 CE

Figure 2: Radiocarbon dates from Kogelmoos

Results and Interpretation

In about 600 CE, the area surrounding the Kogelmoos fen was dominated by forests with fir (*Abies*) and spruce (*Picea*). While there are isolated indicators (such as artifacts) of human presence in the area, there is not enough evidence to suggest there were permanent settlements at this time. The low values of microcharcoal indicate moderate local fire activity in the Falkenstein area. The continuous presence of low amounts of cultural indicators over the next several centuries suggests there was human activity in the greater vicinity of Kogelmoos, although the spruce-fir forest of the area remained mainly undisturbed.

Around 1350 CE a major alteration of the vegetation in the Falkenstein district took place. The fir (*Abies*) values decrease dramatically whilst grasses (Poaceae), pasture, and cultural indicators, as well as the values of local microcharcoal, begin to rise (fig. 3). This pattern in the pollen diagram shows a more open landscape and reflects large-scale forest clearance. The first written mention of a farm at “Hohenchogel”

37 Christopher Brock Ramsey, “OxCal Program v3.10,” last modified 9 February 2005, http://c14.arch.ox.ac.uk/oxcal3/oxcal.htm; Atmospheric data from Paula J. Reimer et al., “IntCal09 and Marine09 Calibration Curves, 0–50,000 Years Cal BP,” *Radiocarbon* 51, no. 4 (2009): 1111–50.

(homonymous to the present-day hamlet of Kogelmoos) was found in the oldest rent-roll of the monastery of St. Georgenberg-Fiecht and dates back to the years between 1361 and 1370.[38] The connection between the significant change in the vegetation and the appearance of the farmstead in the second half of the fourteenth century is obvious. The landscape was opened by (fire) clearance to establish space for agriculture

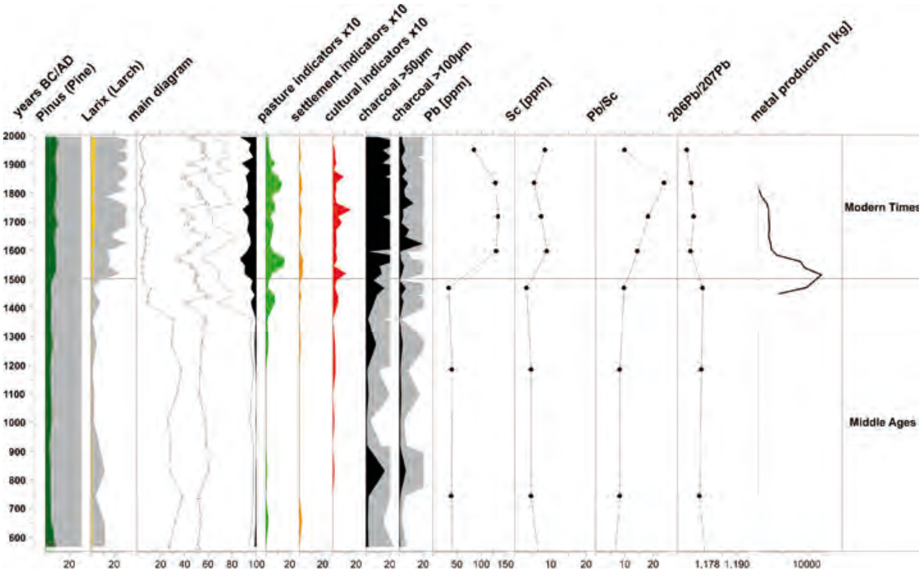


Figure 3: Middle Ages and modern times in the relative pollen diagram (selected species) of the Kogelmoos with geochemistry and historical data (Nöh 1948, 128). Black/colored areas = fraction of different species in %; grey areas = fraction of different species multiplied by 10; main diagram: x = values of fir (*Abies*) in %, Δ = values of spruce (*Picea*), solid line = border of fraction of tree and non-tree-species, black area = values of grasses (Poaceae).

and livestock farming, which is shown in the continuous curves of cultural and pasture indicators. The establishment of the farmstead at Kogelmoos reflected the expansion of settlement activities in the mining area of Schwaz at the end of the Middle Ages. At that time the small marketplace expanded and left multiple historical traces in clerical, sovereign, and municipal archives.[39]

A further intensification of settlement activities in the surroundings of the Kogelmoos farmstead is documented in the pollen diagram a century later. The data show an increase in pine (*Pinus*), larch (*Larix*), and grasses (Poaceae). Additionally, charcoal values increase synchronously with the values of the heavy metal lead. There is no doubt that there was a major change in vegetation occurring, but was this vegetation

38 Bachmann, *Die Mittelalterlichen Stiftsurbare.*
39 Tschan, "Das Schwazer Berglehenbuch."

change caused mainly by farming or mining activities? The intense admixed usage of the former woodland area of the Falkenstein district for agriculture and mining is shown in a historical drawing from the sixteenth century (fig. 4).

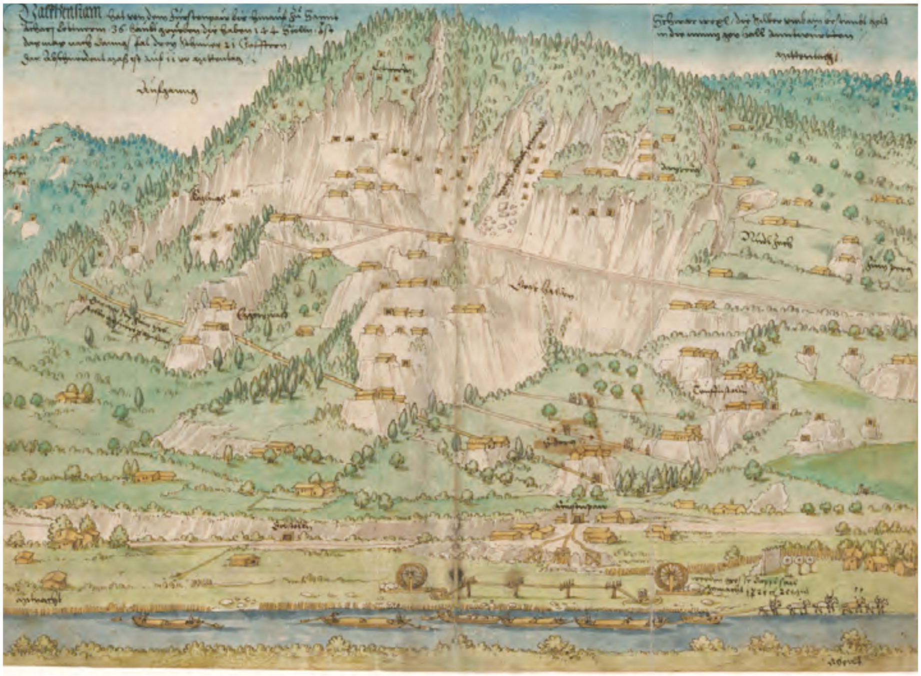


Figure 4: The formerly dense fir-spruce forest in the Falkenstein district was thinned out by mining and farming activities. (Source: Illustration from the *Schwazer Bergbuch,* Tiroler Landesmuseum Ferdinandeum, Innsbruck)

The implication of mining activities as the dominant shaping force of the vegetation could also be seen in increasing lead values at the beginning of the modern era. As there is always a natural input of lead to the wetland, indicated by the variation of mineral matter in the peat, this fraction has to be deducted from the measured lead values. The Pb/Sc ratio displays the measured lead values in the deposits normalized to the lithogenic fraction.[40] At the transition from the Middle Ages to the modern era, the silver and thus also copper production in the Falkenstein mine eventually reached its peak.[41] At the same time, the Saiger technique was implemented in the Tirolean

40 William Shotyk et al., "Geochemistry of the Peat Bog at Étang de la Gruère, Jura Mountains, Switzerland, and Its Record of Atmospheric Pb and Lithogenic Trace Metals (Sc, Ti, Y, Zr, and REE) Since 12,370 14C yr BP," *Geochem Cosmochim Acta* 65 (2001): 2337–60.

41 Albert Nöh, "525 Jahre Schwazer Bergbau: Eine geschichtliche Zusammenfassung der Verhältnisse des Schwazer Bergbaues vom Beginn 1420–1945," unpublished manuscript 1948.

Figure 5: Recolonization of a mining dump in the Falkenstein district by pine (*Pinus mugo, P. sylvestris*) and larch (*Larix decidua*) trees

mining sites at around 1492.[42] This special smelting technique enabled the extraction of silver from the fahlore by using high amounts of lead. The use of this heavy metal in the metallurgical process caused an elevated emission of lead from the smelting works and an increased concentration of lead in the vicinity, including the surrounding wetlands. Because of the lack of profitable lead ore deposits in the lower Inn valley, the lead was imported from neighboring regions, like mining districts near Villach in Carinthia, Gossensass in South Tirol, and others.[43] Another sign of the usage of external lead in the smelting process is the alteration of the isotope ratio in the fen. The reduction of the $^{206}Pb/^{207}Pb$ ratio at the beginning of the modern era might be a result of added lead with a different isotope ratio.

As mentioned, the crucial problem in the palaeoecology of mining is to distinguish between mining activities and agriculture in the pollen data. The vegetation change caused by mining activities is partly the result of large-scale stockpile areas. These mostly steep areas of loose coarse rock offer very difficult conditions for recolonization

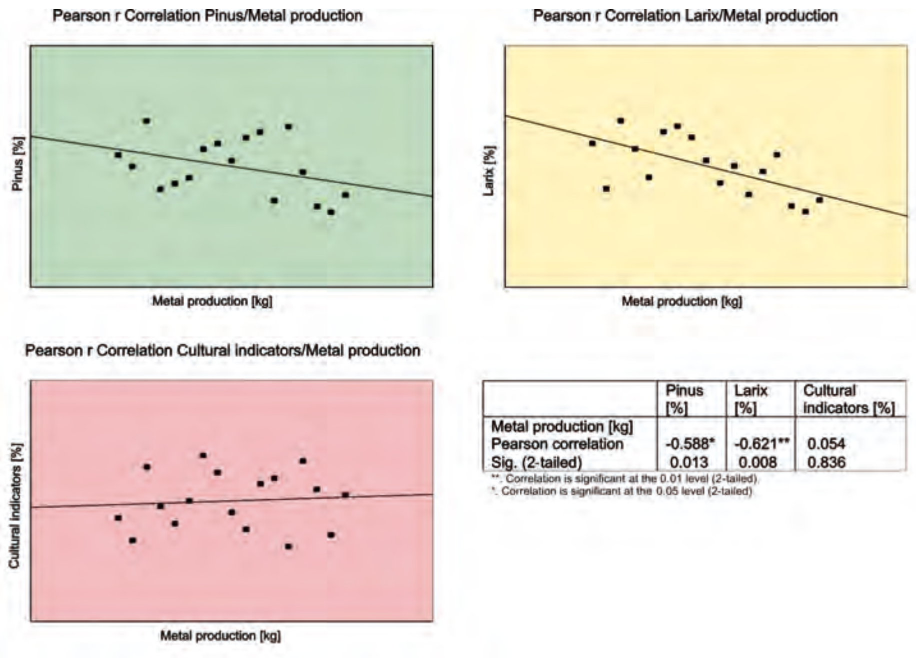
42 Wolfgang Ingenhaeff and Johann Bair, eds., *Schwazer Silber—vergeudeter Reichtum? Verschwenderische Habsburger in Abhängigkeit vom oberdeutschen Kapital an der Zeitenwende vom Mittelalter zur Neuzeit,* Tagungsband, 1. Internationales Bergbausymposium (Innsbruck: Berenkamp, 2003).

43 Bartels and Bingener, *Der Bergbau bei Schwaz.*

by plants. The low nutrient availability and the poor water balance allow only very specialized plants to colonize the mining dumps. The vegetation development on these rock piles is similar to that on natural rockslides. The succession of the tree vegetation is indicated by pine (*Pinus mugo, P. sylvestris*) and larch (*Larix decidua*) (fig. 5). With increasing soil development and water-holding capacity, spruce (*Picea abies*) is able to immigrate and finally a larch-spruce forest develops. However, the conditions on mining dumps correspond to the situation of an artificial rock fall caused by ore extraction, in which waste rock material is deposited continuously in the course of intensive ore extraction in the galleries. The permanent supply of scree material causes constant mechanical stress and inhibits the recovery of the vegetation on the loose rock material. On the other hand, the decrease of the mining activity, which is indicated by lower copper and silver production rates[44] in the Falkenstein area, implicates less mining waste or even abandoned galleries. Consequently, the reduction of the mechanical stress on the mining dumps speeds up the secondary succession of vegetation on the former spoil piles in the mining area. The data of the Falkenstein district show a decline in the copper and silver production in the area from 1520 onward.[45] Contemporaneous with the cutback of mining activities in the vicinity of the fen, pine (*Pinus*) and larch (*Larix*) values in the pollen diagram rise, reflecting the spread of these heliophile pioneer tree species on abandoned mining dumps.

The relationship between the decline of the ore production and the expansion of the pioneer species mentioned above is shown by the correlations between pine (*Pinus*), larch (*Larix*), cultural indicators, and the calculated copper and silver ore production volume. The Pearson product-moment correlation coefficients of both pine (*Pinus*) and larch (*Larix*) with the ore production in the Falkenstein area indicate a significant and highly significant negative relationship (fig. 6). The correlation between cultural indicators and ore production is not significant, however, and seems to be independent of the copper and silver production volume. There is no doubt that the ore production is connected with ore extraction in the mines. The decrease of the copper and silver production reflects lower activities in the mines of the Falkenstein district. With the decrease in mining activities, the amount of waste material deposited on the dumps also decreases. This in turn initiates or intensifies the recolonization of the spoil piles by pine (*Pinus*) and larch (*Larix*), as mentioned above.

44 Nöh, "525 Jahre Schwazer Bergbau."
45 Ibid.



	Pinus [%]	Larix [%]	Cultural indicators [%]
Metal production [kg]			
Pearson correlation	-0.588*	-0.621**	0.054
Sig. (2-tailed)	0.013	0.008	0.836

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Figure 6: Correlation diagrams and the Pearson correlation coefficient of *Pinus, Larix* and cultural indicators [%] with the metal production (copper/silver) [kg] in the Falkenstein district.

Conclusion

In this study, the data show that increased mining activity in the Falkenstein area is indicated by elevated Pb/Sc ratios and decreasing lead isotope ratios in the fen deposits. The decreasing copper and silver production from the sixteenth century onwards initiates the intensified recolonization of the mining dumps. This change in the vegetation is shown by increasing pine (*Pinus*) and larch (*Larix*) values in the pollen diagram. The assemblage of palynological, geochemical, and historical data provides a detailed picture of past mining phases and helps explain the human-environment interactions in a mining landscape.

Laura Hollsten

Mercurial Activity and Subterranean Landscapes: Towards an Environmental History of Mercury Mining in Early Modern Idrija

> Mercury appears sometimes in the form of a fluid metal, sometimes in the form of a hard brittle metal, sometimes in the form of a corrosive pellucid salt call'd Sublimate, sometimes in the form of a tasteless, pellucid white Earth, call'd Mercurius dulcis, or in that of a red opake volatile Earth, call'd Cinnabar; or in that of a red or white Precipitate, or in that of a fluid Salt; and in distillation it turns into a Vapour, and being agitated in vacuo, it shines like Fire. And after all these Changes it returns again into its first form of Mercury. – Sir Isaac Newton, *Opticks*[1]

To humans, mountain rock represents constancy, stability, and long duration; the stable basis upon which various forms of organic life originate. However, mountains have a "life" of their own in the sense that they themselves come into being, grow, and are worn down by the effects of climate and erosion. For instance, the so-called Alpine orogeny began 65 million years ago, and the mountains which were created at that time are still growing.[2] The change is so slow that it is invisible to the human eye. Some of the minerals which constitute the mountain rock, however, are perceived as "quicker" and more "alive" than others. The formation of mercury deposits is a slow process occurring in the earth's crust as magma invades sedimentary rocks during volcanic activity. In the timescale of mountains, mercury ore is found in very young orogenic belts. As it changes from one form to another as described by Newton above, mercury can seem to be alive and active in its native liquid state, for instance, when it occurs as small drops on mercury ore minerals.[3] The citation by Newton reflects the volatile and mobile nature of mercury, which has intrigued people since antiquity. It was (and is) primarily mined from cinnabar ore, which is often found only deep beneath the surface of the earth: about 90 percent of all cinnabar deposits are at depths that require underground mining. In Europe the most important mercury deposits are found at Almadén in Spain, Idrija in Slovenia, and Monte Amiata in Italy. The Almadén mines have been in operation since antiquity, when the Romans extracted cinnabar

1 Isaac Newton, *Opticks, or, A Treatise of the Reflections, Refractions, Inflections and Colours of Light* (London: Printed for W. and J. Innys, 1717), 350.
2 Martin F. Price, *Mountains: Geology, Natural History, Ecosystems* (Stillwater, MN: Voyageur, 2002), 17.
3 Strictly speaking mercury is not a mineral but a mineraloid.

from the area. Idrija is one of the few places in the world where mercury can be found in both its elemental liquid state and as cinnabar (mercury sulfide) ore. A legend about the beginnings of the mine is often repeated in texts about Idrija: according to this, mercury mining began in the 1490s when a tub-maker spotted a small amount of liquid mercury while working at a local spring. This eventually led to a mining operation which came to be the second-largest mercury mine in the world, surpassed only by the Almadén mine.[4]

This paper is a part of an ongoing research project studying the movement of mercury in early modern Europe. Mercury and humans have a long shared past, with mercury occurring in contexts ranging from medicine to technology. In the field of environmental history, mercury offers an interesting opportunity to combine cultural history and the history of science with a history of the ecosystems influenced by mercury mining, transport, and use. Mercury mining has impacted people and their environments in several ways. Besides thoroughly transforming the landscapes around the mines, mercury mining has contaminated the local soil, water, and air for long periods of time. Moreover, mercury has affected the health of the miners, causing a variety of occupational diseases, often leading to an early death. Perhaps more than any other metal (with the exception of gold and silver) mercury carries a very rich environmental and cultural history as a result of its distinctive characteristics. Not only does mercury have certain unique properties, making it a useful metal in a variety of ways, but it also carries a considerable symbolic significance. The mutable and liquid qualities of mercury have fascinated people for thousands of years, involving it in practices of magic, medicine, science, and technology.

The Latin name of mercury is *hydrargyrum*, meaning "water-silver," and refers to its mobility and volatility. These properties also earned it the name "quicksilver" in English. Because of its fluid quality, alchemists have associated mercury with the mysteries of matter (mercury, sulfur, and salt were thought to be the three principal substances of the earth, and mercury was believed to be at the core of all metals) and it was even credited with divine properties. In addition, mercury is one of the few metals

4 Mateja Gosar, Tatjana Dizdarev, and Miloš Miler, *Environmental Influences of Mercury Ore Processing—Case Studies Selected at Slovenian, Mexican, Hungarian Group Meeting in Idrija in July 2012* (Ljubljana: Geological Survey of Slovenia & Idrija Mercury Mine, Ltd. – in liquidation, 2012). Accessed 8 February 2013. doi:10.5474/9789616498340. See also Aleksander Recnik, *Minerals of the Mercury Ore Deposit Idrija* (Berlin: Springer, 2013).

that are liquid at room temperature, and it also evaporates relatively easily. It can be combined with other metals to make amalgams, or solutions, of metals, and it has been used in the extraction of gold for this reason. Mercury is also a highly toxic substance which has caused serious health problems in a great number of people during the long history of its use. Moreover, mercury is a pollutant which has profoundly affected the ecosystems everywhere it has been mined, transported, and processed. Finally, mercury mining has bored into the rock and reshaped whole regions, creating a subterranean landscape, most of which is visible only to the people working the mine.

