Nature's Working Worlds: Science, Industry, and Environment in the Time of Alexander von Humboldt, ca. 1770–ca. 1860

By

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Dissertation

Submitted to the Faculty of the

Graduate School of Vanderbilt University

in partial fulfillment of the requirements

for the degree of

DOCTOR OF PHILOSOPHY

in

History

May 14, 2021

Nashville, Tennessee

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For my grandmother,
Gladys Anthony
1932–2018

Acknowledgments

The years of my graduate education, from 2015 to 2021, will no doubt be remembered by historians as a time of callous incivility and needless suffering. Yet I have been fortunate to spend these years amongst people whose dignity, empathy, and optimism never wavered. Thanks to them I will remember this also as a time of fellowship and learning.

I wish, first, to thank my dissertation committee, led by David Blackbourn. The scholar I aspire to be is drawn from their example—kind, dependable, and ceaselessly curious. During my course work at Vanderbilt, they encouraged me to pursue a wide range of interests across the history of science, environmental history, and German history. As I turned to dissertation research, they supported my *Wanderjahre* through archives and academic communities across Europe. Over the past year, I have learned that dissertation writing is something of a dialogue between student and advisor—a very joyful one in my case. Composing "Nature's Working Worlds" with David as my first audience was a tremendous honor, and the promise of his thoughtful feedback sustained me as I wrote. Thank you, David, for your guidance through worlds past and present.

Committee members Laura Stark, Helmut Smith, Celia Applegate, and Simon Schaffer made for a remarkable team. My dissertation's approach to the history of knowledge first emerged through science studies theory-sessions in Laura's seminars. It is thanks to Laura, with whom I have had the privilege of teaching and marching, that I understand the vital continuity between theory, education, and activism. "Nature's Working Worlds" brings theory into the archives, tracing history's imponderable through social and material landscapes. In attempting a holistic history of the sort Celia and Helmut have been tremendous sources of inspiration. I thank Celia for encouraging me to ponder those most profound questions of historical change and the power of culture, especially as I prepared for my comprehensive exams. May we never stop meditating on historical practice, nor ever forget that while "Men make their own history … *sie machen sie nicht aus freien Stücken*"! In Helmut's seminars on methods and the history of cartography I spent some of the happiest hours of my life. Rarely has history felt more active and adventurous as when we charted its topography in maps and travelogues. Many of the paths pursued in "Nature's Working Worlds" lead back to those seminars—and to the backyard dinners that frequently followed. I trust, Helmut, that you will find no shortage of cartophilia in this dissertation. Finally, Simon, I thank you for the stirring discussion we had at the ESHS Bologna symposium on Sensory and Material Economies in early Fossil Capitalism, for your warm welcome into the Climate Histories reading group at Cambridge HPS, and for the unmatched example of your scholarship and generosity.

My passion for the history of science began as an undergraduate, in Michael Reidy's classroom at Montana State University, where mountains meet minds. It was also there that I saw Paige Madison, a recent Montana graduate, deliver a guest lecture on the history of paleoanthropology that so inspired me I decided to apply for graduate school myself. Once at Vanderbilt, new friends and mentors made it possible for me to thrive, and I thank J'Nese Williams, Carolyn Taratko, Jessica Lowe, Hillary Taylor, Kelsey Ensign, and Susan Hilderbrand for their comradery and support. I am grateful to professors Ole Molvig and Arleen Tuchman for anchoring our history of science community, and to Bill Caferro for sharing with me his philosophies of life, scholarship, and baseball. To have spent so much time amongst people who

simply *love to think* is a very special thing; and I will never forget the long hours I shared with John Speed, Brianne Wesolowski, and Jean-Michel Johnston wandering through Innsbruck, Dresden, and Utrecht discussing our projects and passions. To Martin Rempe, my first and truest friend through these years, I thank you for watching out for me and, of course, for encouraging my *fränkische Wissensgeschichte* at the History Seminar of Universität Konstanz. Let us never stop planning the next sunny summer day in the land where the Rhine meets the Bodensee.

My research was made possible by the German-American Fulbright Commission, the Social Science Research Council Mellon International Dissertation Fellowship, the Staatsbibliothek zu Berlin – Preußischer Kulturbesitz, the Lichtenberg Kolleg – Göttingen Institute for Advanced Study at the Georg-August-Universität Göttingen, and the J. Léon Hulguera Fellowship at Vanderbilt University. While abroad, the Lichtenberg Kolleg in Göttingen provided an intellectual atmosphere befitting of the city's history of Enlightenment. I am immeasurably fortunate to share with Laura Nicolì, Hanna Roman, Joanna Wharton, and Martin Gierl such fond memories of our lively little Enlightenment Reading Group, led by the ever compassionate and deeply knowledgeable Dominik Hünniger. Thank you also to Marie Louisa Allemeyer, Kora Baumbach, Martin van Gelderen, and Heidi Hopf for their support. It is true, as historians say, that instruments, metrological standards, and coordinates are invested with social values: Göttingen's Historic Observatory and its Gauss Meridian will always have a place in my heart.

I also wish to thank the wider network of scholars who warmly welcomed me into their communities and enriched my perspective by sharing their own. This project owes a tremendous debt to Anne Secord, Kärin Nickelsen, Richard Hölzl, Dominik Erdmann, and Susanne Henschel, who invited me to share my research with the Cabinet of Natural History at Cambridge University, the Historisches Seminar at the Ludwig-Maximilians-Universität, the Forschungskolloquium Neuere Geschichte at the Universität Göttingen, the Berlin-Brandenburgische Akademie der Wissenschaften, and the Staatsbibliothek zu Berlin. This project's approach to scientific labor owes thanks to correspondence with Lissa Roberts, Lydia Barnett, Ursula Klein, and Sarah Pickman, as to the brilliant scholars I have had the pleasure of collaborating with on the Special Issue "Working at the Margins: Labor and the Politics of Participation in Natural History, 1700-1830" in *Berichte zur Wissenschaftsgeschichte*: Denise Phillips, Alix Cooper, J'Nese Williams, Dominik Hünniger, Anna Toledano, and Tapsi Mathur.

Throughout this project my family has been the following wind in my sails, to use a language I learned from my parents. Before I studied the history of human engagement with the natural world, I learned to love landscape and wildlife with my brother, Justin, the greatest outdoorsman and chef you'll ever meet; and I thank my sister-in-law, Dawn, for the love and the laughs we share as a family. This dissertation's immersion in the social and material worlds of the eighteenth and nineteenth centuries truly began years ago, seeded in the rough-hewn beams and wrought-iron doorhandles my parents built into our childhood home, in visits to Strawberry Banke with my mom, Kathy, and in summer days spent with my dad, Chris, mending our New England rock walls. "Nature's Working World" is dedicated to my grandmother, Gladys, who was a great scholar in her own defiant and beautiful way. Finally, I get to thank my best friend and life partner, Dana Beltaji, for making the world a better place with the fierce integrity of her journalism and for making me a better person with her curiosity and her courage.

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AA	Steiner, Gerhard et al. *Georg Forsters Werke. Sämtliche Schriften, Tagebücher, Briefe*. Berlin-Brandenburgischen Akademie der Wissenschaften. 20 vols. Berlin: Akademie Verlag 1958–2003.
BJK	Biblioteka Jagiellońska Kraków
GSA	Goethe- und Schiller-Archiv, Klassik Stiftung Weimar
SächsBergAFG	Bergarchiv Freiberg, Sächsisches Staatsarchiv
SBB	Staatsbibliothek zu Berlin, Preußischer Kulturbesitz
SLUB	Sächsische Landesbibliothek, Staats- und Universitätsbibliothek
StABa	Bayerisches Staatsarchiv Bamberg
SUB Gö	Niedersächsische Staats- und Universitätsbibliothek Göttingen
THsaW	Landesarchiv Thüringen, Hauptstaatsarchiv Weimar

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Introduction

Ways of Working, Ways of Knowing

> *Grappling as we are with the connection between knowing and doing, we might recall that Marx originated our endeavor, and accept the injunction "to grasp the implicit plan of practical activity which, whether manifest or mystified, is always present in knowledge."*[1]
>
> Giovanni Ciccotti et al., *L'Ape e l'Architetto*,
> As quoted by Paul Forman

> *…in order to pursue higher scientific plans think I must leave the* [*Prussian Mining*] *Service.* […] *I think that only then will I truly begin to live as a miner, the métier to which I wholly belong, and to perform those essential services, services that will endure for posterity.*[2]
>
> Alexander von Humboldt,
> 1794

History Underground

This dissertation studies the work of knowing over the course of the late eighteenth and earlier nineteenth centuries. Let us begin in the winter of 1777 by following the Genevan savant Jean-André Deluc into the ore mines of Germany's Harz Mountains. Deluc took with him a portable mercury barometer of his own making. In the Alps, he had used the decrement in barometric pressure with altitude to ascertain the heights of mountains. Now he wished to invert the process

[1] Giovanni Ciccotti, Marcello Cini, Michelangelo de Maria, and Giovanni Jona-Lasinio, eds., *L'Ape e l'Architetto: Paradigmi scientifici e materialismo storico* (Milan: Feltrinelli, 1976), 94, as quoted in Paul Forman, "Behind Quantum Electronics: National Security as a Basis for Physical Research in the United States, 1940-1960," *Historical Studies in the Physical and Biological Sciences* 18 (1987): 149-229, on 219-20.

[2] Humboldt to Carl Freiesleben, 21 Nov. 1794, *Die Jugendbriefe Alexander von Humboldts, 1787–1799*, eds. Ilse Jahn and Fritz G. Lange (Berlin: Akademie, 1973), 378: "Dann denke ich, um höhere wissenschaftliche Plane auszuführen, den Dienst zu verlassen. Ihnen brauche ich die Gründe nicht von neuem anzugeben. Ich denke dann aber erst recht *anzufangen*, als Bergmann zu leben, dem Metier, dem ich ganz angehöre, wesentliche Dienste zu leisten, Dienste, die daurend für die Nachkommen sind."

to determine the depths of mineshafts. While making the case for the industrial utility of his instrument to London's Royal Society, Deluc portrayed the mine as a sublime laboratory, a space of inquiry as well as imagination. He also struck a disparaging attitude towards the miners themselves, typical of his generation and his station. "A miner" wanders "in the absolute obscurity of the entrails of the earth" while attempting to connect disparate tunnels, he narrated, until at length "the Gnomes begin to hear each other" through the "subterraneous labyrinths."[3]

Then, subtly, Deluc betrayed a different sort of relationship to the miners, attributing the success of his new instrument to *their* ingenious arts. At first, he feared that the increase in barometric pressure with depth would be distorted by the "pernicious effects of the exhalations" in the earth. Yet Deluc found that his logarithmic calculations came to within 1.5 meters of those previously recorded in geometric surveys. This accuracy he ascribed not to the instrument alone, but to the very construction of the mines, especially the intricate system of fires, ducts, and pumps that circulated air within them. "It is probably to this constant renewal of the air, that the miners of Ramelsberg are indebted for the good health they enjoy," Deluc concluded; "and it is likewise probably from this cause that my barometric observations gave me the heights more exactly than I could have expected from these circumstances."[4] For Deluc, then, the act of making knowledge in the mine was bound up in the making of the mine itself: the instrument and its object were mutually informing, and both depended upon scores of undifferentiated miners who labored deep in the heart of Enlightenment science.[5]

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[3] Jean-André Deluc, "XXI. Barometrical Observations on the Depth of the Mines in the Hartz. By John Andrew de Luc, F.R.S. In a letter to Sir John Pringle, P.R.S.," *Phil. Trans. R. Soc.* 67 (1777): 401-49, on 423-24. On Deluc's role in the development of hypsometry, see Theodore S. Feldman, "Applied Mathematics and the Quantification of Experimental Physics: The Example of Barometric Hypsometry," *Historical Studies in the Physical Sciences* 15, no. 2 (1985): 127-195, esp. 167-69, 177.
[4] Deluc, "XXI. Barometrical Observations," 414-16.
[5] See the "experimenter's regress" in H. M. Collins, *Changing Order: Replication and Induction in Scientific Practice* (London: Sage Publications, 1985), 79-112, esp. 84.

Deluc was later credited with "the first universally valid barometric formula."[6] But that formula derived from a particular world of knowledge making—a *working world* as one historian has described the arenas of economic activity from which scientists abstract local, technical problems into general laws about natural operations.[7] The same epistemic labor process can be found in the science of Alexander von Humboldt (1769-1859), who served as a mining official in the 1790s prior to his voyage through the Americas with Aimé Bonpland from 1799 to 1804. Humboldt looked to Deluc as a model for his own synthetic study of earth, life, and air. By 1792, when Humboldt graduated from the Mining Academy in Freiberg, Saxony and took command of mines in Prussian Franconia, he began to describe this science as a *physique du monde*, or "global physics." Citing the vertical program of instrumentation and experimentation carried out by savants like Deluc and fellow Genevan Saussure (**Figures 1-2**), Humboldt declared "Nature knows no over- and underground."[8] Ostensibly, the phrase concerned meteorological phenomena. Yet it also implied the expanse of Humboldt's own physical-geographic enterprise, which moved rhythmically above and below the surface of the earth. For him, as for Deluc and Saussure, that rhythm relied upon laboring bodies—that "most useful, industrious class of men," as Humboldt described miners.[9] And so the story of Humboldt's global physics is also the story of those whose toil sustained its system of inquiry in mines and

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[6] Oscar Peschel, *Geschichte der Erdkunde* (München, 1865), as quoted in Feldman, "Applied Mathematics and the Quantification of Experimental Physics," 177.
[7] Jon Agar, *Science in the Twentieth Century and Beyond* (Cambridge, UK: Polity Press, 2012), 7.
[8] Alexander von Humboldt, *Ueber die unterirdischen Gasarten und die Mittel, ihren Nachtheil zu vermindern: Ein Beytrag zur Physik der praktischen Bergbaukunde* (Braunschweig: Vieweg, 1799), 201: "…für Wohlstand und Leben einer der nützlichsten, arbeitsamsten Menschenklassen…; möchte ich sie herabziehen wie *Deluc*, *Saussure* und *Lichtenberg* sie aufwärts in die Region der Wolken zogen. Die Natur kennt kein Oben und Unten. Alles im beweglichen Element ist gegenwirkend, ist *mischend*."
[9] Consider Simon Schaffer, "Beware of Precursors: How Not to Trace the History of the Critical Zone," in *Critical Zones: The Science and Politics of Landing on Earth*, eds. Bruno Latour and Peter Weibel (Cambridge, MA: MIT Press, 2020), 154-57.

atop mountains—the hewers, foremen, surveyors, draftsmen, guides, porters, and fellow technicians and travelers enveloped by the sprawling category of "Humboldtian science."

Figure 1. (Above) Horace Bénédict de Saussure's ascent of Mont Blanc in August 1787, a decade after Deluc's descent in the Harz. His guides and assistants (twenty-one in all) are burdened with food stores and physical instruments. Author and date unknown, 11.7 x 15.7 cm. Wellcome Collection, no. 43846i. Figure 2. (Below) Hewers at work in the "subterranean labyrinth" described by Deluc in 1777 and illustrated earlier that decade in *Bericht vom Bergbau* (Leipzig: Crusius, 1772), Plate 2. Münchener DigitalisierungsZentrum, Bayrische Staatsbibltiothek, BHS I B 204.

The working worlds of Humboldt's science were "manifest or mystified" in different ways at different times. In his seminal article on "invisible technicians," Stephen Shapin interpreted the transparency of workers in the history of science (and its historiography) as a measure of the value accorded to skilled labor.[10] Before and after Humboldt, practitioners of science created social, literary, and material technologies that obscured the work involved in making scientific knowledge in order to establish its credibility.[11] Humboldt provides a particularly illuminating study of scientific labor because of his lifelong engagement with mining as an arena of inquiry, experimentation, data collection, and theoretical imagination.

In his earlier projects in Prussian Franconia and New Spain, carried out in the name of economic utility, Humboldt's laboring collaborators were sometimes strikingly visible. On the eve of his departure for the Americas, he even portrayed himself as one who united practice and theory, at once *Techniker* and *Theoretiker*.[12] Thereafter, he continued to perform the hybrid persona of "savant-technician," to use Ursula Klein's term, particularly in works aimed at economic reform in Spanish colonies, like the five-volume *Political Essay on the Kingdom of New Spain* (first published between 1808 and 1811).[13] In these decades Humboldt readily attributed his views of nature to his technical training, as when he claimed to "represent entire countries as one would a mine."[14]

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[10] Steven Shapin, "The Invisible Technician," *American Scientist* 77, no. 6 (1989): 554-63.
[11] E.g. Steven Shapin and Simon Schaffer, *Leviathan and the Air-pump: Hobbes, Boyle, and the Experimental Life* (Princeton, NJ: Princeton University Press, 1985), esp. 76-79.
[12] Humboldt, *Ueber die unterirdischen Gasarten*, 24: "In einer Epoche, wo politische und moralische Verhältnisse in manchen Orten den Techniker von dem Theoretiker zu entfernen drohen, dürfte ein solches Beispiel nicht unwirksam seyn."
[13] Ursula Klein, "The Prussian Mining Official Alexander von Humboldt," *Annals of Science* 69 (2012): 27–68.
[14] As quoted in Hanno Beck, ed., "Alexander von Humboldt's 'Essay de Pasigraphie' (Mexiko 1803/04)," *Forschungen und Fortschritte* 32, no. 2 (1958): 33-39, on 37: "J'ai conçu l'idée de figurer des pays entiers comme on représente une mine."

But the final third of Humboldt's long life reveals a general trend towards the mystification of the working worlds that animated his science. Work and workers are especially hard to pin down in the Cosmos years, spanning the lecture series (1827-28) and subsequent five volumes (1845-62) called *Kosmos*. Here Humboldt articulated the worldview for which he is most famous, a great "confluence and interweaving," or *Wechselwirkung*, of disparate natural forces. But Humboldt also used the same iconic term to describe the confluence of material and knowledge production. It deserves a careful reading:

> What of this [universal or "higher"] knowledge overflows into the industrial life of peoples and increases industrious activity, springs from the happy connection of all human things, according to which the True, the Sublime, and the Beautiful enter, *quite unintentionally*, into perpetual *Wechselwirkung* with the Useful.[15] (My emphasis.)

In reformulating the relationship between *Technik* and *Theorie*, Humboldt siphoned science out of "industrial life," distinguishing a discrete sphere of knowing from the social world of working. Knowledge was no longer constructed through industrious activity, but prior to or outside of it. The *Wechselwirkung* of science and industry was re-cast as a harmonic relationship devoid of human design, as if "unintentional." This had distinct implications for Humboldt's ideas about the environmental agency of humankind—at the precise moment, around 1845, that the consumption of massive coal deposits began to accelerate in Germany as it entered the modern fossil fuel economy. Curiously, though, the human capacity to alter nature, which had been a cornerstone of Humboldt's earlier science, now assumed a more marginal place within the enormity and sublimity of Cosmos.

[15] Alexander von Humboldt, *Kosmos: Entwurf einer physischen Weltbeschreibung*, vol. 1 (Stuttgart: Cotta, 1845), 37: "Was von diesem Wissen in das industrielle Leben der Völker überströmt und den Gewerbfleiß erhöht, entspringt aus der glücklichen Verkettung menschlicher Dinge, nach der das Wahre, Erhabene und Schöne mit dem Nützlichen, wie absichtslos, in ewige Wechselwirkung treten."

Scientific labor, too, became still more alienated from its cosmic product. As the old economic order characterized by agriculture, waterpower, and wood fuel gradually gave way to modern regimes of energy and labor, epitomized by steam and the factory system, so work was reconfigured in Humboldt's epistemology. By the time he set about constructing *Kosmos*, human industry had become ingrained in the language and thought experiments through which he perceived nature—remotely, now, from his home in Berlin. Consider a letter he wrote in 1839 to a young Charles Darwin, recently returned from his Beagle voyage. Darwin described to his hero the extinct mammals and tropical flora he had found fossilized in the plateaus and passes of Patagonia. In response, the erstwhile mine official speculated about the climatic prehistory of the planet by digging a great earthwork of the imagination. "An 1800-3000-foot-deep trench dug from Hamburg to the Alps would once again today give most of Germany a climate suitable for olive and pomegranate trees," Humboldt declared to Darwin, theorizing about the earth's internal heat as a cameralist might assess a territory's economic productivity.[16] It was in this sense that Humboldt did indeed continue to "live as a miner" long after he ceased to serve as one in 1797—and to *think* as a miner even in pursuit of "higher scientific aims."

"Nature's Working Worlds" traces out a history of the relationship between working and knowing from Deluc's time to Darwin's, Humboldt being the bridge between mining in central Europe and travel in Spanish America. After all, Humboldt's free passage through Spain's silver-rich colonies was granted by virtue of his expertise in mining. And his American itinerary lists as many mines inspected as mountains climbed between 1801 and 1803, including a month-long study of the world's most profitable mineral vein, the *veta madre*, in New Spain's Guanajuato

[16] Alexander von Humboldt to Charles Darwin, 18 Sept. 1839, Darwin Correspondence Project Letter no. 534, accessed on 16 Oct. 2020, https://www.darwinproject.ac.uk/letter/DCP-LETT-534.xml.

district.[17] But while Humboldt is the dissertation's central character, this aim here is rather to de-center the celebrated savant and reinterpret his science as a collective enterprise with deep roots in economies of labor and resource management.

This dissertation therefore takes an expansive approach to "working worlds" as sites of political and environmental as well as scientific imagination. Its focus is the hard rock mining industry of central Europe, especially the silver-cities of Freiberg in the Ore Mountains and Clausthal-Zellerfeld in the Harz and the Prussian Principalities of Bayreuth-Ansbach in the Fichtel Mountains of Franconia, where Humboldt rose to *Oberbergrat* (Chief Mine Counselor). Yet this study also makes forays into Thuringian textile schools, Rhenish cloth manufactories, the British dye economy, and the Mining Academy of Mexico City. In these worlds it is possible to pursue a history of Humboldt's science alive to the *Wechselwirkung* of natural knowledge, social governance, and resource management that underpinned it.

Here Humboldt is not a solitary voyager, but one among many moving over (and under) well-trodden routes, his inquiries into geography, geo-theory, and climatology animated variously by cameralist, colonial, and capitalist forms of administration and production. Those inquiries were inflected by the diverse set of knowledge communities Humboldt encountered, from the administrative, visual, and vernacular cultures of mining to the craft skill of cloth and dye manufacturers, Franconian mine foremen, and Creole surveyors. Moreover, this approach shows how the social organization of Humboldt's science—his cosmopolitan "network"—

[17] See Myron Echenberg, *Humboldt's Mexico: In the Footsteps of the Illustrious German Scientific Traveller* (Montreal, Ontario: McGill-Queen's University Press, 2017). Humboldt visited mines, mining archives, mining academies, and saltworks throughout Spanish America, including tours of operations in Manabí and Zipaquirá in the Viceroyalty of New Grenada (1801), Tixán and Cajamarca in the Viceroyalty of Peru (1802), and in Pachuca, Real del Monte, Santa María Regla, and Guanajuanto in New Spain (1803). These and other dates are drawn from Alexander von Humboldt-Chronologie, ed. Ingo Schwarz, in *Edition Humboldt Digital* (Berlin-Brandenburgische Akademie der Wissenschaften, Berlin), Version 6 from 13 October 2020, https://edition-humboldt.de/chronologie/index.xql?l=de.

emerged from the division of labor he managed in the mines. In Franconia as in New Spain, Humboldt's capacity to depict disparate natural forces within a synoptic field of vision depended upon the managerial position he assumed within existing labor relations. Ultimately Humboldt's home at Orianienburger Street 67 served as a scientific *Amt* of sorts, from which he extended his cosmic oversight, working now through bureaucratic and imperial channels to which he had privileged access as a chamberlain in the King's court. Humboldt did not just see nature as one would a mine; he studied nature as such.

Science in the Sattelzeit

Humboldt's life spanned an age of central European history known to scholars as the *Sattelzeit*, the "saddle-time" between the early modern and modern periods. This notion underpinned Reinhart Koselleck's *Begriffsgeschichte* (or history of concepts), which sought to understand how social and political developments transformed the semantic tableaux through which people made sense of the world, as concepts like "nation," "revolution," "history," and indeed "work" and "science," gained their modern meanings. But such profound change to the mental and material landscape of life came gradually, and many concepts "wore a Janus-face," to use another of Koselleck's phrases. To visualize the *Sattelzeit*, consider a deep mountain saddle (such as **Figure 2**) in which the year 1800 rests between two peaks, each about a half-century away. Looking forward, to the mountains of modern civil society, Koselleck argued that much of the language from this period appears familiar and "immediately comprehensible." Looking backward, however, to the peaks of a pre-industrial, corporate society, the semantics of Humboldt's age appear more foreign, "incomprehensible without critical annotation."[18]

[18] Reinhart Koselleck, "Einleitung," in *Geschichtliche Grundbegriffe: Historisches Lexikon zur politischen-sozialen Sprache in Deutschland*, vol. 1, eds. Otto Brunner, Werner Conze, and Reinhart

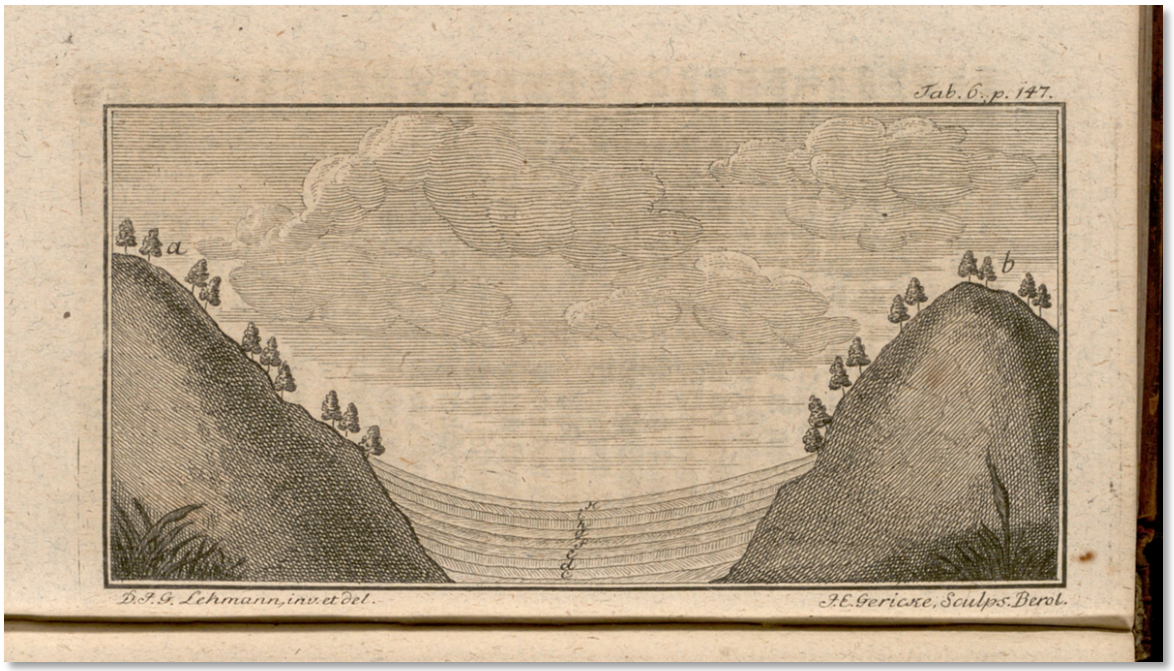

Figure 3. The stratigraphy of a mountain saddle, as illustrated in Johann Gottlob Lehmann's *Versuch einer Geschichte des Flötz-Gebürgen*… (1756), a foundational text for the German earth science of "geognosy." SUB Gö, Mineral III 3260 (2).

The *Sattelzeit* is a helpful heuristic in "Nature's Working Worlds" as it charts the relationship between working and knowing, industry and inquiry, over Humboldt's lifetime. Indeed, this dissertation can be understood as *concept history materialized*. It seeks to understand changing ideas about natural and social order as expressed through various technologies, institutions, and working practices. Unbound by traditional distinctions between mental and manual work, or between the history of ideas and the history of practices, "Nature's Working World" interprets doing and making much like speaking and writing.[19] For such a study, labor

Koselleck (Stuttgart: Ernst Klett Verlag, 1972), xv. See also Reinhart Koselleck, "Richtlinien für das Lexikon politisch-sozialer Begriffe der Neuzeit," *Archiv für Begriffsgeschichte* 11 (1967), 81-99, esp. 86; Daniel Fulda, "Sattelzeit. Karriere und Problematik eines kulturwissenschaftlichen Zentralbegriffs," in *Sattelzeit*: *Historiographiegeschichtliche Revisionen*, Hallesche Beiträge zur Europäischen Aufklärung, eds. Elisabeth Décultot and Daniel Fulda (Berlin: De Gruyter, 2016), 1-16.

[19] *Concept history materialized* is directly inspired by John Tresch, "Cosmologies Materialized: History of Science and History of Ideas," in *Rethinking Modern European Intellectual History*, eds. Darrin M. McMahon and Samuel Moyn (New York: Oxford University Press, 2014), 153-72. Tresch reframes "the history of science as the comparative study of materialized cosmologies—ideas of the order of nature that

history is another rich source of inspiration. "Values," E. P. Thompson wrote, "are not 'imponderables' which the historian may safely dismiss … since they are not amenable to measurement." Instead, values, like concepts, are indicators "of the direction of social change." And so, this dissertation is committed to understanding history's imponderables—social values, ways of knowing, and what Humboldt called "views of nature"—in concrete settings.[20]

Take the Mining School that Humboldt established for "miner's sons" in Franconia in 1793/94, for instance. Designed to cultivate a new generation of "rational" mine foremen disciplined in resource management, the institution substantiated a larger socio-political agenda bent on ordering mines and miners, resources and labor. Its curricula featured foundational works in the new earth science of "geognosy," including the profile of stratigraphy in **Figure 3**, which were explicitly opposed to vernacular traditions of dowsing. Yet this was no simple act of modernization, for the Mining School sat squarely in the saddle of its time. It looked both forward and backward as Humboldt fused the liberal educational reforms advocated by his elder brother, Wilhelm, with the paternalistic ambitions of the autocratic state he served. In the School's technical training, concepts that identified one's place in corporate society, like "honor" (*Ehre*), were recombined with notions of "cultivation" (*Bildung*), which embodied the promises of civil society. Such fusions were typical of Humboldt—and of his time.

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are enacted, embodied, elaborated, and contested in concrete settings, institutions, representations, instruments, and practices." For an example that bridges environmental history and the history of science, see Deborah R. Coen, "Big is a Thing of the Past: Climate Change and Methodology in the History of Ideas," *Journal of the History of Ideas* 77, no. 2 (April 2016): 305-21, esp. 312-13.

[20] E. P. Thompson, *The Making of the English Working Class* (New York: Random House, 1966), 444. Recently, the very "semantics of work" have been taken up by scholars who seek to engage a wider range of labor forms within in a transnational frame of analysis that challenges the field's conceptual anchorage in the North Atlantic and reevaluates its (Marxian and Weberian) notions of free wage labor and the working-class as historically contingent artefacts. Consider Jörn Leonhard and Willibald Steinmetz, eds., *Semantiken von Arbeit: Diachrone und vergleichende Perspektiven* (Köln: Böhlau, 2016) and Andreas Eckert, "Introduction. Why all the fuss about Global Labour History?" in *Work in Global and Historical Perspective,* Bd. 1: Global Histories of Work, ed. Andreas Eckert (Berlin: De Gruyter, 2016), 3-22.

The vast literature on Humboldt yields an enigmatic figure: was he Enlightened or Romantic, an ardent republican or an agent of empire, a proto-ecological visionary or a hard-nosed industrialist? But the apparent paradoxes in Humboldt's life and views are, in fact, what make him so revealing of an age, the *Sattelzeit*, characterized by its essential duality and dynamism. In other words, Humboldt presents us with the opportunity to understand how it was then possible to support republican independence movements, for instance, while relying upon imperial regimes for scientific inquiry. In describing his "amazement" at the "rapid progress" of science in the young American Republic, Humboldt confessed that "one was inclined to doubt, and certainly not without reason, whether republican governments from their very nature were not hostile to the active promotion of scientific undertakings."[21] Conversely, the passage betrays his own faith in the scientific patronage of autocratic rulers, like the kings he served in Prussia.

Humboldt's multidimensionality has been the subject of much debate. Early efforts to define a "Humboldtian" style of science struggled to reconcile its namesake's dedication to both precise measurement and romantic sensibility. In an effort to "rescue a great scientist from his romantic admirers," Susan Faye Cannon listed some 50 different instruments and apparatuses that Humboldt brought on his American journey, from theodolites and hygrometers to microscopes and chemical reagents.[22] A more recent consensus views the union of affect and instrumentation as the hallmark of Humboldt's science.[23] Instruments were artificial extensions

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[21] Alexander von Humboldt to Johann G. Flügel, 19 June 1850, in *Alexander von Humboldt und die Vereinigten Staaten von Amerika. Beiträge zur Alexander-von-Humboldt-Forschung, 19. Briefwechsel*, ed. Ingo Schwarz (Berlin: Akademie Verlag, 2004), 269-70.

[22] Susan Faye Cannon, "Humboldtian Science," in *Science in Culture: The Early Victorian Period* (New York: Dawson/Science History Publications, 1978), 73-110, on 79. Cannon responded here to William H. Goetzmann, who first identified "the Humboldtian spirit" with Romanticism in his book *Army Exploration in the American West, 1803-1863* (New Haven, CT: Yale University Press, 1965), 16-18.

[23] Michael Dettelbach, "Humboldtian Science," in *Cultures of Natural History*, eds. Nick Jardine et al. (Cambridge: Cambridge University Press, 1996), 287–304; John Tresch, "Even the Tools will be Free: Humboldt's Romantic Technologies," in *The Heavens on Earth: Observatories and Astronomy in*

of the "properly sensitive" savant, "new organs" he wrote. In turn, the savant's fine-tuned perception of a landscape functioned "as a measure or 'barometer' of the human soul."[24]

Humboldt's environmental views must be read with the same subtlety. It has often been said that he drew from nature an image of society as free and harmonious, what one scholar described as a "Humboldtian social ecology."[25] Here I argue instead for a Humboldtian social economy, which originally understood *Wissenschaft* as a feature of statecraft and approached nature with the assumption of its being an inherently political realm. Where popular writers have recently lionized Humboldt as the "forefather" of modern environmentalism, Laura Dassow Walls reminds us that Humboldt's "proto-ecological view" of nature, as a confluence of natural and human forces, was rooted in "ecology's originating discipline, economics, which then meant not simply financial administration … but something closer to the original Greek: *oikonomia*, 'household management.'"[26] Michael Dettelbach has similarly emphasized Humboldt's implicit sense of "oversight," a legacy of his training and service as a mining administrator.[27] From these points of departure, this dissertation pursues a deeper social history of the (o)economic field of vision from which Humboldt's holistic worldview emerged.

Nineteenth-Century Science and Culture, eds. David Aubin, Charlotte Bigg, and H. Otto Sibum (Durham, NH: Duke University Press,), 251-84.

[24] Michael Dettelbach, "The Face of Nature: Precise Measurement, Mapping, and Sensibility in the Work of Alexander von Humboldt," *Studies in the History and Philosophy of Biology and Biomedical Sciences* 30, no. 4 (1999): 473-504, on 499, 491. On Humboldt's "organs" of perception and their politics, see also Nina Gerassi-Navarro, *Women, Travel, and Science in the Nineteenth-Century Americas: The Politics of Observation* (London: Palgrave Macmillan, 2017), 44.

[25] Aaron Sachs, *The Humboldt Current: Nineteenth-Century Exploration and the Roots of American Environmentalism* (New York: Penguin, 2006), 351-52.

[26] A groundswell of popular literature around the 250th anniversary of Humboldt's birth has emphasized his "proto-ecological" legacy, the most celebrated example being Andrea Wulf, *The Invention of Nature: Alexander von Humboldt's New World* (New York: Knopf, 2015). Laura Dassow Walls, *The Passage of the Cosmos: Alexander von Humboldt and the Shaping of America* (Chicago: University of Chicago Press, 2009), 122. Ecology's roots in economy are thoroughly explored in Donald Worster, *Nature's Economy: A History of Ecological Ideas* (Cambridge: Cambridge University Press, 1994).

[27] Michael Dettelbach, "Romanticism and Administration: Mining, Galvanism and Oversight in Alexander von Humboldt's Global Physics" (PhD diss., University of Cambridge, 1992).

The development of Humboldt's science reflects a larger historical transition from the eighteenth-century world of "oeconomy," which extended an ideal of domestic management to states as to nature (e.g. *Staatshaushalt* and *Haushalt der Natur*), to the nineteenth-century invention of "the economy," as a discrete sector of monetary exchange.[28] In northern and central Europe especially, a "cameralist" tradition of governance effectively viewed the state and the economy as a single entity. Cameralists aimed to raise the revenue of the royal court (or *Kammer*) with a heavy hand in domestic manufacturing, protectionist tariffs, and state-sponsored science.[29] Schooled in cameralism at the University of Frankfurt/Oder and the commercial and technical academies in Hamburg and Freiberg, Humboldt belonged to a generation of reform-minded administrators who idealized a prudent "balance" between natural and human economies. (The "growth" of markets, cordoned off from the state, was largely a product of the nineteenth century.[30]) This generation also experienced the Enlightenment *within* existing governing and religious institutions, not in opposition to them, as in the case of France.[31] Emblematic of the *Aufklärung* were the *Bergakademien* and other technical institutes established in states like Austria, Saxony, and Prussia in response to the economic turmoil wrought by the

[28] See Lissa Roberts, "Practicing oeconomy during the second half of the long eighteenth century: an introduction," *History and Technology* 30, no. 3 (2014): 133-48 and Joppe van Driel, "The filthy and the fat: Oeconomy, chemistry and resource management in the Age of Revolutions, 1700-1850" (PhD diss., University of Twente, 2016). Further studies of oeconomic practice can be found in Lissa Roberts and Simon Werrett, eds., *Compound Histories: Materials, Governance and Production, 1760-1840* (Leiden: Brill, 2017) and Simon Werrett, *Thrifty Science: Making the Most of Materials in the History of Experiment* (Chicago: University of Chicago Press, 2019).

[29] On cameralism, see Keith Tribe, "Cameralism and the Science of Government," *The Journal of Modern History* 56, no. 2 (June 1984): 263-84; David. F. Lindenfeld, *The Practical Imagination: The German Sciences of State in the Nineteenth Century* (Chicago: University of Chicago Press, 1997); Ere Nokkala and Nicholas B. Miller, eds., *Cameralism and the Enlightenment: Happiness, Governance, and Reform in Transnational Perspective* (London: Routledge, 2019).

[30] Joachim Radkau, *Nature and Power: A Global Environmental History*, trans. Thomas Dunlap (Cambridge, UK: Cambridge University Press, 2008), 202.

[31] Timothy Blanning, *Reform and Revolution in Mainz, 1743-1803* (Cambridge: Cambridge University Press, 1974), 11-12.

Seven Years War (1756-1763). Indeed, they constituted an *Aufklärung* of their own, what Jakob Vogel has called the "Underground Enlightenment."[32] The role of these institutions was to produce "good cameralists," an "administrative elite" that filled the expanding bureaucracies of central European states and practiced science to the ends of political (o)economy.[33]

In this context, working worlds of ore extraction, iron refinement, porcelain manufacture, glassmaking, and dye production—whether owned, subsidized, or managed by the state—were also sites of geological, chemical, and natural-historical inquiry.[34] Historians have devoted considerable attention to the hierarchies established between manual and mental labor in such spaces. They have also shown how much "new" knowledge emerged, in fact, from traditional modes of production. "Knowledge was made in contexts of application, disciplines were fluid, work took place across many social sites," two scholars have written of early modern Europe more generally, adding that "there was a pervasive reflection on the grounds of knowledge in the process of making knowledge."[35] This is true for Humboldt's generation of mining technicians, who shared the assumption that knowing and exploiting nature were one and the same endeavor.

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[32] Jakob Vogel, "Aufklärung untertage: Wissenswelten des europäischen Bergbaus im ausgehenden 18. und frühen 19. Jahrhundert," in *Staat, Bergbau und Bergakademie: Montanexperten im 18. und frühen 19. Jahrhundert*, eds. Hartmut Schleiff and Peter Konečny (Stuttgart: Steiner, 2013), 13–31. Another example of cameralist science comes from the Swedish context: Lisbet Koerner, *Linnaeus: Nature and Nation* (Cambridge, MA: Harvard University Press, 2001). On cameralism and mining, see Michael Fessner and Christoph Bartels, "Von der Krise am Ende des 16. Jahrhunderts zum deutschen Bergbau im Zeitalter des Merkantilismus," in *Geschichte des deutschen Bergbaus*, vol. 1, eds. Christoph Bartels and Rainer Slotta (Münster: Aschendorff Verlag, 2012), 471-74.

[33] Andre Wakefield, *The Disordered Police State: German Cameralism as Science and Practice* (Chicago: The University of Chicago Press, 2009). On the German culture of reform in which Humboldt came of age, see David Blackbourn, *History of Germany, 1780-1918: The Long Nineteenth Century*, 2nd ed. (Malden, MA: Blackwell Publishing, 2003), 11-15.

[34] For other related examples in the early modern world, see Ursula Klein and E. C. Spary, eds., *Materials and Expertise in Early Modern Europe* (Chicago: University of Chicago Press, 2010) and Pamela H. Smith, Amy R. W. Meyers, and Harold J. Cook, eds., *Ways of Making and Knowing: The Material Culture of Empirical Knowledge* (New York: Bard Graduate School, 2014).

[35] Lissa Roberts and Simon Schaffer, "Preface," in *The mindful hand: Inquiry and invention from the late Renaissance to early industrialization*, eds. Lissa Roberts, Simon Schaffer, and Peter Dear (Amsterdam: Royal Netherlands Academy of Arts and Sciences, 2007), xix.

Years before Humboldt determined to travel to Spanish America with Bonpland, he was profoundly shaped by these cultures of oeconomy, utility, and administration. This connection was first identified by East German scholars who glorified a working-class version of Humboldt-the-miner.[36] Still today, a GDR-era bust stands in the park behind Freiberg's Mining Academy (**Figure 4**), which was renamed the *Technische Universität* after reunification in 1990. Two years later Michael Dettelbach offered the first comprehensive study of mining as a stimulus for global physics, exploring the disciplinary imperative that undergirded Humboldt's administration of the self, the mine, and the earth. Humboldt's physiology and geognosy "were simply the obverse of his professional office as a Prussian mining official," Dettelbach wrote, "tools of both leisured self-cultivation and territorial administration."[37] Recently, Ursula Klein has identified Humboldt as the quintessential "savant-technician," a hybrid persona born of Prussia's Enlightened culture of "useful knowledge."[38]

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[36] See an overview of East German scholarship on Humboldt in Nicolaas A. Rupke, *Alexander von Humboldt: A Metabiography* (Frankfurt: Lang, 2005), 119-23. A significant study from this period, produced by the Mining Academy itself, is Rektor der Bergakademie Freiberg, ed., *Alexander von Humboldt (1769-1859). Seine Bedeutung für den Bergbau und die Naturforschung*, Freiberger Forschungshefte Kultur und Technik D33 (Berlin: Akademie Verlag, 1960). A collection of Humboldt's administrative documents, compiled by the Mining Academy during this time, is Alexander von Humboldt, *den Zustand des Bergbaus und Hütten-Wesens in den Fürstentümern Bayreuth und Ansbach im Jahre 1792*, Freiberger Forschungshefte D23, eds. Herbert Kühnert and Oscar Oelsner (Berlin: Akademie Verlag, 1959).

[37] Dettelbach, "Romanticism and Administration." These arguments are also developed in Michael Dettelbach, "Global physics and aesthetic empire: Humboldt's physical portrait of the tropics," in *Visions of Empire: Voyages, Botany, and Representations of Nature*, eds. David Philip Miller and Hanns Reill (Cambridge: Cambridge University Press, 1996), 258-92. Also from this moment, see also Ulrike Leitner, "Studia Fribergensia. Vorträge des Alexander-von-Humboldt-Kolloquiums in Freiberg vom 8. Bis 10. November 1991 aus Anlass des 200. Jahrestages von A. v. Humboldts Studienbeginn an der Bergakademie Freiberg," *Beiträge zur Alexander-von-Humboldt-Forschung 18* (Berlin, 1991).

[38] Klein, "The Prussian Mining Official Alexander von Humboldt." Cf. Ursula Klein, *Humboldts Preußen: Wissenschaft und Technik im Aufbruch* (Darmstadt: Wissenschaftliche Buchgesellschaft, 2015); Ursula Klein, *Nützliches Wissen: Die Erfindung der Technikwissenschaften* (Göttingen: Wallstein, 2016); Ursula Klein, *Technoscience in History: Prussia, 1750-1850* (Cambridge, MA: MIT Press, 2020). While the Klein's work on Humboldt focuses on Prussia, she has studied other hybrid experts of the period outside of Prussia in Ursula Klein, ed., "Artisanal-scientific Experts in Eighteenth-century France and Germany," Special Issue of *Annals of Science* 69 (2012): 303-433. Another study of Humboldt in this

Figure 4. East Germany's working-class Alexander Humboldt, who dropped his aristocratic "von." Located in the park behind the TU's mineralogical collections and mining archive (*Bergarchiv*), the bust reads: "Geowissenschaftler und Oberbergrat, Kosmopolit und Literat," Geo-scientist and Chief Mine Counselor, Cosmopolitan and Writer. Wikimedia Commons.

Figure 5. Humboldt's Freiberg legacy updated with a new inscription in 2010 reflecting the Technische Universität's dedication to "sustainable and environmentally-compatible methods" of resource use. The TU's slogan is "The Resource University. Since 1765," the year of its founding as a *Bergakademie*. Here Humboldt is depicted on a rocky ledge drafting the "Tableau physique" as his feet dangle over the subterranean world of mining operations. Wikimedia Commons.

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vein is Frank Holl and Eberhard Schulz-Lüpertz, *'Ich habe so große Pläne dort geschmiedet…': Alexander von Humboldt in Franken* (Gunzenhausen: Schrenk-Verlag, 2012).

This dissertation gives the figure of the "savant-technician" a longer history and wider geography. In doing so, it reconciles Humboldt's managerial-industrial sciences with his proto-environmental outlook. One might suppose Humboldt's administration of mines in Prussia to have been at odds with the conservationist and "proto-ecological" sensibilities he exhibited in the Americas—his concern for the climatic effects of deforestation and his study of *Kultur*, in turn, as a product of *Klima*.[39] But it is fitting that, in 2010, a new monument was erected in Freiberg, now reflecting the TU's dedication to "sustainable and environmentally-compatible methods" of resource use (**Figure 5**). In it, Humboldt's "Tableau physique des Andes" is set above a mine profile, as though a reflection of the world below.[40]

As this study argues, Humboldt exemplified an age, around 1800, in which resource use was constitutive of natural inquiry and early environmental thought.[41] Humboldt's theorizing about the primacy of human activity in the geography of plants, for instance, and his

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[39] On Humboldt's environmentalist legacy, see Aaron Sachs, "The Ultimate 'Other': Post-Colonialism and Alexander von Humboldt's Ecological Relationship with Nature," *History and Theory* 42 (Dec. 2003): 111-35; Rupke, *Alexander von Humboldt*, 185-87; Laura Dassow Walls, "Rediscovering Humboldt's Environmental Revolution," *Environmental History* 10, no. 4 (Oct. 2005): 758-60; Heinrich Detering, *Menschen im Weltgarten: Die Entdeckung der Ökologie in der Literatur von Haller bis Humboldt* (Göttingen: Wallstein Verlag, 2020).

[40] "Vernetztes Universitätsprofil," Technische Universität Bergakademie Freiberg, accessed 21 Jan. 2021, https://tu-freiberg.de/universitaet/profil.

[41] This argument builds upon a number of studies have shown the intricate relationship between political economy, empire, environmental thought, and early climate science. Throughout Europe's colonies in the eighteenth and nineteenth centuries, islands served as laboratories for environmental engineering. In eighteenth-century Scotland, liberal-laissez faire and cameral-statist interpretations of nature's economy charged "rival ecologies." In the Hapsburg Empire, the imperial scope of "climatography" gave rise to the practice of "scaling." And in Humboldt's Germany, "sustainability" itself emerged through statist efforts to enroll nature into political economy. See Richard Grove, *Green Imperialism: Colonial Expansion, Tropical Island Edens, and the Origins of Environmentalism* (Cambridge, UK: University of Cambridge Press, 1995); Frederik Albritton Jonsson, "Rival Ecologies of Global Commerce: Adam Smith and the Natural Historians," *American Historical Review* (December 2010): 1342-363; Frederik Albritton Jonsson, *Enlightenment's Frontier: The Scottish Highlands and the Origins of Environmentalism* (New Haven, CT: Yale University Press, 2013); Deborah R. Coen, "Imperial Climatographies from Tyrol to Turkestan," *Osiris* 26, no. 1 (2011): 45-65; Deborah R. Coen, *Climate in Motion: Science, Empire, and the Problem of Scale* (Chicago: Chicago University Press, 2018); Paul Warde, *The Invention of Sustainability: Nature and Destiny, c. 1500-1870* (Cambridge: Cambridge University Press, 2018).

understanding of "sustainable" resource management, both drew upon the practices of cameralist governance in which he had been trained. Indeed, the very construction of ore mineshafts gave Humboldt's geographic imaginary its distinctive vertical orientation—but not just Humboldt. The mining industry's modes of travel and visualization resonated through both the aesthetic culture of the learned classes and the vernacular traditions of laboring miners. Ultimately, these cartographic methods and administrative traditions converged in Humboldt's portrayal of a vertical frontier in the Mexican Cordilleras, where he outlined a plan of high-altitude colonization for his Creole collaborators to pursue.

This perspective offers a fresh interpretation of what it meant to travel through "free nature" or practice "pure" science in the *Sattelzeit*. It was Freiberg's mining and smelting operations—powered by the audible grind of hydraulic wheels, pumps, and presses, coated in the fumes of forges and smelting huts—that Humboldt fulfilled his "ardent desire … to live in *freie Natur*."[42] From the mid eighteenth century to the first decades of the nineteenth, travelers, technicians, naturalists, painters, and poets consistently portrayed mining as a noble engagement with, even an improvement upon, the natural world.[43] In different styles and different periods, artists depicted the hydraulic and smelting works of Freiberg as a fixture of its environs, adorning a sculpted landscape (**Figures 6-7**). Moreover, the presence of men, women, and children recalls the domestic connotations of "oeconomy," emphasizing that the well-worked terrain around Freiberg as a place of human dwelling. In 1784, Georg Forster found in Freiberg and its smelting operations a living example of how "a new, rejuvenated Nature springs forth

[42] Alexander von Humboldt (1853) in Kurt R. Biermann, ed., *Aus meinem Leben: Autobiographische Bekenntnisse* (Leipzig: Urania Verlag, 1987), 88: "…erlangte ich die Erlaubnis, meine nächste Lebensbestimmung zu verändern und, nach meinem sehnlichsten Wunsche, außerhalb der Städte in der freien Natur zu leben, zum praktischen Bergbau überzugehen."
[43] On the Romanic lure of mines, see Theodore Ziolkowski, "The Mine: Image of the Soul," in *German Romanticism and Its Institutions* (Princeton, NJ: Princeton University Press, 1990), 18-26.

from our hands!"[44] Humboldt himself described mining as a set of "entangled relations" (*verwickelten Verhältnissen*) from which Man "gains in intellectual cultivation."[45] It was from this view of nature, as a malleable artefact, that much of Humboldt's "environmental" thinking arose in an age before the bifurcation between nature and society.[46]

Figure 6. Johann Alexander Thiele, "Die Stadt Freiberg von Norden," 1744/45. In the left of the foreground, the Dresden painter Thiele depicted a hydraulic pump with the city of Freiberg on the horizon. Gemäldegalerie Alte Meister, Staatliche Kunstsammlungen Dresden, Photo: Elke Estel/Hans-Peter Klut, Gal.-Nr. 3714.

[44] Georg Forster, "Ein Blick in das Ganze der Natur. Einleitung zu Anfangsgründen der Thiergeschichte," AA VIII, 77-97, on 95-96: "Diese neuen Hülfsmittel nutzen wir zur Vollendung unseres Werkes…. Tausend andere Denkmähler der Macht und des Ruhms beweisen zur Genüge, daß der Mensch als Eigenthumsherr der Erde ihre ganze Oberfläche verwandelt und erneuert, ja daß er von jeher die Herrschaft mit der Natur getheilt hat."

[45] Humboldt, *Ueber die unterirdischen Gasarten*, 34: "Je mannigfaltiger die Beziehungen sind, in welche der Mensch mit den Gegenständen um sich her tritt, je mächtiger und vielseitiger er auf die belebte und unbelebte Natur einwirkt, desto mehr gewinnt unter verwickelten Verhältnissen seine intellectuelle Bildung."

[46] Joppe van Driel and Lissa Roberts, "Circulating Salts: Chemical Governance and the Bifurcation of 'Nature' and 'Society'," *Eighteenth-Century Studies* 49, nr. 2 (2016): 233-63. Even the Prussian state's anti-liberal approach to the management of natural resources, which its Mining Department pursued into the age of capital, may now sound more forward- than backward-looking. See discussion in Eric Dorn Brose, *The Politics of Technological Change in Prussia: Out of the Shadow of Antiquity, 1809-1848* (Princeton, NJ: Princeton University Press, 1993), 137, 161.

Figure 7. Ludwig Richter, "Das Amalgamierwerk in Halsbrücke," 1829. In his compendium of idealized Freiberg landscapes, Richter illustrated men and women working spoil heaps (extracted from the mines) before the fuming iron works. Kupferstich-Kabinett, Staatliche Kunstsammlungen Dresden, Photo: Andreas Diesend, Inv.-Nr. A 130524.

This was also a time when the natural sciences were regularly—and unproblematically—practiced within "territories of intervention," where naturalists, reformers, administrators and their many workers devised specific responses to localized economic problems.[47] Cultures of "useful knowledge" were present in Spanish America as well as central Europe. And Humboldt's reflections on his travels through the "New World" reveal their continuity with the Old:

> As the aim of our journey was purely scientific, Bonpland and I were fortunate to gain the good will of the colonists and the Europeans entrusted with the administration of those vast stretches of land.[48]

For his generation, "pure" science was not apolitical or "objective" inquiry, but science born of enlightened and beneficent designs of territorial rule, conceived as such by Europeans of the

[47] Sophie Brockmann, *The Science of Useful Nature in Central America: Landscapes, Networks and Practical Enlightenment, 1784-1838* (Cambridge: Cambridge University Press, 2020), 2-5, 15.
[48] Humboldt (1859) in Biermann, ed., *Aus meinem Leben*, 71: "Da der Zweck unserer Reise ein rein wissenschaftlicher war, so hatten Bonpland und ich das Glück, und das Wohlwollen der Kolonisten wie der mit der Verwaltung dieser weiten Landstriche betrauten Europäer zu erwerben."

ruling classes. The passport Humboldt carried, signed by the *primera secretaria de estado* in Madrid, betrayed a similar relationship between science and administration. In fact, it carried such instructions as he was already accustomed to carrying out while inspecting and surveilling Franconia's Fichtel Mountains, recently acquired in Prussia's own expansionist exploits:

> I am authorized to employ [*zu bedienen*] my physical and geodetic instruments in full freedom; I shall be permitted, in all Spanish possessions, to make astronomical observations, measure the heights of mountains, collect products of the soil, and otherwise carry out all operations that I deem beneficial to the advancement of science.[49]

Still in the mid-nineteenth century, then, as Humboldt looked back on his early years as an administrator and traveler, the two personae remained inextricably linked. It was a legacy of the culture of oeconomy and utility in which he came of age.

But if the unity of the savant-technician characterizes many of Humboldt's early endeavors, its decoupling also bespoke a gradual reorganization of science and work in the nineteenth century. As Sebastian Felten has shown in his nuanced study of the mining official Heinrich von Trebra, even those who, like Humboldt and Trebra, fused the work of head and hand tended to stress different aspects of their hybrid personae to different audiences, whether colleagues in the industry's bureaus or "disinterested" savants in more erudite circles.[50] In the case of Humboldt, who lived to see a sharp institutional division between the natural and technical sciences in mid-nineteenth-century Germany, this dynamic took on a temporal dimension.[51] And as the gulf between human and natural sciences grew—separating emergent

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[49] As quoted in Biermann, ed., *Aus meinem Leben*, 70-71: "ich sei ermächtigt, mich meiner physikalischen und geodätischen Instrumente mit voller Freiheit zu bedienen; ich dürfte in allen spanischen Besitzungen astronomische Beobachtungen anstellen, die Höhen der Berge messen, die Erzeugnisse des Bodens sammeln und alle Operationen ausführen, die ich zur Förderung der Wissenschaft vorzunehmen gut finde."

[50] Sebastian Felten, "The history of science and the history of bureaucratic knowledge: Saxon mining, circa 1770," *History of Science* 56, no. 4 (2018): 403-31.

[51] See Klein, *Nützliches Wissen*, 181-87. This institutional divergence is further analyzed in Karl-Heinz Manegold, *Universität, Technische Hochschule und Industrie* (Berlin: Duncker & Humblot, 1970).

disciplines of economics from climatology, for instance—so the environmental influence of humankind receded from Humboldt's Cosmos.[52] Climate, seen in the late eighteenth century as an artefact of human activity, was increasingly externalized from it.[53]

Even so, the working worlds of economic and material production remained integral to Humboldt's thinking, albeit in ways more mystified than manifest. Humboldt's own science of "comparative climatology" can be understood as part of a broader "labor theory of knowledge" described by the historian John Tresch.[54] Economists of the period made work the basis of material value. In the same decades, Humboldt's historical study of climate was grounded in an understanding of the earth's own industry. The social, economic, and institutional transformations of the Cosmos years were thus accompanied by epistemological and

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Thomas Gieryn's classic study has also shown how Victorian physicists performed "boundary work" while self-consciously distancing their knowledge from the utility of mechanics: Thomas Gieryn, *Cultural Boundaries of Science: Credibility on the Line* (Chicago: University of Chicago Press, 1999). In Germany, especially during periods of intense industrialization in the second half of the century, the *Bildungsbürger* who dominated state bureaucracies and public debate regarded engineers and *Techniker* as fundamentally distinct, marked apart by their lack of general cultivation (*Allgemeinbildung*). See Adelheid Voskuhl, "Engineering Philosophy: Theories of Technology, German Idealism, and Social Order in High-Industrial Germany," *Technology and Culture* 57, no. 4 (October 2016): 721-52, esp. 725-725. Divisions also emerged amongst engineers themselves, as the "shop culture" of "nonacademic" *Techniker* now vied with "diploma engineers." See Kees Gispen, *New Profession, Old Order: Engineers and German Society, 1815-1914* (New York: Cambridge University Press, 1989). More generally, historians have pointed to a conscious effort in the nineteenth century to separate practical from philosophical pursuits that were once united in the Enlightenment's utilitarian culture. E.g. Celina Fox, *The Arts of Industry in the Age of Enlightenment* (New Haven, CT: Yale University Press, 2010).

[52] Christophe Bonneuil and Jean-Baptiste Fressoz, *The Shock of the Anthropocene: The Earth, History and Us*, trans. David Fernbach (London: Verso, 2017), 30, 203-06. Turning to the earth sciences, Lydia Barnett has recently argued that "The arrival of deep time also undermined the idea of nature as a human artifact," which had been a basic assumption of much early modern earth science. (Lydia Barnett, *After the Flood: Imagining the Global Environment in Early Modern Europe* (Baltimore: Johns Hopkins University Press, 2019), 194.) This period also saw a sharper delineation between the sciences of life and earth with the emergence of disciplines like biology and geology. See discussion in Adam Bobbette and Amy Donovan, "Political Geology: An Introduction," in *Political Geology: Active Stratigraphies and the Making of Life*, eds. Adam Bobbette and Amy Donovan (Palgrave Macmillan, 2019), 5-6.

[53] Theodore S. Feldman, "Climate and History in the Late 18th and Early 19th Centuries," *Eos* 73, no. 1 (7 Jan. 1992): 1-8.

[54] John Tresch, *The Romantic Machine: Utopian Science and Technology after Napoleon* (Chicago: The University of Chicago Press, 2012), 100-05.

cosmological changes. These upheavals are reflected in *Kosmos*, where Humboldt's redoubled commitment to steady-state equilibrium in nature—a quintessentially Enlightened view of "nature's eoconomy"—coexisted with a recognition of the earth's directional rather than cyclical development. At the same time, the harmonic grandeur of the Cosmos now marginalized human activity, even as Humboldt began to view Earth itself as a climate-engine of sorts. That competing worldviews coalesced in Humboldt's writings is not a paradox, however: it is yet more evidence of the forward- and backward-looking nature of science in the *Sattelzeit*.

Peopling Humboldtian Science

It is often assumed that the natural sciences, or *Naturwissenschaften*, of Humboldt's time were practiced exclusively by (male) European and settler elites. Certainly, privileged members of the educated classes defined the boundaries of science and its institutions, whose customs drew upon and also reinforced existing ideas about race, gender, and social order.[55] Indeed, when Humboldt began his university studies in the 1780s, he belonged to a reading public that probably counted for no more than 5 % of Prussian society.[56] But in recent decades, the presumed social homogeneity of *Sattelzeit* science has been dramatically challenged, especially by global histories that show how "European" sciences emerged through unequal collaborations with indigenous, enslaved, and colonized peoples.[57] The history of scientific work is fundamental to

[55] The politics of participation—of who counts as a knower—in the natural sciences were strictly policed in eighteenth- and nineteenth-century Europe, and still more severely disciplined in its colonies. See for instance Londa Schiebinger, *Nature's Body: Gender in the Making of Modern Science* (Boston, MA: Beacon Press, 1993). Yet these boundaries were neither uniform nor static. On the "expanding ranks" of *Naturwissenschaft* in Germany around 1800, for instance, see Denise Phillips, *Acolytes of Nature: Defining Natural Science in Germany, 1770–1850* (Chicago: University of Chicago Press, 2012), 60-85.
[56] David Blackbourn, *History of Germany, 1780-1918: The Long Nineteenth* Century, 2nd ed. (Malden, MA: Blackwell Publishing, 2003), 29-30.
[57] This is a history of global circulation built on one of global exploitation, where the reconfiguration of both Western and non-Western knowledges emerged through the violence of colonial and religious

this pluralistic account of scientific knowledge making.[58] A leading example is Lydia Barnett's recent investigation of the "flickering visibility" of "earth workers" (miners, quarrymen, and ditch-diggers) who supplied savants with knowledge and naturalia from the underground.[59]

Earth workers abound in this study, too, which similarly challenges the false impression of Humboldt's science as a socially homogeneous, if not individually contrived, enterprise. This is indeed the impression given by many of Humboldt's own writings. As Mary Louise Pratt argued in *Imperial Eyes*, the *ur*-critique of Humboldtian science, his thirty-four-volume *Voyage aux regions èquinoxiales du Nouveau Continent* (1808-1834) rendered Latin America a pristine, unpeopled world "waiting to be known and possessed."[60] Such acts of displacement reinforced Humboldt's own intellectual autonomy. Since Pratt, several other scholars have identified Humboldt as emblematic of European travelers whose science relied upon but deliberately

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expansion. Consider Londa Schiebinger and Claudia Swan, eds., *Colonial Botany: Science, Commerce, and Politics in the Early Modern World* (Philadelphia, PA: University of Pennsylvania Press, 2005); Kapil Raj, *Relocating Modern Science: Circulation and the Construction of Knowledge in South Asia and Europe, 1650-1900* (London: Palgrave Macmillan, 2007); Simon Schaffer, Lissa Roberts, Kapil Raj, James Delbourgo, eds., *The Brokered World: Go-Betweens and Global Intelligence 1770–1820* (Sagamore Beach: Watson Publishing International, 2009); Sujit Sivasundaram, "Sciences and the Global: On Methods, Questions, and Theory," *Isis* 101, no. 1 (March 2010): 146-58; Neil Safier, "Global Knowledge on the Move: Itineraries, Amerindian Narratives, and Deep Histories of Science," *Isis* 101 (2010): 133-45; Kathleen S. Murphy, "Translating the vernacular: Indigenous and African knowledge in the eighteenth-century British Atlantic," *Atlantic Studies* 8, no. 1 (2011): 29-48.

[58] Daniel Rood, "Toward a Global Labor History of Science," in *Global Scientific Practice in an Age of Revolutions, 1750-1850*, eds. Patrick Manning and Daniel Rood (Pittsburgh: University of Pittsburgh Press, 2016), 255-74, on 255.

[59] Lydia Barnett, "Showing and hiding: The flickering visibility of earth workers in the archives of earth science," *History of Science* 58, no. 3 (2019): 245-74. Other notably recent studies that add to the complex social topography of early modern and Enlightenment-era science in Europe are Paola Bertucci *Artisanal Enlightenment: Science and the Mechanical Arts in Old Regime France* (New Haven, CT: Yale University Press, 2017) and Philippa Hellawell, "'The best and most practical philosophers': Seamen and the authority of experience in early modern science," *History of Science* 58, no. 1 (2020): 28-58.

[60] Mary Louise Pratt, "Alexander von Humboldt and the Reinvention of América," in *Imperial Eyes: Travel Writing and Transculturation* (New York: Routledge, 1992), 109–40. Cf. Mauricio Nieto Olarte, "Alexander von Humboldt y Francisco José de Caldas: americanismo y eurocentricsmo en el Nuevo Reino de Granada," in *Alexander von Humboldt: Estancia en España y viaje americano*, eds., Mariano Cuesta Domingo and Sandra Rebok (Madrid: Real Sociedad Geográfica, 2008) and Antonello Gerbi, *The Dispute of the New World: The History of a Polemic, 1750-1900*, trans. Jeremy Moyle (Pittsburgh, PA: University of Pittsburgh Press, 1973).

effaced "local knowledge." Jorge Cañizares-Esguerra and Gregory Cushman in particular have located Humboldt's environmental thinking—his ideas about Andean biogeography, for instance, or the link he drew between denudation and desertification—within Creole networks of expertise that he "willfully marginalized" in his narrative of travels.[61]

These critiques, while focused on colonial science, also speak to cameralist spaces of industry and inquiry. Mines in particular have long been seen as spaces of hegemonic statist rule in northern and central Europe. In the final third of the eighteenth century, the expanding ranks of mining bureaucracies in the fiscal-military states were filled by graduates of technical academies, like Humboldt, who enforced severe discipline over every aspect of life and labor in the mines. Science was commonly practiced in the service of "Enlightened" states, whose bourgeois and aristocratic agents viewed "common" laborers like timber and iron ore as a resource, all disciplined in the name of *Gemeinwohl* and *Glückseligkeit* (welfare and happiness). Yet recent accounts complement the postcolonial critique above in understanding eighteenth-century mines as "cultural contact zones" (a term coined by Pratt) where various forms of knowledge—theoretical and technical, bureaucratic and vernacular—circulated among different social groups who worked in highly uneven power relations with varying degrees of visibility.[62]

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[61] Jorge Cañizares-Esguerra, "How Derivative Was Humboldt? Microcosmic Nature Narratives in Early Modern Spanish America and the (Other) Origins of Humboldt's Ecological Sensibilities," in *Colonial Botany: Science, Commerce, and Politics in the Early Modern World*, eds. Londa Schiebinger and Claudia Swan (Philadelphia, PA: University of Pennsylvania Press, 2005), 148–65; Jorge Cañizares-Esguerra, *Nature, Empire, and Nation: Explorations of the History of Science in the Iberian World* (Stanford, CA: Stanford University Press, 2006); Gregory T. Cushman, "Humboldtian Science, Creole Meteorology, and the Discovery of Human-Caused Climate Change in South America," *Osiris* 26 (2011): 16-44. Other significant critiques are Margerita Serje, "The National Imagination in New Grenada," in *Alexander von Humboldt: From the Americas to the Cosmos*, eds. R. Erickson, M. A. Font & B. Schwartz (New York: Bildner Center for Western Hemisphere Studies, 2017), 83-98; Nydia Pineda De Ávila, "A Selenography in New Spain: Colonial Strategies for Mapping Local Knowledge," talk delivered 26 July 2019 at the Annual History of Science Society Meeting, Utrecht, the Netherlands.

[62] Hjalmar Fors, *The Limits of Matter: Chemistry, Mining & Enlightenment* (Chicago: University of Chicago Press, 2015), esp. 7-8. Fors studies the mine as a "contact zone" between Enlightenment chemistry and vernacular traditions, citing Pratt's *Imperial Eyes*. Also consider Wakefield, *The*

Drawing upon these two traditions of scholarship, "Nature's Working Worlds" argues that the erasure—or emphasis—of marginal actors in Humboldt's science had a history and geography of its own. "Not all labor is invisible in the same way," Lydia Barnett reminds us: when early eighteenth-century men of science *did* make natural-historical labor visible, their accounts of work often accorded with cultural norms of elite masculinity, deliberately distinguishing their mental labor from the manual toil of those they exploited.[63] But by the turn of the nineteenth century, the rallying cry of "useful knowledge" prompted savants like Humboldt to occasionally emphasize their proximity to working worlds—the applicability of their science to industry and sometimes even their debt to workers themselves.[64] While Humboldt effaced many of the local naturalists on whom he relied in Spanish America, he also lauded the expertise of the Creole surveyors and draftsmen who made possible the mapping of Mexico, a project designed to promote the metallurgic industry and agricultural development of New Spain. Indeed, by foregrounding labor, the American voyage itself appears in a new light as Humboldt is seen moving through circuits already determined by the exchange of knowledge, minerals, and personnel between the mining academies of central Europe and Spanish America. It was not Humboldt who single-handedly enrolled a sprawling colonial administration into his

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Disordered Police State; Warren Alexander Dym, *Divining Science: Treasure Hunting and Earth Science in Early Modern Germany* (Boston: Brill, 2011). On related themes of territorial administration and local knowledge in Latin American mining, see Heidi V. Scott, "Colonialism, Landscape and the Subterranean," *Geography Compass* 2, no. 6 (2008): 1853-1869 and Heidi V. Scott, "Taking the Enlightenment Underground: Mining Spaces and Cartographic Representation in the Late Colonial Andes," *Journal of Latin American Geography* 14, no. 3 (Oct. 2015): 7-34.

[63] Barnett, "Showing and hiding." Also consider the example of Buffon and other French naturalists of the eighteenth century who, in fashioning themselves as "improving experts," "needed to create a new value for mental labor, one in which the superiority of mind over hand was emphasized." To give another example from the same period, mathematician and astronomer La Condamine stressed his conceptual labor in the building of South American surveying stations in order to claim intellectual ownership over the project. See E. C. Spary, *Utopia's Garden: French Natural History from Old Regime to Revolution* (Chicago: University of Chicago Press, 2000), 32-33 and Neil Safier, *Measuring the New World: Enlightenment Science and South America* (Chicago: The University of Chicago Press, 2008), 44, 49-50.

[64] Cf. Roberts and Schaffer, "Preface," in *The mindful hand*, xxiii; Klein*, Nützliches Wissen*.

scientific designs, but rather the reverse. The *Tribunal de Minería* enlisted the traveling *Techniker* into their own agenda and entrusted him with a large corps of Mining Academy students to this end.[65]

Even here, though, the social organization of Humboldt's science was often obscured by customs of disinterestedness and Eurocentrism that coexisted with the Enlightenment culture of utility. The problem demands an approach as attentive to the materiality of working worlds as to the mentalities they engendered. Here environmental history offers inspiration.[66] Consider Thomas Andrews' concept of the "workscape." In contrast to a landscape that might be "taken in at a glance," the workscape is "a constellation of ever-unfolding relationships—

> not simply land, but also air and water, bodies and organisms, as well as the language people use to understand the world, and the lens of culture through which they make sense of and act on their surroundings. […] Going beyond the hoary dualisms that separate 'man' and 'nature' in much of Western thought, the workscape concept treats people as laboring beings who have changed and been changed in turn by a natural world that remains always under construction. [67]

This spatial-labor approach is a particularly apt for the peopling of Humboldtian science. That is because the social history of that science is often also an environmental history.

The workscapes approach brings us to the heart of the great analogy that undergirded Humboldt's scientific enterprise: the idea that social order must strive to align itself with natural order. In the *Personal Narrative*, Humboldt proclaimed that "in the social body, when governed

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[65] European sciences did not unambiguously promote European designs. Often, these sciences were re-tooled to suit the aims of colonials, the colonized, and other non-Europeans. Consider the example of German mining sciences in China in the nineteenth century, which operated an instrument of both European encroachment and of Chinese resistance to it: Shellen Xiao Wu, *Empires of Coal: Fueling China's Entry into the Modern World Order, 1860-1920* (Stanford, CA: Stanford University Press, 2015).
[66] Studies that draw natural resources and landscapes together with political and cultural histories are David Blackbourn, *The Conquest of Nature: Water, Landscape, and the Making of Modern Germany* (New York: Norton, 2006) and Eric H. Ash, *The Draining of the Fens: Projectors, Popular Politics and State Building in Early Modern England* (Baltimore, MD: Johns Hopkins University Press, 2017).
[67] Thomas G. Andrews, *Killing for Coal: America's Deadliest Labor War* (Cambridge, MA: Harvard University Press, 2008), 125.

by intelligence, there is found, as in organic bodies, a repairing force opposed to the inveterate evils."[68] "As in the life of nations so in nature," Humboldt echoed in *Kosmos*, calling on fellow humanity to emulate the freedom he found in nature.[69] But by analogizing social and natural forces, Humboldt also ensured their mystification. A deeper analogy comes to the fore when Humboldt's science is viewed in the workscapes of its making. In the mines of Prussian Franconia, which he himself was charged to "govern by intelligence," Humboldt approached the administration of nature as a problem of social order and saw natural order, in turn, as a problem of social administration.[70] Such translations between material and moral life were implicit in the oeconomic framework that guided both his practical training and his philosophy of nature.

Workscapes also draw attention to the division of labor that sustained the geographical sciences for which Humboldt is known (plant geography, cartography, meteorology, and climatology), particularly the untold story of mine foremen. Foremen were highly skilled artisans of the underground who, in the industry's estate-like hierarchy, worked between state bureaus and on-site extraction. Humboldt saw foremen as an opportunity to extend his administrative *and* scientific omniscience, and so worked closely with them in his "subterraneous meteorology," a first experiment in global physics. But while Humboldt sought to train foremen in the latest earth sciences and equip them with instrumentation, a closer look shows how he himself relied upon foremen's own expertise and approval for the sciences he carried out in the mines. In the same

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[68] Alexander von Humboldt, *Personal Narrative of Travels to the Equinoctial Regions of America,* vol. 3, trans. Thomasina Ross (repr. New York, 2009), 235.
[69] Humboldt, *Kosmos*, *1*, 35-36
[70] The analogy at the heart of Humboldt's science resonates through many areas of natural inquiry in late eighteenth century, as in eudiometric chemistry, for instance, or studies of soil fertility. See Simon Schaffer, "Measuring virtue: Eudiometry, enlightenment and pneumatic medicine," in *The Medical Enlightenment of the Eighteenth Century*, eds. Andrew Cunningham and Roger French (Cambridge, UK: Cambridge University Press, 1999), 281-318; Simon Schaffer, "The Earth's Fertility as a Social Fact in Early Modern Britain," in *Nature and Society in Historical Context*, eds. Mikuláš Teich, Roy Porter, and Bo Gustafsson (Cambridge: Cambridge University Press, 1997), 124-97.

vein, Humboldt's paternalist views of sustainable resource management, which carried through his American travels, were forged in response to an on-going struggle between state officials and private investors over control of the foreman class. This study therefore accounts for local, working worlds whose social strife and labor relations exist just beneath the global veneer of Humboldt's science.

Humboldt's adaptation to existing labor regimes in cameralist, colonial, and capitalist contexts is a major theme of this dissertation. By the Cosmos years, the division of scientific labor generally tracked with the separation of workers from the means of production in the large-scale factories that sprang up around Humboldt in Berlin, like Borsig's Machine Factory, just a five- or six-minute walk from his apartment.[71] It might be argued that the decreasing visibility of labor and waning appeals to utility resulted from the fact that Humboldt himself no longer worked in the mines. But his science remained deeply enmeshed in domestic and foreign metallurgic industries. In 1829, the Russian Tsar lured Humboldt to the Ural and Altai Mountains, where mineral prospecting served as the operational basis for a much larger scientific enterprise that spanned the sciences of life, earth, and climate in Central Asia.[72] Though it was to

[71] On industrial culture and scientific inquiry in mid-nineteenth-century Berlin, see M. Norton Wise, *Aesthetics, Industry, and Science: Hermann von Helmholtz and the Berlin Physical Society* (Chicago: University of Chicago Press, 2018). Wise shows how Berlin's "technical-industrial environment" profoundly shaped mechanical theory as developed in the Berlin Physical Society.

[72] For Humboldt's mine inspections and prospecting in Russia and its central Asian territories, see Alexander von Humboldt, *Zentral Asien: Das Reisewerk zur Expedition von 1829*, ed. Oliver Lubrich (Frankfurt am Main: S. Fischer Verlag, 2009) and Alexander von Humboldt, *Reise durchs Baltikum nach Russland und Sibirien*, 6th ed., ed. Hanno Beck (Wiesbaden: Marix Verlag, 2009), esp. 98-106, 161-64. It was Georg von Cancrin, the son of Humboldt's predecessor in Prussian Franconia, Franz Ludwig von Cancrin, who, in his capacity as Russian's finance minister, engineered the 1829 journey to Central Asia. See [Alexander von Humboldt], *Im Ural und Altai. Briefwechsel zwischen Alexander von Humboldt und Graf Georg von Cancrin aus den Jahren 1827-1832* (Leipzig: Brockhaus, 1869). Just before setting out for St. Petersburg, Humboldt returned to the mines of Freiberg to conclude a series of studies on magnetic variation above and below the surface of the earth. He had visited Freiberg in December 1826, touring the "Beschert Glück" mine as well as the smelting works in Halsbrücke, then again in July 1828 to begin the studies in magnetism that he concluded in 1829.

be Humboldt's final journey, he continued to consult Saxon mining experts on engineering projects through the 1830s. And in the 40s and 50s, he relied upon the fieldwork of mining technicians in Europe and the Americas who flooded his home with data concerning the nature of the earth's interior. Humboldt managed the emissaries of his scientific administration as he had once managed subordinates who oversaw the mining districts under his command. By this time, the mine workers who were once directly involved, individually differentiated, and even cited in Humboldt's science were nowhere to be seen. Yet Humboldt himself retained the paternalistic ideology and engineering imaginary of his own managerial labor in the mines.

Plan of the Dissertation

This dissertation proceeds in two parts, both of which challenge traditional dichotomies between industry and inquiry, working and knowing, matter and mind. Part One, "Political Landscapes," explores industrial sites from spinning schools to smelting ovens and manufactories to mines as spaces of political imagination, showing how different visions of social order and civil society found expression through practical activity. Part Two, "Epistemic Workscapes," traces the development of Humboldt's geographical sciences in such spaces, again bridging the textile and metallurgic industries. This section demonstrates how global physics described a natural world its author was actively engaged in shaping, particularly as a miner. It also underscores the social heterogeneity of the cultures of work and travel from which that science emerged.

Chapter One, "The Art of Cultivation in the Age of Revolution," opens the dissertation by identifying the central place industry held in German intellectual life through the *Sattelzeit*. Inspired by historians who have taken an expansive approach to "the political" in an age before modern electoral politics, this chapter shows how reformers of Humboldt's time saw the

industrial arts as a vehicle for the realization of their own political aims. In the late eighteenth and early nineteenth centuries, industrialization appeared to many thinkers as an open-ended spectrum of possibilities for an emergent civil society, and "industry" itself carried both its early modern connotation as a personal quality of diligence and, increasingly, its modern institutionalized economic sense. This chapter follows two reformers in particular, the naturalist-revolutionary Georg Forster and poet-philanthropist Julie von Bechtolsheim, whose political ideologies materialized through smelting operations, hydraulic engineering, needlework, and textile production from Saxony to the Rhineland.

But it was not only Germany's *Dichter und Denker* whose civic aspirations found expression in working worlds; in the age of oeconomy, all manner of material practice—whether industrial or scientific—were loaded with moral and political meaning. Chapter Two, "Labor, Folklore, and the Politics of Sustainability," looks at how mining officials and their subordinates commonly understood resource management as a fundamentally social problem. Where officials of Humboldt's ilk approached mineral exhaustion as a question of labor discipline, the vernacular traditions of laboring miners similarly supposed that the yield of a deposit depended upon the virtue of those who worked its pits. Learned and laboring miners may have inhabited different ontological worlds, one beholden to the "mine state" (*Bergstaat*), the other to the "mine spirit" (*Berggeist*). Yet the official and vernacular landscapes of mining found common ground in linking material practice, mineral abundance, and moral constitution.

The chapters that compose Part Two then trace different aspects of Humboldt's science from their origins in the working worlds of late eighteenth-century Europe through the American voyage and the Cosmos years. This begins, in Chapter Three, "Producing the Geography of Plants," by re-casting Humboldt's early botanical pursuits as he understood them, that is, as an

agent of political (o)economy. Following Humboldt's early travels through Europe around 1790, this chapter shows how commercial routes and industrial practices shaped the very conditions of possibility for theorizing about biogeography and the role of human agency within it. Ultimately, the primacy of human activity in determining the global geography of plants would be the hallmark of Humboldt's classic *Essay on the Geography of Plants* (1805). The fusion of "domestic" economic policies and oversees imperial ventures in Humboldt's plant geography would endure in his broader scientific enterprise, which continued to combine cameralist and colonial modes of thought and practice.

Chapter Four, "Mines, Mountains, and the Making of Vertical Nature," reinterprets the spatial imaginary associated with Humboldt as one adaptation of a broader culture of travel in central Europe, where administrators, artists, and savants traced miners' rhythms of work, first with their bodies, then with their pens. The vertical arrangement of nature so famously illustrated in Humboldt's hypsometric profiles and botanical "tableaux" belonged to a widespread vertical thinking that originated in the mining industry he served. That culture was produced as much through the labor of miners and mountain guides as through the maps, poems, paintings, and writings of well-to-do travelers.