How should the various aspects of mercury mining, transport, and use be studied in the context of environmental history? This article suggests that the concept of mobility might offer a starting point for the discussion. Mercury is a substance which throughout history has moved freely between nature and humans, between nature and culture. The fluid character of mercury makes the problem in separating nature and culture particularly obvious. Like the chemicals described by Jody A. Roberts and Nancy Langston in the theme issue of *Environmental History,* "Toxic Bodies/Toxic Environments," mercury occupies a position on the border between the "natural" and "cultural" worlds.[5] Because of its fluidity, mercury moves around the ecosystem: in the cinnabar rock that is being mined, in the air, soil, and water, as well as in amalgamations, turning up in the laboratories of alchemists, apothecaries' shops, hatters' workshops, and human bodies in its capacity as a medicine, poison, or pollutant. As an important export product, mercury has taken part in the increasing geographic mobility of the early modern world, crossing borders while being transported from one country to another and from one continent to another. Much of this mobile activity has been invisible, partly because it has taken place underground, partly because certain forms of mercury pollution are not visible to the eye.

A useful framework for considering mercury mining in environmental history is suggested by the work of Jane Bennett, who maintains that there is a vitality to metals, and, indeed, to many inorganic substances, a "quivering of . . . free atoms."[6] While this "aliveness" of metals is not readily observable to the human eye in all metals, mercury more than any other metal appears to be alive at room temperature, in the form of a flowing

5 Jody A. Roberts and Nancy Langston, "Toxic Bodies/Toxic Environments: An Interdisciplinary Forum," *Environmental History* 13 (2008): 629–35.
6 Jane Bennett, *Vibrant Matter: A Political Ecology of Things* (Durham: Duke University Press, 2010), 59.

liquid. The idea of "living" mercury was widespread in medieval and early modern times when alchemists believed mercury to be the primordial water of creation, which had the ability to transcend both the solid and liquid states, both earth and heaven, and even life and death. But even without endowing mercury with any magical qualities I would like to adopt Bennett's idea of "thing-power," a concept which invites us to observe the vitality and aliveness of inorganic matter. The concept of thing-power has its roots in materialistic philosophy. Rather than being considered as passive and inert, things are seen as forces that play decisive roles in events. Bennett maintains that far from being passive objects in the world, things in fact affect other bodies and have the power of enhancing or weakening them. Her work suggests moving from a world of nature versus culture to one of "many conative actants swarming and competing with each other."[7] Bennett's "thing-power" has important implications for our views on ecology. It emphasizes the closeness of humans and non-humans, and the entire network of relations of which an ecosystem consists.[8] The ecosystem consists not only of living organisms and inorganic matter such as minerals, but of all the various combinations of them, circulating within and around humanity.[9] Regarding the material world in this non-hierarchical manner highlights ways in which the various bodies in motion affect the environment. It also raises the question of non-human agency in the shaping of landscapes. Michael Egan has noted how studying natural and synthetic chemicals such as mercury in landscapes which are rendered harmful for organic beings by their presence offers new opportunities for reflecting on non-human agency in environmental history.[10] Mercury's transitions and its effects on the ecosystems in which it moves can be seen as an example of human and natural cooperation or partnership. When studying the environmental impact of mercury, neither the groups of people or individuals involved in the mining, trade, and use of mercury, nor mercury itself can be regarded as being the principal agents. The changes are rather a consequence of the interplay between humans and non-humans, where agency can be regarded as relational rather than autonomous. In line with actor-network theory, it can described as an assemblage of human and non-human interaction, resulting in changes in nature and the landscape. Mercury mining consequently offers an interesting opportunity to discuss the nature (in all senses of the word) of various agents in shaping the environment.

7 Bennett, *Vibrant Matter*, 122.
8 Jane Bennett, "The Force of Things: Steps toward an Ecology of Matter," *Political Theory* 32 (2004): 365.
9 Bennett, "The Force of Things," 349.
10 Michael Egan, "Forum: Toxic Knowledge: A Mercurial Fugue in Three Parts," *Environmental History* 13, no. 4. (2008), 636–42.

Subterranean Landscapes

The mercury mine at Idrija was famous in early modern Europe. The English traveler and fellow of the Royal Society Edward Browne visited Idrija in 1669 during his tour of Hungary and the Adriatic coast. He reports to Henry Oldenburg that "there is little considerable in this towne or such as might requite the trouble of travelling unto it, butt only the Quicksilver mines."[11] Browne himself travelled to Idrija specifically in order to see the mine, which he describes in his letter and in *A Brief Account of Some Travels*.[12] Idrija, some 50 kilometers west of Ljubljana, was part of the province of Goritia in the eighteenth century. The mine was not only the most important sight to be seen in the region, it was also the backbone of the economy of the area. Idrija was the site of one of the richest mercury deposits in the world, and for centuries mercury was almost like gold to the province. A mining company began to mine the rich deposits of mercury in Idrija in 1493. In the first years of mining, Idrija was part of the hinterland of Venice, but was annexed by the Habsburg dynasty after the successive battles with Venice which took place between 1508 and 1517. The mine came to be part of the Austrian empire and was administered directly under the Austrian court. The province of Goritia, later Carniola, remained under Austrian rule until the First World War.[13]

Janez Vajkard Valvasor's copper engraving of Idrija in the late seventeenth century provides a visual representation of the landscape that Browne saw in 1669. Valvasor was a scientist and fellow of the Royal Society, born in Ljubliana in the Duchy of Carniola, and the engraving appears in his work *Die Ehre deß Hertzogthums Crain* ("The Glory of the Duchy of Carniola") from 1689.[14] The picture shows how the town was built around the mine, which completely dominated it. The town was situated in a valley surrounded by mountains with a river running through it. The Gewerkenegg Castle, built at the beginning of the sixteenth century to serve as the administrative headquarters and warehouse of the mine, is the most prominent building in the picture. In addition, the picture shows a church and other buildings; in Valvasor's estimation there were about 300 houses in Idrija. According to his description, the population of Idrija in the eighteenth century was about

11 Edward Browne, "Letter to Henry Oldenburg, 15 June 1669, from Palmanova in Friuli" (read to the Royal Society, 28 October 1669).

12 Edward Browne, *A Brief Account of Some Travels in Hungaria, Servia, Bulgaria, Macedonia, Thessaly, Austria, Styria, Carinthia, Carniola, and Friuli* (London: Printed by T.R. for Benjamin Tooke, 1673).

13 Alfred Bogomir Kobal and Darja Kobal Grum, "Scopoli's Work in the Field of Mercurialism in Light of Today's Knowledge: Past and Present Perspectives," *American Journal of Industrial Medicine* 53 (2010): 535–36; Z. Z. Slavec, "Occupational Medicine in Idria Mercury Mine in 18th Century," *Vesalius* 4, no. 2 (1998): 52.

14 Janez Vajkard Valvasor, *Die Ehre deß Hertzogthums Crain* (Laybach: W. M. Endter, 1689).

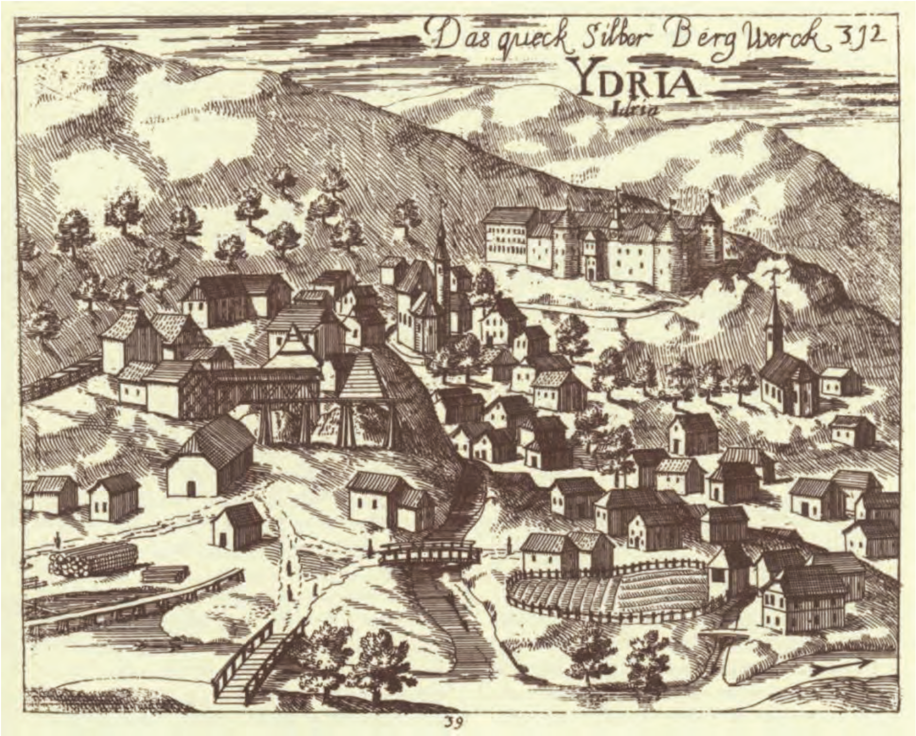


Figure 1: The quicksilver mine at Idrija, 1689. Copper engraving by Janez Vajkard Valvasor.

3,000 inhabitants, out of which 365–900 were miners. Many of the buildings served the mining operation in one way or another, whether as laboratories, offices, or warehouses.[15] The picture shows the River Idrijca, central to the mining operation, which was used as a power source for draining the mine and for transport. Piles of logs lie on the river shores. Browne in his description notes the river as being small and shallow, but in rainy times sufficient to convey the fir trees needed for the building of the mine constructions and the roasting of the ore, as well as providing fuel. Of the mine itself, Browne notes that the entrance was in the town (instead of high upon a hill as in many other mines), which is why engines and devices to draw the water out of the mine could be seen in the town's center.[16] One of the buildings in the picture may have been the entrance to the mine: St. Anthony's Shaft, which was dug in 1500, shortly after the discovery of mercury. The entrance building was constructed in front of the shaft at some point in the eighteenth century.

15 Slavec, "Occupational Medicine," 54.
16 Browne, "Letter to Henry Oldenburg."

More interesting than what can be seen in the picture, however, is everything that it does not show. There are some hints indicating that there is a vast landscape underneath the town; for instance, the extensive water draining devices used to pump water up from the mine. Still, with the exception of the entrance buildings, the laboratories, warehouses, and the castle, the main part of the mine, with its pits and shafts, is not visible. By the time of Valvasor's visit, two hundred years of mining had bored deep shafts in the mountain rock, creating a mining landscape where great areas were subterranean and thus invisible. Since the upper deposits were soon exhausted, the miners had to dig deeper and deeper to get to the ore. Consequently, the miners had to descend into a deep pit along a 300-meter-long shaft. At the end of this shaft the miners descended into the first vertical pit, Ahacij's or Attem's Shaft, which was dug in 1536 and closed in 1746. The miners continued their descent into the pit down some 1,000 steps. In the beginning it was 68.5 meters deep, and by the time it was closed in 1746 it had reached the depth of 133 meters. The deepest of the pits at Idrija was the Barbara's Pit, with a depth of around 200 meters. Joseph's Shaft, built in 1786, eventually became 420 meters deep and it connected all 15 levels of the mine.[17]

Edward Browne mentions a "dreadful description" of the Idrija mine by Athanasius Kircher, based on information provided by a Jesuit called Andreas Siserus.[18] His own description is more positive, focusing on the technical aspects of the mining operation. In his letter to the Royal Society he describes his descent into the mine by ladders, making it sound fairly easy. Browne was clearly impressed by the technicalities of the operation, and notes the absence of damp in the mine. He particularly admires the "excellent engines and devices used to pump up the water from the mines."[19] The water systems at Idrija were extensive and sophisticated. Some years before Browne's visit, the Englishman Walter Pope describes the waterwheels at Idrija as the largest he had ever seen. At the end of the eighteenth century, a large waterwheel was built that could pump water from a depth of 300 meters. Although water was continuously pumped out of the mine, there was always the danger of water breaking in. On the whole, the mine was a dangerous place for the miners working in it. The miners descended into the mine by means of ropes and returned by means of freely hanging rope ladders. When too weak or ill to climb, they were lifted up in baskets. The lowest parts of the pits contained toxic and inflammable gases and were badly ventilated.

17 Slavec, "Occupational Medicine," 52–53.
18 Browne, "Letter to Henry Oldenburg."
19 Ibid.

Lanterns were forbidden because of the possibility of fires, which could be fatal and very difficult to extinguish: for example, fires at the Almadén mine in Spain kept it closed for a long time in the 1770s. In spite of these precautions, 30 miners died in 1550 as a result of methane explosions.[20] As a kind of prophylactic measure, a chapel was built in the eighteenth century at the end of the shaft leading to the mine. Here the miners prayed to their patrons St. Acacius and St. Barbara for a successful day of work and a safe return.

In addition to their patron saints, miners had their own distinct culture, which included characteristic clothing, songs, and dances, as well as many beliefs and superstitions about the mines. Many of these would have reflected their special way of life and the subterranean life they led.[21] In early modern times, the subterranean world was credited with continuous activity. It was generally believed that metals incubated in subterranean caves and mines like embryos. They were to be found in various stages of maturity, ranging from immature metals such as arsenic, metals of middling maturity such as lead, and fully mature metals such as gold. The idea of metals germinating in the bosom of a living earth like embryos or plants was part of an old tradition, common in antiquity and in the European Middle Ages.[22] There were also legends about the spirit of the mines and the supernatural help that could be received if the spirits were appeased. The subterranean landscape was believed to be inhabited by invisible beings who could help the miners find rich deposits but who could also make life difficult for them. For instance, symptoms of mercury poisoning were thought to be caused by spirits taking revenge. Among the supernatural beings were small mountain men or gnomes, described by Georgius Agricola in his sixteenth-century treatise on metallurgy as being dressed like miners, but smaller than dwarfs and believed to wander around the pits and tunnels.[23] These beings can be understood as mediators between the humans and the natural world, represented by the mountain which gave birth to the valuable mineral. One of their tasks may have been to protect the minerals and see to it that they were not excessively exploited. The view of the earth as a living creature also effectively placed restrictions on mining. The precious metals were thought to

20 Slavec, "Occupational Medicine," 53.
21 Peter Burke, *Popular Culture in Early Modern Europe* (1978; repr., Farnham and Burlington: Ashgate, 2009), 63–64.
22 Carolyn Merchant, *Ecological Revolutions: Nature, Gender, and Science in New England* (Chapel Hill and London: University of North Carolina Press, 1989), 114–15.
23 Georgius Agricola, *De Re Metallica*, trans. Herbert Clark Hoover and Lou Henry Hoover (New York: Dover Publications, 1912), 217.

have gestated in the earth's womb, for which reason a variety of ceremonies and sacrificial rituals were connected to mining, reflecting a perceived need to compensate for the deed of plunder. Metallurgy was considered to be a method of hastening the natural growth of what was thought to be living metal and was therefore connected to magic, a belief that explains the special position of the smith in traditional societies. Alchemy was thus a process where the correct combination of mercury and other ingredients would further hasten the maturation of the process and result in gold. Hence the creation of cinnabar or mercury through natural processes, its extraction through mining and metallurgy, and its use in alchemy were all seen as being based on the same principles. Each of these processes is an example of an interplay between humans and the minerals, each exhibiting different degrees of agency.

Mobile Metal

Virtually all mercury is derived from cinnabar, or mercury sulfide (HgS), although in rare cases mercury can also be found as a native metal (i.e., in its elemental form rather than as part of a compound). The red cinnabar at Idrija was so rich in mercury that drops of elemental mercury could be found in samples of the ore. The ore in the mine, according to Browne, was "of a dark color striped with red" and the mercury only became visible when forced out of the cinnabar by fire.[24] Once cinnabar or other metallic ores are mined, brought to the surface, and crushed, mercury can be easily extracted. When heated, cinnabar releases mercury as a vapor which is then cooled and captured as liquid mercury. Because of its changeable character, mercury can assume a variety of chemical forms, including liquid elemental mercury and solid cinnabar in mineral deposits, as well as gaseous elemental mercury in the air and methylmercury in water and sediment.

Mercury has been mined in Europe since antiquity, when mercury was used in ointments and cosmetics. In early modern times, mercury was used not only by alchemists, but also by goldsmiths, who used it for fire gilding, and hatters, who used it in the felting of animal hair. In addition, mercury was used by physicians, who treated their patients with it. Alchemists were important users of mercury mostly up through the sixteenth century, but they continued to practice their art into the seventeenth century.

24 Browne, "Letter to Oldenburg."

The Superintendent of Mines in Sweden, Axel Fredric Cronstedt, and the Counsellor of the College of Mines, Gustav von Engeström, note in their publication *Towards a System of Mineralogy* (1788 translation of the Swedish original from 1758) that "native or virgin mercury was formerly sought for by Alchymists with great anxiety and expence from Idria, for their great object of making artificial gold."[25] According to the authors, who clearly had little time for alchemists, those who were interested in gold had a particularly high regard for Hungarian mercury and its transformative qualities. Not only was the local cinnabar, antimony, and copper thought to be impregnated by gold, but even the vine trees of Hungary were believed to contain gold. Cronstedt and von Engström mention a French "chymist" who claimed to have found gold in the ashes of twigs and stems of vines, and describe how prominent figures in the scientific world believed in occurrences of gold in twigs. The fallacy of this, however, was later demonstrated by Count de Lauragais at the Royal Academy of Sciences in Paris.[26]

Most of the mercury used in Europe came from Idrija, as the Spanish mercury was totally absorbed by the gold and silver mines in South America. Demand for mercury greatly increased in the 1550s with the development of an amalgamation process called the patio process, in which mercury was used to extract silver from its ore. From the seventeenth and eighteenth centuries onwards, the Almadén mine in Spain suffered considerable damage as a result of the depletion of minerals in the extant known deposits and devastating fires, and mercury production temporarily ceased. During this period Idrija increased its production to compensate for the loss. The amalgamation process proved to be very stimulating for the Idrija mine and production was, in the words of mineralogist Ignaz von Born, "pushed and extended with great spirit and exertation."[27] This was a time of prosperity for Idrija. Von Born writes that "the Spaniards, though the profits of their process of amalgamation are to those of ours but as 1 to 10, have no objection to supply even their remotest mines of Peru and Mexico with quicksilver from the imperial warehouses at Vienna, Idria and Trieste."[28] Between 1785 and 1797, up to 700 tons of mercury were exported to Spain yearly.[29]

25 Axel Fredrik Cronstedt and Gustav von Engeström, *Towards a System of Mineralogy* (London: Charles Dilly, 1788), 2:588.
26 Ibid.
27 Ignaz von Born, *Baron Inigo Born's New Process of Amalgamation of Gold and Silver Ores, and Other Metallic Mixtures* (London: T. Candell, 1791), xxxii.
28 Ibid., 158.
29 Ibid.