Chapter Five, "Managerial Science from Prussia to Mexico and Back," traces the social organization of global physics through some of the key institutions where it was practiced, particularly the mining administrations in Franconia and New Spain. The chemical, geognostic, and geographic features of Humboldt's *physique du monde* took the form of the existing division of labor in which he operated. Likewise, the view of nature yielded by this science reflected the managerial position its author assumed—first over subordinates and natural resources in the mines of the Fichtel Mountains and later over scientists and natural phenomena from the

Mexican Cordilleras to the Himalaya. This is as much a story of Humboldt as it is of the foremen, surveyors, and civil servants who made his science possible.

Finally, in "A Deeper Commerce: Humboldt's Labor Theory of Climate," the dissertation concludes by showing how work persisted in Humboldt's science even as workers themselves were increasingly marginalized within his scientific administration. Humboldt's contributions to the emergent field of climatology came at the precise moment that France and then Germany entered the modern fossil fuel economy. Humboldt's geognosy, plant geography, isothermal cartography, and indeed his life-long engagement with mining all came to a head in his historical study of climate. And while it has been argued that climatology signaled the separation of climatic phenomena from human activity, Humboldt's case illustrates how industry was nonetheless integral to the making of climate history, however veiled in algorithms, analogies, and thought experiments.

Above all, this dissertation seeks to present an account of Humboldt's science that is, in a word, accountable. To borrow from a recent volume, this study seeks to explore the ways in which Humboldt and his collaborators, along with "their tools, expedition equipment and teams, are themselves politicians operating in spaces, on behalf of others, and seeking authority."[73] One way to do that, I argue, is to appreciate the work that Humboldt performed, and the work performed by others whom he managed and relied upon—"whether manifest or mystified." As Humboldt's scientific enterprise was first taking shape, he saw little distinction between his "*Dienst*" or service "as a miner" and those "essential *Dienste*" he pursued as a man of science.[74] What follows is a history of those *Dienste* as they were coupled and decoupled time and time again at the dusk of the early modern and dawn of the modern eras.

[73] Bobbette and Donovan, "Political Geology," 1-2.
[74] Humboldt to Carl Freiesleben, 21 Nov. 1794, *Jugendbriefe*, 378.

Part One

Political Landscapes

Chapter One

The Art of Cultivation in the Age of Revolution

The beautiful drama of human industry remains the exclusive property of free peoples.[75]

Georg Forster, 1790

To rouse beautiful industry
This is the noblest science….[76]

Julie von Bechtolsheim, 1810

Karl Marx prefaced the first volume of *Das Kapital* (1867), drawn primarily from English examples, with a warning to German readers: "*De te fabula narrator*," he wrote—"This is your story being told!"[77] Thus, he admonished compatriots not to dismiss English industrialization as an exceptional case, nor delude themselves that Germany had taken a different path into modernity. Instead, he saw the rise of the industrial bourgeoisie in England—the triumph of steam, the accumulation of capital, the alienation of the worker from their product—as the onset of a world-historical process soon to sweep the Continent.

Yet the specter of English industry had been haunting Germany for decades, even before the opening of massive coal fields in Saxony, the Saarland, and the Ruhr ignited its own

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[75] Georg Forster, *Ansichten vom Niederrhein von Brabant, Flandern, Holland, England und Frankreich im April, Mai und Junius 1790* (Leipzig: Dieterich'sche Verlagsbuchhandlung, 1971), 157: "Allein das schöne Schauspiel der Arbeitsamkeit bleibt das ausschließende Eigenthum freier Völker."
[76] Julie von Bechtolsheim, *Der erste September 1810 in Eisenach. Ein Gedicht von Julie Freyin von Bechtolsheim als Augenzeugin. Zum Besten der Hülfsbedürftigen* (Gotha: Becker'schen Buchhandlung, 1810), 43 (SBB, Sig. 19 ZZ 15497): "Schöne Thätigkeit zu wecken | Sey des Edlen Wissenschaft."
[77] Karl Marx, "Vorwort zur ersten Auflage," *Das Kapital* vol. 1 in *Karl Marx–Friedrich Engels–Werke*, vol. 23 (Berlin: Dietz Verlag, 1968), 11-17: "Sollte jedoch der deutsche Laser pharisäisch die Achseln zucken über die Zustände der englischen Industrie- und Ackerbauarbeiter oder sich optimistisch dabei beruhigen, daß in Deutschland die Sachen noch lange nicht so schlimm stehn, so muß ich ihm zurufen: *De te fabula narratur*!"

industrial "take off" around mid-century. Manchester, where Friedrich Engels composed *The Conditions of the Working Class in England* (1844) and began his revolutionary collaboration with Marx, cast a particularly long shadow. Anticipating Marx's own theory of "alienation," German travelers of the early nineteenth century reported on the ghastly "sight of mechanical life without end" in Manchester's mills. "The wheels are truly alive," Johanna Schopenhauer wrote of its steam-powered looms at the turn of the century, "while the humans operating them are but machines."[78]

Schopenhauer's account of Manchester gave voice to widespread anxieties about industrialization. The de-skilling of labor, the exploitation of women and children, and the mechanization of life in the English factory system presented a material and moral threat to the old economic order anchored in agriculture and domestic manufacturing. To be sure, urban industrialization remained more specter than reality in Schopenhauer's Germany: in early nineteenth-century Prussia, some 70 percent of the populace lived or worked in the countryside; in the Rhineland, home weavers actually increased with the advent of steam-powered mills; in Saxony and Silesia, new textile factories arose in rugged, hilly regions where "cottage industries" were already concentrated; and throughout the German lands, large-scale iron foundries, glassworks, breweries and the like remained well dispersed in provincial landscapes.[79]

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[78] Johanna Schopenhauer, *Reise durch England und Schottland*, 2nd ed., vol. 1 (Leipzig: Brockhaus, 1818), 226-28: "Uns schwindelte in diesen großen Sälen bei dem Anblicke des mechanischen Lebens ohne Ende. […] Am Ende schien es uns, als wären alle diese Räder hier das eigentlich lebendige und die darum beschäftigten Menschen die Maschinen." Published between 1813 and 1817, Schopenhauer's *Reise* describes journeys undertaken in the years 1803, 1804, and 1805.

[79] Eric Dorn Brose, *The Politics of Technological Change in Prussia: Out of the Shadow of Antiquity, 1809-1848* (Princeton, NJ: Princeton University Press, 1993), 34; James M. Brophy, "The End of the Economic Old Order: The Great Transition, 1750-1860," in *The Oxford Handbook of Modern German History*, ed. Helmut Walser Smith (Oxford, UK: Oxford University Press, 2011), 169-94, on 176-77. The rural, de-centralized character of early German industrialization was not unintentional. As Brose has shown, entrepreneurs and reformers of the period envisioned an "aesthetic" industry that harmonized town and country. (Brose, *The Politics of Technological Change in Prussia*, esp. 31-33, 71, 98-100.)

Some scholars have described this as a period of "proto-industrialization," where merchants shuttled raw materials and, later, finished goods back and forth between rural producers and urban markets, thus challenging the traditional hegemony of the guilds.[80]

Still, it seemed clear to many that the machine had begun to enter the garden.[81] Around 1830, an uneasy sense of foreboding appears in works of art like Carl Blechen's oil painting of a "Steel Mill in Eberswald," some 50 kilometers north of Berlin (**Figure 1**). Blechen tended to paint idyllic and arcadian scenes—nude women bathing at a spring, or exhausted bridge-builders taking repose in an alpine landscape. In Eberswald, though, the rural idyll of the foreground is starkly contrasted with, if not overtly challenged by, the billowing black smoke and imposing scale of the steel mill towards which a peasant gazes, distracted from his labors at the creek.

Figure 1. Carl Blechen, "Walzwerk Neustadt-Eberswalde," oil on canvas, 25,5 × 33 cm (1830). Alte Nationalgalerie, Berlin, Wikimedia Commons.

[80] Peter Kriedte, Hans Medick, and Jürgen Schlumbohm, eds., *Industrialisierung vor der Industrialisierung: gewerbliche Warenproduktion auf dem Land in der Formationsperiode des Kapitalismus* (Göttingen: Vandenhoeck & Ruprecht, 1978).
[81] This phrase is drawn from the Leo Marx's classic book *The Machine in the Garden: Technology and the Pastoral Ideal in America* (New York: Oxford University Press, 2000 [1964]).

The shifting landscape of economic life was also registered by a marked semantic change. "Industry" was, after all, first in Eric Hobsbawm's list of terms that gained their modern meaning during the "Age of Revolution," a period that spanned the fall of the Bastille in 1789 to the publication of the Communist Manifesto in 1848.[82] It was in this age that industry's original meaning as the human quality of diligence (survived by the adjective *industrious*) was subordinated to its institutionalized, economic form (as in the adjective *industrial*).[83] In the late eighteenth century, industry's many German synonyms (*Fleiß*, *Tätigkeit*, *Arbeitsamkeit*, *Kunst*, *Betriebsamkeit*, or even *Kunstbetriebsamkeit*) commonly connoted moral virtues. Lexica from the period describe industry not only as a process of material production, but also as a "collective virtue," a marker of "civilization."[84] As in English, however, the concept's moral scope gradually constricted and, by the 1840s, came to focus on the refinement of raw materials.

This chapter re-opens the semantic horizons of industry at the turn of the nineteenth century, returning to a moment in which reformers actively theorized the relationship between *industrious* qualities and *industrial* production.[85] Before industry's early modern and modern meanings could be neatly parsed, many understood them in their coalescence. And what Marx and Engels would, with hindsight, view as an inexorable process of modernization appeared to

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[82] Eric Hobsbawm, *The Age of Revolution 1789-1848* (New York: Vintage Books, 1996), 1.
[83] Raymond Williams, *Keywords: A vocabulary of culture and society* (New York: Oxford University Press, 1983 [1976]), 165-68.
[84] Lucian Hölscher, "II. Wort- und begriffsgeschichtlicher Abriß: Industrie," in *Geschichtliche Grundbegriffe: Historisches Lexikon zur politischen-sozialen Sprache in Deutschland*, vol. 3, eds., Otto Brunner, Werner Conze, and Reinhart Koselleck, 239-249 (Stuttgart: Ernst Klett Verlag, 1972), 240-42.
[85] Compare to Lissa L. Roberts and Simon Werrett, "Introduction: 'A More Intimate Acquaintance'," in *Compound Histories: Materials, Governance and Production, 1760-1840*, eds. Lissa L. Roberts and Simon Werrett (Leiden: Brill, 2018), esp. 30-31. In modern historiography, the term *industrious* is strongly associated with Jan De Vries's argument that the industrial revolution was anticipated by an older, more protracted "industrious revolution" that saw a reallocation of labor in the household economies of England, northern Europe, and the North American colonies that made it possible for families to purchase goods from outside the home, thus increasing the demand for market-supplied goods as well as the supply of marketed commodities. See Jan De Vries, "The Industrial Revolution and the Industrious Revolution," *Journal of Economic History* 54 (Jun. 1994): 249-270.

this chapter's central characters, Georg Forster (1754–1794) and Julie von Bechtolsheim (1751–1847), as an open spectrum of possibilities for civil society.[86] They believed that industry—in the hybrid sense in which they knew the word—was to play a catalytic role in the political, moral, and intellectual development of humankind.[87]

Today Forster is best remembered for his ethnographic descriptions of the South Pacific aboard Cook's second voyage (from 1772 to 75), as for the revolutionary role he played in the founding of the short-lived Mainz Republic in 1793. Yet scholars have largely neglected the industrial "interludes"—from studies of mining and metallurgy in Saxony to tours of textile manufactories in England and the Rhineland—that formed the practical substrate of his political philosophy.[88] Bechtolsheim, for her part, is known almost exclusively (if at all) as a muse to literary giants Goethe and Wieland, a salonnière of the small Thuringian city of Eisenach and a

[86] Scholars have emphasized the open-ended, uneven, and protracted nature of German industrialization. Suzanne Marchand's recent study of the porcelain industry, for instance, observed "how impossible it was to foretell what *the* path to modernization might be." (Suzanne L. Marchand, *Porcelain: A History from the Heart of Europe* (Princeton, NJ: Princeton University Press, 2020), 168.)

[87] Recent studies have focused on artisans' own efforts to elevate their political status. In eighteenth-century France, for instance, a caste of artisans distinguished themselves as *artistes* in order to challenge the intellectual and political supremacy of the savants. See Paola Bertucci, *Artisanal Enlightenment: Science and the Mechanical Arts in Old Regime France* (New Haven, CT: Yale University Press, 2017). This might be compared with Celina Fox, *The Arts of Industry in the Age of Enlightenment* (New Haven, CT: Yale University Press, 2010), which argues that no clear-cut distinction existed between mechanical artists and mechanical philosophers in the British Enlightenment. Only in the mid-nineteenth century were the mechanical arts distinguished, culturally and professionally, from philosophy and the "fine arts." In the German lands, Ursula Klein has argued that *Technikwissenschaften* were separated from other sciences (natural sciences, mathematics, medicine, etc.) by the institutional distinctions that arose in the second half of the nineteenth century between technical academies (Berg-, Bau-, und Forstakademien) on the one hand and research universities on the other hand. See Ursula Klein, *Nützliches Wissen: Die Erfindung der Technikwissenschaften* (Göttingen: Wallstein, 2016), 181-87.

[88] The most recent biography of Forster obscures his interest in industry and practical sciences within a period of "interludes" and direct quotations from his time in Freiberg, Saxony are cited out of context. See Jürgen Goldstein, *Georg Forster: Voyager, Naturalist, Revolutionary*, trans., Anne Janusch (Chicago: University of Chicago Press), 87. Another biography devotes just two paragraphs to Forster's study of mining in Saxony and the Harz: Ludwig Uhlig, *Georg Forster: Lebensabenteuer eines gelehrten Weltbürgers* (Göttingen: Vandenhoeck & Ruprecht, 2004), 163-64.

minor poet who may have inspired but did not "make" the Romantic canon.[89] Bechtolsheim's intellectual enterprise, however, extended far beyond her poetic writings or her correspondence with Weimar intellectuals. Her greatest Romantic work will not be found in verse, but rather in the "Spinning Institute" and "Industry School for Girls" she founded as part of Eisenach's "Women's Association" (*Frauenverein*), built to provide work and education girls and women affected by the Napoleonic Wars.[90]

Both Forster and Bechtolsheim understood the world of making as one of political imagination. It has often been said that Forster saw freedom mirrored *in* nature, in keeping with Enlightened zeal for "natural law" and the nature-as-teacher ideology of the early Romantics. Here, though, I suggest Forster understood liberty not as a state of nature, but a resource extracted from it: the cultivation of the earth and that of the mind were one in the same endeavor. This view accorded industry—and the industrious—a central role in the political destiny of humankind. If in Saxon mining Forster found a model of environmental moderation—a pre-requisite, he believed, for social tranquility—his tour through the textile manufactories and commercial landscapes of the Rhineland and Netherlands inspired a view of industry as an agent of *Bildung*.

Bechtolsheim, a baroness who called herself "a most zealous proponent" of the ideals of the French Revolution, similarly saw textile production as a political opportunity.[91] Her Industry School transposed what she called "women's work" (spinning, weaving, and knitting

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[89] Bechtolsheim's legacy as a muse is evidenced in the titles of her two biographies: Volkmar Schumann, *Julie von Bechtolsheim, Eine Eisenacher Persönlichkeit: Wielands 'Psyche' und Goethes 'Seelchen' in Eisenach* (Eisenach: Goethe-Gesellschaft, 1997) and Eva Schmidt, *Julie von Bechtolsheim: Wielands 'Psyche'. Eine Biographie*, 2nd ed. (Rattenkirchen: PlayAlpha-Verlag, 2009).
[90] An extensive study of the *Frauenvereine*, which includes Bechtolsheim's Association in Eisenach, is Dirk Alexander Reder, *Frauenbewegung und Nation: Patriotische Frauenvereine in Deutschland im Frühen 19. Jahrhundert, 1813-1830*, Kölner Beiträge zur Nationsforschung 4 (Köln: SH-Verlag, 1998).
[91] Julie von Bechtolsheim to Christoph Martin Wieland, 2 Jan. 1794, in SLUB, H. 43, Bd. 9, Bl. 13.

traditionally performed in the home) into a civic institution where "girls of all classes and estates" were to participate in the patriotic project of the nation's post-war "rebirth."[92] The Eisenach Association itself was politically amphibious: although sponsored by the Grand Duchess of Saxe-Weimar-Eisenach, Maria Pawlowna, the charitable organization was run, by its noble leader and bourgeois majority, as a sort of constitutional monarchy in miniature, reflecting Bechtolsheim's own hybridity as a liberal aristocrat.

As Forster's Enlightened philosophy materialized around mines and manufactories, so Bechtolsheim's Industry School put Romanticism to work.[93] Both saw industrious activity as a democratizing agent of cultural ideals typically reserved for the educated classes. For Forster it was *Bildung*, a humanistic self-cultivation, that laborers were to produce as a collective good. Bechtolsheim shared this general vision but had to negotiate *Bildung*'s male-gendered exclusivity. Echoing the motif of the Beautiful Soul (*die schöne Seele*), claimed as the domain of women writers, she saw "ensoulment" (*Bese*(*e*)*ligung*) as the end of her spinning collective.

By imagining new forms of social existence through practical activity Forster and Bechtolsheim reflect an era in which Europeans invested automata, engines, and instruments with the aspirations of a new political age.[94] Forster was a leading architect of *Bildung*'s new role in civic life, not as a lofty state of personal refinement but as a collective virtue.[95] In this

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[92] Julie von Bechtolsheim, "Ein Wort an's Herz," 14 Feb. 1814, in THsaW, ZD 1, Bl. 1-3.
[93] For an "institutional approach" to Romanticism, see Theodore Ziolkowski, *German Romanticism and Its Institutions* (Princeton, NJ: Princeton University Press, 1990).
[94] E.g. Ken Alder, *Engineering the Revolution: Arms and Enlightenment in France, 1763-1815* (Chicago: University of Chicago Press, 1997); John Tresch, *The Romantic Machine: Utopian Science and Technology after Napoleon* (Chicago: University of Chicago Press, 2012); Adelheid Voskuhl, *Androids in the Enlightenment* (Chicago: University of Chicago Press, 2013).
[95] A large literature shows *Bildung* as the watchword of liberal reformers in Germany, from the early Romantics through the Vormärz. Consider David. F. Lindenfeld, *The Practical Imagination: The German Sciences of State in the Nineteenth Century* (Chicago: University Chicago Press, 1997); Matthew Levinger, *Enlightened Nationalism: The Transformation of Prussian Political Culture, 1806-1848* (New

formulation, liberals like Wilhelm von Humboldt (1767-1835) began to imagine *Bildung* as a social achievement that cut through the three-estate model of the Old Regime and extended its lofty ideal of self-realization also to "workmen" and artisans.[96] Bechtolsheim's case similarly reflects a broader spirit of reform. One of some 600 *Frauenvereine* to spring up at the end of the Napoleonic Wars, Eisenach's Association was part of a still larger effort to cultivate economically productive citizens at state-funded schools and orphanages as well as other charitable institutions.

Forster and Bechtolsheim's generation also left lasting blueprints for later writers concerned with the specter of "mechanical life without end." The conclusion of this chapter turns to two Berliners of the mid-nineteenth century, Bettina von Arnim (1785-1859) and Alexander von Humboldt (1769-1859). Close friends and correspondents, both Arnim and Humboldt harkened to the industrious ideals of ca. 1800 in their own responses to the first phase of heavy industrialization in the 1840s. Arnim looked to communitarian images of female collectivity and small-scale textile work as an antidote to mechanization and proletarianization in the factory system. Humboldt introduced the first volume of *Kosmos* (1845) with a more optimistic view of industrialization, echoing Forster's faith in the industrial bourgeoisie. But even as Humboldt heralded a "new era of world history" guided by "free" industry and "civic institutions," he drew upon the language of state paternalism he knew well from his years of service to the Prussian Crown. The "backward-looking progressivism" of Arnim and Humboldt, presaged by Forster and Bechtolsheim, are artefacts of an age in flux.[97]

York: Oxford University Press, 2000); Frederick C. Beiser, *The Romantic Imperative: The Concept of Early German Romanticism* (Cambridge, MA: Harvard University Press, 2003).

[96] Denise Phillips, *Acolytes of Nature: Defining Natural Science in Germany, 1770–1850* (Chicago: University of Chicago Press, 2012), 63.

[97] Brose, *The Politics of Technological Change in Prussia*, 136.

Oeconomic Landscapes

"Freyberg, 14 July. Awoke around 4. Strawberries and milk. Rode out into the sun-bathed serenity of the cool dawn in the company of the Master of Machines, [Johann Friedrich] Mende, toward the smelting huts of Halsbrücke." So begins an entry in Forster's diary of 1784, like a page torn out of Goethe's *The Sorrows of Young Werther*, with which he traveled:

> …thickets of oak, beach, birch and alder shone resplendent in their manifold beauty and revitalized the soul thirsting for a lonely shadow! O how is it that the whistling of the wind in uninhabited groves is so lovely; vital breath of Nature….[98]

Yet, with little change in tone, the passage ends in the hydraulic works and metallurgic operations outside Freiberg. "Here, too, is a romantic area," Forster wrote of Halsbrücke, where "even the high mounds of rubble [extracted from the shafts] combine with the totality of the area, with the mass of rock through which the [River] Mulde violently forged its path." Whereas Forster disparaged the "mounds of rubble" that mired uncultivated nature, he venerated Freiberg's spoil heaps as "vestiges of the former industry of the miner." Over the river stood yet another monument to industry (**Figure 2**):

> a beautiful, picturesque archway of hewn stone bearing an aqueduct that carries water to distant mines, communicating the force necessary for the movement of their machines. Under the arch a road leads over a second low-laying row of arches, between which the Mulde rushes on.[99]

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[98] Georg Forster, Tagebuch, 14 July 1784, AA XII, 82: "Bei heiterer Sonnenheller Frühe und Kühle ausgeritten in Begleitung des Kunstmeisters Mende nach ~~der Halsbrücke~~ den Halsbrückner Hütten. Der Weg den wir dahin nahmen ward in einiger Entfernung von der Stadt anmuthig, indem er sich längst Thälern und Dörfen zog, wo Gebüsche von Eichen, Buchen, Birken und Erlen (in) ihre(r) mannigfaltige(n) Schönheit prangten, und den nach einsamen Schatten durstenden Geist erquickten! O wie kommts daß das Sausen des Windes im unbewohnten Hayn so lieblich ist; lebendiger Odem der Natur…." Compare to the following line from Johann Wolfgang von Goethe, *Die Leiden des jungen Werthers* (1774), 10 May: "Eine wunderbare Heiterkeit hat meine ganze Seele eingenommen, gleich den süßen Frühlingsmorgen, die ich mit ganzem Herzen genieße."

[99] Forster, Tagebuch, 14 July 1784, AA XII, 82-83: "So kamen wir an die Mulde, über welche ein schöner malerischer Bogengang von gemauerten Steinen eine Wasserleitung führt, welche verschiedenen jenseitigen Bergwerken die zur Bewegung ihrer Maschinen nöthige Kraft mittheilt. Unter dem Bogen durch geht der Fahrweg, über eine tiefere (liegende) zwote Reihe von Bogen, zwischen denen die Mulde sich hinweg drängt.— — Hier ist auch die mit (Laub-)Wäldern bewachs*ene* Gegend romantisch, und selbst die hohen Schutthaufen, die wild aufgethürmten Halden, ~~welche~~ diese einzigen Ueberbleibsel

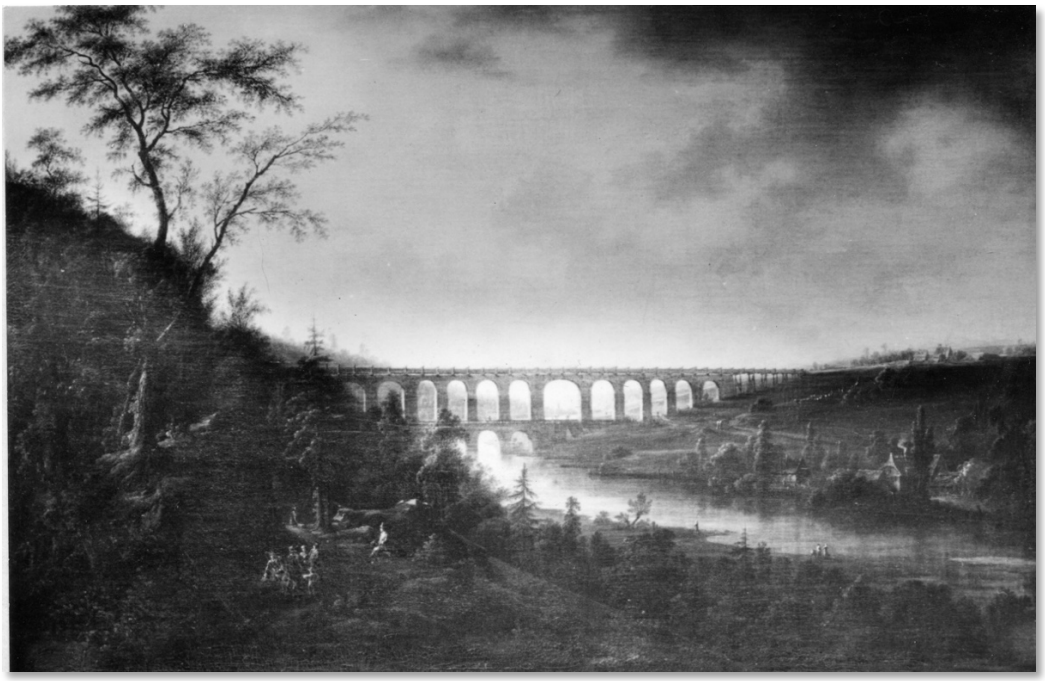

Figure 2. Johann Alexander Thiele, "Die Altväterwasserleitung," oil on canvas, 1744. Stadt- und Bergbaumuseum Freiberg, Inv.-Nr. 50-276.

Erected a century beforehand, the Old Father's Aqueduct appeared to Forster an artificial counterpart to the "violent" Mulde, an example of what he called "built Nature."[100]

At twenty-nine, Forster was known to the reading public as the *Weltumsegler* (or Circumnavigator), thanks to his sensational *Voyage Round the World*. But in April of 1784, Forster charted a different course—into the hard rock mining industries of the Harz Mountains in central Germany and the Ore Mountains along the Saxon-Bohemian border. July 14 was, in fact, the final day of a three-month apprenticeship in *Bergbaukunde*—the study of mining, smelting, hydraulic engineering, and "subterranean geography"—that Forster undertook in preparation for

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ehemaliger Betriebsamkeit des Bergmannes, machten mit dem ganzen, mit den Felslagern, die die Mulde gewaltsam durchbrochen haben muß, um sich den Weg zu bahnen, einen ~~angenehmen~~ guten Effekt."

[100] Georg Forster, "Ein Blick in das Ganze der Natur. Einleitung zu Anfangsgründen der Thiergeschichte" (1779), AA VIII, 94-95. After denigrating uncultivated nature—"die Erde, mit den Trümmern ihrer eigenen Produkte belastet, trägt Schutthaufen"—Forster praised the human capacity to improve the land: "Wie schön ist sie nicht, diese gebaute Natur! Wie hat die Sorgfalt des Menschen sie so glänzend und prächtig geschmückt!" See discussion of Forster's environmental views in Theodore S. Feldman, "Climate and History in the Late 18th and Early 19th Centuries," *Eos* 73, no. 1 (7 Jan. 1992): 1-8.

his new post as professor of natural history in Vilnius. The "primary objective" of this position, he wrote his father, was to "generalize the utilization of indigenous products," and to study "their application in mechanical arts and handcrafts, dying, manufacturing and trade."[101]

Forster's study of mining came at a critical moment in the development of his political consciousness, a decade after his youthful voyage aboard H.M.S. Resolution and a decade before falling fatally ill in Revolutionary Paris. The technologies, landscapes, and engineering practices he encountered in Saxony and the Harz gave form to an emergent political philosophy. This, too, can be gleaned from Forster's entry of 14 July. While examining the blast furnaces (which reduced iron ore to its liquid form, pig iron), Forster observed that Freiberg's were of a "moderate height" (*mittelmäßiger Höhe*) when compared to the "monstrous" ovens in the Harz:

> Nature seems to have prescribed to us in all things an appropriate medium [*in allen Dingen Mittelmaas*], which is itself the end of perfection; if we do not go to a certain point, the force we apply will not be proportionate to that which we seek to overcome; but if we go beyond this point, the advantage will not be so great as we had expected, having wasted that force.[102]

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[101] Georg Forster to Johann Reinhold Forster, 3 Mar. 1784, in AA XIV, 25-26: "Die Hauptabsicht der Erziehungscommission, indem sie die Stelle eines Professors der Naturgeschichte errichtet, ist die Anwendung der inländischen Producte bekannter und allgemeiner zu machen." Requesting books on the utlity of plants, Georg added: "Es ist eine traurige Sache, daß ich so weit zurück bin in der *Geschichte* unsrer Wissenschaft."

[102] Forster, Tagebuch, 14 July 1784, in AA XII, 84: "Die Natur scheint uns in allen Dingen Mittelmaas, als das Ziel der Vollkommenheit vorgeschrieben zu haben; geht man nicht bis an einen gewissen Punkt, so ist die Kraft ~~der~~ die wir anwenden der Kraft die überwunden werden soll nicht angemessen; geht man über jenen Punkt hinaus, so ist der Vortheil nicht so groß, als wir von der Verschwendung der Kraft erwartet hatten." Here Forster's echoes two earlier evocations of *Mittelmaas*. In the same year, Forster authored his essay on the breadfruit tree, written first in Kassel then edited again in Vilnius. Here, too, Forster waxed eloquent about the breadfruit as "beautiful *Mittelmaas* amongst trees": "Schön ist übrigens die Form des durch Kultur veränderten Brodbaums…. […] Selten übersteigt seine Höhe vierzig Pariser Fuß: ein schönes Mittelmaas unter den Bäumen." Unconcerned by contemporary plans to use the breadfruit tree as a cheap source of food for slaves in the plantations of the West Indies, Forster believed the product was beautiful because it was useful, striking a perfect harmony between the two. (Georg Forster, "Der Brotbaum," AA, VI, Pt. 1, 74.) A similar passage comes from his *Voyage Round the World*, where Forster suggested "Nature seems expressly to have intended [dogs] for [eating], by making their offspring so very numerous, and their increase so quick and frequent." (George Forster, *A Voyage Round the World*, vol. 1, eds. Nicholas Thomas and Oliver Berghof (Honolulu: University of Hawai'i Press, 2000), 134.)

At first glance, the passage may appear apolitical: it reflects a mechanical philosophy that sought to meet the forces of nature with proportionate forces of artifice, lest charcoal fuel be wasted in the production of pig iron. But machines and instruments are invested with social meaning.[103] And Forster saw mining technologies—blast ovens, hydraulic pumps, and stamp-mills—as embodiments of a greater socio-political relationship between nature and humanity.

Johann Friedrich Mende (1743–1798) and the technicians who mentored Forster spoke the language of "oeconomy," a conservative ethos of thrift and balanced expenditure. The oeconomic imaginary of eighteenth-century Europe extended an ideal of household management to nature and to the body politic.[104] As a technician, Mende saw his task as mediating between scarcity (e.g. wood shortages) and excess (e.g. seasonal floods) in the natural world. Forster not only adopted this view of nature, but also adapted it into a political vision. Universal history taught him that "a prodigious variety and great excess of natural products" tended to retard the mechanical arts and promote excesses of a political nature: "patriarchal authority becomes wanton and degenerates into despotism," Forster wrote in 1790.[105] According to this formula, the inhabitants of colder, unyielding climates (i.e. Europeans), though less well-endowed with natural products, were more apt to cultivate moral moderation by cultivating the earth itself. Forster thus viewed agriculture and industry as oecomonic agents—moderating forces—

[103] For an example from Forster's time: Lissa Louise Roberts, "An Arcadian Apparatus: The Introduction of the Steam Engine into the Dutch Landscape," *Technology and Culture* 45, no. 2 (April 2004): 251-76.
[104] On the "economy of nature," and "oeconomy" as a political imaginary, see in Donald Worster, *Nature's Economy: A History of Ecological Ideas*, 2nd ed. (Cambridge: Cambridge University Press, 1994) and Lissa Roberts, "Practicing oeconomy during the second half of the long eighteenth century: an introduction," *History and Technology* 30, no. 3 (2014): 133-48.
[105] Forster, *Ansichten*, 160-61: "Hingegen die Indianer, die Chineser, die Ägyptier und alle jene Völker, denen ihr gesegnetes Land eine ungeheure Verschiedenheit von Produkten im größten Überflusse darbot, bildeten sich schnell in ihrer eigenen Mitte, bis auf einen gewissen Punkt wo die patriarchalische Authorität üppig ward und in einen Geist und Herz tödtenden Despotismus ausartete, der alle Kräfte des großen Haufens verschlang und ihnen ausschließender Weise nur zu seinem Nutzen eine Richtung gab."

"inseparable from the development of civil liberty."[106] Before turning to the industrial production of liberty in the next section, the following pages trace the development of Forster's politics of moderation, focusing on the oeconomic landscapes he encountered in Freiberg.

It is something of a cliché that Forster found in the South Pacific an image of humanity free from the hierarchal structure that shackled feudal Europe, and that this experience animated his revolutionary zeal two decades later.[107] But Forster regarded Tahiti and New Zealand as living examples of the malevolent relationship between natural and political excess.[108] Certainly, upon arriving in "O-Aitepeha Harbor" in August of 1773, Forster called Tahiti's climate "the happiest in the world" and lauded the local cloth "manufacture." But the happy impression of Tahitian industry was soon spoiled by the sight of its chief:

> We had flattered ourselves with the pleasing fancy of having found at least one little spot of the world, where a whole nation, without being lawless barbarians, aimed at a certain frugal equality in their way of living…. Our disappointment was therefore very great, when we saw a luxurious individual spending his life in the most sluggish inactivity, and without one benefit to society, like the privileged parasites of more civilized climates, fattening on the superfluous produce of the soul, of which he robbed the laboring multitude.[109]

Forster thought New Zealand's Māori still more "barbaric," their environs "in the rude state of unimproved nature." Here, too, he alleged that natural abundance paired with a dearth of industry to promote "a natural tendency towards despotism."[110]

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[106] Forster, *Ansichten*, 161: "Überall war jedoch diese Entwicklung [von 'Handlungsbetrieb'] von bürgerlicher Freiheit unzertrennlich, und dauerte nur mit ihr." On environmental moderation as a moral imperative, see Anya Zilberstein, *A Temperate Empire: Making Climate Change in Early America* (New York: Oxford University Press, 2016), Chapter 1. "The Golden Mean."
[107] Goldstein, *Georg Forster*, 73-74.
[108] Nicholas Thomas, "Introduction," in Georg Forster, *A Voyage Round the World*, vol. 1, eds. Nicholas Thomas and Oliver Berghof (Honolulu: University of Hawai'i Press, 2000), xxxv-xxxvi. The elder Forster took a more favorable view of the Tahitian aristocracy, "finding them only incipiently corrupted by a taste for luxury…. He moreover considers that the simple patriarchy of the Tahitian polity represents a benevolent amelioration of the autocracy, indeed the 'Oriental despotism' evident in Tonga."
[109] Forster, *Voyage*, *1*, 151, 154, 165.
[110] Ibid., 103-05, 132.

The image of "frugal equality" continued to evade Forster after his return to Europe's "privileged parasites." Though the temperate climate seemed to favor advances in the industrial arts, Forster was quick to scorn excess in every form: material luxury, moral licentiousness, and despotic rule. Towards the end of the century, while writing for an audience steeped in the Sublime, Forster took a more favorable approach to "virile, wasteful nature," describing the awesome beauty of unchecked natural landscapes along the Danube in Austria or in the Peak District of England.[111] Yet he maintained the view that "abundance of wealth in Nature" posed just as great a danger to the social body as "extreme scarcity."[112]

This conception of the natural world, oscillating between "wasteful" abundance and "barren" wilderness, drew upon a matrix of ideas about frugality and civility in early modern Europe. In his widely read "Die Alpen" (1727), Swiss physician Albrecht von Haller fused Classical critiques of luxury with Protestant notions of thrift. Of highlanders who carved out a meagre living from alpine soil he wrote:

> Blessings to you, happy people! o praise the good fortune,
> That abundance, the source of vice, be denied you….[113]

[111] Forster, Tagebuch, 30 July–15 Sept. 1784, AA XII, 127-29: "Die Ebene jenseits der Donau sieht einigermaßen unbebaut aus, doch ist das vielleicht Jahrzeit. […] Hingegen ist das wilde reicher und schöner. Die Buchwaldungen haben so ein sattes Aussehen, sie erinnerten mich die und da an den geilen verschwenderischen Reichthum der Natur in *Neu*-Seeland, und zugleich in sofern die Formen der Berge schön und abwechselnd und die Bäume einerley sind, an die Casselsche schöne Gegend." Forster, *Ansichten*, 628: (from Matlock) "Die Natur ist hier so verschwenderisch mit den schönsten Formen der Landschaft."

[112] Forster, *Ansichten*, 159-60: "Es scheint indeß doch, daß allzugroßer Reichthum der Natur den Handel beinahe eben so wenig begünstigt, wie ihre allzugroße Reichthum."

[113] [Albrecht von Haller], *Dr. Albrecht Hallers Versuch von Schweizerischen Gedichten*, 2nd ed. (Bern: Niclaus Emanuel Haller, 1734 [1727]), 3: "Wohl dir, vergnügtes Volk! o danke dem Gechicke, | Das dir der Laster Quell, den Ueberfluß, versagt; | Dem, den sein Stand vergnügt, dient Armuth selbst zum Glücke, | Da Pracht und Ueppigkeit der Länder Stütze nagt."

Haller himself served as director of salt mines in the Canton of Vaud, where he described the industry as a "remedy to nature's frugality."[114] Haller's "frugal" nature had its counterpart in the "chaos" and "ruin" described by the naturalist Georg-Louis Leclerc Comte de Buffon. Buffon measured the civilizational superiority of (western and central) Europeans by the extent to which they cultivated "rude" nature.[115] Forster translated directly from Buffon while teaching at the Collegium Carolinum in the Landgraviate of Hesse-Kassel between 1778 and 1783. By stemming the advance of nature's "wastelands," he declared in one lecture, "a new, rejuvenated Nature springs forth from our hands!"[116]

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[114] [Albrecht von Haller], *Kurzer Auszug einer Beschreibung der Salzwerke in dem Amte Aelen, auf Hohen Befehl herausgegeben von Albrecht Haller, des Grossen Rathes, und dieser Salzwerke ehemaligem Director* (Bern, 1765), 2: "Die Salzwerke der Republik verdienen allerdings eine Beschreibung, da sie vieles, von allem was man in andern Ländern findet, unterschiedenes haben; wie denn der innere Bau eines Gebürges wohl nirgends deutlicher wie zergliedert worden, und auch nirgendwo so unermeßliche Werke unternommen worden sind, der Sparsamkeit der Natur abzuhelfen." Accordingly, Haller was gravely concerned with preserving wood resources ("die nöthige Holzung zum Feuer, Gebäuden und Röhren") for the good of posterity ("die Nachkommenden dieses"). ([Albrecht von Haller], *Des Herrn v. Hallers Bemerkungen über Schweizerische Salzwerke*, ed. Karl Christian Langsdorf (Leipzig: Krieger dem jüngern, 1789), 285.)

[115] Georges-Louis Leclerc, le Comte de Buffon, *The Epochs of Nature*, trans. and ed. Jan Zalasiewicz, Anne-Sophie Milon, and Mateusz Zalasiewicz (Chicago: University of Chicago Press, 2018), 119-32.

[116] Forster, "Ein Blick," 95: "Laßt uns von jenem wirksamen, und verzehrenden, vorher verborgenen und bloß durch unser Nachforschen entdeckten Elemente Gebrauch machen! Laßt uns diesen überflüssigen Unrath, jene schon halb vergangenen Wälder mit Feuer verbrennen, und, was das Feuer nicht aufreibt, vollends mit der Axt zerstören. …und eine neue verjüngte Natur geht aus unsern Händen hervor!" In this vision, Forster accorded "Man as lord of the earth" an environmental role that reflected early modern ideals of "moderate" masculinity. As Todd Reeser has argued, the standard of masculine comportment in early modern Europe drew upon Aristotle's "golden mean," a sort of *Mittelmaas* between lack and excess in financial, intellectual, and sexual matters. Forster's intimate male friendships and effusive prose place him squarely in the sentimentalist culture of the late eighteenth century. Yet he also kept obsessive records of his own sexual immoderation: "…to bed, where I read Büffon's *Mineralogy*," Forster wrote from Freiberg, "then completely forgot myself. (Onanism) …I sense I shall be punished…." Todd Reeser, *Moderating Masculinity in Early Modern Culture* (Chapel Hill, NC: University of North Carolina Press, 2006). On the "man of feeling," an alternative masculine ideal that emerged within the sentimentalist culture of late eighteenth-century Europe, see Dror Wahrman, *The Making of the Modern Self: Identity and Culture in Eighteenth-Century England* (New Haven, CT: Yale University Press, 2004), esp. 38-39. Forster, Tagebuch, 28 July 1784, AA XII, 59: "Nach dem Bade zu Bett, wo ich Büffons Introduction à la Minéralogie lese, und mich sehr vergesse. (Onanie) – Spatziere im Garten, höchst unzufrieden mit mir selbst, bös über das Geschehene, und die Strafe ahnend, scheint mirs, daß ich heut ~~in der Ecke stehe~~ von der dortigen Gesellschaft scheel angesehen und verachtet werde." Sexual lust, he had written of Europeans and Pacific islanders alike, "instils a poison in the mind." (Forster, *Voyage*, 1:137.)

Ultimately, Forster came to see the mining industry an exemplar of nature's rejuvenation in the hands of "man." First, though, he tested these ideas out as an adept in Kassel's masonic circles. It is tempting to juxtapose the clandestine world of the alchemist with the utilitarian aims of the technician. But in the late 1770s and early 1780s, Forster saw a single Enlightened project: to manipulate nature in the name of the "perfection of humankind."[117] A well-preserved document, signed and sealed by Forster (also known as "Amadeus" to his brethren), reveals the rites of his initiation into Kassel's Rosicrucian Order (**Figure 3**). Given the choice between "the service of God and that of the World," Amadeus elected to pursue the latter, devoting himself to the study of nature's "primordial powers" and the transmutation of base metals into gold and silver.[118] By the early 1780s, Forster had risen to *adepti marjos,* the sixth of nine grades en route to *Magi*. Though he grew skeptical of the Order's secretive nature, Forster maintained an abiding faith in the Order's civic value as a source of both spiritual reformation and economic prosperity.[119]

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[117] Classic studies of alchemy and Rosicrucianism as part of the mainstream of early modern culture and commerce are Francis A. Yates, *The Rosicrucian Enlightenment* (London: Routledge, 2002 [1972]) and Pamela H. Smith, *The Business of Alchemy: Science and Culture in the Holy Roman Empire*, 2nd ed. (Princeton, NJ: Princeton University Press, 2016). On Forster's Rosicrucianism and engagement with masonic circles, see Gerhard Steiner, *Freimauerer und Rosenkreuzer: Georg Forsters Weg durch Geheimbünde* (Berlin: Akademie-Verlag, 1987).

[118] Hessischen Hauptstaatsarchiv Marburg (hereafter HSTM), Religionssachen, 4 i, Nr. 222 Bl. 38: "Dieweilen unseres Ordens Pflicht und Unternehmung in zwey Classen steht, in göttlichen und natürlichen Dingen, und also in ganz abgesonderten Dienste Gottes, und dem Dienst der Welt und unseres Nächstens." Ibid., Bl. 48: "die allgemeinste Erenntniß der Natur und…zuerst nach ihren uranfänglichen Kräften." Among the questions posed in Forster's initiation were: "Können Kunsten, Scienzen, und Handelschaft, oder Adel und weltliche Macht und. d. darzu etwas beytragen? […] 9.) Welche Kunst oder Scienz u.s.w. trägt wol vor allen am meisten darzu was bey?" (Ibid., Bl. 37.)

[119] Forster also grew wary of an alleged "Jesuit conspiracy" within the Rosicrucian ranks. This concern was shared by Saxon mining officials he later worked with in 1784. See Christopher McIntosh, *The Rose Cross and the Age of Reason: Eighteenth-Century Rosicrucianism in Central Europe and its Relationship to the Enlightenment* (New York: SUNY Press, 2011), 133-37. But where McIntosh argued that "Forster was ultimately unable to reconcile alchemy with his Enlightenment position" (ibid., 87), I suggest he turned to practical sciences like mining as an answer to questions probed in alchemy.

The manuscripts Forster left behind from this period show little distinction between alchemical inquiries into the "Philosopher's Stone" and hand-copied treatises on the "The Art of Smelting." Alongside a set of instructions on the refinement of silver from Prince Carl of Hessen, erstwhile leader of the Rosicrucian Order, lay scattered notes on mineral veins and lectures on the structure of the earth, as well as a manuscript on Abraham Gottlob Werner's "System of Metallic Species."[120] In his printed works, Forster would join Buffon in portraying industry as that which elevated humankind above "animality." Alchemy was no different. Forster saw the pursuit of occult forces not as a fanaticism, but rather as a practice in "self-moderation" that brought him closer to God and further from his "animal nature."[121]

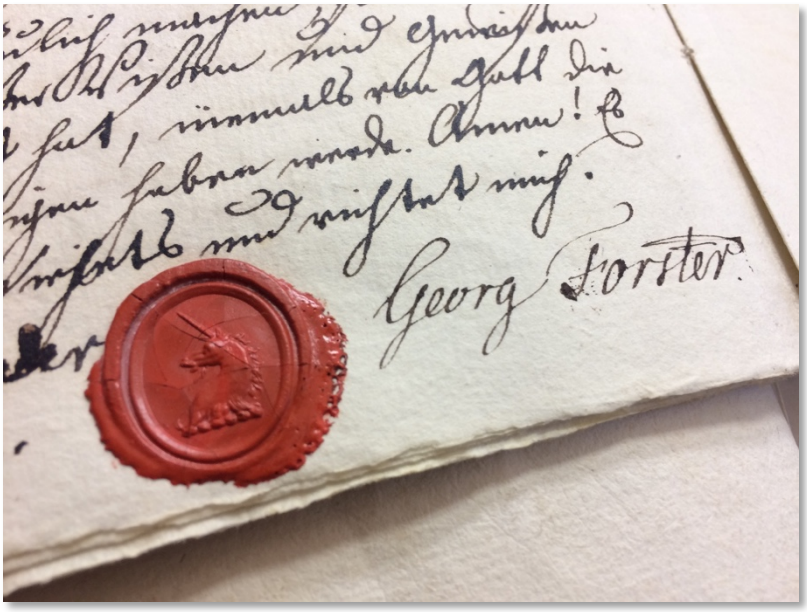

Figure 3. Forster's initiation into the Rosicrucian Order. Being of Scottish heritage on his father's side, Forster used the Scots unicorn—a symbol of purity and innocence in Celtic mythology—as his stamp. Hessischen Hauptstaatsarchiv Marburg, Religionssachen, 4 i, Nr. 222 Bl. 37-54.

[120] These documents are held at the Muséum national d'Histoire naturelle, Paris, in MS 186, 187, and 189. Though titled "Documents sur le voyage" and "Deuxième voyage du Cook," the collections also contain assorted notes and transcriptions concerning mining, smelting, mineralogy, and alchemy, as in a full copy of Johann Jacob Ferber's "Von den polnischen Bergbau" in MS 187 (having been invited, like Forster, by the Polish king in 1781), and in the aforementioned letter of 29 Oct. 1783, which describes a set of metallurgic instructions directly from "Prinz Carl zu Hessen Cassel" in MS 189.

[121] HSTM, Religionssachen, 4 i, Nr. 222 Bl. 45: "Nach eines jedweden Schwäche soll ihm also eine besondere Pflicht zu seine Strafe und Bestimmung unnachläßig aufgelegt werden, bis daß er sich wirklich gebeßert hat, und die Strafe nicht mehr für Strafe, sondern für Wohlthat ansiehet, und ein wahrhafter Weiser geworden ist, der von seiner Thiernatur und der Erde, an der wir kleben, sich nicht mehr beherrschen läßt, sondern mit Gott dem Herrn vereinigt über alle Welt erhoben ist." Cf. Forster, *Ansichten*, 160.

When called to Vilnius "to serve as a useful citizen of the republic," Forster readily translated between the alchemist's stove and the smelter's oven.[122] Believing *Bergbaukunde* the apogee of "useful knowledge," Forster obtained works on Polish mining and cut his course from Kassel to Vilnius via the industry's leading experts, Heinrich von Trebra in Clausthal-Zellerfeld and Abraham Gottlob Werner in Freiberg.[123] Yet it was Freiberg's Master of Machines, Johann Friedrich Mende, who best answered the question posed to Forster during his initiation as a Rosicrucian: "Which is the greater virtue, frugality or a boundless beneficence in excess[?]"[124]

Mende's generation of technician knew the Rosicrucian question as a matter of resource management: at one extreme, the persistent threat of wood shortages and annual summer draught; at the other, violent excess in the form of seasonal floods and ice jams. In answer, Mende's mechanics sought to remedy "nature's frugality" and temper its "chaos" in one fell swoop. By "universalizing stonemasonry" in mines and canals, for instance, Mende believed he could ensure the "protection of our forests" while promoting the "everlasting endurance" of his works. Such projects must be read in the context of the Little Ice Age, when the annual cycle of the winter freeze and spring thaw posed an existential threat to industries built upon rivers like Freiberg's Mulde. Thus, a series of reports from the late 1770s and early 1780s, show Mende engaged in a broad administrative campaign to regulate the local "Pumping-water Oeconomy" with a sprawling network of dams, canals, and "water-saving pumps."[125]

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[122] "Einstellung an der Universität Wilna," in AA XIV, 863: "et utilis Reipublicae civis nomen ac laudem obtineat." Upon embracing the materialistic philosophies he encountered in Freiberg, Forster described experiencing "an inevitable revolution in our entire system of thought" to Rosicrucian brother Samuel Thomas Sömmering. See Steiner, *Freimaurer und Rosenkreuzer*, 173.
[123] On useful knowledge more generally, see Klein, *Nützliches Wissen*.
[124] HSTM, Religionssachen, 4 i, Nr. 222 Bl. 39: "Welche unter den zweien ist eine größere Tugend Sparsamkeit oder eine grenzlose Freigebigkeit in Übermaaß…."
[125] SächsBergAFG, 40010, Nr. 3245, Bl. 63: "…daß zu Schonung unserer Waldung die Ausmauerung derer Stölln und Schächte allgemeiner gemacht werde…." The report on Freiberg's "Aufschlagswasser Oekonomie" is filed in ibid., 40089, Nr. 94, Bl. 106.

But oeconomy was not merely a material concern for miners. Mende's machines doubled as political solutions to the "Water-Controversy" between miners and millers who relied equally upon hydraulic power.[126] Moreover, Mende's case illustrates how contemporaries imbued material practices with moral virtues of thrift and prudence—or decried a lack thereof. In an article entitled "Pride and Addiction to Projects," one anonymous critic blasted the enormous costs of Mende's "excessive constructions," like the "*Kahnhebewerk*" or hoisting mechanism he designed in Halsbrücke to shuttle ore-bearing rafts from one body of water to another. The critic saw in the *Kahnhebewerk* the "arrogance" (*Übermuth*) of its late maker. "He loved neither true order nor frugality nor oeconomy, in his private life as in his professional duties," the article concluded.[127]

By contrast, Forster's Harz mentor, Trebra, lauded Mende as the harbinger of a "new epoch" of waterpower precisely for the oeconomy of his inventions—the "perfect regularity," "admirable facility," "quiet," and "consistency" of the hydraulic landscapes he designed. "*Der Natur anpaßende Mittel*"—a nature-fitting means—was the phrase Trebra used to describe the mechanics of Mende's generation, much as their student, Forster, spoke of a mechanical *Mittelmaas* in Halsbrücke.[128] Trebra had in mind the system of hydraulic pumps and presses that

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[126] Alongside the report on "Aufschlagswasser" is another titled "Den Wasser-Strait des bergbaues mit dem Freiberger Stadt-Rathe ... betreffend." Mende's essay, "Ueber die Ersparniss der Aufschlagswasser" (Bl. 97) is followed by another "lecture" on "neuen projectirten Wasserersparung" (Bl. 158).

[127] "Warnung vor Stolz und Projektsucht," *Nationalzeitung der Teutschen*, 2tes Stück (Gotha, 10 Jan. 1799) in SächsBergAFG 40133-1, Nr. 1563, Bl. 59-60: "Er liebte weder ächte Ordnung und Sparsamkeit in der Geldverwendung noch Ökonomie, in seinem Privatleben so wenig als bey erhaltenen Aufträgen."

[128] Heinrich von Trebra, *Merkwürdigkeiten der tiefen Hauptstölln des Bergamtsreviers Freyberg* (Dresden: Churfürstlichen Hofbuchdruckerey, 1804), 74-75, 82: "Die neue Mechanik verlangte ferner, und besteht noch darauf, *vollkommene Regelmäßigkeit*, Geradheit und Reinlichkeit, in ihren eignen Werktheilen; Geschirren; und zusammen gestimmten Ganzen nicht allein, sondern auch aller der Räume, worinne innerhalb der Felsen Maschinen umgehen sollen, wenn gleich hier ein mitternächtliches Dunkel sie auf ewig einhüllt, und nie ein menschliches Auge, sie in ihrem *Ganzen* überblicken wird, um zu bemerken, wo hier oder da ein hindernder Span etwan sitzen geblieben seyn möchte. Dieß hat nicht allein die mustermäßige, jedem Beobachter bewundernswürdige Leichtigkeit; Stille; und Stetigkeit des Umgangs in die Maschinen gebracht...." Trebra's "neue Epoche der Bergwerksmaschinenverbeßerung"

Mende designed in the village of Gersdorf, some 25 kilometers downstream (north) of Halsbrücke, where Forster rode with the Master of Machines on the morning of July 9th. In Halsbrücke, Forster encountered "one of the *Kunstmeister*'s most beautiful masterpieces," a great weir that concentrated the river's flow into a narrow channel saddled with three waterwheels (**Figure 4**). Coached by Mende, Forster saw the weir's stone construction as the very embodiment of the human capacity to moderate nature's extremes.

Figure 4. (Left) The arch of the Gersdorf weir, photographed by the author in December 2018. The sluice that opens to a canal, which powered three water wheels, is faintly visible on the opposite bank. (Right) Facing downstream, the curling "bulwarks"—*Vestungswerke*, *Schützwerke*, or *Eißkästen*, as Mende variously called them—of the Gersdorf weir, which have indeed survived to the present.

thus began with Mende in 1769. Of the water-drawing pumps Mende fitted within the mines of Gersdorf, Trebra wrote that "[sie] ihrem Erfinder *Mende* so viel mehr Ruhm bringt, weil er so geschickt seine Mechanik den Oertlichkeiten in diesen Gebirgen anzupassen mußte…." (Heinrich von Trebra, *Bergmeister-Leben und Wirken in Marienberg: vom 1. Decbr. 1767 bis August 1779* (Freyberg: 1818), 76-77.).

In his plan of 1779 (**Figure 5**), Mende described the weir as a "fortress" (*Vestung*)—a militaristic metaphor, no doubt, but one that conveys a structure under siege, not laying it.[129] While traveling to Freiberg from the Harz, Forster had seen bridges and mills utterly destroyed by the late-winter deluge, which came to be known as the "High Water of 1784" or the "Ice Flow of the Century" and was thought to have been triggered by volcanic activity in Iceland. All the more striking was Mende's steadfast weir:

> an arch of about 180 feet that presents its back to the force of the river's flow, constructed of nothing ... but buttresses hewn from gneiss blocks, in whose interlacing and connectivity the true excellence of this artifice lay.

In his diary, Forster sketched the weir's peculiar shape (**Figure 6**), bolstered on each side by stone bulwarks (what Mende called "*Schützwerke*" or "*Eißkästen*") that ran along the banks of the Mulde: "On both sides of the arch gneiss walls run downstream, which roundly draw back, and are once curved outwards, in order to mitigate a maelstrom of water." In Gersdorf, nature's maelstrom was not merely tamed, but also harnessed: in the adjacent canal a series of wheels powered the pumps that drained distant mines and drove the stamp-mill that crushed the ore extracted from them. A "fitting application of simple mechanical force," Forster concluded, steeped in the language of Mende's "nature-fitting" mechanics.[130]

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[129] The very word for weir, *Wehr*, connotes defense in German, as in *Landwehr*, or army. Mende used both "Vestung" and "Vestungswerke," which I translate as "bulwarks," in "Vorschläge wie das zur Grube *Seegen Gottes* zu *Goersdorff* gehörige, im Muldenfluße liegende, schadhaft gewordene Pochwerkswehr auf immer in Sicherheit zu sezen sey" (1779), in SächsBergAFG 40174, Grubenakten Freiberg 643, Bl. 73-83. An interesting comparison can be drawn between Mende and the later hydraulic engineer Johann Gottfried Tulla, "the man who tamed the wild Rhine," who also studied at the Mining Academy in Freiberg. See David Blackbourn, *The Conquest of Nature: Water, Landscape, and the Making of Modern Germany* (New York: W. W. Norton, 2006), esp. 90-109. Also consider the humbler language used by Germany's coastal communities to describe dikes as a defense against overwhelming natural forces: Marie Luisa Allemeyer, *"Kein Land ohne Deich…!" Lebenswelten einer Küstengesellschaft in der Frühen Neuzeit* (Göttingen: Vandenhoeck & Ruprecht, 2006), esp. 336, 39.

[130] Forster, Tagebuch, 9 July 1784, AA XII, 74: "…eins der schönsten Meisterstücke des Hr. Kunst-Meister Mende…. Es ist ein Bogen von etwa 180 Fuß entfernten Mittelpunkte wölbt, und gegen den Druck des Stroms den Rücken bietet. Er ist deshalb vertical gewölbt, 12 Fuß dick mit einer Böschung unterwärts, die (20 Fuß weiter) an einem zweiten stets unter Wasser liegenden Bogen stößt, und aus lauter

Figure 5. The "fortress" on the Mulde. In Mende's sketch, we see both the original wooden weir and the three stone arches of its proposed replacement. The sluice that opens to the canal is shown just above the wooden weir, to the right. SächsBergAFG 40174, Grubenakten Freiberg 643, Bl. 81.

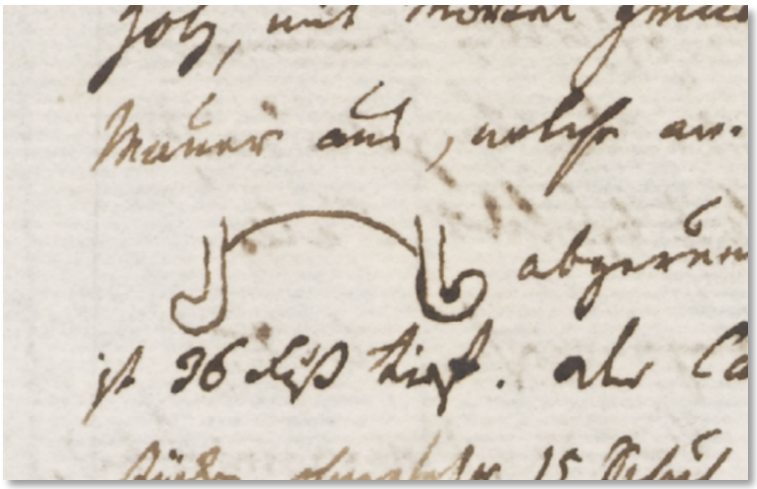

Figure 6. Aerial depiction of the Gersdorf weir in Forster's journal of 1784, GSA 16/3, Bl. 74. The arched weir in the middle meets the river's flow as its curling "Schützwerke" extend downstream.

Strebepfeilern, wenn ich so sagen darf, von Gneusstücken besteht, in deren Verschränkung und Verbindung unter einander eigentlich die Vortrefflichkeit des Baues liegt."

The Gersdorf weir, like the Halsbrücke blast oven, modelled a delicate balance between nature and artifice. Toward the end of the decade, as political revolution broke out in France and the Austrian Netherlands, this model provided Forster a language with which to measure the progress—and criticize the shortcomings—of his age. Everywhere, Forster saw his contemporaries struggle to achieve the "frugal equality" he had long sought. Instead, he saw a world mired in the kind of excess that breeds political apathy and tyranny. In his travels of 1790, Forster commented on how the "luxury" that abounds in English cities stifles "*Politik*." As in New Zealand, social excesses were mirrored in nature. In the English countryside Forster found a "waste of land" that would "bleed the heart of a German oeconomist."[131] But the "German oeconomist" who sought a "prudent harmony with the forces of nature" rebuked both a *lack* of nature's cultivation and an *excess* of its exploitation.[132] Thus, in the Rhineland, Forster remarked that "wood shortages" attributed to the felling of forests—another oeconomic concern he had discussed with Mende—threatened to plunge Europe into "a general revolution."[133] "Are we nearing the highest summit of refinement?" he queried.[134]

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[131] Forster, *Ansichten*, 586, 590: "Wir sahen hier das schönste Rindvieh von der Welt bis an den Bauch in Blumen auf der Weide gehen, so daß einem Deutschen Ökonomen, wie z. B. dem Edlen Herrn vom Kleefelde, das Herz über diese Verschwendung der Grundstücke geblutet hätte. Bald möchte man glauben, daß auf dieser Insel alles, auch selbst das Vieh, im Genusse schwelgen soll…."

[132] Ibid., 591: "…ein gehöriges Gleichgewicht mit den Kräften der Natur in diesem Lande bringen…."

[133] Forster had noted in his journal of 9 July 1784, AA XII, 72: "Es scheint bey so weitläufigem Bergbau im Erzgebirge schwerlich Holz zum Bau genug zu seyn." Joachim Radkau and others have convincingly argued that the perceived wood shortages (*Holznot*) was largely a construct, intended to justify growing state apparatuses and their control of timber resources. See discussion in Chapter 2 of this dissertation, as well as Joachim Radkau, *Wood: A History*, trans. Patrick Camiller (Cambridge: Polity Press, 2012) and Christoph Ernst, *Den Wald entwickeln: Ein Politik- und Konfliktfeld in Hunsrück und Eifel im 18. Jahrhundert* (München: Oldenburg Verlag, 2000).

[134] Forster, *Ansichten*, 169: "Sind wir dem höchsten Gipfel der Verfeinerung nicht nahe? – […] Thöricht wäre es allerdings, eine allgemeine Revolution in Europa die den Zusammensturz politischer, sittlicher und wissenschaftlicher Formen mit sich brächte, im Ernste *nur* vom Holzmangel herzuleiten…. Aber als mitwirkende Ursache kann er immer bestehen, wenn schon das unübersehbare System unserer Kenntnisse ... die Veränderung des Handelssystem, die herannahende Blüthezeit des Amerikanischen Freistaates ... noch ungleich schneller und kräftiger zu jenem Zeile wirken."

Revolution in France posed new challenges to Forster's oeconomic framework, which was closely linked to the paternalistic *Haushalt* ideology of Old Regime rulers. Yet he maintained an overarching faith in industry's moral and political agency. Indeed, Forster came, like Marx, to see industry as an instrument of the bourgeoisie in its struggle against the existing political order. And so he began to invest the industrial arts with the liberal ideals of a new generation, particularly the watchword of German reformers, *Bildung*, even while maintaining the politics of moderation modelled in Gersdorf and Halsbrücke. Grafting the new onto the old, Forster began to see *Bildung* as the product of prudent *Oekonomie*.

Bildung at Work

In March of 1790, Forster set out with the twenty-one-year-old Alexander von Humboldt from Mainz down the Rhine, through the Low Countries, from Amsterdam to England, and back by way of Paris. Chronicled by Forster's *Views of the Lower Rhine* (1791-94), the journey is conventionally known as a cultural and political survey of western Europe. But to capture the spirit of the dawning revolutionary age, Forster also led his protégé through sites of industrious activity—the coal mines of the Rhineland, the bustling wharfs of Amsterdam, the manufactories of Birmingham and Soho.

For young Humboldt, it was to be a *Bildungsreise*, a journey of self-realization. Alexander's elder brother, Wilhelm, said as much in a letter to Forster in early April. "That the good Alexander is your companion gives me endless pleasure," Wilhelm wrote:

> But write me a word on this account, and see to it, when you have the opportunity, to instill in him something of self-possession. […] He appreciates too little what he possesses in so great a mass, and that is knowledge…. I know from personal experience how your handling affects the *Bildung* of your friends.[135]

[135] Wilhelm von Humboldt to Georg Forster, 5 Apr. 1790, AA XVIII, 399-400: "Daß der gute Alexander Ihr Begleiter ist, freut mich unendlich. […] Sagen Sie mir doch ein Wort darüber, und suchen Sie ihm,

Forster agreed with Wilhelm and believed Alexander's intellectual restlessness, emotional volatility, and fragile health were, at heart, a failing of his cultivation. "The body suffers because the spirit is too strained," he wrote of Humboldt the end of their travels in July, "and because his mind has been so taken up by the logical upbringing of Berlin gentlemen."[136]

The concerns that Wilhelm and Forster shared about young Alexander's *Bildung* reflect a formative moment in the very concept of cultivation. Originally used to describe the aesthetic education of young gentlemen, *Bildung*—from *bilden*, "to form"—was re-shaped in the hands of early Romantics as an ideal self-realization that harmonized the development of the individual with that of humankind.[137] In the Jena circle of philosophers whom the brothers Humboldt would join in the mid-1790s, *Bildung* captured the Early Romantic response to the French Revolution. While affirming Enlightenment imperatives of social criticism and freedom of thought, the *Frühromantiker* sought liberty through a holistic rather than mechanistic education, one anchored in idealist rather than rational philosophies.[138] But like the *Aufklärer* before them, the early Romantics understood self-cultivation as part of a civic enterprise, enshrined in public institutions like museums and universities. As Theodore Ziolkowski wrote, "The nineteenth-

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wenn Sie Gelegenheit haben, etwas mehr Selbstzufriedenheit zu geben. […] Er achtet zu wenig, was er in so hohem Maaße besitz, das Wissen, und glaubt von dem, was er eigentlich schätz, philosophischen Kopf, Erfahrung, und Menschkenntniß, weit weniger zu haben, als wahr ist. […] Verziehen Sie, mein Theurer, daß ich so weitläufig über diesen Punkt bin. Aber ich weiß aus eigner Erfahrung, wie Ihr Umgang auf die Bildung Ihrer Freunde wirkt, und mit welchen Eifer Sie daran arbeiten, wenn Sie es für nüzlich halten."

[136] Forster to Christian Gottlob Heyne, 13 July 1790, AA XVI, 156: "Herr von Humboldt, der sich Ihnen bestens empfiehlt, ist bei mir und hat sich die Reise hindurch ziemlich, jedoch nicht so gut, als ich wünschte, gehalten. Er sagt zwar, daß er seit fünf Jahren immer krank sey, und nur unmittelbar nach einer großen Krankheit sich etwas besser befinde, dann aber immer wieder schlechter würde, bis der Ausbruch einer neuen Krankheit…; ich bin aber fest überzeugt, daß bei ihm der Körper leidet, weil der Geist zu thätig ist, und weil die logische Erziehung der Herren Berliner seinen Kopf gar zu sehr mitgenommen hat."

[137] *Bildung* was originally derived from a translation of Anthony Ashley Cooper, the Third Earl of Shaftsbury's *Soliloquy* (1738) and developed in Johann Georg Sulzer's *Bildung des Verstandes und des Urteils* (1745), which Forster read and worshipped about as a young man.

[138] Beiser, *The Romantic Imperative*, 46.

century university"—for which Wilhelm von Humboldt provided early blueprints—"emerged as the institutionalization of Romantic theories of knowledge and *Bildung*."[139]

So, too, the industrial arts were understood as a venue for human cultivation. Forster and Humboldt dined with celebrated actors and philosophers and visited sites of aesthetic allure, like the Cologne Cathedral prized by their *Sturm und Drang* compatriots. But the two also found *Bildung* at work in the commercial life of the Rhineland and its neighboring Low Countries. By late April, Wilhelm's letter on Alexander's *Bildung* would have found Forster and his companion in Amsterdam. There, at the docks of the River Amstel, amidst "the shipyards, depots, and manufactory buildings," Forster recorded the "enchanted movement of the many ships [and] the restless swinging of thousands of windmills all around me." So enchanted was Forster that he began to conceive of reason itself as a grand craft:

> The zeal for profit inspired the first sciences of mathematics, mechanics, physics, astronomy, and geography; Reason incurred a great debt for the labors of her own cultivation [*Ausbildung*]; she knotted distant regions of the world together, conducted the commerce of nations, heaped up the products of various climatic zones—all the while increasing her own fortune of terms and concepts; ever more rapidly their circulation increased, ever sharper their refinement. What new ideas were not manufactured here, came as raw materials to neighboring countries; there they were woven into the mass of knowledge already practically applied, and sooner or later this new product of Reason returns to the banks of the River Amstel.[140]

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[139] Ziolkowski, *German Romanticism*, 13. More recent revisions caution that the direct lineage drawn between modern universities and Wilhelm von Humboldt's ideas about the "unity of teaching and research" is largely a twentieth-century invention, and that Humboldt played a modest role in their institutional development. Consider Martin Eichler, "Die Wahrheit des Muthos Humboldt," *Historische Zeitschrift* 294, no. 1 (2012): 59-78.

[140] Forster, *Ansichten*, 465-66: "Die Stadt mit ihren Werften, Docken, Lagerhäusern und Fabrikgebäuden; das Gewühl des fleißigen Bienenschwarmes längs dem unabsehlichen Ufer, auf den Straßen und den Kanälen; die zauberähnliche Bewegung so vieler segelnden Schiffe und Boote auf dem Südersee und der rastlose Umschwung der Tausende von Windmühlen um mich her—welch' ein unbeschreibliches Leben, welche Grenzenlosigkeit in diesem Anblick! Handel und Schifffahrt umfassen und benutzen zu ihren Zwecken so manche Wissenschaft; aber dankbar bieten sie ihr auch wieder Hülfe zu ihrer Vervollkommnung. Der Eifer der Gewinnsucht schuf die Anfangsgründe der Mathematik, Mechanik, Physik, Astronomie und Geographie; die Vernunft bezahlte mit Wucher die Mühe, die man sich um ihre Ausbildung gab; sie knüpfte ferne Welttheile an einander, führte Nationen zusammen, häufte die Produkte aller verschiedenen Zonen—und immerfort vermehrte sich dabei ihr Reichthum von Begriffen; immer schneller ward ihr Umlauf, immer schärfer ihre Läuterung. Was von neuen Ideen allenfalls nicht

The passage reflects the Enlightened view of intellectual progress as the fruits of imperial expansion and domestic industry. The very idea of cosmopolitanism—or "world-citizenship"—was grounded in a self-aggrandizing *Handelsgeist*, the belief that commerce (i.e. empire) connected disparate lands in a single global economy.[141] To Forster, the union of science, commerce, and cultivation was the crowning achievement of his age.

By the mid-nineteenth century, Germany's educated middle class (or *Bildungsbürgertum*) evoked *Bildung* to distinguish themselves from men of practical rather than humanistic education. Especially during periods of intense industrialization in the second half of the century, the *Bildungsbürger* who dominated state bureaucracies and public debate in Germany regarded engineers and *Techniker* as fundamentally distinct, marked apart by their lack of general cultivation (*Allgemeinbildung*).[142] It is no coincidence that one of Forster's first biographers, Jacob Moleschott, a bourgeois physiologist, found in Forster's depiction of Amsterdam an early iteration of middle-class propriety over both commerce and cultivation. "How the cycle of *Bildung*, propelled by commerce, animated his soul!" Moleschott exclaimed in his 1854, no less animated by the passage.[143]

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hier zur Stelle verarbeitet ward, kam doch als roher Stoff in die benachbarten Länder; dort verwebte man es in die Masse der bereits vorhandenen und angewandten Kenntnisse, und früher oder später kommt das neue Fabrikat der Vernunft an die Ufer der Amstel zurück."

[141] Franz Filafer and Jürgen Osterhammel, "Cosmopolitanism and the German Enlightenment," in *The Oxford Handbook of Modern German History*, ed. Helmut Walser Smith (Cambridge, MA: Cambridge University Press, 2011), 119-43.

[142] Adelheid Voskuhl, "Engineering Philosophy: Theories of Technology, German Idealism, and Social Order in High-Industrial Germany," *Technology and Culture* 57, no. 4 (October 2016): 721-52, esp. 725-725; Ursula Klein, "Science, Industry, and the German *Bildungsbürgertum*," *Annals of Science* 77, no. 3 (2020): 366-76, esp. 376. Norton Wise has recently argued that the educated bourgeoisie who comprised Prussia's mid-century scientific and industrial elite infused technical practice with the aesthetic values of *Bildung*. See Norton Wise, *Aesthetics, Industry, and Science: Hermann von Helmholtz and the Berlin Physical Society* (Chicago: University of Chicago Press, 2018).

[143] Jacob Moleschott, *Georg Forster, Naturforscher des Volks*, 2nd ed. (Frankfurt am Main: Meidinger Sohn, 1857), 263: "Wie lebhaft stand ihm der Kreislauf der Bildung in der Bewegung des Handels vor der Seele!"

Forster's view of intellectual progress—as a collectively "manufactured" product—represents an earlier moment of radical possibility embodied by the concept of *Bildung*. Yet he also anticipated later generations in claiming a privileged view on this "Great Whole" of science and industry. As Forster saw it, the toiling technicians of this great knowledge-manufactory were but "tiny mainsprings in the machine, their labor only piecemeal," while the "wisest among us" are similarly unable to "fathom its workings." It was the prerogative of he who moved between learned and laboring worlds to "endow" the machine "with artistic unity."[144] A year later, Forster made his point more explicit: The "wheels and mainsprings of the old forms have ceased to operate," he wrote of Europe's ruling powers; "the ignorant nobleman … lacks the energy to sustain his usurpation." And so Forster called forth a new caste of social engineers, "the nobler middle class" of which he was a part.[145]

Earlier in April of 1790, while describing the Free Imperial City of Aachen in letters to his wife Theresa Heyne, Forster drew *Bildung* into the purview of the naturalist, positioning himself as a surveyor of moral as well as natural landscapes. "Heritage, climate, mixing with neighboring races, commerce and trade, the influence of the soil and its products"—all these variables, Forster wrote, had a marked effect upon the "physical and moral *Bildung*" of a

[144] Forster, *Ansichten*, 466: "Dies ist mir der Totaleindruck aller dieser unendlich mannigfaltigen, zu Einem Ganzen vereinigten Gegenstände, die vereinzelt und zergliedert so klein und unbedeutend erscheinen. Das Ganze freilich bildet und wirkt sich ins Daseyn aus, ohne daß die Weisesten und Geschäftigsten es sich träumen ließen; sie sind nur kleine Triebfedern in der Maschine und nur Stückwerk ist ihre Arbeit. Das Ganze ist nur da für die Phantasie, die es aus einer gewissen Entfernung unbefangen beobachtet und die größeren Resultate mit künstlerischer Einheit begabt; die allzu große Nähe des besonderen Gegenstandes, worauf die Seele jedes Einzelnen, als auf ihren Zweck, sich concentrirt, verbirgt ihr auch des Ganzen Zusammenhang und Gestalt."

[145] Georg Forster, *Im Anblick des großen Rades: Schriften zur Revolution*, ed., Ralph Rainer Wuthenow (Darmstadt: Herman Luchterhand Verlag, 1981), 228: "Alle Räder und Triebwerke der alten Formen stockten. Der unwissende Adel musste der bessern, edleren Mittelklasse weichen. Er hatte nicht mehr Energie genug, sich in seiner Usurpation zu erhalten."

people.[146] In his *Views* from Aachen, Forster positioned "*Bürger*"—by which he meant private entrepreneurs and bourgeois intellectuals—as the guarantors of a people's cultivation. In this formulation, industry would serve to disseminate *Bildung*. "The state is happy," Forster wrote, "when comprised of citizens whose great undertakings do not just sustain but also nourish the higher cultivation of the mental powers [*höheren Ausbildung der Gemüthskräfte*] of its lesser compatriots."[147]

The textile manufactory in Vaals, several kilometers west of Aachen's city walls, provided the archetype. Its owner Johann Arnold von Clermont, though an aristocrat, was also an advocate of social and economic reform and even served as a member of the provisional government for French-occupied Aachen in 1794-95. Clermont's sprawling industrial complex included needle and cloth manufactories, waulking mills and dying baths, vaulted aqueducts which "supplied sufficient water to each room," and halls full of workers busy carding, spinning, and weaving merino wool imported from Spain—"industry united with science, administration, experience, and integrity," Forster waxed. The motto "*Spero invidiam*" was engraved above the main entrance of the manufactory's grand offices (**Figure 7**)—"I hope to be envied," Forster translated to readers.[148] And so it was.

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[146] Forster to Theresa Forster, 1-2 Apr. 1790, in AA XVI, 49: "Abstamm, Klima, Vermischung mit benachbarten Racen, Verkehr und Handel, Einfluss des Bodens und seiner Erzeugnisse auf die Lebensart, der Lebensart auf die physische und moralische Bildung, der Begriffe und den Sinn, und umgekehrt,—wie viel lässt sich da nicht denken, wodurch in einem gegebenen Zeitraum die merklichsten Veränderungen in den Bewohnern nahegelegener Länder entstehen können."

[147] Forster, *Ansichten*, 162: "Der Staat ist glücklich, wenn er solche Bürger in sich faßt, deren große Unternehmungen nicht nur mit der höheren Ausbildung der Gemüthskräfte seiner geringeren Mitbürger bestehen könne, sondern vielmehr durch dieselbe neue Stätigkeit erhalten."

[148] Forster, *Ansichten*, 158: "Wohin man sieht, erblickt man jetzt große Fabrikgebäude. Außer den eben erwähnten, die dem Wahlspruche: *spero invidiam* (ich hoffe beneidet zu werden), über der Thüre des Wohnhauses ganz entsprechen und zu erkennen geben, was der Fleiß vereinigt mit Wissenschaft, Beurtheilungsgabe, Erfahrung und Rechtschaffenheit, billig erwarten darf, gibt es hier noch andere Tuchmanufakturen, eine Nähnadelfabrik u. s. w. […] So fein ist das Gespinnst, so gleichförmig das Gewebe, so schön die Farbe, so vorsichtig die Bereitung dieser Tücher, daß man bei den soliden

Figure 7. The main office of "Haus Clermont," designed by Milan architect Joseph Moretti and built between 1761 and 1765. Here Forster remarked upon the inscription *Spero invidiam* above the doorway. The inscription is positioned just beneath a clock, which was itself a symbol of the work-discipline administered in large-scale manufactories of the early industrial age. Thus Forster praised the "administration" (*Beurtheilgsgabe*) that made possible the "miraculous precision of textile work" in Vaals. "So fine is the spinning, so uniform the weaving, so beautiful the colors, so careful the preparation of these cloths," Forster waxed, "that one can proclaim, upon these principles, prosperity for years to come." (Forster, *Ansichten*, 158.) Wikimedia Commons.

Forster's *Views* of Vaals echoes the reforming spirit of contemporaries like Johann Heinrich Pestalozzi, the Swiss pedagogue who saw "industry schools" for poor children as a foundation for humanistic education. Forster anticipates even the Welsh textile manufacturer Robert Owen, whose technocratic brand of utopian-socialism materialized in the Scottish industrial settlement of New Lanark in the early nineteenth century. Clermont's complex had no "Institution for the Formation of Character," as at New Lanark and its counterpart in the United States, New Harmony; but Forster believed industry itself might serve as a bridge between manual labor and moral cultivation. In the utopia Forster envisioned, manufactory work was to be coupled with a "theoretical knowledge acquired through expedient instruction and good

Grundsätzen, nach welchen hier verfahren wird, dieser Fabrik einen langen Flor voraus verkündigen kann."

education." Forster was confident, moreover, that while "the despot trembles before the enlightenment of his subjects," the "private man, that is, the manufacturer of a free state, derives his own prosperity from that of his fellow citizens, as from the realization of their intelligence!"[149]

To liberal intellectuals like Forster, industry offered answers to one of the era's most pressing political questions: what was the role of the state in securing the happiness and welfare of its subjects (or "citizens," depending)? Generations of cameralists had defined happiness (*Glückseligkeit*) and welfare (*Gemeinwohl*) as the governing principles of autocratic rulers who served, therefore, as father (*Landesvater*) of the stately household. In the early 1790s, Forster and the elder Humboldt mounted a polemical campaign against the paternalist ideology of German cameralism. They argued that "the deceitful image of *happiness*" had merely served as a pretense for arbitrary rule and despotism.[150] In its place, they developed ideas about innate "human dignity" (*Menschenwürde*) and elevated *Bildung* to a new status as the "supreme social purpose." The role of government was not to provide happiness itself, but to ensure the requisite autonomy for citizens to seek "the highest *Bildung* of which their creative energies are capable."[151]

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[149] Forster, *Ansichten*, 163: "Ganz anders aber verhält es sich, wo Geschicklichkeit und Fleiß, ihres Lohnes sicher, dem, der sie besitzt und anwendet, eine gewissen Grad des Wohlstandes verschaffen, der ihm die Erlangung wenigstens theoretischer Kenntnisse, vermittelst eines zweckmäßigen Unterrichts und einer guten Erziehung, möglich macht. Wie klein und nichtswürdig erscheint nicht ein jeder Despot, der vor der Aufklärung seiner Unterthanen zittert, verglichen mit dem Privatmanne, dem Fabrikanten eines freien Staats, der seinen Wohlstand auf dem Wohlstand seiner Mitbürger und auf ihre vollkommnere Einsicht gründet!"

[150] Georg Forster, "Über die Beziehung der Staatskunst auf das Glück der Menschheit" (1794), in AA X, vol. 1. Cf. Wilhelm von Humboldt, "Wie weit darf sich die Sorgfalt des Staats um das Wohl seiner Bürger erstrecken?" *Neue Thalia* 2 (1792): 131-69.

[151] Hans Frambach, "The Decline of Cameralism in Germany at the Turn of the Nineteenth Century," in *Cameralism in Practice: State Administration and Economy in Early Modern Europe*, eds. Marten Seppel and Keith Tribe (Woodbridge, UK: The Boydell Press, 2017), 239-61, on 247.