Figure 2: Transporting Mercury (Source: Idrija Municipal Museum collections)

Mercury from Idrija was an important factor in the increasing mobility of the early modern economy, involving flows of people, ideas, and material objects. The mercury mined at Idrija was a sought-after export product, and Amsterdam was the main export center where mercury was bought and sold from the mid-seventeenth century onwards. Through its mercury export Idrija became one of the starting points of the so-called Intercontinental Mercury Route. The Mercury Route included the sites of production and the various points on the route along which the mercury travelled from Idrija via Trieste to western Europe. Here it joined the route, which united parts of Southeast Asia and Europe with South America via ports, cities, and transport routes on sea and land. The land transports were hazardous, as Idrija had no road connections until the nineteenth century. The mercury was first transported by horses along narrow rocky paths, either by land to Klagenfurt, or to the seaports of Venice and Trieste, where it was then shipped to the Levant or to Germany, Holland, and Spain, sometimes ending up as far away as Sweden or South America.[30]

30 Slavec, "Occupational Medicine," 52.

Mercury was transported in leather bags during this period. It is difficult to say how safe the transports were and how much mercury may have leaked into the environment during transportation. An incident related in the *Edinburgh Medical and Surgical Journal* indicates that accidents did happen on the often long journeys.[31] According to the report, two ships, the man-of-war *Triumph* and the schooner *Phipps*, picked up a large quantity of mercury from a Spanish ship wrecked off Cadiz in 1810. The report does not say where the mercury originated, but it was probably on its way to the South American mines. According to the report, the *Triumph* took on thirty tons of mercury in leather bags picked up on the shore and saturated with sea water. The bags were kept in a storeroom in the lower regions of the ship. The other ship, the schooner *Phipps*, is reported to have taken a smaller amount of mercury. Within a fortnight many of the bags appear to have decayed and burst, and the mercury thus escaped into the recesses of the ship. As a result, every metallic substance on board was coated with mercury, and an alarming illness broke out among the crew. According to the report, the surgeons, pursers, and three officers who were closest to the storeroom suffered the most, with swollen heads and tongues. The *Triumph* had to be sent to Gibraltar to be cleared, and the sick people were taken to hospital. The other ship, the *Phipps*, was sent to Lisbon, where a hole was bored in its bottom in order to allow the mercury to run out into the sea. As a further measure, every rat, mouse, and cockroach on board was destroyed. The incident was much discussed by physicians trying to explain the phenomena, some attributing the effluvia to the bags having been acted upon by salt water. From a modern day perspective the incident can be categorized as a major environmental disaster. The actions that were taken were intended above all to safeguard the people—the threat to human beings was considered more serious than the threat to the natural world. The sea was not thought of as something which should be protected from the mercury spill.

One eighteenth-century scientist who did address the effects of mercury on the natural environment is the French naturalist Antoine de Jussieu. Jussieu studied the area of Almadén and observed that the mining operations did not emit any exhalations harmful to vegetable life and that the neighborhood was fertile.[32] We now know that plants and mushrooms can accumulate mercury from polluted soils.

31 See George G. Sigmond, *Mercury, Blue Pill and Calomel* (London: Henry Renshaw, 1840), 10–13.
32 Antoine de Jussieu, *Observations sur ce qui se pratique aux mines d´Almaden en Espagne pour en tirer le mercure*. Memoires de l´Academie Royale des Sciences (Paris, 1719), 478.

Mercury Landscapes

Ecosystems in the Idrija region are subject to a certain amount of mercury pollution as a result of natural background levels. The mining and smelting activities considerably increased the amount of pollution. In the environment, mercury can migrate between various media, such as air, soil, and water. By the end of the eighteenth century, two hundred years of mercury mining in Idrija had caused widespread mercury contamination.[33] Even by the seventeenth and eighteenth centuries, visitors to Idrija were beginning to comment on the harmful effects of the mercury and smelting gases on the environment.[34] Several recent studies have been done on the effects of mercury on the natural environment in the Idrija area, and analyses of soil samples show that there is still a high degree of contamination today. High values have been found particularly in the Idrijca River valley and at the base of the mountain slopes.[35] However, results from recent reports do not indicate what degree of pollution existed in the soil, air, and water around the mine three hundred years ago. The pollution would have been mainly concentrated in the areas where mercury was mined, roasted, and processed. In view of the inefficient methods of the day, the leakage during this process is likely to have been considerable. As a result of the inefficient roasting methods, the recovery of mercury was very low, and about half of the mercury disappeared into the ground or evaporated into the atmosphere.[36] Of the five million metric tons of mercury ore mined, over twenty-five percent is thought to have dissipated into the environment during the five hundred years of mining operations. In the early days of mining, the excavation and processing of ore were technologically simple procedures. The mercury was extracted by means of roasting the ore, initially in piles like those used in charcoal extraction. Eventually, earthen vessels began to be used in the roasting process and a system involving two vessels was developed. According to Tersic et al., very few changes occurred in the process between 1510 and 1652. There was no need to develop more efficient methods as the quantity

33 Tamara Tersic, Mateja Gosar, and Harald Biester, "Distribution and Speciation of Mercury in Soil in the Area of an Ancient Mercury Ore Roasting Site, Frbjzene trate (Idrija Area, Slovenia)," *Journal of Geochemical Exploration* 110 (2011): 144; David Kocman, Milena Horvat, and Joze Kotnik, "Mercury Fractionation in Contaminated Soils from the Idrija Mercury Mine Region," *Journal of Environmental Monitoring* 6 (2004): 703.

34 Joze Car and Tatjana Dizdarevic, "Written Reports on the Effects of Mining Activities on the Natural Environment in Idrija in the 19th Century," in "VII International Symposium: Cultural Heritage in Geosciences," ed. C. F. Winkler Prins and S. K. Donovan, *Scripta Geologica Special Issue* 4 (2004): 36.

35 Mateja Gosar, "Mercury in River Sediments, Floodplains and Plants Growing thereon in Drainage Area of Idrija Mine, Slovenia," *Polish Journal of Environmental Studies* 17, no. 2 (2008): 227–36.

36 Joze Kotnik, Milena Horvat, and Tatjana Dizdarevic, "Current and Past Mercury Distribution in the Air over Idrija Hg Mine Region, Slovenia," *Athmospheric Environment* 39 (2005): 7577–78.

of mercury in the ore was very high, probably about 17 percent or more.[37] Old roasting sites at various distances from Idrija have been located in recent studies.[38] These are mainly located on flat terrain next to flowing water. The studies show that the mercury contents in the soil at old roasting sites are extremely high, even surpassing previously studied locations at Idrija.[39]

Today it is difficult to estimate the levels of mercury concentration in the air at Idrija in the early modern period. As for the water, there is a description by Walter Pope, who declared in 1663 that "the waste water is so saturated with mercury that it heals itchiness and other similar discomforts."[40] According to Gosar, most of the material was dumped into the river or deposited along its banks.[41] Highly polluted tailings material was washed down the river during floods. Some of the material was carried downstream along the rivers Idrijca and Soca towards the Gulf of Trieste. The amount of mercury pollution in the ecosystem obviously varied according to the intensity of mining at various times in history. One of the peak periods was during the final decades of the eighteenth century when Austria and Spain contracted mercury supplies from Idrija. During the time of high mercury production, landowners in the surroundings of the smeltery complained about the damage the operation caused to their land, crops, and livestock.[42] As a result, the Idrija mine began to pay indemnity to landowners in 1788. According to Car and Dizdarevic, this compensation paid in the Carniola region may very well be the first "environmental annuity" paid on a regular basis.[43]

Mercury in the Body

The mercury pollution affected not only ecosystems but also animals and humans as well. Mercury finds its way into the body through various channels. It is easily absorbed through the skin as well as through respiratory and gastrointestinal tissues. The animals and humans in the Idrija region were constantly exposed to mercury to varying degrees. The animals and miners working in the mining operation would have

37 Tersic, Gosar, and Biester, "Distribution and Speciation of Mercury," 136, 143–45.
38 Ibid., 136–37.
39 Ibid.
40 Cited in Kotnik, Horvat, and Dizdarevic, "Current and Past Mercury Distribution," 7577.
41 Gosar, "Mercury in River Sediments," 233.
42 Ibid.
43 Car and Dizdarevic, "Written Reports," 36–37.

been exposed to mercury gases. However, there were two sides to mercury in early modern Europe. Despite its toxicity, it was also widely used in medicine, applied in liquid and vapor forms from ancient times in many societies around the world, including China, India, Tibet, and the Arab world. The mobility of mercury was believed to make it particularly useful in that it facilitated the passage of other substances in the body as well. The physicians who used mercury credited it with a penetrating quality, believed to enter the deepest recesses, pulling out poisons in sweats, purges, and saliva.[44] Part of its attraction is undoubtedly due to its powerful volatility and showiness, which probably created associations of efficacy. Mercury became increasingly important after the outbreak of syphilis in Europe in the fifteenth century, and its use as a remedy against syphilis continued into the late nineteenth century. Mercury was used in the form of ointments rubbed into the body, as mercury water, and little blue pills.

Even though mercury was widely used as a remedy, its toxicity has also been known since antiquity. Mercury is a neurological poison causing tremors, extreme mood changes, and eventually restricted vision and loss of hearing. Certain forms of mercury poisoning also cause damage to the liver and kidneys. The first observations of mercury-related diseases at Idrija are made by Paracelsus in *Von der Bergsucht und anderen Bergkrankheiten* (1533). When Paracelsus visited Idrija in around 1527, he found people who were paralyzed, deformed, asthmatic, and trembling, without any hope of recovery.[45] He accurately describes the symptoms of mercury poisoning, such as tremors, loss of teeth, and diseases of the digestive organs, skin, and kidneys. As a prophylactic measure he suggested a kind of respirator that miners could use to protect themselves from the toxic mercury vapors.[46] Before Paracelsus, miners' diseases were often ascribed to mountain spirits.

Mercury poisoning, or mercurialism, was the tragic fate of many miners at Idrija. From the seventeenth century onwards, visitors describing the Idrija mine note the ill-health of the miners due to mercury vapors. Elemental mercury easily became volatile in the limited space of the mine, particularly at its deeper levels, where temperatures were high. The mercury vapors entered the bodies of the miners mainly through inhalation, slowly accumulating in the tissues. Valvasor remarks on the miserable social condition

44 Richard M. Swiderski, *Quicksilver: A History of the Use, Lore and Effects of Mercury* (Jefferson, North Carolina and London: McFarland & Company, 2008), 7.
45 Cited in Kobal and Kobal Grum, "Scopoli's Work," 535–36.
46 Slavec, "Occupational Medicine," 53.

of the sick miners. He recounts how miners working with native ore were in particular danger as the mercury vapors could easily penetrate the human body and completely saturate it.[47] Miners who worked in front of furnaces suffered especially from mercury poisoning. As a result, they became incapacitated and had to resort to begging for the rest of their lives. Although the miners at Idrija were not slaves like some of the miners at Almadén, they most likely had little choice in how they made their living. For many, mining was probably the only possible way of supporting themselves and their families. However, the well-being of the miners was considered important enough for the officials to organize something which could be termed one of the earliest forms of occupational health care. In the mid-eighteenth century, J. A. Scopoli was employed as the first physician at the Idrija mercury mine. This was a time of significantly increased mercury production, which must have resulted in higher numbers of mercury-related diseases.[48] Scopoli recommended that the miners at Idrija should work only six- to eight-hour days at a time when ten hours was considered the minimum for a workday. Scopoli further recommended that miners should be paid enough so as not to be forced to work after hours and that they should stay at home when symptoms of mercury poisoning appeared.[49] This shows that the health problems caused by mercury mining were now being taken seriously and that certain measures were undertaken to remedy the situation. Still, protecting the miners was very difficult in a situation where mercury could be found in the air breathed by miners, in the soil, and in the water.

Mercury saturated entire ecosystems, including human, plant, and animal realms. The whole mining operation created a mining landscape that was shaped by several agents. The miners, digging for cinnabar and exposing themselves to serious health hazards caused by mercury gases, do not come across as the principal agents in the shaping of the landscape. Neither do the supervisors of the operation, nor yet the owners of the mine, represented by bodies such as the Royal Office for Coinage and Mining. Rather, the agents and causes at play were embedded in material networks consisting of both human and non-human beings, both organic and inorganic components. Mercury in its various forms was one of these components, the reason this landscape came into being. And, I would like to suggest, mercury should be credited with what Jane Bennett has called "thing-power" in the process of creating the Idrija

47 Ibid., 54.
48 Kobal and Kobal Grum, "Scopoli's Work," 537.
49 See Slavec, "Occupational Medicine," 55.

landscape. It had “thing power” in the sense that a whole mining operation was created around it, extending from areas deep in the earth to destinations in Europe and beyond. Mercury had power in the sense that it was perceived as a potent mineral with the ability to participate in the creation of gold. In addition, mercury had power in that it was thought that it both cured people from diseases and had the power to make people seriously ill.

The challenge of writing the history of the effects of mercury mining at Idrija or any other mining area lies in following the transportation of mercury, from its extraction from cinnabar mined deep in the earth, to the various processing operations taking place above ground. It lies in combining the themes of mobility, pollution, conservation, science, medicine, and occupational health, and identifying the agents in the networks operating in the ecosystems. This requires further work, both with existing studies on the environmental impact of mercury at Idrija and with primary sources that could clarify further details in the early modern environmental history of mercury mining at Idrija. This will hopefully cast light on how the “mercury landscape” at Idrija was created in networks and partnerships including humans and the mobile mineraloid that made some people prosperous, while at the same time making others sick or forcing them to spend their days in the subterranean landscapes they played a role in creating.

Jan Ludwig

Ore Mining in the Sauerland District in Germany: Development of Industrial Mining in a Rural Setting[1]

Introduction

Ore mining requires natural deposits; these may be very large or relatively small. Broken Hill in Australia, Rio Tinto in the southwest of Spain, and Chuquicamata in the north of Chile are some prominent examples of large ore deposits. These deposits became sites for large-scale industrial mines and important mining enterprises (e.g., the Broken Hill Proprietary Company and the Rio Tinto Company). But smaller deposits can also be sites for industrial mining. During industrialization in Europe in the nineteenth century, many of these smaller ore mines supplied the growing industry not only with iron, but also with lead, zinc, copper, and other metals. In many cases—before they were squeezed out of the market by larger mines as a consequence of globalization at the end of the nineteenth century[2]—these mines were situated in rural and relatively remote regions.[3]

One example of mining in a remote rural region is the Sauerland district in Germany, a hilly region located just southeast of the Ruhr district in the west of Germany.[4] In the nineteenth century it was (and today it still is) a mostly agricultural and silvicultural region. At the same time that the coal and steel industry were transforming the Ruhr district into the most important industrial region of Germany, some ore mines in the Sauerland district were also taking part in the industrialization of central Europe as well.

1 This paper is based on my dissertation project at the university of Bonn (department of constitutional, social and economic history, doctoral adviser: Prof. Dr. Günther Schulz). It also modifies and expands (especially in relation to the environmental impacts) my unpublished paper presented on 19 September 2008 at the Advanced Seminar 2008 of ESTER (European Graduate School for Training in Economic and Social-historical Research), "Industrial History, Industrial Culture: Representations—Past, Present and Future," at Swansea University, Wales.

2 See for example Sebastian Conrad, *Globalisation and the Nation in Imperial Germany*, trans. Sorcha O'Hagan (Cambridge: Cambridge University Press, 2010) and Niels P. Petersson, "Das Kaiserreich in Prozessen ökonomischer Globalisierung," in *Das Kaiserreich transnational: Deutschland in der Welt 1871–1914*, ed. Sebastian Conrad and Jürgen Osterhammel (Göttingen: Vandenhoeck and Ruprecht, 2006).

3 A comparable example can be seen in Hallas's study of the North Yorkshire Pennines. Christine Hallas, *Rural Responses to Industrialization: The North Yorkshire Pennines 1790–1914* (Bern: Peter Lang, 1999).

4 Jan Ludwig, *Blei, Zink und Schwefelkies: Erzbergbau im Sauerland 1740–1907* (Bochum: Deutsches Bergbau Museum Bochum, 2010). My dissertation may be referred to for more information and documentation on topics discussed in this text when no other references are provided.

In pre-industrial times, the ore mines situated in the Sauerland district were mostly of local or regional importance.[5] Starting in the first half of the nineteenth century, some of these ore mines and the corresponding processing plants and smelting works developed into reasonably successful industrial mines. As a consequence of the more limited ore resources available—primarily local and relatively small deposits—these mines did not constitute a (self-contained) ore-mining district or create a predominantly industrial landscape such as in the adjacent Ruhr district. However, some of the villages and small towns in the Sauerland district developed into "isles of industrialization" during the nineteenth century as a result of ore mining. The more localized structure of the ore deposits of the Sauerland district in comparison with the large ore deposits (bonanzas) or the huge coal fields in the Ruhr district (or in other industrial regions based on coal mining) was the geological cause of this development. But industrialization was not limited to building factories, mines, processing plants, and smelting works. Changes in the local economy also generated a particular social and cultural structure in these settlements. In some cases, miners from outside the region were hired, creating a separate community of industrial workers in these villages.

Another consequence of mining is the impact on the environment, which occurs even in the case of relatively small-scale mining. In the Ramsbeck district, this resulted in a situation that is particularly interesting for research, namely the conflict between two economic interests: ore mining on the one hand, and farming on the other. Especially in "isles of industrialization," this conflict is more balanced than in large industrial regions where industry is much more dominant. Pre-industrial societies often had a traditional balance between different branches of the economy. Each branch had traditional rights concerning the use of the environment in particular. The growing mining sector had to respect these rights to avoid conflicts. But of course this wasn't completely possible.[6]

5 For more detail, see Wilfried Reininghaus and Reinhard Köhne, *Berg-, Hütten- und Hammerwerke im Herzogtum Westfalen im Mittelalter und in der Frühen Neuzeit* (Münster: Aschendorff, 2008).

6 Ulrike Gilhaus, *Schmerzenskinder der Industrie: Umweltverschmutzung, Umweltpolitik und sozialer Protest im Industriezeitalter in Westfalen 1845–1914* (Paderborn: F. Schöningh, 1995), 50f.; Ludwig, *Blei, Zink und Schwefelkies,* 132.

Mining and Smelting in Ramsbeck through the Mid-Nineteenth Century

To show such a typical conflict and especially the development of such an isle of industrialization, this paper focuses on the industrial development of Ramsbeck, a small village in the Sauerland district about one hundred kilometers away from the Ruhr district.

Ramsbeck is located south of the river Ruhr—in the area of Ramsbeck, the Ruhr is only a creek or relatively small river—and the only town (relatively) nearby likely to have been known outside of the region is Arnsberg, which had been the seat of the Prussian government of the Sauerland district since 1816. Like other parts of western Germany, the Sauerland district had become part of Prussia in 1815 as a consequence of the victory of Prussia and its allies over Napoleon Bonaparte. In their new territories, the Prussian government wanted to improve the industry and the economic capability in general so as to benefit the Prussian state. The development of mining in Ramsbeck in the early nineteenth century must be seen in view of this fact.[7]

Before the industrial development in the nineteenth century, Ramsbeck was only a small village, with small-scale ore mining for lead and silver and small smelting works. During early modern times, these smelting works had gained some importance for the territorial state, Kürköln, to which Ramsbeck then belonged. But during the eighteenth century it was of only minor importance for the region. The mines and the smelting works were therefore sold to members of the local nobility, but their attempts to develop the mining activities at Ramsbeck into a profitable business were mostly unsuccessful.[8] At the beginning of the nineteenth century, therefore, there was no economic or social structure which could be considered “proto-industrial” and upon which later industrial development could have been based. At the onset of industrialization only the deposits had been investigated to some extent.

This was the situation when the Ramsbecker Gewerkschaft started to develop the mines at Ramsbeck in 1812. The Ramsbecker Gewerkschaft was a medium-sized regional company organized according to mining law. The Ramsbecker Gewerkschaft was in some respects comparable to a stock company (the shares of a Gewerkschaft

7 See Ludwig, *Blei, Zink und Schwefelkies,* 151f., 384 for further references.
8 See Ludwig, *Blei, Zink und Schwefelkies,* 74–93.

were special mine share certificates called *Kuxen*) but more restricted by mining law and mining administration than a stock company. During the 1830s Joseph Cosack, a dynamic businessman from Arnsberg, acquired the majority of the *Kuxen* of the Ramsbecker Gewerkschaft and created long-term plans for expanding the mining activities in and around Ramsbeck. One aspect of his strategy was the improvement and the construction of new mining facilities. For example, he rebuilt the lead smelting works in 1835 because the old one wasn't state-of-the-art anymore. Another example of his activities was the construction of a second processing plant. This project offers a particularly good example of the conflict between the growing mining industry in Ramsbeck and the farmers in the neighborhood.