Industry and craft are not conventionally regarded as constitutive features of this political philosophy. But they were indeed instrumental to it. Forster's *Views* reflects a genuine, though largely undefined, conviction amongst liberal theorists that "free industry"—as opposed to state paternalism and what he called the "financial speculation of governments"—would promote popular enlightenment, much as reformers of the period saw in "rational agriculture the mark of humanity's transition to civil society."[152] True to the *Handelsgeist* of the cosmopolitans, Forster believed industry was "intimately interconnected" with the "cultivation of the spirit."[153] Wilhelm von Humboldt, who described Vaals as a "paradise," echoed Forster's ideas about industrial enlightenment, supposing free labor would make "artists" of "workmen," "and thereby cultivate their intellectual powers, ennoble their character, and increase their pleasures."[154]

Such expressions, though penned by men who knew nothing of manual labor, are artifacts of a moment in which industry and *Technik* assumed a central role in the learned world of German-speaking Europe. To the mix of bourgeois and noble men who formed that world, many of whom trained at technical academies and served in state-run mines and manufactories, industry came to be seen as a means of nurturing the national community and harnessing the untapped potential of the *Volk*. Writers, poets, and philosophers thus began to glorify miners and artisans while portraying a devotion to "civic life" (*bürgerliches Leben*) as part of the Romantic

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[152] Forster, *Ansichten*, 157: "Ueberall, wo Fabriken nicht das Werk der freien Betriebsamkeit des Bürgers, sondern lediglich Finanzspekulationen der Regierung sind…." Simon Schaffer, "The Earth's Fertility as a Social Fact in Early Modern Britain," in *Nature and Society in Historical Context*, eds. Mikuláš Teich, Roy Porter, and Bo Gustafsson (Cambridge: Cambridge University Press, 1997), 124-47, on 141.

[153] Forster, *Ansichten*, 159: "Das Phänomen des fortwährenden Austausches verschiedener Produkte der Natur und der Kunst gegen einander ist aber unstreitig desto wichtiger, weil die Ausbildung des Geistes so innig damit verbunden ist. Der Handel bleibt die Hauptursache von dem jetzigen Zustande unserer wissenschaftlichen und politischen Verfassungen."

[154] Humboldt, "Wie weit darf sich die Sorgfalt des Staats…," 90-91: "So ließen sich vielleicht aus allen Bauern und Handwerkern *Künstler* bilden, d. h. Menschen, die ihr Gewerbe um ihres Gewerbes willen liebten, durch eigen gelenkte Kraft und eigne Erfindsamkeit verbessern, und dadurch ihre intellektuellen Kräfte kultivierten, ihren Charakter veredelten, ihre Genüsse erhöhten."

project. "Now I live entirely for *Technik*," wrote Friedrich von Hardenberg—known in literary circles under the *nom de plume* Novalis—after graduating from the Mining Academy in Freiberg. He continued, in a letter to the writer Caroline Schlegel, to describe his "mercantile plan": "one must build a poëtic world around one's self," he wrote, "and live in poësy."[155] In what follows we turn to Julie von Bechtolsheim's own efforts to build a poetic world. The vision of industry to which Forster gave expression in the early years of the French Revolution, Bechtolsheim gave form in a Europe torn asunder by the decades of warfare that ensued.

Building a Poetic World

For Bechtolsheim, too, art, industry, and social reform cohered in a single enterprise. The philosophical blueprints for Eisenach's Industry School can be found in a series of poems penned in 1810, which were themselves a response to the social upheaval and bloodletting of the Napoleonic Era. By this time, at the age of fifty-nine, Bechtolsheim had lost her husband and three sons to warfare and the typhus epidemic that accompanied it. Bechtolsheim was once a celebrated salonnière who hosted the likes of Johann Wolfgang von Goethe, Germaine de Staël, and the Duke and Duchess of Saxe-Weimar-Eisenach at her neo-classical Palais am Jakobsplan. Now, she began to use her pen and high connections to spread a particular conception of charity: what she called "beautiful industry."

[155] Friedrich von Hardenberg to Caroline Schlegel, 20 Jan. 1799, in *Novalis Schriften*, *Tagebücher, Briefwechsel, Zeitgenösische Zeugnisse*, vol. 4, eds. Richard Samuel, Hans-Joachim Mähl, and Gerhard Schulz (Stuttgart: Verlag W. Kohlhammer, 1975), 131: "Jezt leb ich ganz in der *Technik*, weil meine Lehrjahre zu Ende gehn, und mir das bürgerliche Leben mit manchen Anforderung immer näher tritt. Für künftige Pläne sammle ich nur jezt und gedenke vielleicht diesen Sommer manches Angefangne oder Entwordne zu vollenden. Die Poësie mit lebendigen Kräften, mit Menschen, und sonst gefällt mir immer mehr. Man muß eine poëtische Welt um sich her bilden und in der *Poësie* leben. Hieher gehört mein mercantilischer Plan." Schlegel chided Hardenberg for his ideas about "mercantile genius": Caroline Schlegel to Friedrich von Hardenberg, 4 Feb. 1799, in ibid., 518: "Ob Sie mich gleich mit Ihren Dithyramben über das mercantilische Genie, das uns fehlt…."

Bechtolsheim advocated a maternal *Haushalts*-ideal. Through poems addressed to duchesses and princesses, she conceived of "noble domesticity" and "tender motherly love" not as virtues confined to one's immediate family or household unit, but rather as part of a civic project that promoted "the happiness of humanity."[156] To do this, she drew upon the collective memory of Elizabeth of Thuringia (or Elizabeth of Hungary), a thirteenth-century princess who, widowed at the age of 20, managed to regain her dowry to build a hospital and thus became an enduring symbol of charity (**Figure 8**). She was said to have cared for the ill and spun wool for the poor at the Wartburg Castle that stands atop a precipice 200 meters above Eisenach, within sight of the Palais am Jakobsplan. As Bechtolsheim wrote under the guise of "a mountain dweller," it was atop the Wartburg:

> Where, ensouled by divine mercy
> Charity gained the greatest luster;
> Elizabeth, the mother of the poor,
> Escaped the vain dance of life.[157]

Harkening to medieval mythology, Bechtolsheim implored noblewomen to see "the people" as their own. This blend of liberal and conservative languages was characteristic of the republican Baroness. "The people's voice"—*vox populi*, as Bechtolsheim added in a footnote—"which is guided by love, | Is also God's voice, which blesses you."[158]

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[156] [Julie von Bechtolsheim], "Abschiedsworte einer Bergbewohnerin an DIE NEU-VERMÄHLTE im Julius 1810," in GSA 20/129, Bestand Jakob Friedrich von Fritsch (unnumbered): "Die goldnen Fäden edler Häuslichkeit; | So winkelt Dir im grössern Wirkungskreise | Bedeutungsvolle schöne Thätigkeit, | Und still im Herzen wird Dir ewig lohnen | Das Selbstgefühl mit seinen reichen Kronen. […] Wie rühren treu pflegst Du die schönste Blume, | Aus Aether-Stoff, durchglüht vom Sonnenblick— | Geschlechtern wichtig wie dem Frauenruhme | Ist ihrem Kelch vertraut der Menschheit Glück; | Die Frucht gehört der Tugend Heiligthume | Und, treu gepflegt, tritt sie nie zurück— | *Der* Blum' entstammen alle schöne Triebe, | Ihr Name heisst: die *zarte Mutterliebe*."

[157] Bechtolsheim's phrase "eine Bergbewohnerin" recalls the title of a weekly journal published by Marianne Ehrmann between 1793 and 1795, *Die Einsiedlerinn aus den Alpen* (*The Woman Hermit from the Alps*), which was "dedicated to Germany's daughters," another phrase Bechtolsheim commonly used. See further discussion in Chapter 4.

[158] Bechtolsheim, "Abschiedsworte": "Wo tief beseelt von göttlichem Erbarmen | Wohlthäthigkeit erwarb den höchsten Glanz; | Elisabeth, die Mutter aller Armen, | Hier oft entrann dem eiteln Lebenstanz—."

Figure 8. "St. Elizabeth spinning wool for the poor" by Marianne Stokes (1895). Wikimedia Commons. So invested in St. Elizabeth's mythology was Bechtolsheim that she orchestrated a festive visit in 1816, complete with songs of the "Minnesänger" and troubadours. The guest of honor was also named Elizabeth. A description of the event, published in the *Journal für Luxus und Mode* (January 1816): 21-27, was titled "Apparition of the Holy Elizabeth atop the Wartburg in Eisenach." The articles praises "the inventor of the entire scene and the author of the stanzas, which the holy Elizabeth allegorized, the Frau Privy Counselor Julie Baroness v. Bechtolsheim" (ibid., 26).

Bechtolsheim's own charitable enterprise was sparked by the explosion of a black powder store in Eisenach's central market, accidently ignited while being transported through the city by occupying French forces. According to contemporary accounts, the explosion, which occurred on 1 September 1810—the day Bechtolsheim's husband died a year earlier—decimated twenty-four houses, killed at least sixty-eight, and wounded many hundreds more.

"Des Volkes Stimme, *) welche Liebe leitet, | Ist Gottes Stimme, die Dir Segen deutet. […] *) vox populi, vox Dei."

"Eyewitnesses" spoke of "half-burnt corpses of humans and animals" and limbs "scattered in the streets." Some claimed to hear the explosion as far as Erfurt, some fifty-five kilometers away.[159]

In response to the conflagration, Bechtolsheim published a 44-page poem, which was written rather more as prophecy than eulogy. She called upon "sublime persons and the generous humanity of all estates" to bring about the city's "rebirth." In the drama's second part—"The Funeral Rites"—Bechtolsheim blended real and mythical elements, as well as Christian and Classical themes. In a "hall of cypress trees" all members of society gathered—the "savant," the "administrator," the "burgher"—the men to one side, the women to the other, as "white-clad boys" burned frankincense atop the "sacrificial altar" and "white-clad girls" scattered flowers over the ashes. "The music inclines again towards a gentle adagio," Bechtolsheim narrates, as the so-called "Principal" (*Vorsteher*) addresses the townspeople:

> To rouse beautiful industry
> This is the noblest science;
> Each thinks, each does
> As though another's fate was his own,
> And a dignified peace resides,
> Here in the lap of our valley![160]

In response, the "Choir of the People" echoed the Principal's solemn oath, sanctifying Bechtolsheim's own communitarian ideal. "The goal is the *well-being of the whole*," spoke the "Superior One": "Your numbers are few, but in unity | Your powers quickly accrue."[161]

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[159] Bechtolsheim, *Der erste September*, 2: "Als dieser Wagen auf den Markt ankam entzündete er sich und flog mit einem schrecklichen Schlag, den man bis Erfurt 12 Stunden weit, hörte, in die Luft. […] Hier fehlt ein Kind, dort ein Bruder, da der Vater, hier wieder ist eine ganze Familie unter dem Schutt vergraben; dort liegen verstümmelte, halb verbrannte Leichname von Menschen und Thieren…."

[160] Bechtolsheim, *Der erste September*, 43: "Schöne Thätigkeit zu wecken | Sey des Edlen Wissenschaft; | Jeder denke, jeder thue | Als erwart' ihn gleiches Loos, | Und ein holder Frieden ruhe, | Hier, in unsers Thales Schoos!"

[161] Bechtolsheim, *Der erste September*, 36: "Klein ist eure Zahl, doch Einheit | Sammelt leicht der Kräfte viel | Zu dem Brennpunkt goldner Reinheit, | Die uns führt zum höchsten Ziel | Dieses Ziel ist *Wohl des Ganzen*."

Thereafter, the townspeople slipped back into the realm of reality, marching "solemnly" to the site of the explosion, where the city would soon rejuvenate through "industry and diligence," much "as dead matter is divinely ensouled."[162]

Over the next seven years, Bechtolsheim dedicated herself to the realization of this industrious utopia, participating in various charitable projects before positioning herself as "First Principal" (*erste Vorsteherin*) of the Eisenach Women's Association.[163] Though Bechtolsheim publicized plans for the Association in an 1814 letter entitled "A Word to the Heart," the organization did not find sufficient funds until 1817, when it was incorporated into the charitable network overseen and, for the most part, financed by the Grand Duchess in Weimar, Maria Pawlowna. Bechtolsheim then added the Industry School for Girls (specifically middle- and lower-class girls and unemployed domestic servants), which grew from 26 to 86 students in its first two years. Composed of four local branches, the Eisenach Association was in a constant state of evolution, adding soup kitchens, gardens, and tree nurseries, all the while maintaining a primary focus on textile production in its Spinning Institute.[164]

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[162] Bechtolsheim, *Der erste September*, 28-29: "Ein Denkmal herrlicher Wohlthätigkeit. | Denn schöpferisch beseelt das stumpfe Leben | Der holde Geist der edlern Menschlichkeit, | Er fühlt, und theilt, und lindert die Beschwerden, | Und zeigt das Bild der Gottheit hier auf erden." A note added to these pages explains: "Wirklich ist nicht ohne Grund zu hoffen, daß durch die Nothwendigkeit der Schaden-Ausbesserung und des Aufbauens neuer Häuser, welche Betriebsamkeit und Fleiß erregen und einen stärkern Geldumlauf veranlassen wird, die arbeitsamen Klassen des Volks, dem es leider sehr an Nahrungszweigen gebrach, sich wieder emporheben und einen erneuerten Wohlstand für sie aufblühen sehen werden. Die ansehnlichen Beyträge welche erhabene Personen und großmüthige Menschenfreunde aller Stände den Verunglückten dieser schönen Wiedergeburt um vieles beschleunigen."

[163] The spinning institute might be compared with the spaces identified by Nicole Pole as sites of utopian imagination amongst women writers of the seventeenth and eighteenth century. See Nicole Pohl, *Women, Space and Utopia 1600-1800* (Burlington, VT: Ashgate, 2006). Compare also Alessa Johns, *Women's Utopias of the Eighteenth Century* (Urbana, IL: University of Illinois Press, 2003).

[164] Reder, *Frauenbewegung*, 284-306; Schmidt, *Julie von Bechtolsheim*, 164-72.

Bechtolsheim's regular reports to the Grand Duchess reflect needlework's traditional association with morality.[165] But in these letters, the virtues of spinning and weaving are not strictly bound to domesticity. The very nature of the Industry School—led and composed entirely of women and girls—made small-scale textile work visible in a manner that contrasted starkly with needlework's usual confinement to home and hearth.[166] The Industry School can therefore be seen as a third space between the household (the traditional site of "proto-industrial" production) and the factory (the emerging site of mechanized manufacturing), which drew the personal qualities of "women's work" into a civic and self-consciously "patriotic" project.[167] Where the Association initially aimed to clothe soldiers fighting the "Wars of Liberation" against Napoleon's Grand Armée, it evolved, after Napoleon's defeat, into an enterprise in its own right. While the School placed some of its eldest and most skilled pupils in local textile factories, it trained those who did not marry to serve as spinning instructors to incoming cohorts.

Among the School's first full-time instructors was "Madame Grambow," whom they selected not only because she "gives the most precise instruction in flax spinning [and] sees to the condition of the spinning wheels and purchasing of flax with true circumspection," but also because her "example is good encouragement for others who now seem to want to do something significant."[168] To assist Grambow, "older schoolgirls" were selected and specially trained in

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[165] See Daryl M. Hafter, "Introduction: A Theoretical Framework for Women's Work in Forming the Industrial Revolution," in *European Women and Preindustrial Craft*, ed. Daryl M. Hafter (Bloomington and Indianapolis: Indiana University Press, 1995).

[166] For studies of the (in)visibility of gendered textile work, see Mary Harris, *Common Threads: Women, Mathematics and Work* (London: Trentham Books, 1997) and Kathy M'Closkey, "'Trading is a White Man's Game': The Politics of Appropriation: The Lessons from Navajo Women's Weaving," in *Ethnographic Feminisms: Essays in Anthropology*, eds. Sally Cole and Lynne Phillips (Ottawa: Carleton University Press, 1995), 97-118.

[167] Bechtolsheim, "Ein Wort an's Herz," THsaW, ZD 1, Bl. 1-3.

[168] "Unterthängister Vortrag," 24 Sept. 1823, THsaW, ZD 296, Bl. 78: "An Madame Grambow scheinen wir einen treflichen Gewinn für unser Institut erhalten zu haben. …die gute Frau geht Nachmittags täglich in die Schule wo sie an sechs andere Mädchen im Flachsspinnen den genauesten Unterricht gibt,

using, cleaning, and maintaining the School's spinning wheels. When Grambow's health began to fail, she prepared an elder student, one "Sülzeern," to succeed her. Sülzeern had already "learned to spin a truly beautiful and fine thread." But like Grambow, she was selected primarily because "she is very moral and good, and, when she is a grown adult and becomes an instructor, she will impress this upon the pupils."[169] Sülzeern's case also shows how the Association's local branches began to specialize in various aspects of textile production. Before her appointment as instructor in Eisenach, Sülzeern was sent on a "journey to Langsfeld" (presumably Stadtlengsfeld in Thuringia) to learn the complexities of "flax preparation": "retting" stalks to loosen their fibers, breaking off the dry core (or "boon") of the flax, aligning the remaining fibers through the process of "scutching" and "hackling," and producing silvery, hair-like fibers with which to dress the distaff that is, finally, fixed upon the spinning wheel.[170]

Bechtolsheim walked a fine line between the promoting the civic virtues of "women's work" and tempering the perceived moral threat of factory work.[171] Onlookers in Eisenach sometimes criticized the Industry School itself as a mere "work-house." "[O]ne often hears the complaint in public," Bechtolsheim wrote, "that in the so-called Industry School girls cannot be

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bekümmert sich selbst um die Beschaffenheit der Räder um den Einkauf des Flachses mit wahrer Umsicht…. Zugleich ist ihr Beyspiel eine gute Aufmunterung für Andere welche wirklich zu wünschen scheinen jetzt auch etwas Wesentliches zu leisten." Records suggest Madame Grambow was of middle-class standing, being married to a court solicitor in Eisenach.

[169] "Unterthänigster Bericht," 29 Dec. 1823, THsaW, ZD 296, Bl. 106, 108: "Die junge Sülzeerin, die auch Ew. Kaiserlichen Hoheit Befehl nach Lengsfeld geschieht wurde, hat daselbst recht hübsch die feine Spinnerey erlernt." "[S]ie ist bis jetzt noch recht sittlich und gut, und wird wann sie erst ganz erwachsen ist der Schule als Lehrerin mehr imponiern."

[170] On the technical aspects of pre-modern spinning and weaving in Germany, see Almut Bohnsack, *Spinnen und Weben: Entwicklung von Technik und Arbeit im Textilgewerbe* (Hamburg: Rowohlt, 1981), esp. 151-183.

[171] By the late-nineteenth century, many Germans feared that women's presence in factories signaled the demise of the family, and thus of society. See Kathleen Canning, *Languages of Labor and Gender: Female Factory Work in Germany, 1850-1914* (Ithaca, NY: Cornell University Press, 1996).

made into anything more than stocking-hands," that is, unskilled laborers.[172] But records suggest the School's instructors and pupils understood themselves as markedly distinct from factory workers. In May 1818, Bechtolsheim described the "touching sight" of a pupil's departure from the School to a local factory.[173] "Gushing tears" and reluctant to leave, the pupil departed only at the "admonition of the Principals" and the "wishes of her sisters." "We saw in her a soul that had torn itself from vice," Bechtolsheim noted of this "best and most applied" of pupils, as though morally fortified for a new life in the factory.[174] In fact, Bechtolsheim reported that Sülzeern's time working in local factories had "diminished the love and trust that the other girls felt towards her, as well as her reputation as an instructor."[175]

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[172] "Unterthänigster Bericht," 8 Apr. 1820, THsaW, ZD 294, Bl. 166: "…im Publikum oft die Klage verlautet daß man in der sogenannten Industrie-Schule nicht anders als Strümpfe-Handen pp gemacht bekommen könnte…."

[173] Dirk Reder noted that the Association's leaders preferred to keep pupils in the School rather than see them off to factories, but that factory wages ultimately drew the elder girls away and lowered the School's average age throughout the 1820s. (Reder, *Frauenbewegung*, 299.)

[174] "Unterthänigster Bericht," 6 May 1818, THsaW, ZD 294, Bl. 31: "Einige Schülerinnen sind zur hiesigen Spinnfabrik übergegangen, zwey sind als Dienstmädchen entlaßen und jede mit doppelten Anzügen beschenkt worden. Es war heute ein wirklich rührender Anblick wie die beste davon unter den Vermahnungen der Vorsteherinnen, den Wünschen ihrer Mitschwestern und ihrem eignen Thränenerguß Abschied nahm. Sie ist die größte und hübschste auch gewandteste aus unsrer Anstalt und wir sahen in ihr eine dem Laster entrißene Seele welches unsere Heiligen doppelt erregt."

[175] "Unterthänigster Bericht," 29 Dec. 1823, THsaW, ZD 296: 108: "daß die Sülzeern eigentlich nicht mehr in der Schule war, sondern diese aus Nachgiebigkeit gegen ihre Verwandten verlaßen hatte um in den hiesigen Fabriken zu arbeiten, welches die Liebe und das Zutrauen der andern Mädchen zu ihr verminderte, und ihrem Ansehen als Lehrerin Abbruch thun könnte." Bechtolsheim also expressed her concern that because Sülzeern was "very beautiful," she might soon marry and leave the School without an instructor: "…ist sie sehr hübsch und vielleicht dadurch Nachstellungen oder auch rechtlichen Bewerbungen mehr als andere ausgesetzt wodurch wir vielleicht Gefahr liefen sie bald zu verlieren." Records suggest it was indeed primarily unmarried women who served as instructors in the School, as in "Ew. Kaiserlichen Hoheit," 9-12 Mar. 1817, THsaW, ZD 293, Bl. 90: "Außerdem haben sich 19 unverheyrathete Frauenzimmer, deren Nahmen einmal eingesendet werden sollen wenn sie sich erst bewährt erfunden haben werden, und eine junge Frau erboten, die Schule Reihenweise zu besuchen und selbst Unterricht darinnen zu ertheilen."

The Needle and the Pen

While pupils' views of textile work remain elusive within the Association's records, Bechtolsheim's own ambitions for the School become clearer within the wider context of her aspirations as a poet and an advocate of women writers.[176] The literary critic Elaine Hedges once characterized the dilemma faced by female protagonists in nineteenth-century fiction as a choice between "the needle or the pen," that is, between the confines of domestic life or the freedoms of the public sphere.[177] Bechtolsheim's case bridges the dichotomy: for her, the needle was a pen.[178] As Maureen Daily Goggin argued, "the powerful ideological construct of needlework as 'women's work,' and all that term has come to mean and the pejorative baggage it carries, obscures the richness of this practice as potent rhetorical tool."[179] Bechtolsheim's efforts to establish an industrious role for women and girls in the life of the nation was bound up in her efforts to carve out a space for women intellectuals in German culture.

As a young salonnière in the 1780s and 90s, Bechtolsheim made no such claims to intellectual authority. On the contrary, when told by the Weimar literary giant Christoph Martin Wieland that she was "no poet," Bechtolsheim resigned herself to what she called "an epistle tone blended with a superficial philosophy of life." Wieland's harsh judgment of Bechtolsheim's

[176] For a micro-historical study of a linen producing community that does draw out the daily practices and beliefs of pre-industrial textile workers in the eighteenth and nineteenth centuries, see Hans Medick, *Weben und Überleben in Leichingen, 1650-1900: Lokalgeschichte als Allgemeine Geschichte* (Göttingen: Vandenhoeck & Ruprecht, 1997).
[177] Elaine Hedges, "The Needle of the Pen: The Literary Rediscovery of Women's Textile Work," in *Tradition and the Talents of Women*, ed. Florence Howe (Urbana, IL: University of Illinois Press, 1991), 338-64.
[178] See Heather Pristash et al., "The Needle as the Pen: Intentionality, Needlework, and the Production of Alternative Discourses of Power," in *Women and the Material Culture of Needlework and Textiles, 1750-1950*, eds. Maureen Daly Goggin and Beth Fowkes Tobin, 13-29 (London: Routledge, 2016). Compare also Laurel Thatcher Ulrich, *The Age of Homespun: Objects and Stories in the Creation of an American Myth* (New York: Vintage Books, 2001).
[179] Maureen Daly Goggin, "An *Essamplaire Essai* on the Rhetoricity of Needlework Sampler-Making: A Contribution to Theorizing and Historicizing Rhetorical Praxis," *Rhetoric Review* 21, no. 4 (2002): 309-38, on 312.

poetry was not entirely based upon her sex. In fact, he compared her supposed "lack of interior matter" to the intellectual depth of other contemporary female writers, like Caroline Rudolphi, whom he believed capable of true poetry.[180] Bechtolsheim was aghast—"devoid of thoughts! …you counsel me like Hamlet to Ophelia: to the convent with you!" Yet she also embraced her reputation as a muse, called "Psyche" in a poem by Wieland and "Little Soul" (*Seelchen*) in another by Goethe.[181]

Bechtolsheim thus minimized her own literary aspirations in these years, describing her poetry, like her needlework, as a pastime of "domestic joy." This attitude is reflected in contemporary representations of Bechtolsheim as a muse playing a harp or a housewife knitting (**Figure 9**). Writing to the Weimar publisher Friedrich Justin Bertuch in 1784, Bechtolsheim described her "cabinet" within the Palais as a place "where I collect my thoughts, manage accounts, work on my embroidery, or write letters and occasionally think up little rhymes."[182]

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[180] Like Bechtolsheim, Caroline Rudolphi would turn from poet to social reformer. Her *Gemälde weiblicher Erziehung*, published thirteen years later in 1807, described natural inquiry as integral to girls' education and upbringing. As Denise Phillips observed of the text, "Girls botanized on their walks and in the garden. A thunderstorm offered their guardian an opportunity to discuss electricity." However, Rudolphi also maintained that women ought not conduct research by themselves. See Phillips, *Acolytes of Nature*, 153-56.

[181] Bechtolsheim to Wieland, 2 Jan. 1794, in SLUB, H. 43, Bd. 9, Bl. 18: "kurz, ich sey—keine Dichterin… […] Mangel an innerem Gehalt. Also ... Gedanken-Leere! lieber Wieland das ist ja ganz abscheulich! arme Psyche! ich rathe Dir's wie Hamlet der Ophelia: geh in's Kloster." Ibid., Bl. 19: "Allein mein Fach ist nicht Darstellungen von Scenen der Natur, sondern die leichtere flüchtige Poesie von der ich obenhin sprach, und der Epistel Ton mit einem bisher oberflächlichen Philosophie des Lebens vermischt."

[182] Bechtolsheim to Friedrich Justin Bertuch, 1784, in GSA 06/100, Bestand Friedrich Justin Bertuch, Bl. 3: "In meinem eigenen Cäbinet wo ich meine Gedanken samle, Rechnungen führe, an meinem Stickerey Rahmen sitze, oder Briefe schreibe und hie und da Reimchen hasche, brennt ohne Glanz und Anmuth ein einziges mattes Lämpchen, aber der Geist meiner Freude umweht mich." Bechtolsheim's letters to Bertuch span four decades, during which they shared a close friendship. Bertuch published the *Journal des Luxus und der Moden*, where Bechtolsheim published her writings, and co-founded the Drawing School in Weimar where Bechtolsheim took classes as a young woman. Later in life, Bechtolsheim frequently sought Bertuch's advice in another passion: gardening and tree husbandry.

Figure 9. Silhouette of Bechtolsheim, ca. 1780, by Johann Wilhelm Wendt, courtesy of the Goethehaus Frankfurt. Bechtolsheim, then twenty-nine years old, is depicted before an umbrella swift winding yarn into a ball for knitting. 22.0 x 14.6 cm. © Freies Deutsches Hochstift, Frankfurter Goethe-Museum.

After the turn of the century, however, Bechtolsheim struck a different tone as she endeavored to define the unique qualities of the "female pen." Literary genres were already rigidly gendered in Bechtolsheim's day: drama and the novel were generally coded male and letter-writing female while poetry cut across the sexes.[183] Some women openly defied these boundaries in novels like Dorothea Schlegel's *Florentin* (1801) and Charlotte von Stein's *Die Zwey Emilien* (1805). Bechtolsheim favored the hybrid genre of dramatic verse—a small revolt in its own right; and she preferred to work with, rather than overtly challenge, existing stereotypes about femininity. In a letter to Friedrich Schiller, which conveyed her tragic ballad about a woman's suicidal "Leap from the Cliffs," Bechtolsheim argued that while "frightful images of remorse and despair" ought to "be painted by Man," "strokes of the finer sentiments, be it pain, self-denial, higher ideals of love etc.," belonged to women:

> This love shall lead to suicide—it must therefore walk along the border of madness, a friendly madness that does not unhinge the strength of the soul…. It is this fine borderline that I have wished to portray; but my ideal shall not be read as poutiness, it does not express a sentimental illness, rather this ideal is hearty and powerful, tender and protective of one's own love, surrendering only to death.[184]

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[183] See Astrid Weigert, "Gender and Genre in the Works of German Romantic Women Writers," in *Oxford Handbook of European Romanticism*, ed. Paul Hamilton (Oxford, UK: Oxford University Press, 2016), 240-55; Suzanne Zantop, "Trivial Pursuits? An Introduction to German Women's Writing from the Middle Ages to 1830," in *Bitter Healing: German Women Writers 1700-1830*, eds. Jeannine Blackwell and Susanne Zantop (Lincoln, NE: University of Nebraska Press, 1990), 9-50; Lorely French, *German Women as Letter Writers: 1750-1850* (Cranbury, NJ: Associated University Presses, 1996).

[184] Bechtolsheim to Schiller, 27 Mar. 1805, GSA 83/194: "Schreckbilder der Reue und Verzweiflung gehören nicht für einen weiblichen Pinsel: die stärkeren Tinten des Mannes müßen sie ausmalen, und nur die Kraft des hohen Künstlers kann sie glücklich benutzen. Züge der feinern Empfindung hingegen, sey es Schmerz, SelbstVerläugnung, hohe idealische Liebe p p könen uns gelingen wenn wir anders einige Darstellungsgabe besitzen. […] Diese Liebe sollte zum Selbstmorde führen—sie mußte also an Wahnsinn gränzen aber an einen freundlichen der die Seelenkräfte nicht zerrüttet sondern nur *eine* der zarten Seiten des innern Wesens verstimmt. Diese feine Gränzlinie habe ich zeichnen wollen; dabey sollte mein Ideal nicht weinerlich seyn, keine sentimentalische Kränklichkeit äußern, sondern hochherzig und kraftvoll, zärtlich und den Geliebten schonend, sich dem Tode Preis geben." The ballad "Der Sprung von Felsen" was first published in the *Journal für deutsche Frauen* (February 1806): 61–67, which Schiller edited. When Schiller died, Bechtolsheim's eulogy nodded to his appreciation for women writers with references to "Germaniens Töchter." See "Blumen auf Schillers Grab," THsaW, Großherzogliches Hausarchiv A XXV, Nr. 1067, Blatt 85. Where Wieland said she was no poet, Bechtolsheim told Schiller: "ich glaube Sie hätten mich zur Dichterin entflammt." Bechtolsheim also referred Schiller's theory of an "aesthetic

Bechtolsheim's letter to Schiller reflects the efforts of many writers of the period to creatively reconceive female-gendered traits—sentimentality, tenderness, even madness, the very antithesis of masculine *Vernunft*—in order to construct a positive intellectual role for themselves within the cultures of Enlightenment and Romanticism.[185]

Bechtolsheim took a similar approach in defining a civic space for women's textile work. Like Forster, she envisioned a vaguely defined "higher cultivation" through material production. But Forster's brand of industrial *Bildung* was implicitly masculine; and while Bechtolsheim occasionally employed the same concept in her Industry School for Girls, along with other male-coded terms, she also articulated a sort of self-cultivation specific to "women's work." Such was the fine line Bechtolsheim walked while simultaneously utilizing and defying the gendered norms of her time. If Wilhelm von Humboldt dreamt of workmen become artists, Bechtolsheim told the Grand Duchess of her intent "to cultivate skilled masters [*Meisterinnen*] in all fine feminine work."[186] In this, Bechtolsheim joined a minority of educational reformers who

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state" in her letter of 1805 by expressing a desire to live in an "aesthetischen Kultur." (See Friedrich Schiller, *Über die ästhetische Erziehung des Menschen*, originally published in a series of letters in the journal *Die Horen* (Tübingen: Cotta, 1795). For Schiller, the "aesthetic state" is that which promotes the freedom required for individuals to harmonize their own aspirations with the development of the whole, and which ostensibly scorns privilege and aristocracy. In their common philosophy of civil freedom as the bedrock of intellectual cultivation, Schiller, Bechtolsheim, Forster, and the brothers Humboldt belong to a common philosophical camp.

[185] Bechtolsheim's 1805 letter to Schiller strikes what Mary Terrall has described as a "self-denigrating posture of humility," a deferential attitude towards men that can sometimes be read as a strategic effort to carve out a space for one's own legitimacy. See Mary Terrall, "Émilie Du Châtelet and the Gendering of Science," *History of Science* 33, no. 3 (Sept. 1995): 283-310. On women writers in German Romanticism, see Marjanne E. Goozé, ed., *Challenging Separate Spheres: Female Bildung in Eighteenth and Nineteenth-Century Germany* (Bern: Peter Lang, 2007). Foucault famously argued that Enlightenment needed the antithesis "un-reason" in order to define itself as the Age of Reason. (Michel Foucault, *Madness and Civilization: A History of Insanity in the Age of Reason* (New York: Vintage Books, 1988).

[186] "Unterthänigster Bericht," 8 Apr. 1820, THsaW, ZD 294, Bl. 166: "…in allen feinen weiblichen Arbeiten so geschickten Meisterin sich vollkommen auszubilden, und diese künstlichen Arbeiten dann wieder einigen Mädchen in der Schule zu lehren, die im Strumpfstricken und Hemd-Nähen hinlänglich geübt, eine höhere Ausbildung in weiblichen Arbeiten fähig wären, und dadurch der Schule einen neuen Erwerbzweig gewönnen würden so wie es in einigen Schulen des Eisenach-Oberlandes der Fall ist."

believed women ought to have equal access to Enlightenment ideals of self-improvement. At the same time, she echoed a more mainstream position, particularly amongst Romantics, that women's intellectual abilities were more innate or "natural" than actively learned.[187]

It was not *Bildung*, therefore, that Bechtolsheim stressed amongst her pupils, but *Beseligung*, animation or ensoulment. Amongst women writers of Bechtolsheim's generation, the soul—and particularly the ideal of the Beautiful Soul (*die schöne Seele*)—had become integral to efforts at conceiving of a female *Bildungsroman*.[188] Denied the male protagonist's freedom of movement within society, the Beautiful Soul allowed women writers to pursue self-cultivation within the constraints of conventional roles as wives or virtuous victims. Through such plot-lines women represented—and protested—their own limitations in society.[189] Ensoulment is a defining feature of Bechtolsheim's poetic oeuvre, much of which was, as she wrote, "dedicated to my German sisters."[190] Often Bechtolsheim used the verb *beseelen* to

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[187] Silvia Bovenschen, *Die imaginierte Weiblichkeit: Exemplarische Untersuchungen zu kulturgeschichtlichen und literarischen Präsentationsformen des Weiblichen* (Frankfurt am Main: Suhrkamp, 1979), 17-18; Peter Petschauer, *The Education of Women in Eighteenth-Century Germany: New Directions from the German Female Perspective* (Lewiston, NY: Edwin Mellen, 1989), 50-51, 282.
[188] Suzanne Zantop, "The Beautiful Soul Writes Herself: Friederike Helene Unger and the 'Große Göthe'," in *In the Shadow of Olympus: German Women Writers Around 1800*, eds. Katherine R. Goodman and Edith Waldstein (Albany, NY: State University of New York Press, 1992), 29-52. On women and *Bildung*, see Marjanne E. Goozé, "Challenging Separate Spheres: Female *Bildung* in Eighteenth- and Nineteenth-Century Germany – An Introduction," in *Challenging Separate Spheres*, ed. Marjanne E. Goozé, 11-31; Christina K. Lindemann, *Representing Duchess Anna Amalia's Bildung: A Visual Metamorphosis in Portraiture from Political to Personal in Eighteenth-Century Germany* (New York: Routledge, 2017). The view that *Bildung*, as defined by theorists like Wilhelm von Humboldt, was inherently male-gendered is challenged in Simon Richter, "Weimar Heteroclassicism: Wilhelm von Humboldt, Caroline von Wolzogen, and the Aesthetics of Gender," *Publications of the English Goethe Society* 81, no. 3 (2012): 137-151.
[189] In the case of Bechtolsheim's "Leap from the Cliffs," for instance, suicide is the inevitable and virtuous consequence of the heroine's mistreatment by "the false man." Bechtolsheim to Schiller, 27 March 1805, GSA 83/194: "Liebe? Leben? alles ist zerronnen, | Jede Wonne aus der Brust gescherzt: | Der falsche Mann hat mir das Herz umsponnen— | Hinab! daß ihn kein Meineid schmerzt."
[190] Bechtolsheim once titled an essay "Meine Gefühle über weibliche Verhältnisse, meinen deutschen Mitschwestern gewidmet." (Bechtolsheim to Wieland, 2 Jan. 1794, in SLUB, H. 43, Bd. 9, Bl. 22.) In her poetry she spoke of "Germania's daughters," while in the records of the Eisenach Association Bechtolsheim often referred to the pupils as "*Mitschwestern*."

describe the animating action of Nature, the Godhead, in her pantheistic poems, though she also evoked *Beseligung* in its more conventional Christian sense. Flowers were "ensouled by the pure breath of the gods"; the poets and troubadours of old "surrendered themselves to the spirit's ensoulment"; and Elizabeth of Thuringia, as we have seen, was "ensouled by divine charity."[191] Certainly, "ensoulment" and "animation" were relatively common features of intellectual parlance in the period. Forster and Alexander von Humboldt, for instance, both evoked the term in the 1790s to describe the animating powers of Nature and its "Life Force," though Forster, in his reverence for the capitalist bourgeoisie, also praised civic culture in England as being "*beseelt*" by a "*public Spirit*."[192] For Bettina von Arnim, who used the term repeatedly in her epistolary novels of the 1830s, *Beseligung* represented a soul's earthly state, the corporeal habitation of a spirit that seeks communion beyond this world.[193] By the mid-nineteenth century, the term became increasingly female gendered as piety itself was feminized: "femininity," one author wrote, is "pure, simple ensoulment."[194]

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[191] "Die Blumen aus Norden," in THsaW, Großherzogliches Hausarchiv A XXV, Nr. 1067, Blatt 87: "Du, aus Aetherdüften zaubervoll gewebet, | Du, von hoher Götter reinem Hauch beseelet, | Blume sanfter Huld!" "Abschiedsworte einer Bergbewohnerin," in GSA 20/129: "Der Minnesinger*) herzergreifend Lied [...] Sich überliess des Geist's Beseeligung."

[192] Alexander von Humboldt, "Die Lebenskraft oder der Rhodische Genius: Eine Erzahlung," *Die Horen: Eine Monatsschrift* 2, no. 5 (1795): 90-96, on 96: "…*Lebenskraft*, wie sie jeden Keim der organischen Schöpfung beseelt." Georg Forster, "Geschichte der Kunst in England," in *Georg Forster's sämmtliche Schriften*, vol. 3, ed. G. G. Gervinus (Leipzig: Brockhaus, 1843), 455: "Diese Anerkennung des Verdienstes um den Staat und seine Bürger, dieser *public Spirit*, der gewöhnlich nur Privatpersonen beseelt, ergreift auch zuweilen ganze öffentliche Corpora und selbst die Repräsentanten des gesammten Volkes."

[193] The Grimm *Wörterbuch* cites Bettina von Arnim's *Tagebuch zu Goethe's Briefwechsel mit einem Kind* (Berlin, 1835) in defining *Beseligung*. (*Deutsches Wörterbuch von Jacob und Wilhelm Grimm*, 16 vols (Leipzig, 1854-1961), Online Version, accessed 24 September 2020, http://woerterbuchnetz.de/cgi-bin/WBNetz/wbgui_py?sigle=DWB&mode=Vernetzung&lemid=GB05313#XGB05313.) For further uses of *Beseligung* in Arnim's works, see Bettina von Arnim, *Goethe's Briefwechsel mit einem Kinde*, vol. 1 (Berlin, 1835), 133-34; ibid., vol. 2, 149, 328; Arnim, *Tagebuch*, 66, 123, 134, 206.

[194] On the feminization of piety in nineteenth-century Germany, see David Blackbourn, *Marpingen: Apparitions of the Virgin Mary in Bismarckian Germany* (New York: Alfred A. Knopf, 1994). Ferdinand Kürnberger, *Der Amerika-Müde* (Frankfurt am Main, 1855), 142: "…wenn Sie die Weiblichkeit als etwas Fertiges empfinden, als reine einfache Beseligung."

Bechtolsheim used the same language to describe the aims of her Industry School, thereby distinguished from mere "work-houses." To friends, she said her own role as First Principal, as a "useful instrument of the ... charitable plans of our highly esteemed Grand Duchess," "has also been ensouling for me."[195] To the Grand Duchess herself, she described a "sense of ensoulment" at the sight of the warm clothing spun for poor children at the Spinning Institute.[196] And to the public at large, she declared that her Association's highest aim was "the ensoulment of your innermost *Gemüth*."[197] *Gemüt*, another term Forster used to imbue industry with moral and intellectual virtues, was a philosophical codeword relating to the inner nature of the soul or mind, closely connected with artistic creativity.[198] In Bechtolsheim's intellectual milieu, to be "*Gemüthreich*"—rich in mind and soul, as she described one close friend—was among the highest achievements of self-cultivation.[199] Bechtolsheim thus shared with Forster the belief that such cultivation was a matter of practice as well as intellect.