To understand the conflict, it is necessary to point out some technical facts about mining and of the processing of ore in particular. Ore deposits in general consist of various kinds of ore, with varying amounts of metal in relation to impurities. Some kinds of ore require only a small amount of manual preparation before they can be used in the smelting works; the majority of the ore smelted in Ramsbeck until the first half of the nineteenth century was of this type. Workers at the dumps near the adits (horizontal entrances to underground mines) crushed the ore by hand and separated the waste rock. The crushed ore was then smelted.

Other kinds of ore, in which the valuable metal is mingled more closely with the waste rock, couldn't be prepared by hand. To use this ore (called "Pocherz"), processing plants were necessary (and still remain so in operating mines today). Processing plants can be built in various technical designs; in Ramsbeck, stamp mills ("Pochwerke") were used in combination with settling ponds where the metal particles could be separated out. The first processing plant in Ramsbeck was built in 1825 and a second one in 1840. The conflict potential of the processing plants in Ramsbeck was the sewage which streamed out into the creek. Because the crushing mills needed hydropower and water from the ponds to work, the processing plants were situated on the Valme, the small creek which flows through the Ramsbeck valley.

Conflicts between farming on the one hand and mining (or industry in general) on the other may be based on the question of energy. This was a problem especially when it was not possible to supply the growing demand for energy with steam engines, with the result that all economic branches depended on the limited resource of hydropower. In

Ramsbeck this wasn't the problem, because only a few mills existed in the Valme valley.[9] Instead of grain farming (with their accompanying demand for flour mills, which need hydropower to work), the valleys around Ramsbeck were used for dairy farming. The dairy farmers weren't interested in water energy in this case, but in clean (one might also say "unleaded," since lead was one of the primary water pollutants produced by the mines) water to irrigate their meadows. Therefore the Ramsbecker Gewerkschaft had to keep periods of inactivity (called "Stillstandszeiten") when the meadows were being irrigated. Unfortunately for the mining operation, the periods of inactivity of the two processing plants weren't the same. The older processing plant had to keep a period of inactivity during April and June, the newer one from 15 April to 15 June. So the Ramsbecker Gewerkschaft couldn't prepare the ore at a constant rate because there were times when neither of the processing plants were in operation. This created a significant obstacle to supplying the smelting works steadily with prepared ore.[10]

The argument for this restricted operating license was the fact that the farming interests were strong enough to assert their traditional claims. The mining industry in Ramsbeck, which was still in its infancy at the time, was expected to prevent any environmental impact—at least in theory. In reality, however, by the 1840s the environmental impact was already quite high. Indeed, downstream from the mills the environmental impact in the Ramsbeck valley was greater than in many areas in the Ruhr district during the same period, and the Valme was one of the significantly polluted waters in Westphalia at this time.[11]

The concession made by the processing plants of limiting their periods of operation is just one example of the restrictions to which the early industrial mining industry in Ramsbeck were subject. Cosack was not only the majority shareholder of the Ramsbecker Gewerkschaft but also their commercial manager. He had plans for installing an industrial cluster in Ramsbeck which would be his property alone. With the aid of a complex strategy he tried to squeeze out the other shareholders of the Ramsbecker Gewerkschaft.[12] But their interests, combined with the restrictive mining laws, hindered

9 Before the second processing plant was built, one opponent to the project voiced the concern that mills would no longer have enough water energy once the processing plant was in operation. The mining administration overruled this objection by arguing that this fear was unfounded. See Ludwig *Blei, Zink und Schwefelkies,* 131 and Gilhaus, *Schmerzenskinder der Industrie*, 45.

10 Gilhaus, *Schmerzenskinder der Industrie,* 35f., 39; Ludwig, Blei, *Zink und Schwefelkies,* 129–32.

11 Gilhaus, *Schmerzenskinder der Industrie*, 76f.; Ludwig, *Blei, Zink und Schwefelkies,* 132.

12 I have examined Cosack's strategies in more detail in Ludwig, *Blei, Zink und Schwefelkies*, 135–42.

him in realizing his complete strategy. It wasn't until 1851 that the restrictive mining law was replaced by new regulations that favored the mine owners.[13] As a result of these circumstances, Cosack prepared Ramsbeck for the industrial take-off but failed to make it a reality in the 1840s.

The Investment of a New Company and the "California in the Sauerland" in the 1850s

But the mining activities were developed enough that from the 1840s onwards foreign entrepreneurs and stock corporations became interested in the ore deposits of Ramsbeck. The general industrial take-off in central Europe generated a rapidly growing demand for lead and zinc; Ramsbeck had deposits containing both. Zinc became an important raw material in the middle of the nineteenth century as techniques requiring zinc were developed to galvanize steel and to protect steam engines from rust corrosion. Before this technical development, zinc ore had no important role in Ramsbeck and only became relevant from around 1850 onwards.[14]

The enterprises that were interested in Ramsbeck were mostly financed by investors from France and Belgium, a typical situation for the western German mining sector at this time of early industrialization.[15] The Ramsbecker Gewerkschaft and several smaller companies operated lead and zinc mines in Ramsbeck for a number of years, until the "AG für Bergbau und Zinkfabrikation zu Stolberg" (Stolberg Mining and Zinc Manufacturing Company) bought the mines in 1853 and consequently changed its name to "AG für Bergbau, Blei- und Zinkfabrikation zu Stolberg und in Westphalen" (Stolberg and Westphalian Mining, Lead, and Zinc Manufacturing Company). The company was headquartered in Stolberg near Aachen in the far west of Germany at the border with the Netherlands and Belgium. It was founded by a French entrepreneur, Henri Stephan Bernard, the Marquis de Sassenay.[16]

13 Until the early 1850s, the mining sector was heavily regulated by the state ("Direktionsbergbau"). In the 1850s, the mining sector—along with economic legislation in Prussia in general—was liberalized and the administration was reduced to an inspection authority ("Inspektionsbergbau"). See Ludwig, *Blei, Zink und Schwefelkies,* 69–73 for further references to this topic.

14 See Ludwig, *Blei, Zink und Schwefelkies,* 55f., 141 (with further references).

15 See Rondo E. Cameron, *France and the Economic Development of Europe 1800–1914* (Princeton: Princeton University Press, 1961); M. Anna Victor Devos, *Kapitalverflechtungen in der Montanindustrie zwischen dem westlichen Deutschland und Belgien von etwa 1830 bis 1914* (PhD diss. University of Bonn, 1986).

16 See Devos, *Kapitalverflechtungen*, 266; Cameron, *France and the Economic Development of Europe,* 377–80 and Ludwig, *Blei, Zink und Schwefelkies,* 193–207.

The executive board hoped to make a big fortune in Ramsbeck. In part this hope was based on the prospering market of zinc and lead.[17] In addition, the deposits were thoroughly investigated and the company obtained a positive assessment from Heinrich von Dechen, a famous geologist and director of the chief mining authority. The chairman of the supervisory board, the French industrialist and financier Andre Koechlin, and the director general, the Marquis de Sassenay, advertised their goal of creating a European industrial center in and around Ramsbeck. An example of their advertising was an article in the *Journal des Chemins de Fer* on 27 August 1853. In it, de Sassenay described the industrial importance Ramsbeck could develop. The public announcements of prospective output figures were beyond all realistic calculations. The prime target of the decision makers was stock speculation; Koechlin and de Sassenay largely profited from under-the-counter sales of shares.[18]

Workers' Settlements in the Rural Landscape around Ramsbeck

Although Koechlin and de Sassenay were ultimately interested in stock speculations, they built a large number of technical facilities in Ramsbeck and in the surrounding valleys between 1853 and 1855.

As mentioned above, the processing plants depended on hydropower, so it was necessary to build them not only on the Valme in the Ramsbeck valley itself, but also in the valleys around Ramsbeck, because much more power was required than the Valme alone could provide. Because the processing plants had to be distributed along the creeks in order to have an effective incline for each waterwheel and hydraulic turbine, it was impossible to settle all the dressing workers at one location. The distances between the dressing plants were too great, and the area of Ramsbeck wasn't easily accessible: it was very laborious for workers to live in one valley and work in another one. Thus, a very small settlement consisting of only one or two houses developed next to nearly every dressing plant for the workers. These settlements might be regarded as a sort of "scattered" industrialization inside the Ramsbeck region. But there were larger settlements of up to 1,500 inhabitants,

17 In addition to the rising industrial zinc production, lead had leapt dramatically in value in western Germany at this time. See Ludwig, *Blei, Zink und Schwefelkies,* 201.

18 Ludwig, *Blei, Zink und Schwefelkies,* 203–12, 252–54; Jean Baptist Maas, *Actenmäßiger Thatbestand in der Proceßsache der Actien-Gesellschaft für Bergbau, Blei-und Zink-Fabrication zu Stolberg und in Westphalen gegen die früheren Administratoren und den früheren General-Director dieser Gesellschaft* (Cologne: Verlag Du Mond-Schauberg, 1863), 55–61.

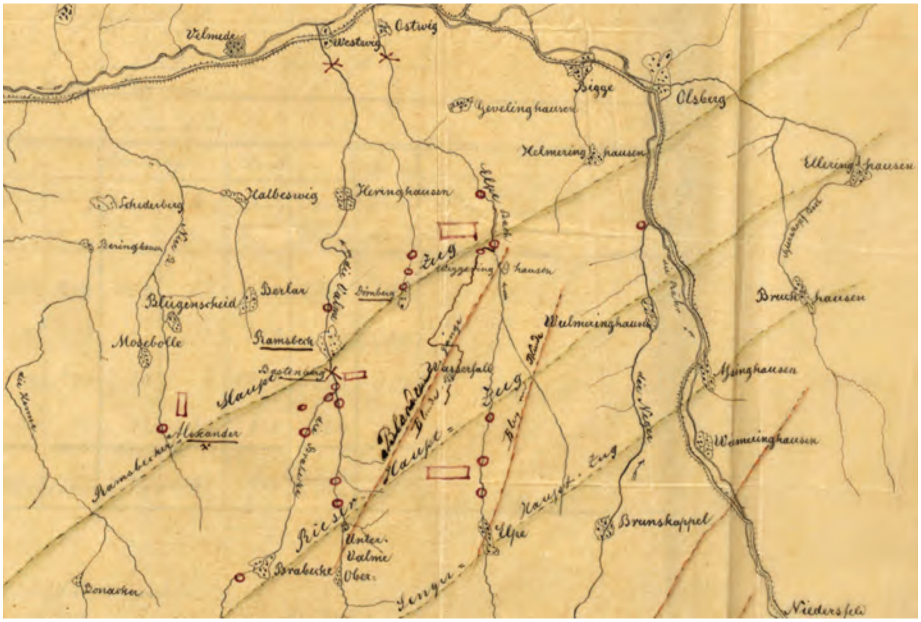


Figure 1: Map of the expansion project in the Ramsbeck district 1854/55. Ramsbeck is underlined (in the middle of the left half of this map). Projected new or enlarged lead smelting works are marked with an **X**, processing plants with an **O**. The newly built workers' settlements are marked with **▯**. (Source: Landesarchiv NRW, Abteilung Rheinland, BR 0005 Nr. 7965, Bl. 354)

too. Because they often used only a few adits of each mine, the company could concentrate the miners at only a few points, and so Koechlin and de Sassenay built two major workers' settlements near Ramsbeck. They named these settlements Andreasberg (from the German spelling of Andre Koechlin) and Heinrichsdorf (after the German spelling of Henri Bernard).

In the autumn of 1854, the executive board hired foreign workers from traditional ore-mining districts in Germany because there weren't enough experienced workers in and around Ramsbeck for their ambitious expansion project. Hundreds of workers and their families came from the Harz Mountains and from Saxony, simply because they trusted the "official" promises they could read in printed advertisements. The executive board guaranteed them work for themselves as well as for their wives and children and adequate domiciles—these were traditional rights of miners in their native regions, especially in the Harz Mountains.[19] In the time that followed, however, the company was not able to fulfill any of these promises. In order to rapidly hire a huge

19 See AG für Bergbau, Blei- und Zinkfabrikation, *Nachrichten über den Bergbau zu Ramsbeck* (Clausthal, 1854); Ludwig, *Blei, Zink und Schwefelkies*, 230–41.

number of workers, the company had made promises that were too optimistic and the immigrant workers were too credulous.[20]

It is interesting that the executive officers promised that the two workers' settlements would have some characteristic elements of the traditional mining district of the Harz Mountains. For instance, they promised the immigrant workers lifelong employment and financial support when they were no longer able to work. This was comparable to traditional benefits in the Harz Mountains. Other promises of this character were that they would get food at cost from the warehouses of the company and that the new settlements would possibly develop into "Bergstädte" (mining towns that enjoyed a special status and certain privileges from the government). Hans Schönian, a former machine builder in Clausthal in the Harz Mountains, and at that time the chief technology officer in Ramsbeck, used this designation to get the attention of the miners in the Harz Mountains.[21] Additionally, the name of the settlement where the miners from the Harz Mountains were to live, Andreasberg, was almost identical to the name of a traditional mining town in the Harz Mountains, St. Andreasberg.

But the two new workers' settlements weren't really similar to mining towns of early modern times. In reality they were comparable to industrial settlements in other mining districts in remote rural regions and to "Zechensiedlungen" (miners' settlements) in the Ruhr district. In the Ruhr district, the only settlement established earlier than Andreasberg and Heinrichsdorf was Eisenheim in Oberhausen. In this regard especially, Andreasberg, a planned village built along either side of the main road, was a pioneering project.[22]

The Dream of "California in the Sauerland" 1854/55

Hans Schönian advertised the new settlements by comparing them not only with the Harz Mountains, but also with another area: California and its goldfields. California was another popular destination of emigrants at that time. In contrast to California, Schönian promised that Ramsbeck would be a safe place for immigrants.[23] This

20 Ludwig, *Blei, Zink und Schwefelkies,* 246–51.
21 Announcement about wages, cited in the *Nachrichten über den Bergbau zu Ramsbeck* published by the AG für Bergbau, Blei- und Zinkfabrikation, 10.
22 See Ludwig, *Blei, Zink und Schwefelkies,* 233–38 for further references.
23 *Nachrichten über den Bergbau zu Ramsbeck*, 6–7.

comparison with California is an example of the perception of the spectacular progress in Ramsbeck. Other public reactions were similar.

Most importantly, a journalist from a Berlin newspaper, the *National-Zeitung,* made a reference to the California Gold Rush. In January 1855 he titled an article about Ramsbeck "Kalifornien im Sauerlande" (California in the Sauerland district).[24] The article reflected the general spirit of optimism in the early 1850s, not only in Ramsbeck and the Sauerland district, but also from a European and a global point of view. This is important in order to understand why hired workers and investors in the company trusted the promises of the management. The spirit of the times favored such rush phenomena; the gold rushes in California and Australia around 1850 are well-known examples.[25]

Especially in light of the regional development, the euphoria relating to Ramsbeck was comprehensible. The industrial take-off of the economy of western Germany (Rhineland and Westphalia) began around this time. In Ramsbeck, both the investors and the miners hoped to become part of this boom. But those who stood to make a direct profit, such as the investors and the miners, weren't the only ones to trust the promises of de Sassenay and Koechlin. The local and regional authorities also took part in this development. So the public reaction to Ramsbeck was interest, especially because of the hope that an increase in mining and lead production in Ramsbeck—the zinc ore, on the other hand, was to be smelted in Dortmund in the Ruhr district—would allow the remote rural region of the Sauerland district to be developed. Success in Ramsbeck would mean the creation of a lot of additional jobs in the rural area, jobs for cart drivers and barkeepers, bakers and butchers, for example. Success would mean the possibility of attracting a railway company to connect Ramsbeck and the Sauerland district with the Ruhr district. Thus the journalist didn't see fit to criticize this development; his only criticism was directed towards laggards who wanted to hold back the spirit of the industrial times. He was enthusiastic about "the wonderful Californian development" of Ramsbeck and expressed his attitude to the industrial development several times.

24 *Berliner Nationalzeitung*, 16 January 1855. This article was also published in the *Siegener Intelligenz-Blatt,* a more regional newspaper, a few days later (Siegen is a traditional mining and smelting town south of the Sauerland district), see *Siegener Intelligenz-Blatt,* 26, 28, and 30 January 1855.

25 For examples see David Goodman, *Gold Seeking: Victoria and California in the 1850s* (Stanford, CA: Stanford University Press, 1994); J. S. Holliday, *Rush for Riches: Gold Fever and the Making of California* (Berkeley: University of California Press, 1999); and Malcolm J. Rohrbough, *Days of Gold: The California Gold Rush and the American Nation* (Berkeley: University of California Press, 1998). Another example of this zeitgeist may be the Great Exhibition in London 1851.

To awaken the interest of the newspaper readers he put his article into the form of a travel report. He opened the article with questions: "Ramsbeck? What's Ramsbeck? Where is Ramsbeck? . . . What [sort of place] might Ramsbeck be, that they need so much coal, so many potatoes and so many workers?" He thus demonstrated that Ramsbeck wasn't yet common knowledge among his readers. Sometimes he used a pictorial narrative, similar to a fairy tale: "The rich industrial life is sending a new artery into the lonely wooded valley to pull it out of the romance of abandoned castle ruins into the heart of modern commerce." At other times he gave output figures as though they were objective descriptions—although the figures he gave were exaggerated: "The company will . . . launch 900,000 cwt of lead per annum with a value of 5.4 million thaler. The previous Prussian production of lead was 120,000 cwt per annum; this company alone hopes to boost the Prussian lead production more than sixfold!"[26]

The first two citations show another aspect typical of rural regions of this time: the hope that a railway would develop the formerly remote region. Many rural regions wanted a railway connection to industrial districts, but only a few actually got one. Ramsbeck was over 40 kilometers away from the next railway station in Lippstadt, west of Paderborn, and so it was comprehensible that the journalist had never heard of Ramsbeck before or—as he reported—was unable to find it on a map. He expected a connection between Ramsbeck and other prospering areas in Westphalia (i.e., the Ruhr district) to be a consequence of the increasing mining and smelting activities in the Ramsbeck district, since a railway connection was important for developing industrial areas. Years later it became clear that there would never be an important rail route; a small industrial railway was only constructed at the end of the nineteenth century.[27]

His enthusiastic article ended with a last mention of California. From his point of view, the development in Ramsbeck was not only a "wonderful Californian development" but also directly financed by the Californian and Australian gold rushes.[28] He argued that the enormous wealth of gold—which circulated into the European economy as a consequence of these gold rushes—was searching for lucrative investments, and that Ramsbeck was one of the investments financed by this foreign capital. Indeed, it was

26 *Berliner Nationalzeitung,* 16 January 1855. Translated by the author.
27 Ramsbeck did not get a connection to the German rail network until 1897, when a narrow-gauge mine railway connected Ramsbeck with the railway station at Bestwig, seven kilometers north in the Ruhr valley (the station itself wasn't opened until 1872). See Ludwig, *Blei, Zink und Schwefelkies,* 233–38.
28 *Berliner Nationalzeitung,* 16 January 1855. Translated by the author.

Figure 2: Illustration of the "California in the Sauerland." Around 1960, unknown artist. (Source: Private ownership, Alfred Braun)

foreign capital which allowed Koechlin and de Sassenay to make such big investments in Ramsbeck. But this capital was generated by the previous economic development in France and Belgium, and not predominantly by Californian gold.