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[195] Bechtolsheim to Ludwig von Herda, 29 Mar. 1823, in GSA 20/129, Bestand Jakob Friedrich von Fritsch: "So flieht mein Leben in Trockene, mir oft sehr lästigen Beschäftigungen dahin, und ich muß dagegen mir Genüsse versagen die Herz und Verstand nähren und mich besonders glücklich machen würden; denn wiewohl es auch beseligend für mich seyn würde ein recht nützliches Werkzeug zur Erfüllung der der höchstrühmlichen Absichten und wohltätigen Pläne unsrer höchstverehrten Großfürstin seyn zu können."

[196] "Unterthänigstes Privat-Schreiben," 23 Dec. 1826 – Jan. 1827, THsaW, ZD 297, Bl. 211: "Hätte Ihr Auge gnädigste Großfürstin auf diese Scene nur einen Augenblick ruhen können, welch beseligendes Gefühl…. Beym Anblick der warmen zweckmäßigen Kleidungsstücke die sie für sich und ihre Kinder erhielt sah sie gerade vor sich hin wie wann sie aus einem Traum erwachte…."

[197] Bechtolsheim, "Ein Wort an's Herz," THsaW, ZD 1, Bl. 3: "Die Beseeligung eures innersten Gemüths wird Euch lohnen, und der rührende Seegen der, durch Eure Beyträge besser gepflegten oder bekleideten Krieger aus allen verbündeten und verbrüderten Nationen, wird auch der schönen Genuß süßer Freudenthränen gewähren!"

[198] Joachim Ritter, ed., *Historisches Wörterbuch der Philosophie*, vol. 3: G-H (Basel: Schwabe & Co. Verlag, 1974), 260; Ute Frevert et al., *Emotional Lexicons: Continuity and Change in the Vocabulary of Feeling, 1700-2000* (Oxford, UK: Oxford University Press, 2014), 26.

[199] Bechtolsheim to Friedrich Justin Bertuch, 3 Apr. 1819, in GSA 68/38, Bestand Friedrich Justin Bertuch; Bechtolsheim to Friedrich von Müller, 4/6 Oct. 1824, in GSA 68/38, Bestand Friedrich Müller, Bl. 6-8. Bechtolsheim also believed that while children's *Gemüter* ought to be carefully guided, *Gemüt* could also serve as an adult's inner repository of youthfulness in mind and spirit. Writing to her friend, the court counselor Fredrich von Müller in 1824, Bechtolsheim assured him: "Sie lieber Herr Canzlar werden mit Ihrem Geist und Gemüth ewig ein Jüngling bleiben; ich, bin und bleibe mit meinem Herzen in

Bechtolsheim's Industry School promoted a work-discipline infused with Romantic theories of mind. In a report from 1817, she described the "influence that this institute has had on the intellectual as well as the physical life of our foster children":

> As evidence for this our first Principal has indicated that our foster children not only received a fresher, healthier look through the washing of their persons and clothes, but she also asserted: the dead, empty masses of flesh were ensouled thereby [*indeß beseelt worden*], and their vacant, inexpressive countenance had transformed into one of joy and love. It is truly touching to see how 40 children sit peacefully alongside each other, still and noiseless, in a very confined space, tirelessly working for 6 to 8 hours a day, and already they display such skill and dexterity that their products are not only useful, but some even deserve to be called quite beautiful.[200]

Viewed within the context of early industrialization, the passage might be read as an antidote to Schopenhauer's description of Manchester's mechanical weavers—with "numbers across their faces, nothing but numbers."[201] From a biographical perspective, the children's "vacant, inexpressive" faces and vacuous bodies echoed the damning criticism Bechtolsheim herself faced as a poet who allegedly lacked "interior matter."

Above all, though, by viewing Eisenach's charitable organization within the broader context of industry schools, we see that even Bechtolsheim's lofty notion of ensoulment actually

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höhern Jahren ewig ein Kind." This was a common belief and expression amongst Romantics. Bettina von Arnim, for instance, wrote "So lang' wir Kinder sind im Gemüt, so lang' übt die Natur Mutterpflege an uns." (Bechtolsheim to Müller, 4/6 Oct. 1824, in GSA 68/38; Walter Schmitz and Sibylle von Steinsdorff, eds., *Bettine von Arnim. Werke und Briefe,* vol. 2, Goethe's Briefwechsel mit einem Kinde (Frankfurt am Main: Deutscher Klassiver Verlag, 1992), 434.)

[200] "Ew. Kaiserlichen Hoheit," 9-12 Mar. 1817, THsaW, ZD 293, Bl. 89: "Mit wahrer Freude und innigster Rührung hat unsere erste Vorsteherin nach ihrer Rückkunft von Weimar den Einfluß bemerkt den diese Anstalt auf das geistige wie auf das physische Leben unserer Pflegekinder gehabt hat. Zum Beweis dafür giebt sie an daß nicht allein durch Reinigung ihrer Personen und Bekleidung sie ein frischeres und gesunderes Ansehen erhalten hätten sondern sie behauptet: die leeren todten Fleischmassen wären indeß beseelt worden, und ihr stierer nichtssagender Blick hätte sich verwandelt in Freude und Liebe. Es ist wirklich rührend anzusehen wie 40 Kinder still und ohne Geräusch in einem sehr beschränkten Raum friedlich beysammen sitzen und 6 bis 8 Stunden des Tags unermüdet arbeiten, auch schon so viel Geschicklichkeit zeigen, daß ihre Produkte nicht allein brauchbar sind, sondern einige schon recht hübsch genannt zu werden verdienen."

[201] Schopenhauer, *Reise durch England*, 224: "…überall hört man das Geklapper der Baumwollspinnereien und der Weberstühle, auf allen Gesichtern stehen Zahlen, nichts als Zahlen."

echoed mainstream ideas about social reform and the so-called "*Geist der Indüstrie*." In a Göttingen journal dedicated to industry schools and poor relief, contributors commonly linked training in manual labor with spiritual education. In its inaugural issue in 1789, editor Ludwig Gerhard Wagemann described material production, like Forster, as a promising medium "to spread *Bildung* throughout the entire manual-laboring classes"—"indeed, where possible, to inculcate some *Rafinement* in the acquisition of skill, that is, in industry."[202] Such views were philanthropic, no doubt, but also self-consciously oeconomic. Bechtolsheim's industry school fits within a wider culture of reform in Germany in which state-run and charitable organizations aimed to raise patriotic and economically productive citizens.[203]

In certain respects, Bechtolsheim's project was truly radical. Eisenach's Industry School for Girls challenged the Enlightenment culture of utility that persisted through her time. And it did so in an age, at the beginning of the nineteenth century, that saw women's participation in the labor force of Continental Europe enter a sharp decline after an unprecedented high point around 1800. For much of the early modern period, married women especially contributed significantly

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[202] Ludwig Gerhard Wagemann, "Ueber Indüstrie-Schulen im Allgemeinen, und über die Göttingische insbesondere," in *Göttingisches Magazin für Industrie und Armenpflege* 1, no. 1 (1789): 1-29, on 3, 5: "Das einzige Mittel also um der Armuth weniger zu machen, und das Uebel welches sie durch sie auf den Staat verbreitet, zu mindern, ist frühe Bildung der Kinder zum Fleiß und Geschicklichkeit in Arbeiten mancher Art, ja selbst wo es möglich ist, zum eignen Rafinement auf rechtmässigen Erwerb, das ist zur Indüstrie." "Dazu kömmt noch, daß wenn die Betrachtung, Verminderung der Bettler kann nicht anders als durch Vermehrung der Indüstrie bewirkt werden, in uns den Wunsch recht belebt hat, den Geist der Indüstrie durch den Theil der Gesellschaft besonders zu verbreiten, der durch Mangel indüstriösen Fleisses bisher der Gegenstand der Armenversorgung wurde; so fällt es uns nur gar zu deutlich in die Augen, daß sich diese Bildung über die ganze handarbeitende Classe in dieser Rücksicht verbreiten müsse; und daß es also nicht hinreiche, blos denen, die sich zur Aufnahme in Waisenhäuser qualificiren, und welche eine Stadt etwa aus ihren Mitteln in selbigen unterhalten könnte, diese Bildung zu geben." Like Bechtolsheim, Ludwig Gerhard Wagemann (1747-1804) was also involved in patriotic societies. On practical education (*Realia*) in Germany through the seventeenth century, see Kelly Whitmer, "Reimagining the 'Nature of Children': Realia, Reform, and the Turn to Pedagogical Realism in Central Europe, c. 1600-1700," *The Journal of the History of Childhood and Youth* 12, no. 1 (Winter 2019): 113-35.

[203] See David Blackbourn, *History of Germany, 1780-1918: The Long Nineteenth* Century, 2nd ed. (Malden, MA: Blackwell Publishing, 2003), 17-18.

to European economies and often worked alongside men as part of the household unit's "two-supporter model," known in German historiography as the *Ganzes Haus*.[204] As Lisbet Koerner has argued, women's centrality to economic sectors like agriculture and textile production in eighteenth-century Europe helps to explain their inclusion, however limited, within the Enlightenment culture of public utility.[205] In German lands in particular, though, the philosophical and legal discourses that underpinned an emergent civil society around 1800 codified women's exclusion from public life. Scientific and legal taxonomies of the period effectively naturalized women's essential passivity.[206] Working against these currents, aided by the privilege of noble rank and royal patronage, Bechtolsheim laid claim to public utility.[207] "Thus, the desire arose in me to be useful to humanity, even in my limited sphere," she wrote, describing the Association's textile work as a "useful branch of industry."[208] Such expressions

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[204] Maria Ågren, ed., *Making a Living, Making a Difference: Gender and Work in Early Modern European Society* (New York: Oxford University Press, 2017), 1-6.

[205] Lisbet Koerner, "Women and Utility in Enlightenment Science," *Configurations* 3, no. 2 (1995): 233-55, esp. 253-54. On the culture of utility more generally, see Dominik Hünniger, "What is a useful university? Knowledge economies and high education in late eighteenth-century Denmark and central Europe," in Larry Stewart und Kelly J. Whitmer, eds., "Expectations and utility in eighteenth-century knowledge economies," Special Issue of *Notes and Records. The Royal Association journal of the history of science* (2018): 173-194.

[206] Isabel V. Hull, *Sexuality, State, and Civil Society in Germany, 1700-1815* (Ithaca and London: Cornell University Press, 1997), esp. 172-97, 251-56; Londa Schiebinger, *Nature's Body: Gender in the Making of Modern Science* (New Brunswick, NJ: Rutgers University Press, 2004). The poet Friedrich von Hardenberg captured the prevailing sentiment in describing woman as the passive *Naturmensch*, and man, the active *Kunstmensch*. Hardenberg to Schlegel, 27 Feb. 1799, in *Novalis Schriften*, vol. 4, 278-79: "…die Frau ist der eigentliche Naturmensch—die wahre Frau das Ideal des Naturmenschen—sowie der wahre Mann das Ideal des Kunstmenschen."

[207] Women's Associations, while led by bourgeois and noble women and often funded by established authorities, also challenged the strict confines of domesticity imposed upon women in the period. As Dirk Reder has shown, *Vereine* were a predominantly male affair prior to the Napoleonic era. The emergence of *Frauenvereine* can be seen as an outgrowth of women-led societies (singing, reading, and theatre clubs, as well as salons like Bechtolsheim's) during the Enlightenment, but also as a new and defiant form of bourgeois sociability. (Reder, *Frauenbewegungen*, 15-22.) Turning to natural historical societies, Denise Phillips has counted about one hundred women, mostly nobles, who belonged to learned societies around the turn of the century, when women's presence became a marker of sociability and liberality. (Phillips, *Acolytes of Nature*, 63-72.) Bechtolsheim likewise benefited from her noble rank.

[208] Bechtolsheim to Maria Pawlowna, 19 Feb. 1814, in THsaW, ZD 1, Bl. 5; Bechtolsheim, "Unterthänigster Vortrag," 6/18 Oct. 1831, in THsaW, ZD 300, Bl. 205.

make for a stark contrast with contemporary educational literature. Typical primers taught "Germany's Daughters" a sort of *Bildung* that equated women's social utility to fertility and domesticity, while other youth readers scorned "the cultivation of girls" outright.[209] In the Association's records, by contrast, not only "utility" (*Nützlichkeit*), but also a host of other masculine-coded words like "industriousness" (*Tätigkeit*) and "circumspection" (*Umsicht*) are used to describe "women's" textile work.[210]

Viewed as a political space, Bechtolsheim's Association was more ambiguous, blending the royal patronage typical of Old Regime science and arts with the electoral practices of Europe's revolutionary age. The Association's political hybridity reflects Bechtolsheim's own duality as a baroness who not only shared in a learned world composed of bourgeois and aristocratic intellectuals, but also expressed genuine support for republican movements. Brought up on the ideals of the Enlightenment, Bechtolsheim described herself as a "true world-citizen" (*eine ächte Weltbürgerin*). In 1794—even after the Reign of Terror in France—Bechtolsheim declared herself "the most zealous proponent of the American Revolution, the first admirer of the French Constitution (this masterpiece of human reason, even if all its components may not be thoroughly applicable to actually-existing humans) [and] the enthusiastic friend of the Polish

[209] E.g. Johann Wilhelm Heinrich Ziegenbein, ed., *Lesebuch für Deutschlands Töchter, zur Bildung des Geistes und des Geschmacks, zur Veredlung des Herzens und zu einer vertrautern Bekanntschaft mit den vorzüglichsten Schriftstellern des Vaterlandes*, 3 vols. (Quedlinburg: Ernst, 1811-12); Samuel Bredetzsky, *Monathliche Unterhaltungen für die Jugend* (Wien: Peter Rehm's Witwe, 1804), 33.
[210] Compare to Weigert, "Gender and Genre," 252.

Constitution of May 1791."[211] But then as later, Bechtolsheim condemned the "still greater thralldom" of violent revolution.[212]

Bechtolsheim's Association functioned a sort of constitutional monarchy. On the one hand, its Industry School and Spinning Institute were heavily reliant upon the patronage of the Grand Duchess, who accounted for 32 % of the Association's funding in 1820 for instance.[213] Bechtolsheim's pen proved a useful instrument in securing patronage. The Association's records contain lyrics dedicated to Maria Pawlowna on her birthday and other poetic gifts given to the Duchess during her visits to its industry schools.[214] One dramatic poem begins in a Grecian temple, where "girls of all estates," "clothed in white dresses," line a great "green hall." It then tours Eisenach and the Wartburg—ever a symbol of charity in Bechtolsheim's verses—and chronicles the city's revival after the infamous powder explosion of 1 September 1810. Like a scene out of Bechtolsheim's eulogy, the white-clad girls stand in awe of their leader, now replaced with the matriarchal allegory of the Duchess: "the sublime Mother" (*die erhabne Mutter*).[215] Ornately bound in a green silk-covered booklet framed by a gold trim (**Figure 10**),

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[211] Bechtolsheim to Wieland, 2 Jan. 1794, in SLUB, H. 43, Bd. 9, Bl. 6, 24: "Ich war die eifrigste Anhängerin der Amerikanische Revolution, die Bewundrerin der ersten französischen Constitution (dieses Meisterstückes menschlichen Verstands wenn es in allen seinen Theilen und für wirklich existierende Menschen durchaus anwendbar wäre) die schwärmerische Freundin der Polnischen Constitution vom May 1791." "Pariser Weiber anzuführen die Sie mit so bitteren Hohne herumnehmen. Ernstlich beweiset ja die Stelle klar doch nur die tadelhafte, gefährliche, gewaltsame Teilnahme an Revolutionen verwerfe. Zweitens konnte ich, da ich als eine ächte Weltbürgerin, mein Opus den guten Weiben aller Klassen widmete…."

[212] Bechtolsheim to Grand Duke Carl Friedrich, 18 Aug. 1830, in Schmidt, *Julie von Bechtolsheim*, 162.

[213] Donations from local citizens amounted to 42 % of their revenue that year, while 18.3 % came from the local court's alms commission; the sale of the School's textile products brought in just 7.4 %. (Reder, *Frauenbewegungen*, 294-95.)

[214] E.g. "Feier des höchsterfreulichen Geburtstages Ihro Kaiserl: Königl: Hoheit Allerdurchlauchtigsten Frau Großfürstin und Erbpgroßherzogin Frau Maria Pawlowna in der Industrieschule zu Creutzburg 1827," THsaW, ZD 297, Bl. 243.

[215] Julie Freifrau von Bechtolsheim, *Empfang ihrer Majetsät der Kaiserin Maria von Russland im Schlosse zu Eisenach im November 1818. Zu wohlthätigen Zwecken des Frauenvereins Gedruckt* (Gotha: mit Rayherschen Schriften, 1818). Herzogin Anna Amalia Bibliothek, Klassik Stiftung Weimar, Huld V 12 [1].

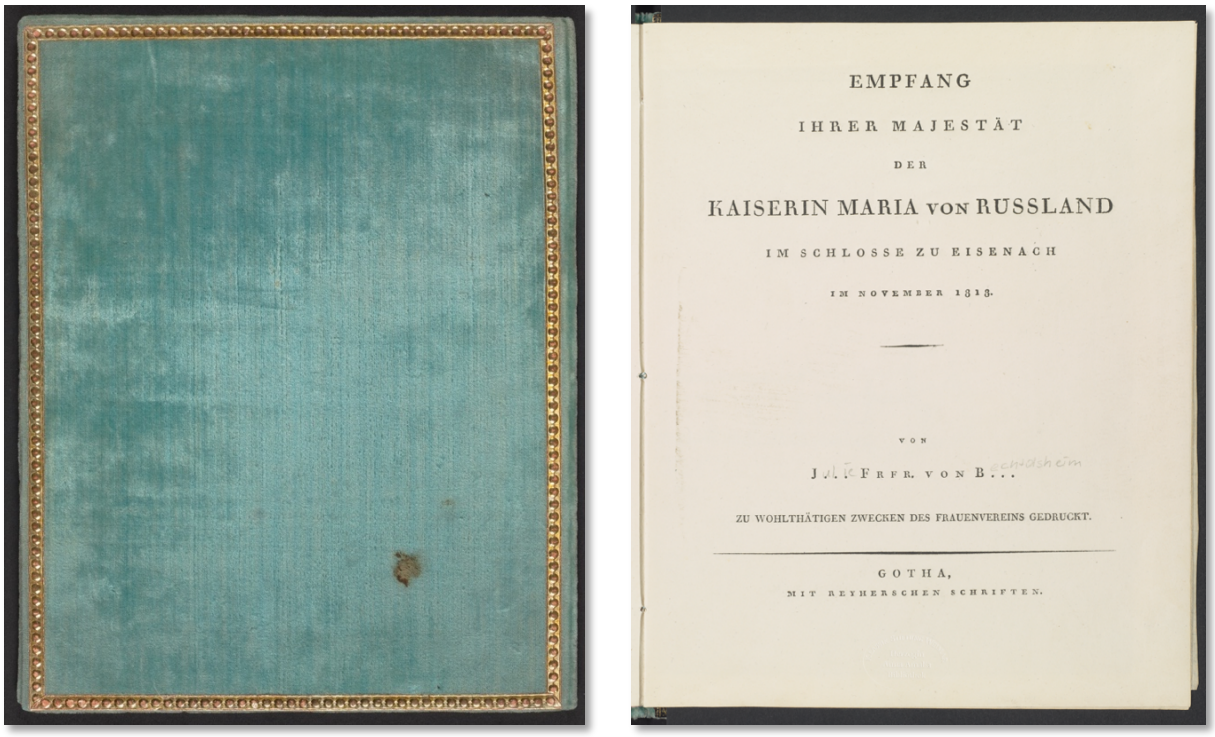

Figure 10. Julie von Bechtolsheim, *Empfang ihrer Majetsät der Kaiserin Maria von Russland im Schlosse zu Eisenach im November 1818. Zu wohlthätigen Zwecken des Frauenvereins Gedruckt* (Gotha: 1818). Herzogin Anna Amalia Bibliothek, Klassik Stiftung Weimar, Huld V 12 [1].

the poem was presented to Maria Pawlowna during a visit to the Industry School. To this day, the booklet remains in Weimar's royal library. "The high mother was followed by the tender, beloved daughter," the poem concludes, with a footnote to Maria Pawlowna's leadership at the head Weimar's Central-Association: "In her image our model is enshrined."[216]

On the other hand, the inner workings of the Eisenach's organization reveal strong republican sensibilities—a general hostility towards "despotism" (*Willkür*) and even the establishment of elections as a "fundamental law" (*Grundgesetz*) of the Association. Unlike the Central-Association in Weimar, dominated by noblewomen, the leadership of its counterpart in

[216] Bechtolsheim, *Empfang ihrer Majetsät*, (unnumbered): "Der hohen Mutter folgt die zarte, | Geliebte Tochter. Sie bewahrte | Ihr Abbild uns, als Helferin.*) […] *) Ebenfalls an der Spitze aller wohlthätigen Frauen-Vereine im Grossherzogthum."

Eisenach was 63 % bourgeois.[217] It was this constituency who would "elect" principals and instructors, for instance, before asking the Grand Duchess for her "eminent approval." The political consciousness amongst Eisenach's leaders makes for a striking comparison with Bonnie Smith's classic study of bourgeois-led charities in nineteenth-century France. As Smith argued, women's charitable organizations then expressed an essentially hierarchal, conservative, and monarchist worldview.[218] In Eisenach's Association, by contrast, members argued that "too few collective resolutions [*Gesammt-Beschlüsse*] were drafted, discussed, and put into action," and that this "resulted in conflict and despotism." Bechtolsheim agreed that the complaint was "not without cause," and informed Maria Pawlowna that "in the interest of preventing all personal despotism," important decisions were henceforth to be "voted upon by convening the Association, or through a written circular."[219]

Bechtolsheim herself was torn between the prejudices of the elite society from which she came and the egalitarian commitments she made to an Industry School in which "girls of all estates" worked side-by-side. In the School's early years, she began singling out "girls from the

[217] Reder, *Frauenbewegung*, 294.
[218] Smith argued that women's charitable organizations in nineteenth-century France typically idealized "authoritarian order": "The bourgeois woman lived in an atmosphere and acted according to precepts entirely at odds with the industrial, market, egalitarian, and democratic world—the world, that is, of her husband." (Bonnie G. Smith, *Ladies of the Leisure Class: The Bourgeoises of Northern France in the Nineteenth Century* (Princeton, NJ: Princeton University Press, 1981), 146-47, 10.)
[219] "Unterthänigster Bericht," 8 Apr. 1820, THsaW, ZD 294, Bl. 165: "…sie zur Vorsteherin des Nedelthor-Bezirks zu erwählen von welchem Amt die Vorsteherin der Schule gern erledigt seyn möchte. Wir fragen also diesen Wunsch Ihrer Kaiserlichen Hoheit zur höchsten Genehmigung vor, und sehen einer baldigen Antwort darüber entgegen. Was die Bemerkungen der Frau Vice-Präsidentin Schwendler in ihrem Abschiedsschreiben anbetrifft daß zu wenig Gesammt-Beschlüsse, gefaßt, berathen, und in Thätigkeit gesetzt würden, woraus dann Collisionen und Willkühr entstünden pp. ist nicht ohne Grund. Es könnten allerdings mehr Zusammenkünfte seyn. […] Allein zur Vermeidung aller persönlichen Willkühr und zum ungestörten Einverständniß des Ganzen ist es nöthig daß in Zukunft dieses Grundgesetz ohne Ausnahmen beobachtet werde, nehmlich: daß wenn eine Vorsteherin zu irgendeiner bedeutenden Hülfsleistung Veranlassung erhält sie ungesäumt ... die erste Vorsteherin oder im Fall ihre Abwesenheit, deren Stellvertreterin in Kenntniß davon setzt, welche alsdann den Verein zusammen zu berufen, oder durch eine Circular-schriftliche Anfrage die Stimmen darüber einzusammeln."

better estates" who, she said, "would feel ashamed to be amongst the lowly, rude children." Instead, she wished to train "already well-raised" girls separately in more refined and less labor-intensive needlework. In this case, it was the sublime Mother herself who reproached Bechtolsheim. Segregating the children by class, Paulowna admonished Bechtolsheim, would only lead to a "detrimental partition of opinions and *Gemüther*."[220]

Conclusion: Industrious Ideals in an Industrial Age

In recent years, historians of Germany have expanded conventional understandings of "the political" to account for the many ways in which people practiced politics in an age before universal suffrage. These scholars have shown how, in the decades around 1800, popular political culture found expression in Jacobin, Patriotic, and Fatherland associations, as through salons, pamphlets, songs, material culture, and social networks.[221] Challenging orthodox narratives about Germany's unequivocally conservative response to the French Revolution, the "reactionary" nature of the Vienna Congress of 1814-15, the "apolitical" inwardness of Romanticism, and the "failure" of 1848, these revisions have inspired a more textured approach to political culture in central Europe, viewed not only through the writings of philosophers and statesmen but also in the practices and institutions of everyday life.

[220] As quoted in Reder, *Frauenbewegungen*, 300-301.
[221] Consider Jonathan Sperber, *Rhineland Radicals: The Democratic Movement and the Revolution of 1848-1849* (Princeton, NJ: Princeton University Press, 1991); Brian Vick, *Defining Germany: The 1848 Frankfurt Parliamentarians and National Identity* (Cambridge, MA: Harvard University Press, 2002); Jonathan Sperber, *The European Revolutions: 1848-1851* (New York: Cambridge University Press, 2005); James M. Brophy, *Popular Culture and the Public Sphere in the Rhineland, 1800-1850* (Cambridge: Cambridge University Press, 2007); Brian Vick, *The Congress of Vienna: Power and Politics after Napoleon* (Cambridge, MA: Harvard University Press, 2014). A study that emphasizes German conservatism in the Age of Revolution is Timothy Blanning, *The French Revolution in Germany: Occupation and Resistance in the Rhineland, 1792-1802* (New York: Oxford University Press, 1983).

Advancing that approach, this chapter has shown how reformers of the period imagined new forms of social and political existence through industrious activity—specifically through mining, textile production, and needlework. However exceptional Forster and Bechtolsheim may be as individuals—a zealous revolutionary and a utopian Romantic—their shared conception of industry as an agent of human cultivation (whether *Bildung* or *Beseligung*) did in fact reflect the reforming spirit of their age. That spirit, the "*Geist der Indüstrie*" as one reformer put it, imbued manual labor with moral and intellectual virtues, the kind of virtues that turned orphans and paupers into productive, patriotic members of the "Fatherland."

Forster and Bechtolsheim thus capture the transitional character of their time, as well as the open-ended nature of its industrial, political, and intellectual transformations. Forster moved seamlessly between reflections on universal history and descriptions of iron and textile production in Saxony and the Rhineland. Likewise, Bechtolsheim made no clear distinction between the lofty literary universe that revolved around Weimar and the collective of middle- and working-class children whom she schooled in needlework.

The political philosophies that manifested at these junctures of industrial and intellectual life also comprised varied ideologies. Forster's views of industry combined the languages of liberal reform and Old Regime paternalism by grafting new interpretations of *Bildung* onto an older "oeconomic" framework. Bechtolsheim similarly oscillated between her aristocratic heritage and egalitarian principles in the organization of Eisenach's Industry School. There she forged a communitarian ideal out of ducal patronage and democratic practice. Reflecting a social order in flux, Forster and Bechtolsheim fused the new and the old, the conservative and the liberal, uniting philosophy and oeconomy, poetry and politics.

The ideals they espoused by also reverberated through the writings of later generations who, like Bettine von Arnim and Alexander von Humboldt, came of age around 1800 but lived to see an entirely new form of industrialization in the mid-nineteenth century. Beginning in the 1840s and 50s, the exploitation of massive coal deposits fueled an unprecedented scale of production in Germany, which developed in pace with its sprawling railway network. In the 1850s alone, the German railway nearly doubled in length from 5,475 to 10,337 kilometers.[222] As agriculture and cottage industry characterized the old economic order, so population growth, urbanization, and a capitalist market defined the new.

Arnim's arc from writer to reformer is reminiscent of Bechtolsheim's. She first committed herself to charity and social criticism after the death of her husband in 1831, as a cholera epidemic devastated working-class neighborhoods in Berlin. Yet Arnim was also a far more radical figure than Bechtolsheim. She collaborated with socialists in the underground group known as "Young Germany" (banned in Prussia in 1835) and corresponded with members of Marx's radical fraternity, the "Young Hegelians."[223] In the 1840s, Arnim commissioned a crew of statisticians to collect information for a project she called *Das Armenbuch*, or "The Book of the Poor," a "discourse on the causes of poverty" directed at King Friedrich Wilhelm IV. In her notes for the project, Arnim pinpointed mechanization as the chief instrument of oppression in modern society. "The great mass of workers," she copied out from a pamphlet on Berlin's

[222] Brophy, "The End of the Economic Old Order," 184.
[223] On Arnim and her politics, see Elke P. Frederiksen and Katherine R. Goodman, eds., *Bettina Brentano-von Arnim: Gender and Politics* (Detroit, MI: Wayne State University, 1995), including a translation of Christa Wolf's classic essay "Nun ja! Das nächste Leben geht aber heute an: Ein Brief über die Bettine" (1979), 35-67; Ursula Püschel, *Bettina von Arnim—politisch: Erkundungen, Entdeckungen, Erkenntnisse* (Bielefeld: Aisthesis Verlag, 2005); Kathleen M. Hallihan, "Envisioning an ideal state: The literary politics of Bettina von Arnim from 1830 to 1852" (PhD diss., The Ohio State University, 2005).

Charlottenburg borough, "are bound until death to the repetitive, insipid movement of machines."[224]

Elsewhere, Arnim laced her critique of mechanization into less polemical works, sure to slip by strict Prussian censors, such as epistolary novels and even fairy tales.[225] In one *Märchen*, which Arnim co-authored with her thirteen-year-old daughter Gisela in 1840, a villain's reductionist obsession with machines is contrasted with the communitarianism of a female spinning and weaving collective.[226] In the Arnims' fantastical spinning school:

> [W]e work together, scutching and spinning the flax; often in the evening hours the little elves join us, and we all spin so merrily in the moonshine. Then we weave and bleach the cloth, going about our work with great care, because we have noticed how gladly the little elves sit beneath the cloth and play all sort of little tricks.[227]

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[224] "Auszug aus: Georg Syederus, über Industrialismus und Armuth, Charlottenburg 1844," in *Bettine von Arnim. Werke und Briefe*, vol. 3, Politische Schriften, eds. Wolfgang Bunzel, Ulrike Landfester, Walter Schmitz, and Sibylle von Steinsdorff (Frankfurt am Main: Deutscher Klassiker Verlag, 1995), 502: "Die große Masse der Arbeiter gleich Galeren Sclaven sind an die bis zum Tod immer wiederkehrende insipide Bewegungsmechanik gefesselt." The passage continues to anticipate Marx's theory of alienation: "Wie die Sachen gegenwärtig stehen, erweitert jede neue Maschiene die Kluft, zwischen Menschlicher Arbeit und armseliger Thätigkeit" (ibid., 504).

[225] One example comes from Arnim's letters with Karoline von Günderrode in the years 1804-06, which she embellished in an epistolary novel. In it, Enlightenment philosophers are described as the operators of a "secret factory": "Mir deucht vielmehr er geht auf Raub, was er ihr abluchsen kann, das vermanscht er in seine geheime Fabrik, und da hat er seine Noth, daß sie nicht stockt, hier ein Rad, dort ein Gewicht, eine Maschine greift in die andere, und da zeigt er den Schülern, wie sein Perpetuum Mobile geht, und schwitzt sehr dabei, und die Schüler staunen das an und werden sehr dumm davon." (Bettine von Arnim, *Die Günderrode*, Pt. 1 (Grünberg: W. Levysohn, 1840), 16-17.)

[226] See Edith Waldstein, "Romantic Revolution and Female Collectivity: Bettine and Gisela von Arnim's Gritta," *Women in German Yearbook* 3 (1987): 91-99.

[227] Gisela and Bettine von Arnim, "Das Leben der Hochgräfin Gritta von Rattenzuhausbeiuns" (1840), in Bettina von Arnim, *Werke und Briefe*, IV, ed. Gustav Konrad (Frenchen: Bartmann Verlag, 1963), 112: "Aber wie schön ist es jetzt im Kloster! Ein jedes hat sein eignes Geschäft…. Sonst arbeiten wir zusammen, schwingen den Flachs und spinnen ihn; dazu kommen öfters in den Dämmerstündchen die Elfchen und erzählen uns die schönsten philosophischen Gedanken, und wir spinnen alle so vergnügt im Mondschein. Dann weben wir und bleichen, wobei wir sehr vorsichtig zu Werke gehen, weil wir bemerkten, daß die kleinen Elfchen gern unter der Leinwand sitzen und allerlei Spuk darunter treiben." On textiles as a leitmotif in Arnim's work, see Viktoria Janssen, "Textile in Texturen: Lesestrategien und Intertextualität bei Goethe und Bettina Brentano-von Arnim" (PhD diss., University of Maryland, 1997).

The image of proto-industrial harmony was meant to contrast with the plight of contemporary cotton weavers. In June 1844, thousands of textile workers in Silesia set about destroying the newly installed machinery that had driven their wages down. Prussian authorities mercilessly crushed the uprising by force. When news of its violent repression reached Berlin, Arnim's confidant at court, Alexander von Humboldt, urged her not to publish the *Armenbuch*. "To write for the poor now means preaching revolt," Arnim lamented.[228]

Nevertheless, Humboldt communicated a selection of Arnim's *Armenbuch*, which analyzed the exploitation of Silesian weavers, to the King the following year.[229] Then again, in 1847, Arnim appealed to the King in defense of the revolutionary Ludwik Adam Mierosławski, recently arrested in Prussia for his role in the Greater Poland Uprising of 1846. Humboldt, a privy counselor, had long served as an intermediary between Arnim and Friedrich Wilhelm, communicating her letters and reports to him. In fact, one contemporary called Humboldt "a pugnacious fighter for Arnim at the court," noting also the "hatred he garnered for this."[230] As calls for democratic representation grew louder within a unified national public, and Humboldt grew more devoted to the cause, he took a different tack in his counsel to Arnim: "Stop writing for the King," he told her after Mierosławski's death sentence: "write for the people!"[231]

This is precisely what Humboldt took himself to be doing in the first volume of *Kosmos*, published in 1845. A "description of the physical universe" from the depths of the deepest mines to the farthest reaches of astronomical observation, *Kosmos* is not typically read as a work of

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[228] As quoted in Ingeborg Drewitz, "Bettina von Arnim: A Portrait," *New German Critique* 27, Women Writers and Critics (Autumn 1982): 115-22, on 120.
[229] Edith Waldstein, *Bettine von Arnim and the Politics of Romantic Conversation* (Columbia, SC: Camden House, 1998), 66.
[230] Karl Varnhagen von Ense noted: "Humboldt ... am Hofe der streitbare Kämpfer für Bettinen, ladet aber dadurch großen Haß auf sich." (*Bettine von Arnim. Werke und Briefe,* vol. 4, Briefe, eds. Walter Schmitz and Sibylle von Steinsdorff (Frankfurt am Main: Deutscher Klassiker Verlag, 1986), 913.)
[231] As quoted in Drewitz, "Bettina von Arnim," 121.

social commentary. Yet it was written against the backdrop of heavy industrialization, workers' uprisings, and widespread political agitation, all of which would soon culminate in the Europe-wide revolutions of 1848. In its introduction, Humboldt heralded the dawning industrial era with the unfettered optimism of his mentor Forster, viewing scientific inquiry as the nexus between "industrial progress and intellectual edification." Humboldt believed "the desire to animate industrious activity" a "defining characteristic of our age" and conceived of industry, like Forster, as a great engine of human cultivation.[232]

In confronting industrialization, both Humboldt and Arnim harkened to the ideals of a pre-industrial age; but they did so in different ways. Arnim was far more politically progressive than Humboldt, yet she also grounded her radical politics in a sort of proto-industrial idyll. Summoned to a Berlin court in 1847 (ostensibly for not having obtained her Prussian citizenship), Arnim used the occasion to denounce the government's disregard for the laboring poor: "The treasure of the poor man consists in the inherent wealth of nature, the profit of bourgeois in utilizing and exploiting this natural wealth," she wrote to the magistrate, describing the industrial bourgeoisie as a class whose "corrupted cultivation" (*Verbildung*) "devours everything precisely because it has no productive power of its own."[233] In search of an authentic

[232] Alexander von Humboldt, *Kosmos: Entwurf einer physischen Weltbeschreibung*, vol. 1 (Stuttgart: Cotta, 1845), 34, 36: "Wir treten in einen innigeren Verkehr mit der Außenwelt, bleiben nicht untheilnehmend an dem, was gleichzeitig das intrustrielle Fortschreiten und die intellectuelle Veredlung der Menschheit bezeichnet." "Die Vorliebe für Belebung des Gewerbfleißes und für Theile des Naturwissens, welche unmittelbar darauf einwirken (ein charakteristisches Merkmal unseres Zeitalters)…."

[233] Bettine von Arnim an den Magistrat von Berlin, 19.02.1847, in Arnim, *Werke und Briefe*, *4*, 579: "Der Schatz des Armen besteht im angeborenen Reichthum der Natur, das Verdienst des Bürgers im Anwenden und Ausbeuten dieses Naturreichtthums, welchen er vermittelst seiner thätigen Gewandtheit und zum eignen Vortheil derjenigen Menschenklasse zuwendet, deren Hochmuth, Verwöhnung und geistige Verbildung Alles verschlingt, eben weil sie keine ProduktionsKraft hat." See also Deborah Janson, "The Path Not (Yet) Taken: Bettine von Arnim's Ecological Vision in Her Romantic Fairy Tale 'The Queen's Son'," *Feminist German Studies* 34 (2018): 1-24.

source of "productive power," Arnim looked to the metaphor of the "house-mother," which, prior to the nineteenth century, conveyed the image of an economically productive woman at the center of an industrious household.[234] In yet another work directed at the highest authority in the land, provocatively titled *This Book Belongs to the King* (1843), Arnim described Nature itself as a *Hausmutter* whom the "housewife ought to mirror and emulate in her utility and her beauty with spinning and weaving and embroidery and cooking."[235] Arnim thus found in early modern cottage industry an exemplar for her radical politics.

Humboldt's mid-century writings exhibit a different blend of new and old. An avowed liberal who had long served an autocratic state, Humboldt's vision of industrial capitalist society carried elements of older forms of paternalist governance. *Kosmos* opened by celebrating the liberalization of the economy:

> The perfection of agriculture in free hands and in small plots of land, the blossoming of manufacturing liberated from the bondage of the guilds, the multiplication of trade relations, and unhindered progress spiritual culture of mankind, as in the civic institutions (that is, the first image of a new era of world history, which is now foisted upon the reluctant) are in a state of enduring commerce [*daurend wirksamen Verkehr*].[236]

Yet even this vision is laced with the oeconomic ideals of an earlier age. Like Forster, Humboldt believed the "active exchange" (*regem Wechselverkehr*) between intellectual and industrial life

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[234] Goozé, "Challenging Separate Spheres," 14-15; Ingeborg Weber-Kellermann, *Die deutsche Familie: Versuch einer Sozialgeschichte* (Frankfurt am Main: Suhrkamp, 1974), 103.
[235] "Dies Buch gehört dem König," in *Bettina's sämmtliche Schriften. Neue Ausgabe*, vol. 9 (Berlin, 1857), 259: "Auch die Natur ist doch eine Hausmutter, sie eilt jedem Bedürfniß zuvor, und verherrlicht's in seiner Befriedigung. Und die Hausfrau soll sich in ihr spiegeln und ihr alles nachmachen im Nützlichen und im Schönen mit Spinnen und Weben und Blumensticken und Kochen, ja der häusliche Heerd der ist auch ein Platz wo jene idealische Natur des freien Geistes manche Anregung fühlt."
[236] Humboldt, *Kosmos*, *1*, 37: "Vervollkommnung des Landbaus durch freie Hände und in Grundstücken von minderem Umfang, Ausblühen der Manufacturen, von einengendem Zunftzwange befreit, Vervielfältigung der Handelsverhältnisse, und ungehindertes Fortschreiten in der geistigen Cultur der Menschheit, wie in den bürgerlichen Einrichtungen, stehen (das erste Bild der neuen Weltgeschichte dringt diesen Glauben auch dem Widerstrebendsten auf) in gegenseitigem, dauernd wirksamen Verkehr mit einander."

was grounded in a particular relationship to the natural world—"a deeper commerce" (*innigeren Verkehr*) with nature's forces. But this great *commerce* also demanded a great deal of *care*. While describing an ideal relationship to nature in *Kosmos*, Humboldt regularly used the term *Sorgfalt* (care or prudence), a word charged with cameralist connotations. As a mining official in the 1790s, for instance, Humboldt had praised King Friedrich Wilhelm II for the "paternal care" (*landesvaterl*. *Sorgfalt*) he showed the "industriousness of Your subjects." A half-century later, while serving King Friedrich Wilhelm IV, Humboldt maintained that "the material wealth and the growing prosperity of nations are grounded in a careful utilization [*sorgfältigen Benutzung*] of natural products and forces."[237]

Arnim and Humboldt were children of the eighteenth century who lived long into the nineteenth. Their views of industrial society reflect a "backward-looking progressivism" in mid-nineteenth-century Prussia—a manner of meeting the industrial future with the instruments, images, and ideologies of the pre-industrial past.[238] In returning to that past, this chapter has opened the mental and material terrain of the dissertation as a whole. Through the lives of Forster and Bechtolsheim, it has examined spaces of material production as sites of social and political imagination around 1800. For them, worlds of making were also sites of world-making.