Indeed, some features of Ramsbeck are reminiscent of the Californian Gold Rush from 1848 to 1855. The kind of overhasty actions and the euphoria of the investors and miners were similar to California, although on a smaller scale. It was also comparable in that the real profits at the end weren't made by enlisted workers from far away but by local marketers and especially the speculators in the background.[29]

Awaking from the Dream—the Reality in "California in the Sauerland" 1855

Initially the Ramsbeck district was only attractive for immigrants because of the hope of getting well-paid employment at the mines and smelting works. The company therefore searched for strategies to retain their employees for the long term so that they wouldn't emigrate once again if they saw a better option somewhere else. Some options for this purpose were the promises mentioned before. Another strategy was home ownership by the workers in the Ramsbeck district. Accordingly, the workers

29 See for example Holliday, *Rush for Riches,* 69–71.

were given the opportunity to cheaply purchase the houses that they had initially rented.[30] Over the long term this strategy was extremely successful.[31]

But the first two winters were disastrous for such ambitions. The inhabitants became ill due to the drafty and damp domiciles, because the houses were built imperfectly.[32] Following the catastrophic winter of 1854/55, part of the (immigrant) workers emigrated (again). Others stayed in and around Ramsbeck and became an industrial workforce in the rural region. After the reorganization of the company in 1855—president Koechlin was forced to resign as a consequence of the failed stock speculations, and director general de Sassenay disappeared to Naples before he was put on trial—the ore mining changed from a pseudo-take-off into a real take-off, but with realistic, non-Californian dimensions, and there was a real need for the workers.

Public opinion changed after the resignation of de Sassenay and the other directors of the Ramsbeck establishment. After the regional government recognized that it was mostly a scam, they too used the comparison with California to describe the situation in Ramsbeck, but with a negative connotation. In April 1855 they denounced the "magnificence of the so-called Westphalian California" ("Herrlichkeiten des sog. Westfälischen Kaliforniens").[33]

Not only Koechlin and de Sassenay were blamed for being responsible for the disaster in Ramsbeck; the local officers of the company were blamed as well. The debate focused on Philipp von Beust, the CEO of the Ramsbeck mines, and Chief Technology Officer Hans Schönian. Both reacted to their loss of position with public statements that the rush in Ramsbeck and the following disaster hadn't been their fault.[34] For his part, von Beust accused de Sassenay, Koechlin, and a member of the supervisory board. He showed that they induced him to build such a large number of unnecessary preparation works and furnaces. He described the situation in Ramsbeck as such a catastrophe that a reader may well wonder why he didn't throw in the towel earlier. Nevertheless his

30 *Nachrichten über den Bergbau zu Ramsbeck*, 10.
31 See Ludwig, *Blei, Zink und Schwefelkies*, 280.
32 See for example Landesarchiv NRW, Abt. Westfalen, Kreis Meschede 3302.
33 Landesarchiv NRW, Abt. Rheinland, Regierung Aachen 7966, folio 121–22r.
34 Philipp von Beust, *Die Actien-Gesellschaft für Bergbau, Blei- und Zink-Fabrikation zu Stolberg und in Westphalen: Abtheilung Ramsbeck im Jahre 1854–55* (Soest, 1855); Hans Schönian, *Das Bergbau-Unternehmen zu Ramsbeck in Westphalen im Jahre 1854* (Nordhausen: Eberhardt, 1855). For some citations of their public defense statements, see Ludwig, *Blei, Zink und Schwefelkies*, 224–26.

attempt was successful: neither von Beust nor Schönian were among the accused in a later trial against the former members of the supervisory board and the director general. The prolonged lawsuit ended with a printed report which exposed the kind of stock-market speculations Koechlin and de Sassenay engaged in and the state of anarchy that had prevailed in Ramsbeck.[35]

The Real Take-off after 1855

All expectations of a colossal industrial take-off in Ramsbeck had now been destroyed. But with the new administration came a significant upturn in Ramsbeck: the ore mining activities increased for a long period and continued to be the most important local employer until the end of mining activities in Ramsbeck in 1974. In contrast to the Ruhr district nearby, the mining activities in the Sauerland district didn't create an industry-dominated economic structure and an industrial culture that spanned an entire region. Many locations like Ramsbeck only created "isles of industrialization" in a region that continued to be essentially rural.[36] Ramsbeck became a small industrial cluster with ore mines surrounded by industrial facilities as well as lead smelting works. As the map of 1872 shows (fig. 3), the village of Ramsbeck was extended with several industrial buildings. Additionally, nearly ten of the more than twenty ore-preparation facilities that were constructed prematurely during the "California in the Sauerland" rush were genuinely needed in the time after 1855 because of the real take-off then.[37]

Furthermore, Ramsbeck itself was part of a greater industrial cluster. As mentioned above, the zinc ore from Ramsbeck was smelted in Dortmund. In addition to the smelting works there, the company owned a coal mine which supplied the lead and zinc smelting works in Ramsbeck and Dortmund with coal. The facilities for producing higher-valued products such as zinc-based glass from the raw metals were located in Stolberg near the corporate head office.[38] Thus Ramsbeck mostly continued to have the status of a mono-structured mining area which supplied outside industrial areas with zinc ore and lead.

35 Maas, *Actenmäßiger Thatbestand in der Proceßsache.*
36 Cf. Georg Goes, *Arbeitermilieus in der Provinz: Geschichte der Glas- und Porzellanarbeiter im 20. Jahrhundert* (Essen: Klartext, 2001); Klaus Tenfelde, *Proletarische Provinz: Radikalisierung und Widerstand in Penzberg/Oberbayern 1900–1945* (Munich: R. Oldenbourg, 1981).
37 See Ludwig, *Blei, Zink und Schwefelkies,* 270–72.
38 See the Statues of the Aktien-Gesellschaft der Aachener Spiegelmanufaktur, 1853. Accessed at http://commerce01.doshisha.ac.jp/statuten/pdfdata1/18510122AGASM_A.pdf.

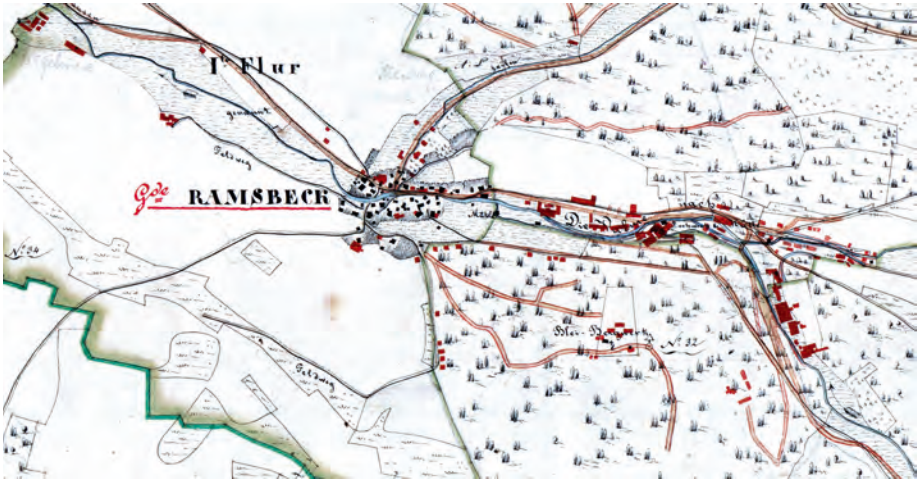


Figure 3: Map of Ramsbeck, 1872. The buildings older than 1827 are represented in black, the predominantly industrial buildings which were built from 1827 to 1872 are represented in red. (Source: Hochsauerlandkreis FD 55 Geoinformationen und Liegenschaftskataster)

The Environmental Impact since the Industrial Take-off

Nevertheless, the impact of mining activities on the landscape was even more appreciable than before in the Ramsbeck district. The meadows in the narrow valleys in particular were burdened with lead from the dressing plants to a greater extent than during the time of the Ramsbecker Gewerkschaft in the first half of the nineteenth century.

Around 1860, though, more than one thousand miners and other workers were employed in the mines, the processing plants, and the lead smelting works. Additionally, their wives and children had jobs in the preparation works.[39] Compared to the few jobs in dairy farming or forestry (and in contrast to the situation before 1850), the Ramsbeck mines became the primary employer in the area from the 1860s. As a result, the balance of power between farming and mining changed; the Ramsbeck mining district now dominated the local economy.[40]

The system of periods of inactivity during the times when the meadows were being irrigated was anachronistic now. An industrial cluster like Ramsbeck couldn't maintain this system: it would create such significant operational restrictions that the competing

39 See Ludwig, *Blei, Zink und Schwefelkies,* 269.
40 See Gilhaus, *Schmerzenskinder der Industrie,* 56, 77, and *Ludwig, Blei, Zink und Schwefelkies,* 281.

power of the whole company would be at risk. The continuity of the company and its function as the predominant local employer were strong arguments made by the company for abolishing the old system step by step. In 1857/58 the company reached an agreement that the periods of inactivity were to be harmonized for all processing plants. Following the introduction of a new Prussian mining law (the Allgemeines Berggesetz für die preußischen Staaten) in 1865, which was more liberal than previous mining regulations, the company managed to have the restrictions completely abolished.[41]

Figure 4: Photograph of measuring haystacks around 1900. The left haystack is from an unfertilized field, the right haystack from a fertilized one. (Source: Sachtleben Bergbau Verwaltungs-GmbH)

Instead of the system of periods of inactivity, another system to balance out the continual conflict between dairy farming and mining was used from that point on: the system of equalization payments. This system was based on the realization that while it wasn't possible to prevent the environmental impact anymore (it hadn't really been possible since the first processing plant was opened, but it was crucial that the mindset had changed), it was possible to offer compensation for the negative impact.[42]

The company therefore had to find out how much (financial) compensation they had to pay to the farmers. They measured the impact of lead on the meadows by measuring haystacks: one from a meadow which was watered with brook water polluted by the processing plants

41 See Gilhaus, *Schmerzenskinder der Industrie,* 57f., and Ludwig, *Blei, Zink und Schwefelkies,* 281f.
42 See Gilhaus, *Schmerzenskinder der Industrie*, 51, and Ludwig, *Blei, Zink und Schwefelkies,* 132.

and one from an "unleaded" meadow as a control. The meadow with the lead-carrying water was separated into several sections, each of which was fertilized with different quantities of fertilizer (Chilean saltpeter, lime, kainite, and others). The company then looked at the quantity of hay to see what quantity of mineral fertilizer was needed to compensate for the impact of the lead-laden water. Finally the price of the fertilizer was calculated; this sum was the annual equalization payment. To give a concrete example: in 1906 the calculated equalization payment in one case was around 360 marks.[43]

Figure 5: Picture of the south part of the Ramsbeck valley, early twentieth century. The building in the right half is the part of the smelting works of Ramsbeck where the ore was roasted ("Rösthütte"). As the picture shows, the smelting works had a high chimney, too. The smoke exhaust duct from the "Rösthütte" to the mountain on the right side can't be seen in this picture; however, it appears in the left part of figure 2 (Source: *Chronik der Familie J. Cosack*, 1913)

Legal processes between the owners of the meadows and the Ramsbeck mines with equalization payments as a result are mostly documented for the period around 1900. It is unclear whether this is just because earlier documents are lost, or because of the improved technical capabilities to measure the need for fertilizer.

Another environmental impact of the Ramsbeck mining industry was the smoke pollution from the ore roasting process, especially zinc ore: it was necessary to roast

43 The relevant sources are records of the Ramsbeck mines which are now property of the Sachtleben Bergbau Verwaltungs-GmbH. The document in which the system of measuring the haystacks and the experiments with fertilizers are described is recorded for the Sachtleben Bergbau Verwaltungs-GmbH in 2010 under the signature 1105; compare Ludwig, *Blei, Zink und Schwefelkies,* 438.

zinc ore and reduce the sulfuric parts of the ore before it was usable in the smelting works. The smoke pollution wasn't such an important area of conflict as the water pollution; nevertheless during the time of "California in the Sauerland" in the 1850s the enterprise was required to build a smoke exhaust duct from the smelting works in the Ramsbeck valley to a chimney on a mountain nearby to keep the smoke out of the valley.[44]

Conclusion

The history of mining in Ramsbeck in the nineteenth century is one example of mining in a rural environment. It shows typical aspects like the development of a small industrial cluster, as well as special phenomena like the rush phenomena of the "California in the Sauerland." Nevertheless, these phenomena should also be considered in relation to the greater historical background; the developments in Ramsbeck were simultaneous with the California Gold Rush, for example.

The development of Ramsbeck is not unique. In some aspects it was the typical response of a small, remote rural region to an external demand for raw materials. Spectacular examples like that of Ramsbeck, with exorbitant promises at the beginning and modest actual growth in comparison with the earlier hopes, may be found in a number of mining areas. It is important to situate such a development in its historical context. In the case of Ramsbeck, the contemporary reference to the Californian Gold Rush is important. This may be one way to explain why so many people—workers, journalists, the government, and some of the executive officers of the company—believed the promises they heard. By studying other locations—there are further examples in the Sauerland district—it is possible to differentiate between developments particular to Ramsbeck and general aspects of industrialization in rural environments. For example, when looking at Iserlohn, a town with a long tradition of metalworking industries in the west of the Sauerland district, it becomes clear that there was a take-off in the 1850s there too.[45] But in Iserlohn local investors were involved and prevented an irrational "Californian" rush after the fashion of Ramsbeck.

44 See Gilhaus, *Schmerzenskinder der Industrie*, 171, and Ludwig, *Blei, Zink und Schwefelkies,* 282.
45 See Wilfried Reininghaus, *Die Stadt Iserlohn und ihre Kaufleute (1770–1815)* (Dortmund: Gesellschaft für Westfälische Wirtschaftsgeschichte, 1995); Rolf Klostermann, *Der Bergbau in Iserlohn in der zweiten Hälfte des 19. Jahrhunderts* (Schacht-Audorf: Köller, 1996); Ludwig, *Blei, Zink und Schwefelkies;* Landesarchiv NRW, Abt. Westfalen, Regierung Arnsberg 1113.

From an environmental perspective, too, Ramsbeck shows some typical aspects of the mining industry in rural regions in the nineteenth century. Lead and zinc ore mining had significant impacts on the environment, with the degree of impact dependent on the mining technique. Thus, substantial conflicts arose throughout the nineteenth century and isolated the miners from the farming population. This phenomenon is not present in every rural region with lead production. There are other examples where miners and farmers were closely linked and miners often took up dairy farming as an additional occupation.[46]

But in the case of Ramsbeck miners and farmers were two different groups and the conflict couldn't be solved this way. Both the mining industry and the dairy farmers needed the water of the brooks for their economic interests: The processing plants needed water as an energy source and to separate the metal parts of the ore, while the dairy farmers irrigated their meadows with brook water. Because it was impossible to keep the water in the processing plants clean using the techniques available at the time, and because the dairy farmers needed clean water, this conflict couldn't be solved while taking both interests into account. The environmental impact was unavoidable and the crucial question was how to deal with it.

The development of Ramsbeck shows a general change of mindset regarding the environmental impacts during the industrialization process. The conflict between mining and farming therefore had two stages in Ramsbeck: The pre- and early industrial stage, and the stage following the take-off around 1860.

In the first half of the nineteenth century, the mining sector of Ramsbeck was part of a group of economic interests which had to respect the traditional rights of the other sectors. The mines had to avoid causing a significant impact, especially on the meadows, by limiting their operation in certain places. Periods of inactivity of the processing plants were (in theory) designed to allow dairy farming to irrigate the meadows as before.

By the late nineteenth century, this system was no longer practical; the pollution of the brooks was too great. The farmers received an equalization payment, calculated using the price of fertilizer required to compensate for the impact of the lead-carrying water of the brooks. This aspect may be seen from a more abstract perspective: It

46 Cf. Hallas, *Rural Responses to Industrialization*, 83–149.

became obvious that the environmental impact of the industry couldn’t be prevented completely; it was only possible to reduce and compensate for the impact. And the example of Ramsbeck shows one way to measure the environmental impact and give pollution a price.

Sebastian Haumann

Ubiquitous Mining: The Spatial Patterns of Limestone Quarrying in Late Nineteenth-Century Rhineland

Introduction and Conceptual Framework

Open-pit mining has altered the earth's surface in significant ways. Operations such as the Anaconda Copper Mine in the US state of Montana or the huge "brown coal" (lignite) fields in Germany frequently come to mind. Their sheer vastness and the associated processing of ores and fossil fuels implies a massive environmental impact.[1] By contrast, the extraction of materials other than precious ores and fuels is rarely noted because it is less spectacular. However, mining for materials that are abundant and common natural resources leaves behind marks on the earth's surface that are no less significant. In fact, gravel, clay, and sand pits, as well as slate, sandstone, limestone, and other quarries are the most ubiquitous form of open-pit resource extraction. While individual pits and quarries are usually smaller in size than ore and coal mines, their agglomeration is in many cases no less impressive and their impact on the environment no less significant. Many regions have been shaped entirely by these allegedly less spectacular mining operations. The reason for the relative "invisibility" of this kind of mining is that its effects are usually not considered to pose a vital environmental threat. Despite the fact that such operations consume land, alter the water table, and intervene in established habitats, they rarely leave behind defunct environments, instead creating lakes, rocks, and non-toxic dumps that are frequently reused by humans, animals, plants, and other organisms.

It is not the intention of this essay to judge whether these changes are for the better or for the worse. Instead it will draw attention to some conditions that have historically shaped these changes and present a tentative framework to reconstruct the emergence of the spatial patterns they left behind. The essay will take the spatial patterns of the pits and quarries, their shapes and regional distribution, as a starting point and

1 Timothy J. LeCain, *Mass Destruction: The Men and Giant Mines that Wired America and Scarred the Planet* (New Brunswick: Rutgers University Press, 2009); Kerstin Kretschmer, *Braunkohle und Umwelt: Zur Geschichte des nordwestsächsischen Kohlenreviers (1900–1945)* (Frankfurt am Main: Lang, 1998); Johann Paul, "Risikodebatten über den Tieftagebau im rheinischen Braunkohlenrevier seit den 1950er Jahren," *Technikgeschichte* 65 (1998): 141–61.

try to explain why these "holes" are in the places they are and why they took the shape they did. This rather narrow perspective will eventually have to be placed in a broader environmental, cultural, and economic context, which I have omitted from this essay for the sake of clarity.

The development of open-pit mines and quarries can best be analyzed by adopting Theodore Schatzki's concept of "practice-arrangement nexuses," which he introduced as an alternative to the nature-culture dichotomy by examining human practices in relation to the physical properties of materials. Citing the example of the construction of a house, Schatzki argues: "Although a house, for instance, is both a human artifact and a social phenomenon, the physical properties of its construction materials . . . are facts of nature."[2] The same can be claimed to be true of the extraction of materials from the earth's surface, i.e., that mining is a "social phenomenon," but also relates to the material properties of the underground terrain as "facts of nature."

Open pits and quarries are therefore the result of human action structured in relation to geological characteristics. The drastic changes of topography and land-use patterns caused by quarries can be best understood as the alteration of "practice-arrangement nexuses." While the existence of underground resources is a necessary precondition for mining that determines where materials can be extracted, the actual spatial patterns of open-pit mining are restrained by an amalgamation of physical and social factors. This is especially true of the more common materials of interest here, since their relatively broad distribution allows for considerable variability in locating mining activities. Schatzki suggests that technological development is the primary factor that brings about change within "practice-arrangement nexuses." However, the development of knowledge and legal practices form another, arguably more important set of determinants shaping the relation between human action and materiality in the transformation of the earth's surface. This essay will therefore concentrate on knowledge relating to exploitation of resources as well as the rights to do so and will analyze how they translate into changes in topography and land-use patterns following the conceptual framework of "practice-arrangement nexuses." This essay cannot provide a comprehensive analysis; instead, it tries to illustrate pathways of interpretation and further investigations.