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[237] Humboldt, *Kosmos*, *1*, 34-36: "Wir treten in einen innigeren Verkehr mit der Außenwelt, bleiben nicht untheilnehmend an dem, was gleichzeitig das industrielle Forstschreiten und die intellectuelle Veredlung der Menschheit bezeichnet." "Gleichmäßige Würdigung aller theile des Naturstudiums ist aber vorzüglich ein Bedürfniß der gegenwärtigen Zeit, wo der materielle Reichthum und der wachsende Wohlstand der Nationen in einer sorgfältigen Benutzung von Naturproducten und Naturkräften gegründet sind." "Diejenigen Völker, welche an der allgemeinen industriellen Thätigkeit, in Anwendung der Mechanik und technischen Chemie, in sorgfältiger Auswahl und Bearbeitung natürlichen Stoffe zurückstehen, bei denen die Achtung einer solchen Thätigkeit nicht alle Classen durchdringt, werden unausbleiblich von ihrem Wohstande herabsinken. Sie werden es um so mehr, wenn benachbarte Staaten, in denen Wissenschaft und industrielle Künste in regem Wechselverkehr mit einander stehen, wie ein erneuerter Jugendkraft vorwärts schreiten." Cf. Alexander von Humboldt to King Friedrich Wilhelm II of Prussia, 10 Mar. 1794, in Ilse Jahn and Fritz Lange, eds., *Die Jugendbriefe Alexander von Humboldts, 1787–1799* (Berlin: Akademie Verlag, 1973), 326.

[238] Brose, *The Politics of Technological Change in Prussia*, 136.

Chapter Two

Labor, Folklore, and the Politics of Sustainability

> *…it was determined that I should take to what in Germany is called the Cameral Sciences, the art of governing the world, which one first understands only when one knows absolutely everything.*[239]
>
> Alexander von Humboldt, 1801

> *But there was something else that could not be weighed, measured, heard, or seen, and which had to do with the mine*.[240]
>
> From "Grabenspuk," a Saxon mining tale

By the close of the eighteenth century, a peculiar tale had spread throughout the mining communities of the German states. In fields and forests a stag appeared to the miners, now with a blinding golden luminescence, now with antlers of silver ore. "Still in 1793," Alexander von Humboldt (1769–1859) griped, miners continue to believe that "a 'Golden Stag' (a four-footed mine-spirit)" aided them in their search for metals. Stationed as a mine official (*Oberbergmeister*) in Prussia's Franconian territories, Humboldt evoked the Golden Stag in a memorandum that outlined his plan for a "Royal Free Mining School," established in Bad Steben

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A version of this chapter has been published as Patrick Anthony, "Labour, folklore, and environmental politics in German mining around 1800," *The Historical Journal* (23 Dec. 2020), First View, pp. 1-23: https://doi.org/10.1017/S0018246X20000588.

[239] Alexander von Humboldt, 4 Aug. 1801, in Kurt R. Biermann, ed., *Aus meinem Leben: Autobiographische Bekenntnisse* (Leipzig: Urania Verlag, 1987), 33: "…man bildete mir ein, daß ich Lust zu dem habe, was man in Deutschland Kameralwissenschaften nennt, eine Weltregierungskunst, die man erst dann versteht, wenn man alles, alles, weiß."

[240] "Grabenspuk," in Dietmar Werner ed., *Bergmannssagen aus dem sächsischen Erzgebirge* (Leipzig: Deutscher Verlag für Grundstoffindustrie, 1985), 164: "Aber da gab es noch etwas, das man nicht wägen, messen, hören und sehen konnte, aber dennoch mit dem Graben zusammenhing."

in the winter of 1793/94. Its aim: to cultivate miners' children into a new generation of "rational" mine foremen.[241]

To the young administrator, recently graduated from the Mining Academy in Freiberg, Saxony, talk of spirits—gnomes, goblins, witches and the like—made for "feeble-minded" miners. It epitomized the "ignorance" that "undermines prosperity" in Franconia and which allegedly made miners vulnerable to the "greed of the investors" (*Gewerken*, who comprised *Gewerkschaften*).[242] Though deeply dependent upon investors, state officials were also wary of those who, "left to their own free will," would dig pits too hastily and exploit only the most immediate ores, "thereby blocking the way to future exploitation."[243] This they called *Raubbau*, literally "robbery-construction."[244] Definitions of *Raubbau* regularly targeted investors, reminding them of their obligation to abstain from "*räuberisch*" practices and encouraging officials to mind "that investors not build to steal" (*daß die Gewerken nicht auf den Raub*

[241] Alexander von Humboldt, "Ganz gehorsamstes Promemoria, die Errichtung einer königlichen freien Bergschule zu Steben betreffend," in Karl Bruhns, *Alexander von Humboldt: Eine wissenschaftliche Biographie*, vol. 1 (Leipzig: Brockhaus, 1872), 293-94: "In einem Gebirge, wo so vielerlei Erze einbrechen, und wo die Bewohner oft aus Aberglauben und bergmännischer Unwissenheit durch thörichte Unternehmungen ihren Wohlstand untergraben, in einem solchen Gebirge ist es doppelt wichtig, deutliche und vernünftige Begriffe zu verbreiten. Noch im Herbst 1793 hat man in der Dürrenweid geschürft, wo der 'Goldene Hirsch' (ein vierfüßiger Berggeist) weidete…!!"

[242] StABa, Kriegs- und Domänenkammer (hereafter KDK), Nr. 7114, vol. 1, Bl. 88; Nr. 7124, Bl. 465: "Eigensinn der Gewerken."

[243] Carl Hartmann, *Handwörterbuch der Mineralogie, Berg-, und Hütten- und Salzwerkskunde*, vol. 2 (Ilmenau, 1825), p. 555: "Würde man nun einzelnen Lehen- und Gewerkschaften freien Willen lassen, so würden sie, um sobald als möglich einigen Gewinn zu ziehen, alle nutzbaren Mineralien, wie sie vorkommen, ohne weitere Rücksicht hinwegnehmen, sich dadurch den Weg zur weitern Fortsetzung selbst versperren, und daher *räuberisch*, nicht aber wirtschaftlich bauen."

[244] On *Raubbau* see Ursula Klein, *Humboldts Preußen: Wissenschaft und Technik im Aufbruch* (Darmstadt: Wissenschaftliche Buchgesellschaft, 2015), 77; Hans Baumgärtel, *Bergbau und Absolutismus: Der sächsische Bergbau in der zweiten Hälfte des 18. Jahrhunderts und Maßnahmen zu seiner Verbesserung nach dem Siebenjährigen Kriege* (Leipzig: Deutscher Verlag für Grundstoffindustrie, 1963), 63-64. *Raubbau* was later evoked to disparage certain agricultural practices, as documented in Elizabeth B. Jones, "No Smoke Without Fire: Moor Burning, the Environment, and Social Reform in the German Empire, 1866-1914," *Agricultural History* 88, no. 2 (2014): 207-36.

bauen).[245] Yet as state records would have it, "ignorant foremen" and other undisciplined officials were also complicit in investors' myopic designs. *Raubbau* thus posed a grave threat to the long-term interests of the state. In fact, mining law from the period explicitly opposed *Raubbau* to "sustainability" (or *Nachhaltigkeit*), part of a broad lexicon with which officials drew wood and mineral resources into political economy.[246]

Figure 1. The antlered Rübenzal (or Rübezahl) in the Sudeten Mountains of Silesia as depicted in a detail of the map "Silesiae typus descriptus et editus a Martino Heilwig Neissense" (Breslau, 1685). 57.5 cm x 73 cm. Map Department of the Wroclaw University Library, 2448-IV.B.

[245] E.g. Johann Bergius, *Neues Policey- und Cameral-Magazin*, vol. 1 (Leipzig, 1775), 291; Joseph Tausch, *Das Bergrecht des österreichischen Kaisserreiches* (Wien, 1834), 290.
[246] Tausch, *Das Bergrecht*, 289: "Man nennt einen Bau Raubbau, wenn der Bau eilfertig ohne eine gewisse Ordnung und ohne Rücksicht auf dem Bestand der Grube in die Zukunft (Nachhältigkeit) getrieben." Sustainability has typically been studied within the context of forestry, yet miners of the period also evoked the term. See Sebastian Felten, "Sustainable Gains: Dutch Investment and Bureaucratic Rationality in Eighteenth-Century Saxon Mines," *Journal for the History of Knowledge* 1, no. 1 (2020): http://doi.org/10.5334/jhk.19. It is also important to recognize, with Joachim Radkau, that "sustainability" was "only one aspect among others" in the contemporary language of resource management. See Joachim Radkau, *Wood: A History*, trans. Patrick Camiller (Cambridge: Polity Press, 2012), 173.

In the realm of mining mythology, the tale of the Golden Stag similarly condemned greed and avarice amongst miners. Like other spiritual entities said to govern the underground—Rübezahl, for instance, who sometimes bore the antlers of a deer and more often appeared as a monk (**Figure 1**)—the Golden Stag was the keeper of subterranean riches that might otherwise be plundered. So said legends that miners passed from the mountains of Silesia to those of Saxony, the Harz, and Franconia. In Saxony's Ore Mountains, the luminous Stag identified mineral riches to a man in sworn secrecy. Soon, though—according to a modern collection of *Bergmanssagen*—word of the treasures spread amongst the villagers, who besieged the earth in a "feverish search for the treasure." Their lust was their demise. For the coveted deposit of gold "remains undiscovered to this day, concealed and protected" in the earth. In the Harz, too, the tale of a White Stag warned miners that if new pits were dug before exhausting the old, their toil would only beget misfortune.[247]

This chapter views Humboldt's Mining School within administrative and vernacular discourses. It argues, first, that mine officials of the period understood sustainable resource management—questions of the exhaustion or endurance of mineral deposits—as a matter of labor discipline. Political concerns about social order in the "mining state" (or *Bergstaat*) were constitutive of material concerns about natural resources. Humboldt's School not only sought to discipline the physical practice of mining, but also its moral and psychological substrate. In this, he aimed to promote a culture of work closely aligned with state interests.

Academy-trained officials of Humboldt's generation intervened in mining culture in order to align workers' identities with state interests and "make labor supply to mines more

[247] Werner, *Bergmannssagen* (1985), 94-96; Dietmar Werner, ed., *Bergmannssagen aus dem Harz* (Leipzig: Deutscher Verlag für Grundstoffindustrie, 1990), 50.

reliable."[248] Humboldt's particular case shows how labor discipline in mining entailed a re-working of the industry's deep-seated analogy between material practice and moral constitution. Administrative and folkloric discourses betray a common view of excessive exploitation as a moral offence, whether punishable by the *Bergstaat* or the *Berggeist*. And in promoting a "spirit of the practical" (*Geist fürs Praktische*) to supplant the "mine spirit" (*Berggeist*), Humboldt actually drew upon elements of the industry's rich vernacular culture.[249]

In a literature that identifies eighteenth-century Germany as a fountainhead of modern environmental thought, scholars have devoted special attention to the concept of sustainability as it developed within the field of "scientific forestry." A central thesis of this literature is, as Paul Warde writes, that "sustainability emerged from acts of political as much as ecological imagination."[250] As the fiscal-military states of early modern Europe consolidated their territorial units and developed expansive bureaucracies to manage growing populations and standing armies, resource management became a central feature of statecraft.[251] Thus, in 1713, the Saxon mining official Hans Carl von Carlowitz called for a systematic "conservation and cultivation of wood" to ensure the metallurgic industry's "continuous, durable and sustained use [*nachhalthende Nutzung*]" of timber resources.[252] But sustainability's first utterance was also

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[248] Sebastian Felten, "Mining culture, labour, and the state in early modern Saxony," *Renaissance Studies* 34, no. 1 (2019): 125-38, on 124, 136-38.
[249] Humboldt to Carl Freiesleben, 20 Jan. 1794, in Ilse Jahn and Fritz Lange, eds., *Die Jugendbriefe Alexander von Humboldts, 1787–1799* (Berlin: Akademie Verlag, 1973), 311.
[250] Paul Warde, *The Invention of Sustainability: Nature and Destiny, c. 1500-1870* (Cambridge: Cambridge University Press, 2018), 145. Warde's account also emphasizes how knowledge about the circulation of nutrients in nineteenth-century Germany prompted concern for the permanent degradation of natural systems. (Ibid., 228-64.)
[251] Note also the influential and complementary argument of Richard Grove, *Green Imperialism: Colonial Expansion, Tropical Island Edens, and the Origins of Environmentalism* (Cambridge: University of Cambridge Press, 1995).
[252] Translation from Richard Hölzl, "Historicizing Sustainability: German Scientific Forestry in the Eighteenth and Nineteenth Centuries," *Science as Culture* 19, no. 4 (2010): 431-60, on 438. See also Hans Carl von Carlowitz, *Sylvicultura Oeconomica oder Haußwirthliche Nachricht und Naturmäßige Anweisung zur Wilden Baum-Zucht* (Leipzig, 1713), 105.

steeped in political design. As Joachim Radkau writes, the "specter" of wood shortages that haunted Carlowitz's age served as a regulatory instrument "to open up fines for forestry violations as a source of revenue"—a tool for the state to extend its dominion over the mining industry and its primary source of fuel.[253] In turn, efforts to quantify and control forests sparked violent conflict after the turn of the nineteenth century as states restricted local populations' access to timber, so vital to everyday life in the period.[254]

Shifting from wood to mineral resources, the case of Humboldt's Mining School underscores an overlooked aspect of the social strife embedded in early environmental thought: resource management in late-eighteenth-century Germany also entailed the strict control of labor relations and a programme of "psychological policy."[255] Cameralist parlance for the state's paternalist oversight of the mental life of the commonwealth, *psychologische Polizey* is the heading under which Humboldt's School fell in the Franconian records of the Prussian Mining Department.[256] In Humboldt's own words, the School was to promote Prussia's interests by

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[253] Joachim Radkau, *Nature and Power: A Global Environmental History*, trans. Thomas Dunlap (Cambridge: Cambridge University Press, 2008), 139. See also Radkau, *Wood*, 172-77 and Christoph Ernst, *Den Wald entwickeln: Ein Politik- und Konfliktfeld in Hunsrück und Eifel im 18. Jahrhundert* (München: Oldenburg Verlag, 2000).

[254] Richard Hölzl, "Forests in Conflict: Rural Populations and the Advent of Modern Forestry in Pre-Industrial Germany, 1760-1860," in *Managing Northern Europe's Forests: Histories from the Age of Improvement to the Age of Ecology*, eds. K. Jan Oosthoek and Richard Hölzl (New York: Berghahn, 2018), 198-223; Richard Hölzl, *Umkämpfte Wälder: Die Geschichte einer ökologischen Reform in Deutschland, 1760-1860* (Frankfurt: Campus Verlag, 2010); Dirk Blasius, *Kriminalität und Alltag. Zur Konfliktgeschichte des Alltags im 19. Jahrhundert* (Göttingen: Vandenhoeck, 1978); Jonathan Sperber, *Rhineland Radicals: The Democratic Movement and the Revolution of 1848-1849* (Princeton, NJ: Princeton University Press, 1991).

[255] A pioneering effort to unite labor history and environmental history, which also centers on mining, is Thomas G. Andrews, *Killing for Coal: America's Deadliest Labor War* (Cambridge, MA: Harvard University Press, 2008).

[256] The title given to the Mining School's records, ten years after Humboldt left his post, reads: "psychologische Polizey, Industrie u. Kunstschulen. Bergschulen," in StABa, KDK, Nr. 7114, vol. 2. While this reflects the state's development of "industry schools," *psychologische Polizey* also referred more broadly to the state's oversight of pedagogy, literature, and religious education. (Consider as an example *Intelligenzblatt der allgemeinen Literatur-Zeitung vom Jahre 1790* (Jena, 1790), 501.) *Polizei* itself—a compound of policy, politics, and police—was a watchword of cameralist administration, as in

combatting "minerly ignorance" (*bergmännische Unwissenheit*) with a "minerly sense of honor" (*bergmännisches Ehrgefühl*), curbing *Raubbau* by cultivating miners.[257] Indeed, the term *bergmännisch*—"minerly"—opens a vast lexicon through which miners expressed normative claims about social order through resource management. In its narrowest sense, the adjective refers to all things mining, *Bergmann* being the German for miner. Within the industry, however, to be "minerly" was to embody the virtues of piety, loyalty, order, and (o)economy. Conversely, officials used "un-minerly" interchangeably with *Raubbau*, demarcating the miner's very identity by his adherence to state protocol.[258]

By studying the early history of sustainability with respect to mining culture, this chapter joins in a broader effort to bring "vernacular knowledges" to bear on histories of science and environment.[259] The sense that nature defends itself against the greed and immoderation of miners, which echoes through mining mythology, might well be called an "environmentalism of the poor," a sort of care ethic that arises amongst people for whom preserving nature accords with the preservation of their livelihood.[260] (Hence the Stag's mythological role of safeguarding the earth against those who would plunder it hastily.) Yet the case of early modern mining also resists the dichotomy sometimes drawn between the "official landscapes" of the powerful and

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the common phrase "good police." See discussion in Andre Wakefield, *The Disordered Police State: German Cameralism as Science and Practice* (Chicago: University of Chicago Press, 2009), 9-10.

[257] Humboldt, "Promemoria," 294: "1) Der Zweck der königlichen Bergschule zu Steben ist zwiefach: a. das junge Bergvolk in dem Neilaer Revier zu verständigen und brauchbaren Bergleuten auszubilden, b. ihm von Kindheit an Liebe für ihr Metier und bergmännisches Ehrgefühl einzuflößen."

[258] "Das Gegentheil heist: Bergmännisch bauen." (Mineralophilo Freibergensi, *Neues und Curieuses Bergwerks-Lexicon* (Chemnitz, 1730), 504.)

[259] On vernacular knowledge in the history of science, see Helen Tilley, "Global Histories, Vernacular Science, and African Genealogies; or, Is the History of Science Ready for the World?" *Isis* 101, no. 1 (March 2010): 110-19.

[260] Joan Martínez-Alier, *The Environmentalism of the Poor: A Study of Ecological Conflicts and Valuation* (Cheltenham, UK: Edward Elgar, 2002).

the "vernacular landscapes" of the powerless.[261] Folklore was fundamental to what Tina Asmussen called the "intrinsic logic of the early modern mining industry." Mine spirits gave meaning—even a sense of equity and hope—to the violence of underground labor and the volatility of the industry's booms and busts.[262] Often *Bergmännlein* and other spirits took revenge upon miners for invading their realm, thus explaining mine collapses and other fatal accidents. Other times mine spirits were thought to protect miners from the exploitation of their superiors. But belief in mine spirits was not exclusive to "common" miners. Keeper entities were minted on silver coin and reported in official records of the sixteenth and seventeenth centuries, and the educated officials of the early eighteenth century still "left some room for otherworldly forces to operate," while pastors warned workers of the "Mine Devil." "Learned worldviews functioned well in conjunction with folk beliefs," Hjalmar Fors writes of Swedish mining in the period, describing keeper entities as "vital parts of widely held cultural belief structures, according to which the material world was closely intertwined with, indeed inseparable from, spiritual and subtle realms populated by mostly unseen denizens."[263] Certainly, by the century's close, Humboldt's generation of officials tried to purge their practice of "occult" beliefs about mine spirits and mineral effluvia. Yet even the "rational" sciences of Enlightened elites have

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[261] In Rob Nixon's formulation, "the environmentalism of the poor is frequently triggered when an official landscape is forcibly imposed on a vernacular one." (Rob Nixon, *Slow Violence and the Environmentalism of the Poor* (Cambridge, MA: Harvard University Press, 2013), 17.)

[262] Tina Asmussen, "Wild men in Braunschweig – Economies of hope and fear in early modern mining," *Renaissance Studies* 34, no. 1 (2020): 31-56, on 3. Asmussen notes that Gerhard Heilfurth's compendium of mining myths—*Bergbau und Bergmann in der deutschsprachigen Sagenüberlieferung Mitteleuropas* (Marburg, 1967)—remains an "essential reference" for historians of early modern mining.

[263] Ortrud Krause, "Sagenhafter Rammelsberg: Historie, Berggeister und zauberhafte Kräfte in der bergmännischen Erlebniswelt und Volksdichtung," in Reinhard Roseneck, ed., *Der Rammelsberg: Tausend Jahre Mensch-Natur-Technik*, vol. 2 (Goslar: Verlag Goslarische Zeitung, 2001), 14-33; Hjalmar Fors, *The Limits of Matter: Chemistry, Mining & Enlightenment* (Chicago: University of Chicago Press, 2015), 38-39. More generally, historians have shown how "common" folk in eighteenth-century Germany often relied on quasi-magical beliefs, blended with more mainstream Christian traditions, to ward off misfortune in daily life. (See e.g. Hans Medick, *Weben und Überleben in Leichingen, 1650-1900: Lokalgeschichte als Allgemeine Geschichte* (Göttingen: Vandenhoeck & Ruprecht, 1997), 533.)

been shown to coexist with folk knowledge about dowsing and divining for instance.[264] Ostensibly, Humboldt's Mining School aimed to expel "superstition" from the mines. Yet his generation's call for a "measured exploitation" also bears a striking semblance to the extractive ethos embedded in mining mythology.[265]

Humboldt himself has recently received considerable attention for his own environmental stance, which placed human activity amidst the confluence of forces in nature and taught that society ought to mirror the harmony found there.[266] "A Humboldtian social ecology would have to be as fluid and inclusive as the world itself" Aaron Sachs has written, tracing Humboldt's influence upon later conservationist movements alive to the malevolent relationship between environmental degradation and human subjugation.[267] But before Humboldt drew from nature an image of society, his administrative gaze had already constituted the natural world as a political realm.[268] This aspect of the "Humboldtian social ecology" has deep roots in the social ecology of mining, where environmental concerns found expression through social governance.

It is not the savant-explorer of the famed American voyage that makes Humboldt particularly illuminating in this study, but rather the "savant-technician" of Germany's emergent

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[264] Warren Alexander Dym, *Divining Science: Treasure Hunting and Earth Science in Early Modern Germany* (Boston, MA: Brill, 2011).
[265] Bergius, *Neues Policey- und Cameral-Magazin*, 264.
[266] Aaron Sachs, "The Ultimate 'Other': Post-Colonialism and Alexander von Humboldt's Ecological Relationship with Nature," *History and Theory* 42 (2003): 111-35; Laura Dassow Walls, "Rediscovering Humboldt's Environmental Revolution," *Environmental History* 10, no. 4 (2005): 758-60; Heinrich Detering, *Menschen im Weltgarten: Die Entdeckung der Ökologie in der Literatur von Haller bis Humboldt* (Göttingen: Wallstein Verlag, 2020).
[267] Aaron Sachs, *The Humboldt Current: Nineteenth-Century Exploration and the Roots of American Environmentalism* (New York: Penguin, 2006), 351-52.
[268] Relatedly, Laura Dassow Walls locates the origins of Humboldt's "proto-ecological view" of New Spain in contemporary notions of political economy, in the broad sense of economy derived from the Greek *oikonomia*, that is, "household management." (See idem, *The Passage of the Cosmos: Alexander von Humboldt and the Shaping of America* (Chicago: University of Chicago Press, 2009), 122-23.)

administrative elite.[269] In recent years, scholars like Ursula Klein, Frank Holl, and Eberhard Schultz-Lüpertz have re-interpreted Humboldt within a generation of officials who graduated from technical institutes like Saxony's *Bergakademie* to pursue practical science—"useful knowledge"—in the service of absolutist states, as chemists, cartographers, mechanics, and miners.[270] Though Humboldt's later renown as the leading polymath of his day would certainly distinguish him as a singular figure, his zeal for "sustainability" and hostility to *Raubbau* as a Prussian official in the 1790s are more illustrative than exceptional.[271] Like many of his generation, gravely concerned with wood shortages, Humboldt set out to increase the efficiency of blast furnaces and substitute peat and coal for wood and charcoal.[272] Thus one managed the so-called "mine-household" (*Grubenhaushalt*), echoing the popular view that the state itself ought to be managed like a thrifty household (*Staatshaushalt*).[273]

This chapter examines the socio-political project undergirding "sustainable" resource management in Humboldt's Germany—and, more specifically, in his Mining School. *Raubbau*, as we will see, was an affront, at once ethical and economic, to the prudence with which officials

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[269] Ursula Klein, "The Prussian Mining Official Alexander von Humboldt," *Annals of Science* 69 (2012): 27–68; Ursula Klein, *Nützliches Wissen: Die Erfindung der Technikwissenschaften* (Göttingen: Wallstein, 2016); Hartmut Schleiff and Peter Konečny, eds., *Staat, Bergbau und Bergakademie: Montanexperten im 18. und frühen 19. Jahrhundert* (Stuttgart: Steiner, 2013).

[270] Frank Holl and Eberhard Schulz-Lüpertz, *'Ich habe so große Pläne dort geschmiedet…': Alexander von Humboldt in Franken* (Gunzenhausen: Schrenk-Verlag, 2012); Klein, *Humboldts Preußen*.

[271] Ursula Klein, "Alexander von Humboldt – Vater der Umweltbewegung?" in *Achtsamer Umgang mit Ressourcen und miteinander – gestern und heute. Abhandlungen der Humboldt-Gesellschaft für Wissenschaft, Kunst und Bildung e. V.,* vol. 37, Manuskript des Vortrags, gehalten am 6. Mai 2016 anlässlich der 103. Tagung der Humboldt-Gesellschaft in Freiberg/Sachsen (September 2016): 115–127.

[272] On Humboldt's environmental concerns, particularly about wood shortages, see Engelhard Weigl, "Wald und Klima: Ein Mythos aus dem 19. Jahrhundert," *HiN* 5, no. 9 (2004): 81-99; Ulrich Stottmeister, "Umweltgedanken zu Alexander von Humboldt," *HiN* 18, no. 35 (2017): 75-94.

[273] Anton von Heynitz as quoted in Baumgärtel, *Bergbau und Absolutismus*, 163. Humboldt himself spoke of a lack of oversight in the mines as a "failure of *Haushalt*." (Humboldt to Untergebirgische Kammer zu Ansbach, 31 Mar. 1794, *Jugendbriefe*, 333.) This conception of the body politic as a household unit is thoroughly analyzed in Lissa Roberts, "Practicing oeconomy during the second half of the long eighteenth century: an introduction," *History and Technology* 30, no. 3 (2014): 133-48.

sought to manage the "mine-household." For Humboldt and his ilk, governing the natural meant governing the social: to expand state territory deep into the earth, they sought to expand its sovereignty into the minds and bodies of those who worked there. And yet this state-building project also echoed older vernacular traditions that, in miners' songs and sagas, had long conceived of mineral resource extraction as a fundamentally moral concern.

Foremen and the Problem of *Raubbau*

Foremen (*Steiger*) were the highest-ranking of laboring miners but lowest in the state's bureaucratic apparatus.[274] Amongst workers, the foreman was feared and revered in equal measure. "*Glück auf*, *Glück auf!* | The foreman comes," goes the canonical "*Steigerlied*," beginning with the miner's famous mantra, "and his miner's lamp – in the night – | he has already lit."[275] Here the foreman is idolized as a guide in the depths: "Our foreman must lead the others | breaking a path through the mine."[276] In folklore, the foreman appears a familiar but formidable figure, a commoner cloaked in authority. The social distance between foremen and hewers was marked not only by the uniforms they donned (**Figure 2**), but also by the distinctive etchings they carved into the walls of the shafts.[277]

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[274] Foremen were divided into *Unter*- and *Obersteiger*, who ranked amongst "common" miners and minor administrators respectively. Foremen might also rise to the rank of *Geschworner*, tasked with supervising multiple mines. But even these figures were hybrid in nature: they performed administrative functions, adjudicating legal disputes for instance, but also carried out on-site mine inspections. Though Humboldt wrote specifically of training foremen, the School's records also include young "shift bosses" (*Schichtmeister*), the rank of its first instructor, Georg Heinrich Spörl. Shift bosses ranked above, and supervised, foremen. Yet they were also administrators "of the *Leder*."

[275] Reinhold Köhler, ed., *Alte Bergmannslieder* (Weimar: Hermann Böhlau, 1858), 49-50: "Glück auf, Glück auf! | der Steiger kommt | und er hat sein Grubenlicht – bei der Nacht – | schon angezündt."

[276] Gerhard Heilfurth, *Neuvermehrtes vollständiges Bergliederbüchlein: Eine buntgemischte Singgut-Sammlung aus Mitteldeutschland um 1700* (Hildesheim, 1988), 102: "Unser Steiger muß vor allen | brechen in die Grube Bahn."

[277] Felten, "Mining culture," 131-33; Wolfgang Lampe, "Stuffen-zeichen im Harzer Bergbau," *Ausbeute: Mitteilungsblatt der Arbeitsgemeinschaft Harzer Montangeschichte* 3 (2008): 26-30.

Figure 2. The foreman (left), as shown in his distinguished parade uniform, and the hewer (right), portrayed in his every-day work garments, or *Berghabit*. From G. E. Rost, *Trachten der Berg- und Hüttenleute im Königreiche Sachsen* (Freiberg: Verlag Rost, 1831). SLUB Dresden Commons, Signatur: Hist.Sax.M.171.m.

Yet foremen also inhabited an extremely precarious position in the social ecology of mining. In the industry's estate-like hierarchy, they were situated between "service of the *Leder*" (the miner's leather smock) and "service of the *Feder*" (the bureaucrat's feather pen).[278] So said Johann Gottlieb Voigt's *Mining State*—one of the eleven texts listed in the Mining School's "inventory" of 1802—which defined the foreman as a figure who fused practical skill with administrative oversight. But the foreman's ambiguity also represented a threat to the state.

One-part laborer, one-part administrator, foremen were caught between the long-term interests of state mining departments and the short-term interests of private investors, as between

[278] Johann Gottlieb Voigt, *Bergwerksstaat des Ober- und Unterhaarzes* (Braunschweig, 1771), 102.

competing claims for authority.[279] The "Principle of Direction" (*Direktionsprinzip*), a legal-bureaucratic complex first imposed in Saxony after the Thirty Years War and later taken up by Prussia after the Seven Years War, outlined the territorial state's control over mining and smelting operations, allowing investors to open mines provided that 10 % of their earnings flowed into state coffers.[280] This allowed mining administrations to enforce a "military-like" discipline over labor in the second half of the eighteenth century, and it also ensured that foremen were directly answerable to the state.[281] In parts of the Harz, for instance, foremen were forced to pledge their own homes as collateral for any "mine-mischief"—fires, collapses, or theft.[282] Investors, meanwhile, came to see foremen as an instrument "of their resistance against the rigid administration of the *Direktionsprinzip*."[283] In late-eighteenth-century Saxony, for instance, local investors sometimes waged "personnel-politics," appointing their own foremen and shift bosses in a direct affront to the Principle of Direction.[284] These circumstances help to explain why, although various parties could be accused of *Raubbau* (including state officials and surveyors), administrators often identified foremen as the culprits of the earth's "robbery."

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[279] Helmuth Trischler, *Steiger im deutschen Bergbau: Zur Sozialgeschichte der technischen Angestellten, 1815-1945* (München: C. H. Beck, 1988), 18-19; Sebastian Felten, "The history of science and the history of bureaucratic knowledge: Saxon mining, circa 1770," *History of Science* 56, no. 4 (2018): 403-31, esp. 421, 424.

[280] Michael Fessner and Christoph Bartels, "Von der Krise am Ende des 16. Jahrhunderts zum deutschen Bergbau im Zeitalter des Merkantilismus," in *Geschichte des deutschen Bergbaus*, vol. 1, eds. Christoph Bartels and Rainer Slotta (Münster: Aschendorff Verlag, 2012), 453-590; Tina Asmussen, "The *Kux* as a Site of Mediation: Economic Practices and Material Desires in the Early Modern German Mining Industry," in *Sites of Mediation: Connected Histories of Places, Processes, and Objects in Europe and Beyond, 1450-1650*, eds. Susanna Burghartz et al. (Leiden: Brill, 2016), 159-82.

[281] Jakob Vogel, "Auf dem Weg zum "Bergarbeiter": Zur Sozialgeschichte der bergmännischen Arbeit im 18. und 19. Jahrhundert," in *Geschichte des deutschen Bergbaus*, vol. 2, ed. Wolfhard Weber (Münster: Aschendorff Verlag, 2015), 100.

[282] Hans-Joachim Kraschewski, "Arbeitsorganisation und Sozialstruktur im Rammelsberger Bergbau des 16. bis 18. Jahrhunderts," in *Der Rammelsberg: Tausend Jahre Mensch-Natur-Technik*, vol. 1, ed. Reinhard Roseneck (Goslar: Verlag Goslarische Zeitung, 2001), 280-91, on 290.

[283] Trischler, *Steiger im deutschen Bergbau*, 19.

[284] Baumgärtel, *Bergbau und Absolutismus*, 64.

What is *Raubbau* exactly? A broad survey of *Raubbau* in the parlance of miners reveals three interlinked notions of the concept: (1) a literal "robbery" by which miners transgress property lines; (2) an architectural definition referring to the lack of structural integrity in a mine's timber work; and, relatedly, (3) a general definition of mining "without consideration for the future."[285] In defining *Raubbau*, cameralists dreamt of a "measured" rather than "excessive exploitation," a regulated practice of extracting ore "according to the powers of the mine."[286]

Above all, the *Raubbau* discourse reveals the way in which officials understood resource exhaustion chiefly as a matter of labor discipline. Indeed, officials of Humboldt's time sometimes wrote that mineral deposits would yield inexhaustible riches if properly mined and managed. Some experts maintained a belief in the regeneration of metals within the earth. Such claims testify to the persistence of early modern ideas about the "vegetable" ripening of minerals, grown according to the influence of the moon and stars, or produced by a "juice" secreted from the rock by subterraneous heat.[287] The eminent German mineralogist Heinrich von Trebra, for instance, wrote of the "continual generation" of ore and described the "growth" of silver on wooden struts fixed within a mineshaft some 200 years beforehand.[288] And learned

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[285] Hartmann, *Handwörterbuch der Mineralogie, Berg-, und Hütten- und Salzwerkskunde*, 555: "Raubbau (*Exploitation par Gaspillage ou rapine*), derjenige Grubenbau, welcher unwirthschaftlich, ohne Rücksicht auf die Zukunft, und endlich so geführt wird, daß man zuletzt noch einen großen Theil nutzbarer Mineralien ungewonnen stehen lassen muß."

[286] Bergius, *Neues Policey- und Cameral-Magazin*, 264: "Indesses ist hiebey hauptsächlich die Regel beständig vor Augen zu haben, daß kein Raubbau geführet, a) sondern die Erzeugung immer nach den Kräften der Grube abgemessen, durch Hoffnungsörter neue Erztanbrüche erbauet, und folglich der Bau nach aller Möglichkeit verewiget werde."

[287] Georg Agricola, *De ortu et causis subterraneorum libri V* (Basel, 1546) in *De Re Metallica*, trans. Herbert Clark Hoover and Lou Henry Hoover (New York: Dover Publications, 1950), 51; Pamela H. Smith, "Making as Knowing: Craft as Natural Philosophy," in *Ways of Making and Knowing: The Material Culture of Empirical Knowledge*, eds. Pamela H. Smith et al. (New York City: Bard Graduate School, 2014), 17-47, esp. 23-30; Pamela H. Smith, "The Codification of Vernacular Theories of Metallic Generation in Sixteenth-Century European Mining and Metalworking," in *The Structures of Practical Knowledge*, ed. Matteo Valleriani (Basel: Springer, 2017), 371-92; Radkau, *Nature and Power*, 227.

[288] F. W. H. Trebra, *Erfahrungen vom Innern der Gebirge* (Dessau, 1785)*,* 45, 55: "Um diese 4 Stempel herum, und zwar gleich da, wo der Spath des hangenden Trumms, das Holz der Stempel auf allen Seiten

officials in France reported on "inexhaustible" (*inépuisable*) matrices of iron in the Parisian *Journal des Mines*.[289] But mining experts did not, to my knowledge, explicitly link theories of metallic growth to speculations about the inexhaustibility of subterranean resources. Instead, a deposit's inexhaustibility was thought to depend, paradoxically, on the manner in which it was exhausted. For certain mines "would be inexhaustible," wrote one inspector in 1794, "if they were not abandoned to laborers who, having no other interest than the present moment, extract only that which costs them little trouble, and leave that which presents difficulties."[290]

This *Ur*-conception of "sustainable" resource extraction is markedly distinct from modern meanings, which express concern for the degradation of fragile environments and the depletion of scarce resources. "It remains the duty of the miner to set his sights henceforth on the most exhaustive measures," wrote one Saxon official, speaking to the "well-being" of "many ages of Mankind" in the same breath.[291] Mining with consideration for future generations meant digging deeper—and doing so *bergmännischer*. For officials evoked *Raubbau* not to forewarn an impending exhaustion, but to decry the under-development of mines. As Paul Warde notes,

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umschlossen, habe er angeflogenes Glaserz und gewachsenes Silber, auch Schwärze, und Kobold, wiewohl beydes ersteres in den allerzärtesten Blätterchen, fast wie Schaum, desgleichen auch Kobaldblüthe und Kupfergrün gefunden." Trebra illustrated this phenomenon in Tafel IV. Nr. 4.

[289] E.g. M. Giobert, "De la Magnésie de Baudissero en Canavais, Department de la Doire," *Journal des Mines* 20, no. 2 (1806): 293-94: "Ce dernier village, célèbre autant par ses mines de fer que par la manière dont on les travaille, renferme entre autres mines dans une montagne, une mine en amas et inépuisable de fer ... d'une pureté très-remarquable, où l'on a établi, depuis plusieurs années, la fabrication du sulfate de fer par la combustion du sulfure"; "Il me paraissait que la nature, en plaçant d'un côté une mine inépuisable de soufre qui fournirait l'acide sulfurique, de l'autre, des carriers inépuisables d'une terre destinée à en fournir la base…."

[290] Citoyen Baillet et Rambourg, "D'un mémoire sur la fabrication des aciers de fonte du département de l'Isère," *Journal des Mines* 1, no. 4 (1794): 3-23, 6: "Elles seraient inépuisables, si elles n'étaient pas abandonnées aux ouvriers, qui, n'ayant d'autre intérêt que celui du moment, n'extraient que ce qui leur coûte peu de peine, et laissent ce qui leur présente quelques difficultés."

[291] "Freyberg, den 6ten Januar 1830. Königlich Sächsisches Ober-Bergamt," GSA, Bestand Goethe 26 LXVI, 2, 85, Bl. 178: "[S]o bleibt es doch die Pflicht des Bergmanns, hierauf bis zu den erschöpfendstend Maasregeln das Absehen zu richten. Auch ist wohl nicht zu verkennen, daß eine Ausführung, wie der Meißner Stolln, die ... auch vor vielen andern auf mehrern Menschenalter hinaus vielleicht Tausende von Menschen mittel- oder unmittelbar beschäftigt, ihren Wohlstand vermehrt…."

sustainability itself then referred not so much to the *over*-use of wood resources as to their *under*-use.[292] Thus, some definitions of *Raubbau* even suggest leaving "*Reservebaue*" of unexploited ore in the upper sections of a mine to ensure its longevity.[293] In one case from Saxony's Schwarzenberg District in 1820, a mine official (*Geschworner*) was censured for "leaving the minor deposit of iron untouched," while elsewhere carrying out a "true and entirely prohibited *Raubbau*"—a practice judged "un-minerly" for compromising "posterity."[294]

Humboldt spoke the same language when he arrived in the Franconian Principalities of Ansbach and Bayreuth. In his initial report of 1792, he described an alum mine, for instance, as "utterly irregular and more un-minerly than anything I have seen in both principalities."[295] And in his "Oeconomic-Plan" of 1794, Humboldt encouraged fellow officials "to persevere in regular operations and beware the unruly", "obstinate investors." "Resistant shift bosses and foremen," who worked at the bidding of the investors, were to be "reprimanded" for their first offence of disobedience to the state and "punished with a monetary fine for all further insubordination."[296]

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[292] Warde, *Invention of Sustainability*, 205.

[293] Hartmann, *Handwörterbuch,* 555: "Der Raubbau kann auf mancherlei Weise statt finden. Das preuß. Landrecht (a. a. D. S. 206 und 207) rechnet hauptsächlich dazu: 1) Das unwirthschaftliche Aushauen der *obern Mittel*, d. h. des obern Theils einer Lagerstätte, wodurch das Wasser in die tiefern Baue gezogen wird und daselbst so überhand nimmt, daß es nicht gewältigt werden kann. Auch liegt bei dem Schonen der obern Mittel noch eine besondere Absicht zum Grunde, weil sie die sogenannten *Reservebaue* ausmachen, welche man zu den Zeiten angreifen kann, wo auf den tiefern Bauen wegen des Wassers nicht mit Arbeit anzukommen ist, und wodurch der ununterbrochene Betrieb eines Grubengebäudes gesichert wird."

[294] SächsBergAFG, 40169, Nr. 1748, Bl. 3-4: "…nur die guten Eisensteine heraushaue, die geringern Eisensteine aber unabgebaut stehen lassen…; so soll dieser ganz unbergmännische, den Berggesetzen nach, völlig unstatthafte wahrhafte Raubbau bey welchem nicht nur der gesammte geringere Eisenstein, sondern auch sehr viele Einzelne einbrechende gute Niveau sowohl dem jetzigen Herrn Eigenlohner, als dessen Nachfolgern ganz verloren gehen, ... für die Zukunft gänzlich untersagt worden."