2 Theodore Schatzki, "Nature and Technology in History," *History and Theory* 42, no. 4 (2003): 85.

The Case of Limestone Mining in the District of Mettmann

One of the more commonly found materials that humans extract from the earth's surface is limestone. Limestone was already widespread as a sideline product in agricultural economies long before the nineteenth century. During the late nineteenth century, however, some limestone businesses grew in size and became professional operations serving distinctive regional markets. The limited research on limestone mining that exists on the Rüdersorf quarry near Berlin suggests that this operation flourished in close relation to the construction boom in the nearby metropolis.[3] In regions that were not urbanizing, burnt lime became increasingly important in the agricultural business. In the 1840s the chemist Justus von Liebig published on the qualities of burnt lime as a fertilizer.[4] From the 1850s onwards the demand for limestone in the vicinity of industrializing regions such as the Ruhr increased dramatically due to its use in the iron-smelting process.[5]

The limestone quarries that I will focus on in this essay developed in the context of the demand from the iron industry in an area just south of the Ruhr between the cities of Essen, Düsseldorf, and present-day Wuppertal in the district of Mettmann. Large-scale limestone quarrying in the district started in the 1850s in the Neanderthal valley. (The first discovery of *Homo sapiens neanderthalensis* in 1856 was the result of limestone mining activities in the valley.) By 1876 the industry in the district had grown to 59 quarries employing more than six hundred workers.[6] The size of the individual operations varied greatly. Some were not much more than a one-man business, while other entrepreneurs, such as Wilhem Schüler or Johann Friedrich Schürmann, owned several large quarries with up to 30 workers each.[7] In 1887, Schüler and Schürmann merged their operations with those of several other local businessmen and formed the Rheinisch-Westfälische Kalkwerke as a single joint stock company. Their intention

3 Gernot Wittling, "Der Staat als Innovator im Rüdersdorfer Kalkbergbau während der Frühindustrialisierung," in *Vom Bergbau zum Industrierevier: Montandistrikte des 17./18. Jahrhunderts auf dem Weg zur industriellen Produktionsweise des 19. Jahrhunderts*, ed. Ekkehard Westermann (Stuttgart: Steiner, 1995), 113–24.

4 Werner Kasig and Birgit Weiskorn, *Zur Geschichte der deutschen Kalkindustrie und ihrer Organisationen: Forschungsbericht* (Düsseldorf: Beton-Verlag, 1992), 67.

5 Günter von der Gathen, "Kalkindustrie und Eisen- und Stahlindustrie in Nordrhein-Westfalen," (Diss., University of Cologne, 1955).

6 Bericht über die Steinbrüche und Sandgruben im Kreis Mettmann, 30 March 1876, Landesarchiv Nordrhein-Westfalen, Abteilung Rheinland (LANRW), BR 0034, 24.

7 Mayor's office Wülfrath, Nachweisung über die in der Bürgermeisterei Wülfrath belegenen Sandsteingruben und Steinbrüche, February 1876, LANRW, BR 0034, 24.

was to monopolize the local market and serve the growing demand of the iron industry. In fact, the new stock company expanded aggressively up until the eve of the First World War by buying out competitors.[8]

In 1903, however, the steel magnate August Thyssen, who was looking for a cheap alternative source of limestone, founded his own limestone mining company, the Rheinische Kalksteinwerke. In contrast to the businesses of Schüler and Schürmann, Thyssen's Rheinische Kalksteinwerke did not develop out of preexisting local operations but was constructed from nothing in just a few years. Where the Rheinisch-Westfälische Kalkwerke had depended on existing infrastructure, the new competitor was able to build a whole new system, including up-to-date technologies such as electric lighting in the mine and a railroad to connect the newly opened quarries with the Thyssen ironworks in Essen and Duisburg.[9] The competing companies could not have been more different: the locally based and aggressively growing Rheinisch-Westfälische Kalkwerke, and the operations of the Rheinische Kalksteinwerke, built rapidly from scratch and backed by the immense funds of Thyssen's iron and steel production empire. Despite the fierce competition between them, the two companies did not merge until 1997, when both were bought by the Belgian Lhoist company.

Today, there are about ten major limestone quarries in the district that are visible features of the landscape. While most of these have been abandoned along with the many minor quarries, the four largest quarries are still mined today. All these former and current operations are scattered along a winding ribbon of land some 20 kilometers in length. This belt of quarries marks the course of a limestone deposit embedded in the northwestern edge of the Rhenish Massif.[10] However, the quarries themselves, which today vary in size from between about five hundred meters to two kilometers in diameter, actually form a discontinuous and fragmented pattern that leaves large portions of the resource virtually untouched. Two of the historical factors restraining the wholesale extraction of the deposit that resulted in the fragmented patterns shaping the area today will be of special interest in the following parts of this essay.

8 Kasig and Weiskorn, *Zur Geschichte der deutschen Kalkindustrie*, 77; Rheinisch-Westfälische Kalkwerke AG, *Die Geschichte vom Kalk* (Wülfrath, 1978), 38–39.

9 Bundesverband der deutschen Kalksteinindustrie, *Vom Kalk zum Kalkstein* (Wiesbaden, 1963), 18; Rheinische Kalkwerke, *50 Jahre Rheinische Klakwerke Wülfrath: Ein Beitrag zur Geschichte der deutschen Kalkindustrie* (Wülfrath, 1953); *Wülfrather Zeitung*, 27 January 1904.

10 Rudolf Gotthardt, *Karbonatgesteine in Deutschland: Rohstoff, Nutzung, Umwelt* (Düsseldorf: Beton-Verlag, 1996); Hellmut Grabert, *Abriß der Geologie von Nordrhein-Westfalen* (Stuttgart: Schweizerbart, 1998).

Knowledge of the Underground Terrain

Resources are embedded in broader material structures underground. Of these, the thickness and the physical quality of the layers covering the resource to be mined are of special importance for the emergence of spatial patterns. The spatial distribution of open pits depends in part on the depth of the material and whether the expected gains outweigh the mine spoilage and effort required for extracting it in a given location. However, in order to explain the patterns of open-pit mining one needs to explore how the physical conditions were intertwined with knowledge of these conditions. At the end of the nineteenth century, no systematic corpus of knowledge about the underground terrain of the Mettmann district existed. A thorough geological survey was only started in 1914.[11] Therefore, much of the mining activity simply expanded from points were limestone had already been extracted and followed the shape of the material arrangements underground as they were unveiled in the process of mining. As the pattern of quarries grew denser at the end of the nineteenth century, experienced workers were able to predict the course of the deposits still underground by bringing together knowledge from various quarries.[12] Increasingly, limestone companies also invested in professional exploration by trained geologists.

In an extension of Schatzki's concept of "practice-arrangement nexuses," Verena Winiwarter and Martin Schmid have pointed out the importance of the ways human perceptions of the natural environment shape our interaction with it.[13] In the case of limestone quarrying, perception of the underground terrain gradually changed between the 1880s and the 1910s. While informal local knowledge was the dominant basis of perception as late as the mid-1900s, an alternative means of knowledge production based on the systematic application of scientific methods gained in importance. In 1912 the geologist Wilhelm Wunstorf, regional head of the Prussian Geological Institute, devoted himself to exploring one particular limestone deposit in the Mettmann district. Drawing on numerous probes that were taken and analyzed, the results were assembled into a comprehensive description of the deposit.[14]

11 *Jahrbuch der Königlich Preußischen Geologischen Landesanstalt zu Berlin* 35, no. 2 (1914): 565.
12 Krumm, Dolomitvorkommen am Sandfeld zu Dornap, 1 November 1905, Rheinkalk, Archiv der Liegenschaftsabteilung (RhK), 00, 10a.
13 Martin Schmid and Verena Winiwarter, "Umweltgeschichte als Untersuchung sozionaturaler Schauplätze? Ein Versuch, Johannes Colers 'Oeconomia' umwelthistorisch zu interpretieren," in *Umweltverhalten in Geschichte und Gegenwart*, ed. Thomas Knopf (Tübingen: Attempto, 2008), 158–73.
14 Wilhelm Wunstorf, Bericht über die Untersuchung des Kalksteinvorkommens im Gutsbezirk Haus Schöller, 1912, Archive of the Geologischer Dienst NRW, L3G, 4708/002.

Wunstorf's evaluation was, however, informed by expectations that related to the extraction of the deposit. Even though he captured the overall composition and the arrangement of the material underground according to scientific rules, his conclusions highlighted two features of the underground terrain that were relevant for open-pit mining: the thickness of top soil and the depth of the water table. Both of these factors delimited the extent of the space where it was possible, and above all feasible, to extract the limestone deposit: "There is no doubt that a layer of top soil of less than 2 m will not cause any difficulties in the extraction of the limestone. . . . It can therefore be calculated that limestone can feasibly be extracted from an area of about 20 ha. The second factor for the calculation of the overall dimension of the exploitable deposit is its thickness, in our case the depth above the water table."[15] The assessment of what was possible and feasible was defined in relation to technological practices of the day, of course. While these permitted the removal of a maximum of about two meters of topsoil and restricted the digging to areas above the water table, the geologist was sure that these conditions would change in due course. Regarding topsoil removal, Wunstorf claimed: "It is a safe conclusion that if the limestone industry progresses at the same pace as in previous years, and there is no doubt about this, a topsoil of 3 m thickness will not pose an economic obstacle to the extraction."[16]

Technological and, implicitly, economic conditions clearly framed the spatial patterns of mining activities. Knowledge about the distribution of the material underground was an important form of perception that preconfigured these activities. In fact, this argument can be extended further if one recognizes that knowledge related not only to the mere distribution of the resources, but also to their specific characteristics. Jacob Vogel has recently demonstrated how the perception and the construction of knowledge about the properties of salt shaped the use of that mineral over the past centuries.[17] The same is true for limestone as a resource needed for the process of smelting iron. Certain characteristics of limestone suited it for use in conjunction with certain types of ore. Wunstorf's analysis of the deposit in the district of Mettmann again shows how physical characteristics and purpose-led knowledge production were intertwined: "The chemical analysis of the sample taken shows that the limestone contains 97–98%

15 Ibid. All quotations from German sources have been translated by the author.
16 Ibid.
17 Jakob Vogel, *Ein schillerndes Kristall: Eine Wissensgeschichte des Salzes zwischen Früher Neuzeit und Moderne* (Cologne: Böhlau, 2008).

carbonate lime and, of particular importance, less than 1% sand and clay (silicic acid and clay silicate). The concentration of magnesia and potash is extremely low. This composition is very advantageous and makes the limestone deposit suitable for use in blast furnaces."[18] From the geologist's perspective, the deposit that he had mapped also seemed extremely desirable as a source for extracting limestone.

Thus, as we have seen, the construction of knowledge was not independent of the actual material structure of the underground terrain. Instead, both the social practice of knowledge construction and the factual properties of the deposit—its specific location and its characteristics—have to be understood as interrelated factors in the anthropogenic change of the environment that followed Wunstorf's assertions. On the one hand, the physical exploration of the underground terrain served as the basis from which comprehensive knowledge was extrapolated. On the other hand, this knowledge was streamlined and eventually applied according to the needs of mining, thus creating patterns in which material change of the earth's surface could take place.

Legal Practices

Constructing knowledge about deposits was only the first layer of social practices that shaped the spatial patterns of the actual exploitation of the limestone deposits in the Mettmann district. Legal practices constituted a second layer that further constricted what shape the mining-related changes in the earth's surface actually took. In contrast to the mining of ores and fuels, limestone quarrying was not governed by any special laws. While a host of materials, such as coal, iron ore, certain minerals, and precious metals, were listed in the Prussian Mining Law of 1865, limestone and other common substances were not included in the regulations.[19] Social practices and factual properties of the underground terrain were again intertwined in "practice-arrangement nexuses" where legal practices diverged depending on the material properties of the resource that was to be extracted.

18 Wunstorf, Bericht.
19 Peter C. Brown, "Mining Legislation, the Consultation Process and the Reform of Mining Law: Their Significance for Company Form in Ruhr Coal Mining in the 19th Century," in Westermann, *Vom Bergbau zum Industrierevier,* 296–316; Wilhelm Westhoff, *Die deutsche Berggesetzgebung: Von den Anfängen bis zur Gegenwart* (Essen: Glückauf, 1977).

This had significant implications. On the one hand, limestone mining operations had to comply with regulations that were on the whole less strict than those put down in the Mining Law of 1865. They were also not subject to supervision by the state mining authorities, but instead were controlled by local authorities.[20] On the other hand, limestone mining companies did not enjoy the right to expropriate land as permitted by the Prussian Mining Law. They therefore had to bargain with landowners who held the titles to the properties under which the deposits lay. For both these reasons, the development of limestone quarries was almost always piecemeal. Each and every new quarry or extension of an old one had to be negotiated anew with the local authorities and with property owners.

From 1871 onwards, the relevant ordinances regulating mining for limestone were enacted and administered independently by the municipalities. The decentralization of authority over quarrying—resulting in the fragmentation of legal practices—was attributed to the fact that the material conditions in the various localities were too diverse to subordinate the extraction of limestone to national legislation.[21] Not only was the state apparently less interested in these more common resources, but the decentralization of the jurisdiction was also justified by pointing out the diversity of local material conditions. In the Mettmann district, most municipalities adopted ordinances that included provisions about the spatial properties of quarries. Slopes of more than 80 degrees were prohibited and the removed topsoil had to be at least six feet away from the edge of the quarry.[22] However, the same ordinances also allowed for considerable deviations from the rule, stating that: "The local police has to make sure that the face of the quarry has a slope that is in accordance with the properties of the material."[23] In practice, this meant that decisions were largely made on a case-by-case basis. While the entrepreneurs in the limestone business (who were often also members of the local political elite) were easily able to influence decisions, their influence ended where adverse physical conditions conflicted with their assumptions about what could be permitted. There are several cases where further exploitation of a deposit was limited by local authorities after public roads had slipped into quarries.

20 Polizei-Verordnung über das Verfahren bei Anlage und Betrieb von Steinbrüchen, Mergel-, Thon-, Lehm-, Kies-, und Sandgruben, 1871, LANRW, BR0034, 24, §1.
21 Letter from the government of Düsseldorf to all district administrators, 29 July 1870, LANRW, BR 007, 24577.
22 Polizei-Verordnung.
23 Ibid., §5.

In such cases, revised regulations could be restrictive not only in terms of permissible mining techniques, but also in terms of spatial development of the operation. Local authorities dictated details such as the direction of further exploitation and the slope that was thought to be necessary to secure the adjacent public roads.[24] Despite frequent accidents that could be easily attributed to the local authorities' laxity, it was generally not deemed necessary to regulate the exploitation of limestone on a national level. The actual mining of limestone, however, was perceived as equally dangerous and as having equally severe effects on the environment as mining for other materials that were included in the Mining Law of 1865.[25] This discrepancy clearly reflected the relative value of the different resources, with limestone having less worth than ores or fuels. In other words, the regulation of mining in Prussia in the nineteenth century was not primarily considered from the perspective of the activity of mining itself, but rather from the material to be mined.

In consequence, practices that evolved within this legal framework were not at all uniform and instead encouraged an individualized handling of mining operations. In a situation where mine owners were relatively powerful and local authorities relatively ignorant, the reference to the variability of material conditions in effect justified a laissez-faire approach.[26] This approach was only modified where the factual properties of the material obviously contradicted the assumptions under which mining operations were approved. This set of practices around the applicability and actual application of legal regulations affected the spatial patterns of open-pit mining for limestone.

These patterns were further reinforced by the necessity to negotiate with landowners. While owners were seldom able to dictate the prices, the relative cost of land did influence the calculation of where mining was feasible. Thus, the spatial pattern of limestone quarrying was to some degree an outgrowth of the local real estate market. More significant, however, were cases in which landowners aspired to become mining entrepreneurs themselves. This was a relatively common strategy pursued by holders of large estates who had both the land and the capital to engage in the business. In

24 District administration of Mettmann, Note, 19 September 1872, LANRW, BR 0007, 24577; Letter from Wolff to the district administration of Mettmann, 12 April 1881, LANRW, BR0034, 24; Mayor of the township Wülfrath, Note, 5 May 1881, LANRW, BR 0034, 24.

25 Letter from the government of Düsseldorf to the district administration of Mettmann, 18 April 1876, LANRW, BR 0007, 24577

26 Letter from the district administration of Mettmann to the government of Düsseldorf, 5 June 1876, LANRW, BR007, 24577.

fact, most of the successful limestone businesses, like those of Schüler and Schürmann, which were eventually consolidated in the Rheinisch-Westfälische Kalkwerke, started out in this way.

The case of Nicolai Müller is a typical example. In 1885 Müller allowed the newly founded Actiengesellschaft Hochdahler Kalk-Industrie to mine his property. At the same time, he was one of the founding shareholders and was able to secure his interest in the operations, which largely took place on land that he continued to own. This situation only changed in 1907, when the Rheinisch-Westfälische Kalkwerke bought out its competitor and also took over the right to exploit Müller's property by making Müller a shareholder of the enlarged Rheinisch-Westfälische Kalkwerke.[27]

What is of interest here are the conditions under which Müller had originally allowed the exploitation of his land in 1885. The contract stated first, "the Hochdahler Kalk-Industrie is obliged to leave the topsoil intact [until mining takes place], removing no more than two *Morgen* of topsoil in advance."[28] Two *Morgen*—about 5,000 square meters—seems to have allowed only for a very modest pace of extension of the quarry. In fact, agreements such as the one between Müller and the Hochdahler Kalk-Industrie further contributed to the fragmented character of the small-scale mining operations in the Mettmann district. The contract also laid out what to do with the land after the mining operation was finished. Preference was given to using the exploited quarries as dumps for topsoil removed elsewhere. However, the mining company could also pay for dumping topsoil on other parts of Müller's premises.[29] Given the fact that the quarries were scattered, the solution of dumping excavated material just at the edge of the quarry was often more economical than moving it to inoperative mines. This was even more sensible since the Hochdahler Kalk-Industrie did not have any responsibility to recultivate the land. The contract with Müller simply stated that "the exploited land and the removed topsoil remain in the property of Müller and shall be returned three years after exploitation."[30] While the ownership of the material was clearly divided between Müller and the Hochdahler Kalk-Industrie, the spatial distribution of the material was not determined by the agreement.

27 Rheinisch-Westfälische Kalkwerke AG, *Die Geschichte vom Kalk*, 41; Note, RhK, 06, 2.
28 Contract between Nicolai Müller and Actiengesellschaft Hochdahler Kalk-Industrie, 28 March 1885, RhK, 06, 2.
29 Ibid.
30 Ibid.

Both types of legal practices, namely the supervision of limestone quarrying by local authorities and the necessity for contractual agreements with land owners, had a decisive impact on the spatial patterns of limestone mining in the Mettmann district. These practices were based on the material properties of the earth and its resources, and they also shaped its transformation. The specific form of the legal organization of limestone mining was held to be appropriate because of the specific material that was to be exploited. Limestone was considered too unimportant and the conditions underground too diverse to set up a rigid legal framework that would uniformly regulate the exploitation of limestone. The result was an extremely fragmented and varied spatial structure of mining operations, with each mine following a distinct set of regulating ordinances and individual contracts.

Conclusions

Knowledge and legal practices were only two determinants that shaped the spatial patterns of open-pit limestone mining in the Mettmann district, albeit arguably the most important ones. If we follow Schatzki's suggestion of conceptualizing social practices and factual properties of the underground terrain as intertwined factors in our understanding of anthropogenic environmental change, then knowledge and legal practices appear as specific nexuses that are worth exploring in detail. In this essay, I have attempted to show how this approach can be gainfully applied to understand how spatial patterns of limestone mining emerged in the late nineteenth century and subsequently shaped the environmental characteristics of an entire region. On the one hand, social practices related to the material properties of the underground terrain. Even though the practices that shaped mining activities can to some extent be described in constructivist terms, the "facts of nature," as Schatzki has it, appear to be essential, for they remain, in a factual sense, an authoritative point of reference for the social construction of knowledge and legal organization. On the other hand, the social practices that were established in this way also had far-reaching impacts upon these very "facts of nature." Schmid and Winiwarter have reminded us that knowledge about material properties of the environment was eventually transformed into actual physical "work," which resulted in changes not just of perception, but also of the material properties of the environment.[31]

31 Schmid and Winiwarter, "Umweltgeschichte als Untersuchung sozionaturaler Schauplätze?"

The approach presented in this essay is thus helpful in understanding why mining takes on specific forms at different places and times. To explain the emergence of these forms and their specific characteristics, the cultural contexts of social practices are just as important as the material context in which these social practices developed. Only when both factors are considered in conjunction will it be possible to understand why limestone quarries in the Mettmann district are less spectacular and almost "invisible" when compared to the eminent copper mining operations in the USA or the open-pit lignite mines in nearby Rhenish districts.

Manuel Schramm

Uranium Mining and the Environment in East and West Germany

The comparative method in historiography is not a recent invention. Yet even today studies seldom center on a systematic and explicit comparison of two or more cases. In environmental history, as in other subfields of the historical profession, either detailed case studies or global overviews predominate. This article tries to demonstrate the advantages of the comparative method through the example of uranium mining in East and West Germany during the Cold War. The remainder of this section will look at the comparative method and its potential benefits for environmental history. Section One describes the extent of uranium mining in East and West Germany in general, while Sections Two and Three analyze in detail the pollution due to uranium mining in East and West Germany respectively. Section Four discusses the results and tries to identify the advantages of the comparative approach.

Basically, the comparative method in history can have one or more of the following functions: first, a heuristic function, discovering phenomena that otherwise would have been overlooked. Second, a descriptive function, making the peculiarities of one case more visible. Third, an explanatory function, helping to identify important variables that shape a particular development. In this function, the comparative method works as an indirect experiment. Fourth, it can deprovincialize historiography by making familiar events appear in a new light.[1]

Comparisons try to identify similarities and differences. Depending on the subject and interpretive framework, they may stress the former or the latter. Paul Josephson's study *Industrialized Nature* is a particularly useful example of how the comparative method may be applied, for his subject, the environmental history of the Cold War era, suggests a number of ideas that are relevant to the present essay. Josephson looks at large-scale technological changes in the landscape, such as river dams, irrigation systems, and highways. Without denying national differences in the application of these technologies, he stresses the similarities even between such different societies as the

1 Juergen Kocka and Heinz-Gerhard Haupt, "Comparison and Beyond: Traditions, Scope, and Perspectives of Comparative History," in *Comparative and Transnational History: Central European Approaches and New Perspectives*, ed. Heinz-Gerhard Haupt and Juergen Kocka (New York: Berghahn, 2009), 3–5.

USA and the USSR. Fuelled by a belief in science-driven progress, these (and other) societies have developed and put into practice what Josephson calls "brute force technologies" with an "overemphasis on unforgiving technologies of massive scale."[2] With their faith in the ability of technology, so the argument goes, US and Soviet engineers and politicians had more in common than often assumed.[3] Obviously, for the present study this assertion is a useful starting point. Were East and West Germany really different in their exploitation of natural resources like uranium? Or is uranium mining just another example of "brute force technology"?

Uranium Mining in Germany

The beginnings of uranium mining in Germany are to be found in the aftermath of World War II and the incipient Cold War, when both the USA (and its Western allies) and the USSR began to look for uranium deposits, as they were in need of raw material for nuclear weapons, and later for nuclear reactors as well. However, whereas uranium mining was new, a tradition of radium mining already existed in the Erzgebirge (Ore Mountains) on both sides of the German-Czech border. The first regulations setting limits on miners' radiation exposure were enacted here during World War II.[4] However, they were limited to the protection of the workforce, and no attempt was made to measure or limit the damage to the environment. It was known that uranium mining caused lung diseases. Moreover, while the carcinogenic effect of radiation had already been discovered in the 1920s, little research existed about the dangers of radiation in mining.

In the 1950s, the recommendations of the International Commission on Radiological Protection (ICRP) provided the most important point of reference. They set limits to the maximum exposure considered safe for both workers exposed to radiation and the general population. The background was the controversy about fallout from nuclear weapon testing during that time.[5] By introducing a unit for measuring exposure (rem),

2 Paul R. Josephson, *Industrialized Nature: Brute Force Technology and the Transformation of the Natural World* (Washington, DC: Island Press, 2002), 12.
3 Ibid., 3.
4 W. Schüttmann, "Das Radonproblem im Bergbau und in Wohnungen: Historische Aspekte" in *Strahlenrisiko durch Radon*, ed. Christoph Reiners and Dietrich Arndt (Stuttgart: Fischer, 1992), 14.
5 Samuel Walker, *Permissible Dose: A History of Radiation Protection in the Twentieth Century* (Berkeley: University of California Press, 2000), 12, 23f.; Catherine Caufield, *Multiple Exposures: Chronicle of the Radiation Age* (New York: Perennial Library, 1989), 64–74, 134–39.

an attempt was made to find a common denominator for the effects of different kinds of radiation.[6] According to the ICRP recommendations of 1956, a person should not be exposed to more than 500 mrem a year (for employees exposed to radiation, the limit was set at 5 rem). This was not legally binding, but the ICRP values influenced radiation protection measures in both East and West Germany. Also, the differentiation between employees exposed to radiation and the general population was one which has been upheld ever since. In general, this distinction is based on arguments that the general population never willingly accepted the health risks resulting from exposure, that the effects are not monitored (as for miners) by regular medical examinations, and that this group consists mainly of women and children. Radiation protection regulations that were passed in West Germany (the Federal Republic of Germany, FRG) and in East Germany (the German Democratic Republic, GDR) in 1964 also made this distinction. The latter was especially strict in limiting the exposure of the general population to only 1/100 of the maximum exposure for employees.[7] Before the early sixties, Soviet regulations were applied in the GDR.

The scale and scope of uranium mining in both German states showed vast differences. In East Germany, uranium prospecting began immediately after World War II, with mining operations starting in the Erzgebirge in 1946. Later, mining activity shifted to Ronneburg and other places in Thuringia, also situated in the south of the GDR. The mining company, called "Wismut" (bismuth), was at first fully controlled by the Soviet government. In 1954, it was changed to a Soviet-German joint venture. The uranium produced continued to be delivered to the Soviet Union, however. It is estimated that this amounted to more than 200,000 tons of uranium between 1946 and 1990, making the GDR the third largest producer of uranium in the world. At its peak in the early fifties, Wismut employed more than 200,000 workers (including administration).[8]

In West Germany, uranium mining began later and never reached similar dimensions. First of all, suitable deposits had to be found. A number of possible sites in various regions were found, but actual mining activities took place in only two of them: in

6 The unit "rem" means "roentgen equivalent in man." It is a combination of the absorbed dose of radiation with weighting factors that take the different nature of radiation (x-rays, gamma rays, alpha rays etc.) into account. It is used to measure the biological effect of radiation. Today, the more commonly used unit is "sievert" (1 rem = 0.01 sieverts).

7 *Gesetzblatt der DDR,* Teil II, no. 76, 6.8.1964.

8 Rainer Karlsch, *Uran für Moskau: Die Wismut—eine populäre Geschichte,* 3rd ed. (Berlin: Ch. Links, 2008), 83, 260f.

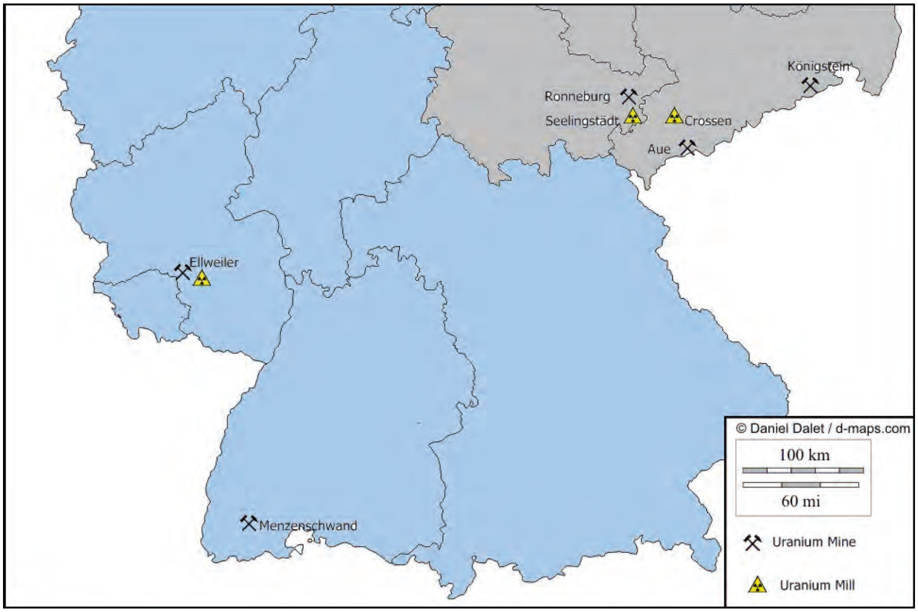


Figure 1: Sites of uranium mines in the southern part of East and West Germany (Source: d-maps.com. Markings added by the author)

Ellweiler (Rheinland-Pfalz) and in Menzenschwand in the Black Forest (Baden-Württemberg).

Furthermore, mining was limited in time and scope: in Ellweiler open-pit mining took place between 1959 and 1964. It was abandoned largely for economic reasons. In Menzenschwand, mining began in 1961, but had to be stopped two years later and was resumed from 1974 to 1982 and again from 1989 to 1991. Officially, it was never more than prospective drilling.[9] All in all, no more than 720 tons of uranium were produced in Menzenschwand between 1961 and 1991—in other words, less than half a percent of the Wismut production.[10]

There was one feature of both German states that distinguished them from other areas where uranium was mined: the high population density. Whereas in most other countries (USA, Canada, Australia) uranium mining took place in sparsely populated areas,

9 Armin Simon, *Der Streit um das Schwarzwald-Uran: Die Auseinandersetzung um den Uranbergbau in Menzenschwand im Südschwarzwald 1960–1991* (Bremgarten: Donzelli-Kluckert, 2003); Wolfgang D. Müller, *Geschichte der Kernenergie in der Bundesrepublik Deutschland*, vol. 2 (Stuttgart: Schäffer-Poeschel, 1996), 483–90.

10 Simon, *Schwarzwald-Uran*, 194.

such was not the case in Germany. The southern part of East Germany in particular had long been an industrial area and was one of the most densely populated areas in Germany.[11] This made uranium mining even more hazardous than elsewhere.

Pollution at Wismut AG

We do not have much information about the environmental impact of the mining during the early years of Wismut, due to the fact that pollution had yet not been recognized as a problem and there were no measurements of radioactive (or, indeed, any other) emissions. This state of affairs changed only in the late fifties. The immediate trigger was a 1958 investigation which looked for the possible causes of radioactive contamination of surface and groundwater observed in the vicinity and therefore measured the emission of radionuclides of a uranium processing plant in Crossen which belonged to the Wismut complex. The results were so alarming that the investigation was extended to two other Wismut facilities in Freital and Ronneburg and to all their emissions. This document was the first environmental report of the Wismut AG. It was compiled in 1959 by a group of Soviet scientists, was originally written in Russian, and was not intended to become public.[12]

The most important results were as follows. The surface water contained 3–4 times more radium and uranium than the limit, sometimes even more. In the Zwickauer Mulde, one of the larger rivers in the region, the contamination covered 150 km. The Oberrothenbach stream contained 12–20 times more uranium than the legal limit. That was especially worrying given the fact that drinking water was taken from the Oberrothenbach near the processing plant in Crossen. At the pumping station, the radium concentration oscillated, but always exceeded the legal limits both for drinking and process water. Investigations were also carried out with regard to soil and plants.

11 The district of Zwickau in southwestern Saxony had a density of 432 inhabitants per km² in 1990. "Demografische Entwicklung," Sächsische Staatskanzlei, accessed November 25, 2011, http://www.demografie.sachsen.de/6421.htm. In Saxony as a whole, the population density was 259 inhabitants per km². In comparison: Thuringia (1990) 161; South Australia: 1.5; Saskatchewan (Canada): 1.5; Arizona (USA): 17; Colorado (USA): 79; New Mexico (USA): 6; Kazakhstan: 5.4. Data from Jan Lahmeyer, "Population Statistics: Historical Demography of All Countries, Their Divisions and Towns," accessed 25 November 2011, www.populstat.info.

12 W. D. Kutscherenko et al., *Bericht über die Ergebnisse der umwelthygienischen Untersuchung des hydrographischen Netzes und der Umgebung von Betrieben der SDAG Wismut*, 1959 (Wismut-Archiv M 428), 4f.

While the plants and soil adjacent to the rivers and streams were contaminated, the contamination near tailing storage areas, by contrast, did not exceed the legal limits, not even in a vegetable garden adjacent to a uranium ore tailing.

The report documented the widespread contamination of surface and ground water in the mining region. The amount of pollution is probably representative for the early period of mining activity in which not much thought was given to potential environmental effects. However, it covers only the pollution caused by the normal working of the mines and processing plants. In April 1961, an accident near Crossen caused a significant increase in pollution levels.[13] Due to a break in a concrete pipe, 700,000 m^3 of radioactive mud poured into the Oberrothenbach and further into the Zwickauer Mulde. For a short time, the contamination rose to unprecedented levels of 100–1,000 times the legal limit. The wells in the vicinity were closed and pasturing livestock was prohibited. With the help of the police, fire brigade, and the Red Army (among others), the mud was cleared by early May. According to a report, the population was pleased with the concentrated and vigorous effort. It must be added, however, that the people were probably not aware of any radioactivity. The local press only published a short notice that spoke of a pipe damage at a mining company's site.[14] Neither the company's name nor the substances concerned were mentioned.

The two instances, the 1959 report and the 1961 accident, ushered in a phase in which environmental concerns were taken more seriously. Another report (again not for the public) was written in 1963.[15] It largely confirmed the results of the earlier report, although the Zwickauer Mulde was slightly less contaminated. A well in Zinnbach, the closing of which had already been recommended in 1959, was still active and still contained a high concentration of uranium. The authors of the report concluded that the investigations showed unequivocal evidence for continuous radioactive contamination of water, soil, plants, and air. Given the dense population of the area, they regarded the problem as very serious.[16] Most serious was the contamination of the smaller waterways and the ground water near the processing plants.

13 Bundesarchiv Berlin DC 20/12062, fol. 3–23.
14 Ibid., fol. 24–27.
15 It is discussed in greater length by Harm Schröter, "Die Wismut, der Umweltschutz und ein zentrales Dokument," in *"Strahlende Vergangenheit": Studien zur Geschichte des Uranbergbaus der Wismut*, ed. Rainer Karlsch and Harm Schröter (St. Katharinen: Scripta-Mercaturae-Verlag, 1996), 356–63.
16 Wismut-Archiv Bestand 13, no. 68, fol. 25.

To ameliorate the situation, a number of measures were necessary. One of them was the containment of seepage coming from the processing plants. A 1974 report pointed out that the seepage from the processing plant in Crossen always contained more uranium than the legal limit and sometimes more radium as well.[17] A containment facility was finished in 1975, but for unknown reasons did not begin to operate until 1978.[18] The increasing amount of regulations in the seventies and eighties made a widespread contamination of waterways, as in the fifties and early sixties, less likely, but at certain points the sewage was still a problem.

In the eighties, new problems arose. One was an accident at the Königstein mine in October 1984, where 120,000 m^3 of wastewater containing 720 kg of uranium poured into the Elbe River.[19] The legal limits for radium, uranium, and solid matter were exceeded. The danger for the population was thought to be small, however, as no drinking water was taken from the Elbe.

Another incident happened at a settling basin near the processing plant in Oberrothenbach village in November and December 1987, when a number of wild ducks and other birds were observed to have died. The cause was at first not known. One day a citizen counted more than 70 ducks and one cormorant being collected by Wismut employees, who claimed that the birds had been killed by a fox. The citizen did not believe this story, as no blood could be seen. He wrote a petition voicing his fears that radioactive dust may have been the cause.[20] Veterinary examinations showed, however, that the birds had not died of radioactivity but of arsenic poisoning. Their arsenic content was between 4 and 120 times higher than normal.[21] Wismut decided early in 1988 to stop arsenic emissions into the Zwickauer Mulde and to erect a fence around the settling basin in Oberrothenbach, even though this was not an insurmountable obstacle for birds.[22]

Arsenic contamination was not limited to Oberrothenbach village, but spread to large parts of southwestern Saxony. A Wismut mine had been emitting mine water with high arsenic content since the fifties. What made the problem worse was that the arsenic con-

17 Ibid., no. 67, fol. 82.
18 Ibid., fol. 111, 137, 161.
19 Ibid., no. 64.
20 Wismut-Archiv Bestand Geschäftsstelle Berlin, no. 39/10.
21 Ibid., no. 39/11.
22 Ibid., no. 39/9.

tent of the uranium ore became higher in the eighties. In addition, Wismut had begun to mine for silver ore with a high arsenic content in 1984. The mine emitted 9.5 kg of arsenic into the Zwickauer Mulde on a daily basis. Drinking water was not taken from this part of the river, so there was no immediate danger to the population, but the arsenic content was so high as to present a danger to birds and animals.[23]

Another problem in the eighties concerned the pollution of the river Weiße Elster. Starting in March 1987, the hardness of the water rose to unprecedented levels because of wastewater from a Wismut mine and processing plant. In October, the hardness of the river water was nearly ten times the recommended amount, making it unsuitable to use even in industrial processes. Complaints came from industrial users downstream, including a chemical factory and a sugar producer. From February 1988 on, a computer-coordinated wastewater management system largely helped to solve the problem.[24]

In an internal report drawn up in 1989, Wismut's scientific and technical center (Wissenschaftlich-Technisches Zentrum, WTZ) wrote about the contamination of waterways. As a whole, there was a considerable increase in the concentration of radionuclides in smaller rivers and streams (especially the Wipse), a demonstrable increase in the rivers Weiße Elster, Zwickauer Mulde, and Pleiße, and only a theoretical increase in the Elbe. According to the report, the concentration as a whole was under the limit for drinking water, and the risk for the population negligibly small.[25] This may be true, but certainly the population was exposed to higher doses of radiation than they would have been without uranium mining. Moreover, the environmental effects were not limited to radiation, but also included arsenic and salt, lowering water quality and endangering the fauna. However, the situation was certainly no longer as bad as in the fifties.

A bigger health hazard for the population was probably the slag and tailings. As early as the late fifties, the Bureau of Nuclear Technology and Nuclear Research (Amt für Kerntechnik und Kernforschung, AKK) conducted investigations of the Wismut tailings.[26] The motivation for this research was a plan to use tailing slag as building material, which was in short supply in the GDR. The measurements of the AKK were not very accurate, but the findings seemed to confirm doubts about its suitability for the intended purpose.

23 Ibid., no. 39/4, 11.12.87.
24 Ibid., no. 39/4, 39/5, 39/13.
25 Ibid., no. 39/27, 3f.
26 Bundesarchiv Berlin DF 1, no. 1550.

For example, tailings contained isolated stones or boulders that were highly radioactive, containing 20 percent uranium. A test house was built in Rossendorf from tailing slag in the summer of 1958. The air within it contained 300 times as much radon as the legal limit. The experts judged the use of tailing slag as building material to be inappropriate.[27] On the other hand, they did not regard the tailings as such as dangerous for people living in the vicinity of the dumps.

Although the potential dangers of uncontrolled use of slag material had been known since the late fifties, no concrete steps were taken until the mid-seventies to limit its use. In the seventies, when shortage of building material became ever more acute, the use of slag material increased, and in 1974 the Federal Office for Nuclear Safety and Radiation Protection (Staatliches Amt für Atomsicherheit und Strahlenschutz, SAAS) issued a guideline for the use of tailing slag that introduced a five-level classification system based on the amount of gamma radiation and radium content.[28] In 1980, this was turned into a regulation and became legally binding.[29]

Officials at the Wismut mines were also aware of the radioactivity of tailings. In 1974, a suggestion was even made to search the tailings for uranium that could be processed, because in some cases the uranium content seemed to be considerable.[30] The use of tailing material for buildings seems to have been quite liberal, even at the Wismut. In a shack erected for the scientific and technical center in 1971, a high concentration of radon daughters[31] in the air was discovered in 1985; contaminated material had been used for the foundations.[32] Even in the eighties, regulations regarding the use of tailing slag were ignored. The SAAS wrote: "It has been observed again and again that combines and territorial institutions are ignoring clear legal regulations in spite of having been informed about this repeatedly, and thus it is essential that these combines and institutions put greater effort into inspection and creating admissible conditions."[33] Examples could be found in newly erected houses in Johanngeorgenstadt (Erzgebirge) and Freital (near Dresden) where the 1980 regulation had been ignored.[34]

27 Ibid., 18.
28 Wismut-Archiv Bestand 13, no. 68, fol. 77.
29 Bundesarchiv DF 10, no. 214, Bündel 2.
30 Wismut-Archiv Bestand 13, no. 68, fol. 81, 83.
31 Radon is a gaseous radioactive element. Its decay products, or daughters, are polonium, astatine, lead, bismuth, and thallium, all of them radioactive.
32 Wismut-Archiv Bestand Geschäftsstelle Berlin, no. 41/3/9.
33 Bundesarchiv Berlin DF 10, no. 45; translation by the author.
34 Ibid., no. 711/7–15.

All in all, the scientific and technical center of the Wismut considered the inhalation of radon daughters as the greatest radiation hazard. They even estimated the concrete exposure of the average population in particular areas to radon and its daughters, including the natural radon content of the atmosphere: around Ronneburg 9 millisievert (mSv)[35] per year, around Seelingstädt 7 mSv, around Crossen 6 mSv, around Aue 9 mSv—with a peak value of 22 mSv.[36] According to the regulations, the maximum exposure should not exceed 5 mSv. The center recommended covering the tailings, which at that time were usually stored open to the air.

How did the people react to the dangers of radiation and other forms of pollution through uranium mining and processing? First of all, the information collected in this article was not known to the East German public. Instead, rumors about radiation circulated. Independent environmental groups became active in the eighties and tried to measure radiation, often with inappropriate means. In the fifties and sixties there seems to have been no critical discussion about Wismut, although the dangers of radiation were known in principle. Even the accident in Oberrothenbach in 1961 did not provoke any nuclear fears, let alone panic. Petitions from worried citizens are first documented in the early seventies. In particular, they expressed fears about uncontrolled radiation from nuclear power plants and the use of contaminated slag. By the late seventies rumors were circulating about allegedly dangerous radioactive tailings adjacent to residential houses, for example in Schmiedeberg (Erzgebirge).[37]

The activities of independent environmental groups often took up these rumors. The inhabitants of Crossen and Oberrothenbach (near Zwickau) in particular complained about symptoms such as cancer, hair loss, tiredness, and impotence, which they attributed to radiation exposure. The two villages became known as the "tired villages."[38] This caused environmental activist Michael Beleites to investigate the radiation on his own initiative. He gathered information through his own measurements and observation and also received valuable data from the department for water management (Wasserwirtschaftsdirektion) in

35 Like rem, sievert is a unit measuring the equivalent dose of radiation. Cf. footnote 6.
36 Wismut-Archiv Bestand Geschäftsstelle Berlin, no. 39/27.
37 Bundesarchiv DF 10, no. 214, 14.9.1978.
38 Michael Beleites, *Altlast Wismut: Ausnahmezustand, Umweltkatastrophe und das Sanierungsproblem im deutschen Uranbergbau* (Frankfurt am Main: Brandes und Apsel, 1992), 130; see also Michael Beleites, *Untergrund: Ein Konflikt mit der Stasi in der Uran-Provinz*, 2nd ed. (Berlin: Basis Druck, 1992), 89; Wismut-Archiv Bestand Geschäftsstelle Berlin, no. 39/1.

Gera.[39] He published the results in samizdat copies under the title “Pechblende” (“pitchblende,” that is, uranium-rich ore) in May 1988. Only a few East German citizens ever saw a copy, but the information in the pamphlet was passed on to West German media (both newspapers and television), who ran features in November 1987 and summer 1988.[40] However, due to lack of knowledge and a desire to dramatize, these reports contained exaggerations and sometimes even outright nonsense, for example in claims that the government distributed free wigs in the mining areas to alleviate hair loss caused by radiation. Still, the West German media reports also had a wide reception in the GDR and sensitized people to the dangers of radiation. Wismut employees were confronted with the content of these reports, while parents discouraged their adolescents from seeking employment at Wismut. One citizen who had moved to Aue in the Erzgebirge reported that he had been repeatedly discouraged from doing so because the air was allegedly so bad that wounds would not heal.[41]

Due to the continuing rumors, the council of the district of Karl-Marx-Stadt, where a large part of the mining took place, felt compelled to compose an informational brochure about radiation in the southern districts of the GDR. This was unusual, because until then the official media had never discussed the dangers of radiation. The informational brochure, of course, tried to downplay the radiation risks. Both the high exposure of miners and radioactive pollution were portrayed as a problem of the early years of uranium mining that had been overcome in the meantime. The emissions had been controlled since the sixties, the brochure claimed, the radiation of tailings was in the range of natural rocks, and even in the immediate vicinity of the tailings there was therefore no cause for concern. Interestingly, the records of the SAAS contain a comment that this information was correct in substance, but problems arose because of the deviation from legal norms like the 1980 regulation about tailing slag.[42]

It is no new finding in environmental history that the perception of pollution does not always correspond to actual pollution levels. Still, it is a point worth noting. The radioactive contamination of waterways, as well as of soil and plants, was much higher in the fifties and early sixties than in later decades. This does not mean, however, that everything was fine in the eighties. A particular cause for concern was the tailings and the irresponsible

39 Beleites, *Untergrund*, 120, 167.
40 Ibid., 111.
41 Wismut-Archiv Bestand Geschäftsstelle Berlin, no. 39/3, 39/7.
42 Bundesarchiv Berlin DF 10, no. 45, 28.10.88.

use of contaminated slag as building material. Another important result is that pollution through uranium mining consists of not only radioactive substances, but also salt and arsenic. It was not until the eighties that serious protests started to come from the population living near the mines, when both local environmental activists and especially West German media made it an issue. Towards the end of the eighties, many people lost confidence not only in the political elite, but also in the scientific and technical elite who tried to dissipate fears. So it is probably correct to say that the environmental problems were a nail in the coffin of the socialist regime,[43] even though, ironically, the perception was in some ways worse than the actual problems. The blame lies with the information policy of the regime, which tried to stifle discussion and hence lost credibility.

Pollution in West Germany: Ellweiler and Menzenschwand

Admittedly, the problem of pollution did not present itself to the same degree in West Germany simply because uranium mining took place on a much smaller scale. Still, environmental aspects did play a role even at a fairly early stage. In Menzenschwand, where uranium was discovered relatively late, mining was unpopular from the beginning. The reasons for what would become a long conflict were simple: the community wanted to protect its status as a popular tourist resort in the Black Forest. So protests not only arose from local activists, but also had the support of the local and parts of the regional administration. The federal government, however, was not prepared to give up on Menzenschwand, because this was by far the most promising deposit in West Germany, if not in Western Europe. The uranium content of the ore was estimated to lie at one percent or more.[44] The mining company, the Gewerkschaft Brunhilde, was also responsible for exacerbating the relations by proceeding in a manner that was regarded as high-handed, selfish, and reckless by the local administration.[45] But it was not only, as sometimes argued in the literature,[46] a problem of diplomacy or of conflicting personalities. Rather, right from the beginning the fear of pollution played a role in motivating local resistance. So the municipality and the Office for Water Management (Wasserwirtschaftsamt) expressed

43 So Ilko-Sascha Kowalczuk, *Endspiel: Die Revolution von 1989 in der DDR* (Munich: C. H. Beck, 2009), 127.
44 Bundesarchiv Koblenz B 138, no. 2278, Bd. 1, fol. 199 f.; no. 2281, Bd. 1, fol. 23–25.
45 Ibid., Bd. 2, fol. 531.
46 Müller, *Kernenergie*, 485; Joachim Radkau, *Aufstieg und Krise der deutschen Atomwirtschaft 1945–1975: Verdrängte Alternativen in der Kerntechnik und der Ursprung der nuklearen Kontroverse* (Reinbek bei Hamburg: Rowohlt, 1983), 442–45.

concerns that uranium mining presented a danger to the local waterways and ultimately also to the drinking water supply, as radioactive water might seep from the tunnels and shafts to other, uncontaminated areas. The critics found support from the regional government, which argued that the mining plans were irreconcilable with the Feldberg conservation area.[47] As a compromise, regional and federal governments agreed to spare the Farnwitte, a part of the Feldberg conservation area.[48]

Other factors contributing to the protests were the environmental consequences of prospective drilling, including noise from ore transports and, as critics had feared, problems of water management. Untreated mine water drained into the river Alb, where it caused episodes of fish die-off. Later a settling basin was built; however, it was inadequate to clear the water of minerals.[49] The radioactive contamination of the water was measured by an independent institute in 1964. It showed an increase of 10–20 times above normal values in the area. This was not considered a health hazard, however.[50] Another issue was the blastings, which caused a spring to run dry that had hitherto provided water for part of the town. The replacement well did not work properly.[51] The mining company defended itself by declaring that the fish deaths had been caused by other forms of pollution, that they had built a new waterworks facility, and that only two trucks a day drove through town to make transports.[52] The municipality remained unimpressed, sued the company, and won. The prospective drillings were stopped in October 1963.[53]

When they were resumed in the seventies, the public had become more critical of nuclear power in general. Leading environmental organizations such as the BUND (Bund für Umwelt und Naturschutz in Deutschland) were opposed to uranium mining, not simply because of its direct consequences for the environment, but because it was part of the nuclear industry.[54] However, it was a small group from the university town of Freiburg, calling themselves "Arbeitskreis Strahlenschutz" ("Working Group for Radiation Protection") that made the issue public in 1978. The focus of their protests was the use of slag from uranium mining for road building, as they feared an uncontrolled spread of radioactive material. Further, the transport of uranium ore caused problems. Members

47 Bundesarchiv Koblenz B 138, no. 2278, Bd. 1, fol. 64f., 138; Bd. 2, fol. 486–88.
48 Ibid., Bd. 2, fol. 399.
49 Ibid., Bd. 2, fol. 415.
50 Staatsarchiv Freiburg, F 235/9, no. 61, Bd. 1, 20.1.64.
51 Bundesarchiv Koblenz B 138, no. 2278, Bd. 2, fol. 408f.
52 Ibid., Bd. 2, fol. 534, 557–60.
53 Ibid., Bd. 1, fol. 135–52.
54 Simon, *Schwarzwald-Uran,* 160f.

of the Freiburg group made their own measurements with Geiger counters and found higher than normal radiation in certain places, for example at a parking lot at the end of Menzenschwand, and on the loading ramp and the freight cars at the railway station. Measurements by the Landesanstalt für Umweltschutz (State Environmental Protection Agency) largely confirmed these findings, but the mining authorities and a report by a radiologist did not consider them a danger to the population. Still, recommendations were made to reduce radiation, for example to cover the ore that was transported in trucks to the next railway station, to put up warning signs around the company grounds, and to clean the loading ramp (which was not actually done until 1992).[55] In the late seventies, the inhabitants of Menzenschwand seemed to have come to terms with uranium mining, and saw the activists from Freiburg not as their allies but as their enemies who brought the town into disrepute. This attitude changed suddenly in 1982, when measurements by a local group of activists and subsequently by the Landesanstalt für Umweltschutz found high concentrations of radionuclides in the sediment of the Alb river. Up to 370,000 Bq/kg were measured, 1,000 times more than in 1978.[56] The ensuing local protest made the regional government decide in 1983 that no further concessions for uranium mining would be given.[57]

In the town of Ellweiler, too, water quality was the dominant issue. The wastewater from the mine flowed into the Steinaubach stream. Proposals to build a wastewater canal to protect a nearby water collection point were rejected because it might give rise to concerns about pollution.[58] In January 1960 the mining company (the Gewerkschaft Brunhilde, as in Menzenschwand) received permission for a test run of in situ leaching with an acid solution that began on 1 February. The wastewater was collected at the beginning. It contained three times as much salt as declared, and the limit for copper was exceeded. The leaching had to be stopped after five days, because pipes and pumps had been damaged by the acid solution. The wastewater basin was then emptied without permission.[59] The legal limit for uranium in wastewater was not exceeded, but measurements in July 1959 showed it to be close to the limit.[60]

55 Simon, *Schwarzwald-Uran*, 143–58, 195.
56 Ibid., 172f.
57 Ibid., 178.
58 Bundesarchiv Koblenz B 138, no. 2282, fol. 122, 165–67.
59 Ibid., fol. 144.
60 Ibid., no. 2281, fol. 55, 71f.

Open-pit mining in Ellweiler was abandoned in 1967, not because of protests but for reasons of economy. However, a uranium processing plant was in use there until 1989. A medical investigation of the early nineties showed that there was a significantly higher incidence of leukemia among children and adolescents between 1970 and 1989 in the surrounding area (5 km around the plant). The reasons were not quite clear, but the author assumed that a higher than normal radium content in drinking water could be responsible. There is no reliable time series data about radium in drinking water in this area, but measurements from 1979/80 suggest it is possible that the limit of 40 mBq (megabecquerel, a unit of measuring radioactivity) per day was exceeded.[61]

Although pollution in the FRG was certainly less serious than in the GDR due to the smaller scale of uranium mining, a link has been established between the incidence of cancer and uranium mining (and processing) in Ellweiler. This makes it difficult to believe that no such connection existed in East Germany, even if definitive evidence has not been found. An exception is the miners, where the higher incidence of lung cancer is well known. Aggregate data about cancer rates show a higher incidence of lung cancer in males in the district of Aue, where many miners live.[62]

In West Germany, then, uranium mining led to considerable environmental stress that was not limited to radiation exposure. Most important was the danger for surface and ground water and therefore also for drinking water. The resistance to uranium mining in Menzenschwand was not irrational. It can be explained by the mixture of very concrete environmental damage (noise, fish die-off) and very abstract dangers (radiation).

Uranium Mining and the Environment in Comparative Perspective

It would be useful to extend this comparison to other countries. It seems plausible, for example, that uranium mining in a colonial context was even more devastating than in

61 Wolfgang Hoffmann, *Inzidenz maligner Erkrankungen bei Kindern und Jugendlichen in der Region Ellweiler, Rheinland-Pfalz: Epidemiologie und biologische Dosimetrie zur Ermittlung möglicher Belastungspfade* (Aachen: Shaker, 1993), II.39, V.1.

62 "Krebsregister Sachsen 2001–2005," Gemeinsames Krebsregister der Länder Berlin, Brandenburg, Mecklenburg-Vorpommern, Sachsen-Anhalt und der Freistaaten Sachsen und Thüringen, accessed 25 November 2011, http://www.berlin.de/imperia/md/content/gkr/daten/sn_daten.pdf.

the two German states.[63] However, more research needs to be done before this hypothesis can be accepted. The following remarks are therefore limited to the case studies presented here. Even so, the comparison shows interesting similarities and differences.

As was to be expected, the forms of pollution were similar. Above all, the dangers were the pollution of waterways, the emanations from tailings, or the use of contaminated slag. However, the environmental problems of uranium mining were not limited to radiation; they included a number of other emissions as well, from noise to salt and arsenic. While the concrete problems differed from one place to another, the multi-faceted nature of pollution through uranium mining is similar. Broadly similar were also the risks of higher cancer rates for the population, although experts still disagree about how risky low-level radiation really is. It is worth noting, however, that there did not seem to be a general disagreement between East and West German scientists over this question. In the political arena, similarities arose despite the different political systems. In both countries, national governments faced a difficult choice between the protection of their population and the exigencies of the Cold War, which made uranium a strategic resource. As the comparison shows, it would be simplistic to claim that the East German dictatorship opted for reckless exploitation of natural resources whereas the West German democracy opted for protection of the population. Compromises had to be made in both cases. Still, as will be argued below, differences in the political systems did have an effect.

Another similarity is the lack of effective environmental protection. It is hard to escape the conclusion that at least some of the pollution was avoidable. The reason was not so much lack of knowledge in general; the dangers of radiation were already well known in the 1950s. The problem was rather the tradition of self-regulation in mining. The companies were often left to their own devices, and authorities only intervened when problems became acute and obvious. The SDAG Wismut was not as much of an exception in this respect as has often been assumed.

Similarly, there was a lack of social acceptance of uranium mining in the 1980s. In East Germany, however, protests arose much later than in the West Germany. Indeed, it is perhaps in this area—namely, the attitudes of the population to uranium mining—

63 Rainer Karlsch, "Das Erz des Kalten Krieges: Uranbergbau in West und Ost," in *Uranbergbau im Kalten Krieg: Die Wismut im sowjetischen Atomkomplex,* ed. Rudolf Boch and Rainer Karlsch (Berlin: Ch. Links, 2011), 1: 101–107.

that the differences between the political systems were most pronounced. In Menzenschwand, local activists and the regional government already raised opposition to uranium mining in the 1960s with a certain degree of success. This was not only due to the more pluralistic political system, but also to the freedom of the press. In the GDR, uranium mining was at first hidden under a veil of secrecy. The environmental reports cited in this article were never published, and it was only in the 1980s that an independent environmental movement formed and began to ask critical questions. Another important difference, of course, is the scale of mining activities. The effects of pollution in West Germany were bound to be more local, given the limited scale of operations. Here, it would be an exaggeration to speak of "brute force technology" in Paul Josephson's sense. The mining activities of the SDAG Wismut in the early years up to the late 1950s come closest to this notion, perhaps. Thereafter, steps were taken to limit the damage to the environment, even if more could have been done.

This article is meant to show that the comparative approach makes sense in environmental history, as in other historical fields. As already noted in the introduction, a comparison can have different functions and serve different purposes. In this case, it was helpful in several ways. It had a heuristic function by highlighting that environmental damage from uranium mining is not confined to East Germany, but also exists in West Germany where it is much less well known. While some historical work has been done on the Menzenschwand mine, there is still no substantial research on the Ellweiler mine and processing plant. Further, the comparison has an explanatory function in the sense that we can see how different political regimes dealt with uranium mining. As mentioned above, environmental protection was deficient in both countries. The real difference lay in the fact that there were more opportunities for dissenting voices to make themselves heard, from both inside and outside the political system of the FRG. The comparison also helped to deprovincialize research that hitherto has often looked at the SDAG Wismut in isolation. At least some features that were seen as peculiarities, such as the low level of direct government control and interference, appear in a new light.

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This volume of *RCC Perspectives* offers an interdisciplinary look at mining and its environmental impacts in central Europe. The metals and minerals covered in the articles include copper and silver in Tirol, mercury in Slovenia, lead and zinc in Westphalia, lime in the Rhineland, and uranium in East and West Germany. The authors also use a wide variety of methodologies, looking at pollution and health hazards, spatial patterns, arrangements between the mining and agriculture industries, and even reconstructing the vegetation of the past through detailed pollen, microcharcoal, and geochemical analyses of a Tirolean fen.

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