[295] As quoted in Holl and Schulz-Lüpertz, *Humboldt in Franken*, 58.

[296] StABa, KDK, Nr. 7124, Bl. 465: "Da Wir aus euere über die Recherchirung der Nailaer BergAmtsRevier unterm 12. v. M. erstatteten Bericht mit Wohlgestatten ersehen haben, daß ihr die im Zwecke liegende von Unserm OberBergRath von Humboldt vorbereiteten Plan mit Eifer zu verfolgen euch angelegen seyn lasset. So wird euch alles dasjenige was ihr während der Recherchirung auf den Gruben sogleich veranstaltet habt, hiermit vollkommen genehmiget und ihr besonderes angewiesen, in Verbesserung des gewerkschaftlichen GrubenBaues euch den Eigensinn der Gewerken und ihrer

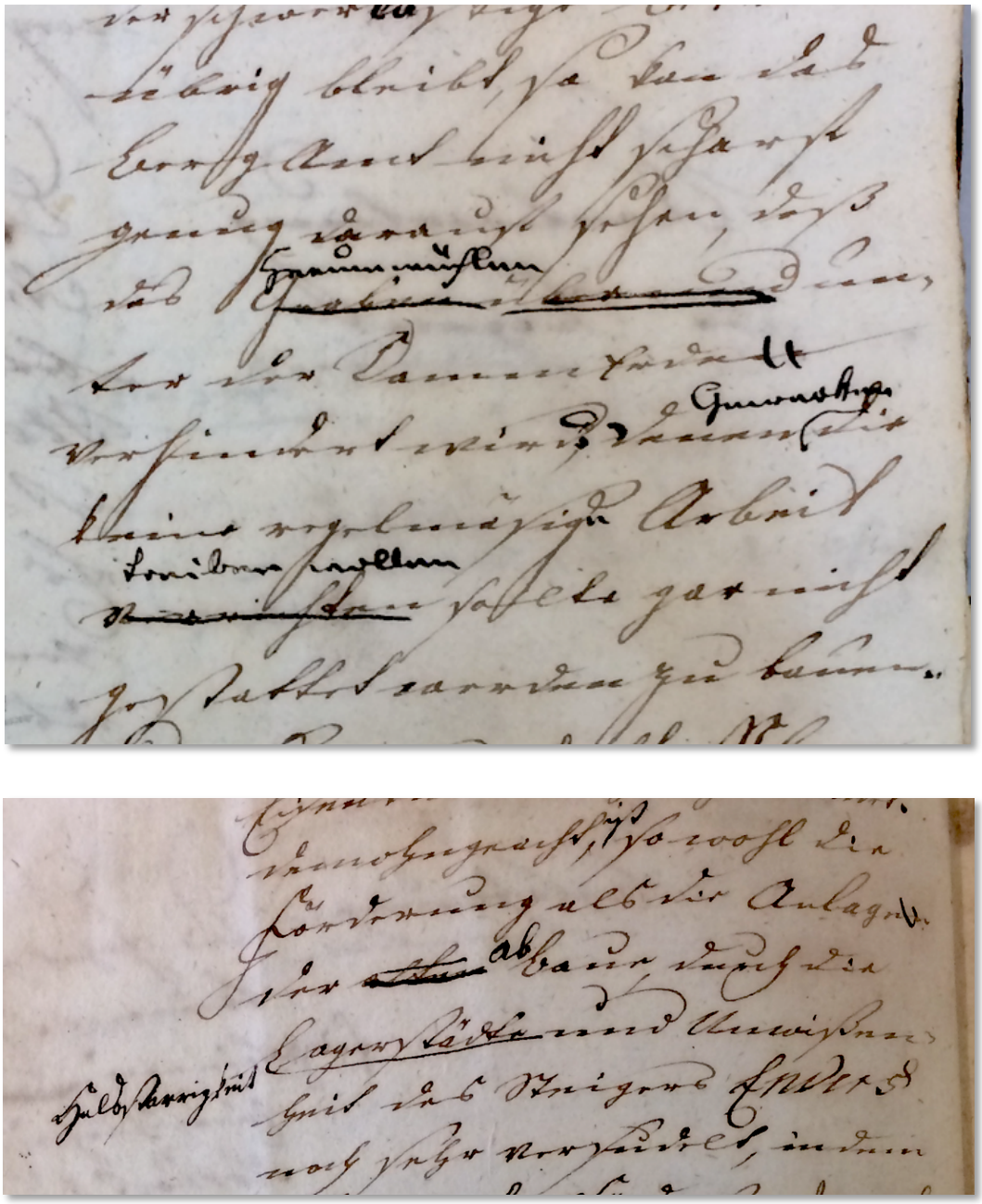

Figure 3. Mine officials in Lichtenberg-Lauenstein lash out against the corrupting influence of investors over the foremen. Signed by Eberhard Friedrich Killinger, the reports respond to "the plan prepared by Humboldt" in Bayreuth on 21 Nov. 1795. The annotations added to the text—about the "ransacking" of mines by "obstinate" investors and "ignorant" foreman—expose the alleged culprits of *Raubbau* and the bitterness they felt towards them. StABa, KDK, Nr. 7124.

Unwissenheit entstehenden Einwendungen nicht irre machen zu lassen, vielmehr auf regulähren Betrieb und Abbau zu beharren und gegen die Widerspenstigen nachdrucksame Unterstuzung zu gewärtigen. […] Die neurer Anordnungen widerstrebende Schichtmeister und Steiger sind das erstemal mit Verweiß das anderemal mit Geld Bußen zu bestrafen bey fernerer Insubordination aber nach vorheriger Berichtserstattung zu removiren, und die Stellen anderweit zu besezen."

From such documents, an image emerges of internal court proceedings by which officials in Saxony and Prussia disciplined labor relations. Once a complaint of *Raubbau* was lodged, an official "of the *Leder*" was often "summoned to speak" (*zu Rede gesetzt*). In the tomes of documentation that such disputes yielded, losses were quantified, and infractions mapped—a process by which state surveyors made the earth's "robbery" a legible offense.[297]

Reports compiled in response to "the plan prepared by Humboldt" reveal the bitterness with which officials condemned the "un-minerly" (**Figure 3**). In one document, the mine official Eberhard Friedrich Killinger strikes out another's tempered description of "~~overcoming the mine~~," adding "ransacking" (*Herumwühlen*) to disparage the practice of "investors who have no desire to work according to regulations." Where the report continues to describe how "the exploitation as well as the very construction of the ~~old~~ mine are defiled by the ignorance of the foreman named *Ender*," Killinger again adds his own repudiation—"obstinance" (*Halsstarrigkeit*)—in the margin.[298] A liability when working under the influence of investors, foremen like Ender might, Humboldt thought, be turned into a valuable asset.[299] It was the foreman class, therefore, that the Mining School hoped to make anew.[300]

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[297] This reconstruction draws upon examples of *Raubbau* and "un-minerly" activity catalogued in SächsBergAFG 40169, Nr. 119, Bl. 8-13; Nr. 1680, Bl. 3-4; Nr. 1211, Bl. 5-6; SächsBergAFG 40010, Nr. 3349, Bl. 205-06; SächsBergAFG 40010-1, Nr. 3349, Bl. 207.

[298] StABa, KDK, Nr. 7124, "Generalbefahrungsprotokolle für das Revier Lichtenberg-Lauenstein" (unnumbered): "Gewerken, die keine regelmäsige Arbeit treiben wollen." "…sowohl die Förderung als die Anlage~~n~~ der ~~alten~~ (Ab)baue, durch die ... Unwißenheit des Steigers ... noch sehr versudelt." I translate "defile" from "versudeln," which the Adelung dictionary (1st ed. 1774–1786) defines as a synonym of "*besudeln*," meaning to defile, besmirch, or befoul. The document is signed by Eberhard Friedrich Killinger (1770-1826), one of Humboldt's subordinates who, having studied at the Mining Academy in Freiberg, rose to the rank of Vize-Oberbergmeister by 1796. The pen used to make his signature matches the marginalia and editing discussed above. On Killinger and Humboldt, see Chapter 5.

[299] Ursula Klein notes that Humboldt believed foremen lacked authority and worked too closely with the hewers, and that these concerns bespoke greater concerns about fraud amongst foremen. Klein, "The Prussian Mining Official," 41-42.

[300] On Humboldt's purchase of mine shares and his efforts to secure other investors, see Michael Dettelbach, "Romanticism and Administration: Mining, Galvanism and Oversight in Alexander von Humboldt's Global Physics" (PhD diss., University of Cambridge, 1992), 50-51.

Psychological Politics

One of the School's pupils was Johann Georg Spörl, who left behind only a faint paper trail in its records. Encircled by low-lying hills mined for silver and iron ore since the early medieval period, Bad Steben came under Prussian aegis in 1792, when Spörl was 11 years old. This is the age when he would have joined the other miners' sons (and in some cases daughters) in various above-ground tasks—hoisting rock out of the shafts, sifting through heaps of extracted earth, washing and crushing iron ore en route to the ovens. Then, at age 17 or 18, Spörl would begin his apprenticeship, assisting the master hewers, masons, carpenters, smelters, or mechanics until achieving a specialization of his own.[301]

Figure 4. The Rathaus of Bad Steben, where the Mining School was held from 1793 to 1806. At the time, rooms were let to "Berggeschworner," lower-ranking members of the Mining Administration to which Georg Heinrich Spörl (1764–1830), the School's first instructor, belonged. Humboldt wrote that the School was "held in the very spacious, well-lit room of Spörl." Image reprinted from Sebastian Mayer, "Alexander von Humboldt und die Bergschule im oberfränkischen Steben" (Technische Universität Dresden, 2008), 13.

[301] Wilfred Liessmann, *Historischer Bergbau im Harz: Kurzführer*, 3rd ed. (Berlin: Springer, 2010), 36.

It is in this latter phase that we find Spörl in the attendance charts of the Mining School (**Figures 4**). Spörl attended the School since at least the winter of 1800, alongside 36 other boys and young men who gathered at the instructor's lodgings twice a week through the winter months. By 1806, the instructor noted that while the younger two Johanns in the family "learn slowly," twenty-four-year-old Johann Georg was "the most diligent and best of them all, possessing also the greatest knowledge." Perhaps, the teacher wrote, eighteen-year-old Georg Heinrich Spörl would follow the elder Johann's example, if his "diligence does not abate."[302]

We can get a sense of Spörl's exemplary knowledge from the schoolbook that Humboldt drafted in 1794, and which, the instructor noted, "was nearly unreadable from long years of use" but still taught a decade on.[303] Humboldt's text buttressed practical knowledge of ore extraction with a sort of geophysical journey that oscillates between local and global phenomena, working out from the "ancient, sedimentary, and alluvial" strata of Franconia to the "heights of mountains" on far-off continents, like South America's "Schimborasso" before circling back to the "ore-bearing rock masses" beneath their feet.[304] Eventually, students graduated to lessons that were both increasingly theoretical and increasingly practical. In a set of exercises from his time at the School, we find Spörl trained in "subterranean surveying," defining and measuring various features of the mine. As a future foreman or shift boss, he also practiced drafting administrative reports, on the location and extraction of a local vein of "thick brown iron ore" for instance, "not more than 10 inches in breadth."[305]

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[302] The following records track Spörl's education over the course of six years: StABa, KDK, Nr. 7114, vol. 1, Bl. 35, 286, 288, 394: "dies ist der fleisigste und beste unter allen, und besitz auch die mehresten Kentnisse"; "wann dieser im Fleiß nicht nachläst so wird er den vorigen nachkommen."
[303] Ibid., Bl. 80. The School's "Inventarium" of 1801 records "56 Vorschriften; diese sind aber durch den langen Gebrauch fast ganz unbrauchbar worden."
[304] StABa, KDK, Nr. 7114, vol. 1. The book spans Bl. 82-103; quotations are from Bl. 82-83, 88.
[305] Ibid., Bl. 323, 324, 45.

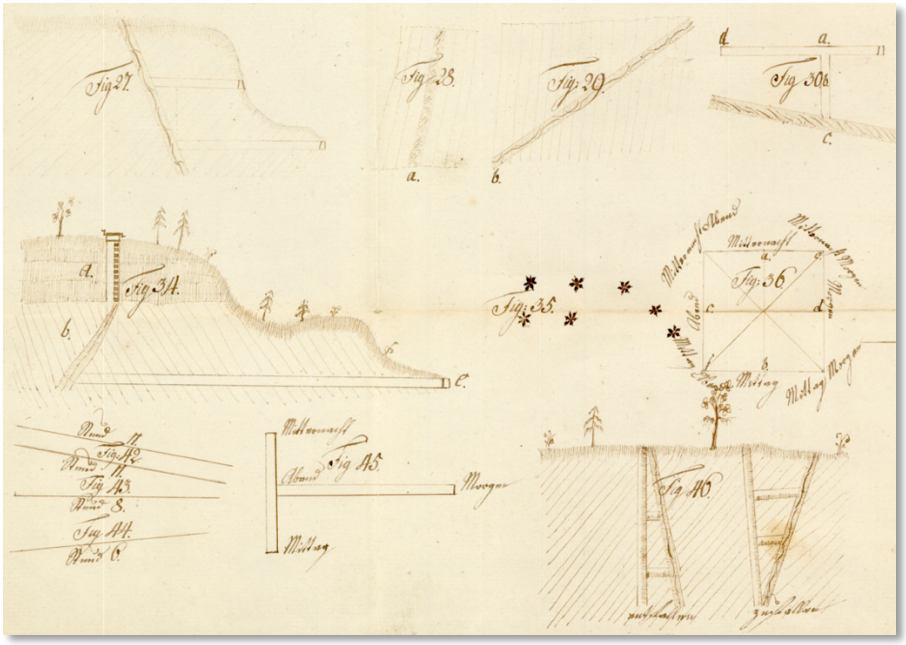

Figure 5. Detail from Humboldt's schoolbook. These figures correspond to lessons in "subterranean surveying." Note the specific instruction on how to read the orientation of mineral veins and mineshafts in the industry's parlance, as indicated by the compass on the right. StABa, KDK, Nr. 7114, vol. 1, Bl. 102-03. StABa, Karten und Pläne (A 240), T 5022. Compare to Chapter 5.

Spörl was schooled, therefore, in solutions to the problem of *Raubbau*. Officials saw *Raubbau* manifest in the very construction of the mines, where poorly built shafts prevented a deposit's "sustained" exhaustion. Humboldt specifically lamented that the "boys" were ignorant of framing devices meant to keep the shafts from caving in.[306] As a corrective, lessons on structural integrity began with the rudiments of underground orienteering, as instructed by a set of figures Humboldt drafted himself (**Figure 5**).[307] Later, advanced students like Spörl would learn the "rules" of blasting, boring, and framing.

But there was also a political agenda embedded within Spörl's education in the physical properties of the earth and the material demands of mining operations. In the School's founding

[306] Humboldt to Carl Freiesleben, 21 Jan. 1794, *Jugendbriefe*, 312: "Man muß den Knaben sagen, was ein geschuhter Thürstock sei, ihn außer der Grube nicht lehren wollen, ihn zu sezen." In the *Jugendbriefe*, the editors define "Türstock, geschuhter" as "Holzgerüst zum Schutz gegen Einsturz, bestehend aus Stempeln, Jöchern und Kappen sowie einem vor Zerstörung schützenden Teil (Schuh)." (Ibid., xxlviii.)
[307] See further analysis in Holl and Schulz-Lüpertz, *Humboldt in Franken*, 62-64.

document, Humboldt criticized the notion that the industry would advance in pace with the rising number of administrators produced by technical academies in Schemnitz and Freiberg and training schools in Berlin and Clausthal-Zellerfeld.[308] The core idea of these institutions was to produce cameralists, like Humboldt, tasked with overseeing mining and smelting operations. Yet Humboldt's School had a different aim: rather than install more administrators (what he decried as a "miserable policy of tutelage"), he wanted to instill administration in the miners themselves—as a set of practices, a way of thinking, an atmosphere.[309] Humboldt's agenda in Bad Steben is consistent with a broader surge in *Bergschulen* and other "industry schools" founded throughout Germany's mining centers at the turn of the century.[310]

Considering again the education of Spörl, we see that lessons in the construction of mineshafts and methods of mineral extraction were bound also to the School's "psychological policy." Alongside the two-dozen mineralogical specimens listed in the School's "inventory" were books ranging from mathematics and mining law to stratigraphy and carpentry. Leafing through them, one finds descriptions of mining practice laden with prescriptions about miners'

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[308] This was the argument of an earlier generation of cameralist literature, as in Christoph Traugott Delius, *Anleitung zu der Bergbaukunst nach ihrer Theorie und Ausübung...* (Wien, 1773), 2: "wo so viele Hindernisse, die die Natur dem Bergbaue selbst in den Weg leget, weggeräumet werden müssen; anderer Hindernisse nicht zu gedenken, die demselben öfters aus Unwissenheit, falschen Begriffen und Nebenansichten gemacht werden; daß, sage ich, bey diesen Umständen, wenn der Bergbau anderst dem Staate Vortheil schaffen, und in glücklichen Umständen fort und fort erhalten werden soll, auf die immerwährende Nachziehung geschickter, und sowohl in Grundsätzen als in der Ausübung erfahrner Bergbeamten das vorzüglichste Augenmerk genommen werden muß; damit der Bergbau in allen seinen Theilen nach gesunden mit der Erfahrung verknüpften Grundsätzen regelmäßig, ordentlich, fleißig und wirthschaftlich behandelt werde."

[309] Humboldt, "Promemoria," 293: "Man vermehre die Receptivität des gemeinen Bergvolks, suche es nachdenkend und verständig ... so wird die Tutel endlich aufhören, hinter die eine armselige Politik sich so gern verbirgt."

[310] Heinz Kelbert noted that Humboldt's School took after a *Bergschule* founded in by Anton von Heynitz in Freiberg in 1776 as a subsidiary of the Mining Academy, which was founded by the same Heynitz in 1765. In Freiberg, the top eight students would be admitted into an abbreviated course of study at the *Bergakademie*. See Heinz Kelbert, *Das Bildungswesen auf den fiskalischen Berg- und Hüttenwerken in Preussen am Ausgang des XVIII. Jahrhunderts* (Berlin: Volk und Wissen, 1955), esp. 50-51, 119-30, 144-48.

behavior—a self-conscious analogy between structural and moral integrity. "The greatest possible utility combined with the most enduring sustainability," says one text on timber work, preaching "oeconomy in all aspects of mining" and stressing, like Humboldt's *bergmännisches Ehrgefühl*, the "honorableness of the carpenters."[311] "The children must not turn their backs to the instructor," Humboldt wrote while describing the very architecture of the School's classroom.[312] Indeed, one course of study during Spörl's time at the School culminated in a final "Lesson on the conduct of the students towards their superiors as well as their co-workers."[313]

Humboldt's Mining School fused the enlightened humanism of contemporary educational reform with statist ambitions. In 1792, Alexander's elder brother Wilhelm began outlining his now-famous vision for the humanistic cultivation of common people at a time when literacy rates were rising in Germany, from about 15 % in 1770 to 25 % in 1800.[314] "In this way," Wilhelm wrote, "*artists* may be made of all peasants and workmen, that is, men who learn to love the craft of their craft" (*die ihr Gewerbe um ihres Gewerbes willen liebten*).[315] It was the role of the state,

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[311] Friedrich Dingelstedt, *Versuch einer Anleitung zur Grubenzimmerung und Mauerung für angehende Bergleute* (Schneeberg, 1793), 13, 12, 8: "in allen Theilen des Bergbaues der Oekonomie äußerst befleißigen muß"; "den möglichsten Nutzen mit dem längsten Nachhalt verbindet"; "Die Arbeiten, vorzüglich in der Grube, hier zu verdingen, würde nicht ratsam sein, indem man an der Güte der Arbeit zu verlieren Gefahr laufen würde, wodurch fürs Ganze beträchtlicher Schade entstehen könnte, da außerdem, die Fälle beim Bergbau nicht selten sind, wo man sich mehr auf die Ehrlichkeit der Arbeiter (Zimmerlinge) verlassen, sogar wo man solche durch kleine Lohnzulagen eher zur Arbeit aufmuntern muss, als durch Strenge dazu anhalten kann…."

[312] Humboldt, "Promemoria," 297: "Die Kinder dürfen z. B. dem Lehrer nicht den Rücken zukehren, sich nicht ansehen, u. dgl., alles dies stört die Aufmerksamkeit."

[313] StABa, KDK, Nr. 7114, vol. 1, Bl. 42: "Lehre über das Betragen der Schüler gegen ihre Vorgesezten als auch Mitarbeiter und Nebenmenschen."

[314] James Brophy, *Popular Culture and the Public Sphere in the Rhineland, 1800–1850* (Cambridge: Cambridge University Press, 2007), 22.

[315] Wilhelm von Humboldt, "Wie weit darf sich die Sorgfalt des Staats um das Wohl seiner Bürger erstrecken?" *Neue Thalia* 2 (1792): 131-69, on 157: "Alles, womit sich der Mensch beschäftigt, wenn es gleich nur bestimmt ist, physische Bedürfnisse mittelbar oder unmittelbar zu befriedigen, oder überhaupt äußere Zwecke zu erreichen, ist auf das genauste mit inneren Empfindungen verknüpft. […] So ließen sich vielleicht aus allen Bauern und Handwerkern *Künstler* bilden, d.h. Menschen, die ihre Gewerbe um ihres Gewerbes willen liebten, durch eigen gelenkte Kraft und eigne Erfindsamkeit verbessern, und dadurch ihre intellektuellen Kräfte kultivierten, ihren Charakter veredelten, ihre Genüsse erhöhten."

moreover, to ensure the individual freedom required for such *Bildung*. These lofty ideas found a home in the lesser-known educational reforms of Wilhelm's brother, who similarly exalted "the value of the education of common people." But the political language with which the Mining School treated foremen is also revealing of a more localized agenda. Cultivating foremen into loyal "citizens" of the cameralist state, Humboldt wished to "stimulate them to intellectual independence"—independence, that is, from the "stubborn will of the investors."[316] Moreover, in texts like Voigt's *Mining State*, pupils learned that decisions about labor organization were "not to be left to the despotism of the foreman [but] rather to the Mining Administration."[317]

Humboldt's own schoolbook makes a concerted effort to normalize miners' judgment by stigmatizing ignorance. While comparing the heights of Harz Mountains to other peaks around the world he was sure to note, for instance, how only "simple-minded people believe that witches dance" on the Brocken.[318] To a fellow Freiberg graduate, Humboldt complained of finding "everywhere ignorance amongst the miners," noting above all the "prejudices of prospecting"—that is, folk knowledge about dowsing and divining.[319] Against these "prejudices," the School marshalled Abraham Gottlob Werner's science of geognosy, which ordered the earth's strata (*Gebirgsarten*) according to the age of their formation.[320]

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[316] Humboldt, "Promemoria," 293: "Der Werth der Erziehung des gemeinen Volks ist längst erkannt." StABa, KDK, Nr. 7124, Bl. 465.
[317] Voigt, *Bergwerksstaat*, 102: "Hier ist zu bemerken, daß es nicht in des Steigers Wilkühr stehe, eine gewisse Triebenzahl zu thun. Es wird ihm dieselbe vielmehr vom Bergamt, oder dem Bergmeister und Geschwornen, allezeit bey jährlicher *Generalbefahrung*, nach Beschaffenheit der Anbrüche und der Zahl der vorhandenen Arbeiter, aufgeleget, und entweder vermehret oder vermindert."
[318] StABa, KDK, Nr. 7114, vol. 1, Bl. 88: "Dagegen ist am Harz der Brokken oder Bloksberg; wo, wie einfältige Leuthe glauben, die Hexen tanzen sollen, nur 3012 Fuß hoch."
[319] Humboldt to Carl Freiesleben, 21 Jan. 1794, *Jugendbriefe*, 311: "Als ich auf Nailaer Refier ankam, fand ich überall ~~krasseste~~ Unwissenheit unter dem gemeinen Bergvolke, Vorurtheile von Schürfen…."
[320] Rachel Laudan, *From Mineralogy to Geology: The Foundations of a Science, 1650–1830* (Chicago: University of Chicago Press, 1987), 87-96, 106-09. On *Gebirge* and Werner's geognosy, see Martin J.S. Rudwick, *Bursting the Limits of Time: The Reconstruction of Geohistory in the Age of Revolution* (Chicago: University of Chicago Press, 2005), 84-99.

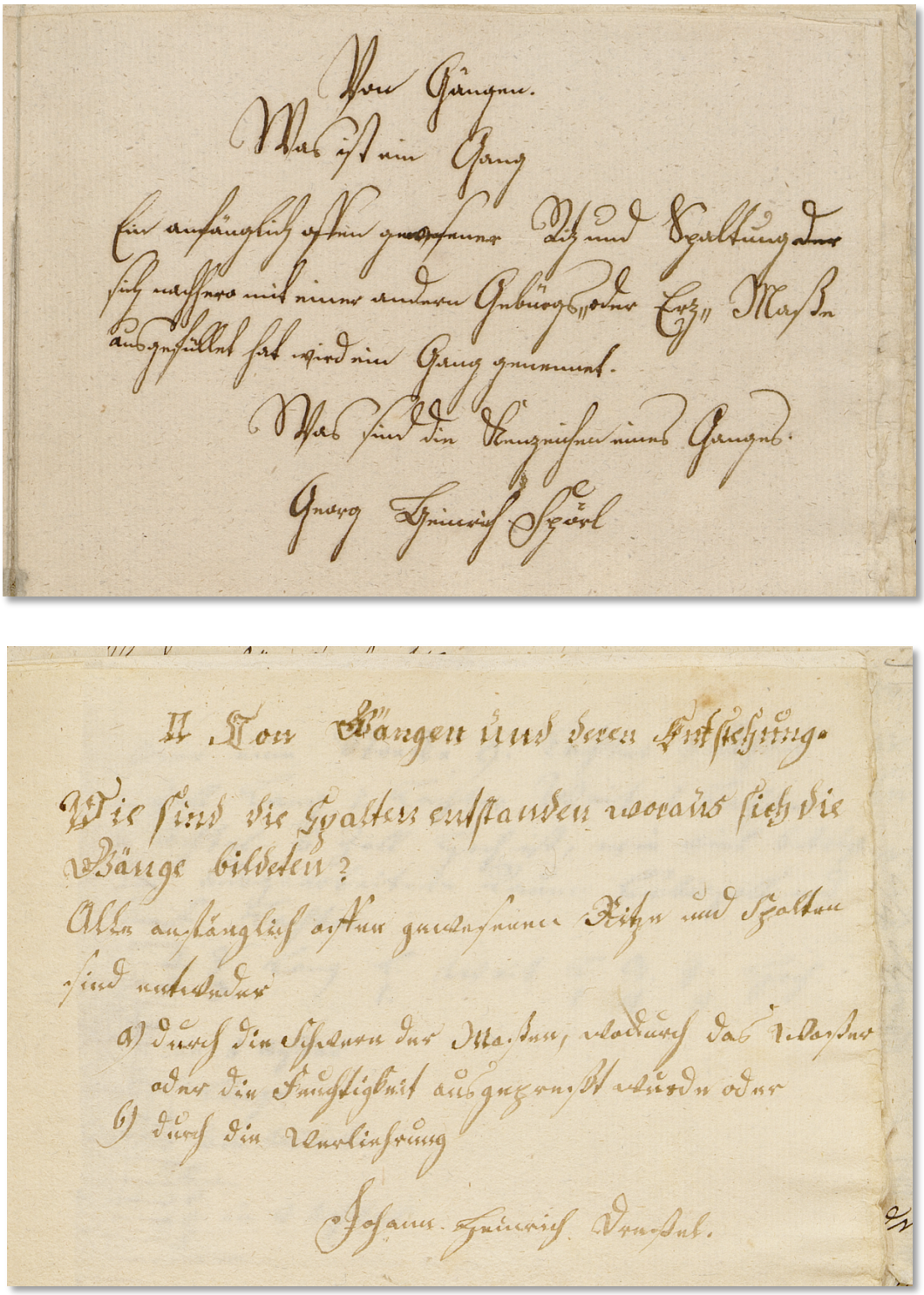

Figure 6. The careful penmanship of Mining School pupil Georg Heinrich Spörl (b. 1788), presumably a relative of the School's instructor (of the same name) and possibly the brother of Johann Georg Spörl (b. 1781). The document lay amongst exercises dated 1804. In the second exercise, the pupil Johann Heinrich Drecßel adds the aqueous component—"*Waßer oder Feuchtigkeit*"—of Werner's theory of vein formation. StABa, KDK, Nr. 7114, vol. 1, Bl. 314, 321.

Combatting the dowser's occult sense of mineral effluvia, Werner's geognosy made ore veins a mappable phenomenon, the result of a historical process by which metal-rich liquids were deposited within the fissures of the rock.[321] When asked "What is a vein," sixteen-year-old pupil Georg Heinrich Spörl offered a distillation of Werner's theory (**Figure 6**): "A cleft originally open and a cleavage which has then been filled by another *Gebürgs*—or ore—mass is called a vein," Spörl wrote, drawing upon the School's lessons "on the formation-time" and "formation-type of *Gebirge*, after Werner's theory."[322] Replacing the dowser's rod with the geognist's map, the Mining School was to "bring the mountain folk to science."[323] Armed with compasses, surveying skills, and geognostic theory, schooled in masonry and carpentry, the "citizens" of Humboldt's mining state were to serve the Administration in its campaign against *Raubbau* and the "obstinate investors." Indeed, they were to embody administration itself.

Between Spirit and State

How did laboring miners view *Raubbau* and resource use, investors and administrators? Miners' voices are all but silent in the School's records, noted only when reproducing knowledge bestowed upon them. But this diffusionist model of knowledge was itself a fantasy of the cameralist elite.[324] In truth, miners of various ranks mediated between a variety of knowledge-forms, translating ontological worlds that were ruled by, or ruled out, spiritual entities. Historians have engaged the vernacular culture of mining as a rich repository of pre-modern beliefs about

[321] Abraham Gottlob Werner, *Neue Theorie von der Entstehung der Gänge*…. (Freiberg, 1791), 54-55.
[322] StABa, KDK, Nr. 7114, vol. 1, Bl. 314: "Von Gängen. Was ist ein Gang. Ein anfänglich offen gewesener Ritz und Spaltung der sich nachhero mit einer andern Gebürgs—oder Erz—Maße ausgefüllet hat wird ein Gang genennet." Ibid., Bl. 40: "Von der Entstehungszeit der Gebirge"; "Ueber die Entstehungsart der Gebirge, nach Werners Torie [sic]."
[323] StABa, KDK, Nr. 7114, vol. 2, Bl. 2: "dem BergVolke zur Wißenschaft zu bringen…."
[324] Wakefield, *The Disordered Police State*, 141-43.

the natural world, its sacral elements, and the place of humankind within it.[325] By reading against the grain of early modern texts on mineralogy and paleontology, moreover, scholars have identified the conditions under which miners, quarrymen, and ditch-diggers supplied savants with knowledge and naturalia from the earth.[326] Mining folklore, in turn, offers a rare, if highly mediated, impression of laborers' own understandings of nature and its exploitation.

Passed through generations of laborers and eventually transcribed by folklorists and local historians in the nineteenth and early twentieth centuries, early modern mining folklore consistently linked good fortune in mineral extraction with moral virtues of thrift, honesty, and modesty. As in the *Raubbau* discourse of officials, so in mining mythology: environmental alarms were triggered by social and ethical concerns. In folklore, this was particularly true when the exploitation of the mines entailed that of miners themselves. Mining myths and songs thus exhibit a set of social sensibilities: deference to investors and hostility towards state officials.

When Humboldt's mentor, the naturalist Georg Forster, witnessed a mining parade in Freiberg in 1784, he noted in his journal the particular "zeal" of the cantor who led the chorus. Forster believed him entirely justified, "for all that the little boys knew, they knew from him."[327] Miners' oral traditions were indeed a vital means of communicating knowledge and identity between generations, and in the days that followed Forster tuned his ear to their vernacular. Forster pinpointed the matter of cobalt, a by-product of copper and nickel whose blue pigment

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[325] Fors, *The Limits of Matter*; Dym, *Divining Science*; Henrike Haug, "In the Garden of Eden? Mineral lore and preaching in the Erzgebirge," *Renaissance Studies* 34, no 1 (2020): 57-77; Warren Dym, "Mineral Fumes and Mining Spirits: Popular Beliefs in the *Sarepta* of Johann Mathesius (1504-1565)," *Reformation & Renaissance Review* 8 (2006): 161-85.

[326] Lydia Barnett, "Showing and hiding: The flickering visibility of earth workers in the archives of earth science," *History of Science* 58, no. 3 (2019): 245-74.

[327] 22 June 1784 in AA XII, 61: "Der Cantor, der die Bande anführte, war bey seiner Musik sehr eifrig, und hatte es auch Ursach, denn alles was die kleinen Knaben wußten, hatten sie von ihm, das fühlte er wohl."

gave Saxon porcelain its distinctive color, in emulation of Chinese ceramics. Forster cryptically asserted that knowledge of cobalt remained "a secret in the hands of common workers that, having fallen into stagnation, will never be improved."[328] People of Forster's education knew cobalt as a "semi-metal," the designation given by Swedish chemist Georg Brandt in 1735.

Humboldt displayed cobalt specimens in the Mining School's cabinets (**Figure 7**), alongside copper, arsenic, and galenite, "useful fossils" of which he believed the children painfully ignorant.[329] The identification of ores and minerals figured into the School's civilizing mission and emulated the Mining Academy's union of practice and theory. Popular mining texts had long evoked the image of the Academy's mineralogical collection (**Figure 8**) to suggest the role "science" would play in promoting "the theories and regulations according to which mining is carried out *bergmännisch*, that is, most advantageously."[330] This helps to explain why a color illustration of the *Bergschule*'s own cabinet appears in its records, and even resembles the Academy's mineralogical collections in its arrangement of drawers and glass displays. But Forster was right that "common" miners possessed a far more expansive understanding of the semi-metal. In defining cobalt as a strictly material phenomenon, Brandt's "discovery" of the metal precluded older understandings of cobalt as a keeper entity.[331]

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[328] 12 July 1784 in AA XII, 77: "Das Arcanisiren ist in solchen Fällen immer schädlich, alles wird handwerksmäßig behandelt weil man einsichtsvolle Leute nicht urtheilen läßt, sondern die Behandlung ohnabänderlich in den Händen des gemeinen Mannes bleibt. […] Der Kobolt oder blaufarbne Handel der für Sachsen so wichtig ist; wird eben dadurch, daß er blos als Geheimnis in den Händen des gemeinen Arbeiters ist, und nie etwas daran gebessert wird, einmal liegen bleiben und ins Stocken gerathen."
[329] Humboldt, "Promemoria," 296; StABa, KDK, Nr. 7114, vol. 1, Bl. 80
[330] *Bericht vom Bergbau* (Leipzig, 1772), Vorbericht: "angewendete Größenlehre sich gründende Regeln, wornach sodann ein Grubenbau Bergmännisch, das ist, am vortheilhafsten, betrieben werden kann."
[331] See Fors, *Limits of Matter*, 99-100.

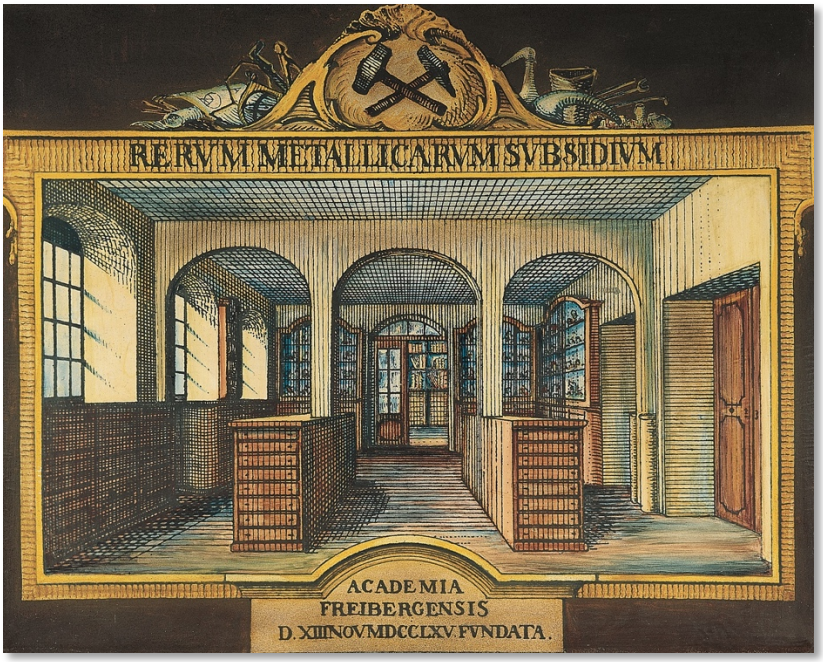

Figure 7 (Above). The five-foot wide bookshelf of the *Bergschule*, designed like a mineralogical cabinet to hold the specimens of cobalt, copper, arsenic, and galenite listed along the eleven books registered in the School's "inventory." The inventory also notes "1 small table," "2 chalkboards," and "6 benches with desks." StABa, KDK, Nr. 7114, vol. 2, Bl. 72. Figure 8 (Below). The mineralogical collection of the Freiberg Mining Academy, as illustrated by Siegfried Leberecht Crusius in *Bericht vom Bergbau*. © TU Bergakademie Freiberg / Waltraud Rabich.

Cobalt itself derives from *Kobold*, meaning goblin. And tales of Kobold and his goblin-kin Nickel, widespread in German and Scandinavian mining culture, were part of a mythological framework through which miners described nature's resistance to exploitation.[332] One legend, sourced from the Ore Mountains north of Franconia, tells of the earth's rebellion again to those who would "ransack it," digging "ever deeper into the subterraneous realm." "I transformed my silver into cobalt," said one goblin, "and I transformed mine into nickel," said the other, as they conspired to destroy the ladders and pumps with which miners assailed their dwellings. "One accident followed another," yet the miners were unrelenting, now exploiting cobalt and nickel instead of silver. "Gradually, Kobold and Nickel came to realize that they had misjudged men. They felt their powers dwindle and they fled the region." Impervious to nature's warnings, deposits of silver, then nickel and cobalt, were utterly extinguished, along with the lives of many miners.[333]

What administrators codified as *Raubbau* resonated also through centuries of mining myth. Not entirely unlike Humboldt, Rübezahl and his kind manifested themselves in the mines to punish the greedy, reward the honorable, and safeguard the earth. Frivolity, excess, arrogance, and recklessness—*Frevel*, *üppiges Leben*, *Hochmut*, and *Übermut*—this was not only the language of administrators, but also that of a mythology whose keeper entities policed administrators in turn.[334] Above ground, administrators condemned *Raubbau* in courts and with the quill, while in the mines such infractions were met with the wrath of the earth's ghostly denizens. Rash exploitation, neglect for the blessing of mines, and cruel treatment of miners were all punishable offenses in the jurisdiction of the *Berggeist*. "The *Berggeist* ought to do

[332] Heilfurth, *Bergbau und Bergmann*, 176.
[333] Werner, *Bergmannssagen* (1985), 92-93.
[334] E.g. Werner, *Bergmannssagen* (1985), 116, 129; Werner, *Bergmannssagen* (1990), 99, 121.

away with him," cursed the hewers in a Harz legend, summoning their patron to punish an official who imposed ten-hour shifts. (In Franconia miners worked twelve-hour shifts, which Humboldt believed "encouraged laziness," and reduced to eight.[335]) Promised unknown treasures by a "Little Man" (*Männchen*), the cruel Harz official was lured into the depths only to be "locked in the earth" by a quake. "Remain here and guard your treasure," spat the *Männchen*, "which means more to you than men!"[336]

Tales about mine officials, captains, and foremen suggest a particular hostility towards state oversight. Lacking the legal-bureaucratic power of the pen, miners wielded the spoken word to right the wrongs of their working worlds. "In the saga—and only in the saga," Ortrud Krause wrote in her study of Harz folklore, "could the unjust master be punished!"[337] Sometimes it was the "Mine-God" who administered justice.[338] More often, it was the Mine Spirit who presided over the subterranean in his many forms. According to the Romantic folklorist Johann Musäus, the "autocratic rule" (*Alleinherrschaft*) of Rübezahl, the "Prince of Gnomes," began "just a few leagues beneath the arable crust of the earth ... extending 860 miles to the earth's center."[339] Where officials imposed "punitive shifts" on the miners, or denied them good pay, Rübezahl sought retribution, tossing entire pits into heaps of rubble.[340] One legend told of a mouse who crawled out of the nostrils of a sleeping "Mine Master" (the rank Humboldt held

[335] As quoted in Klein, "The Prussian Mining Official," 42. See also Kelbert, *Das Bildungswesen*, 52.
[336] Werner, *Bergmannssagen* (1990), 155-58.
[337] Krause, "Sagenhafter Rammelsberg," 15.
[338] Köhler, *Bergmannslieder*, 84-85.
[339] Johann Karl August Musäus, *Volksmärchen der Deutschen* (Paris: Baudry's Europaische Buchhandlung, 1837), 100: "Dieser Fürst der Gnomen besitzt zwar auf der Oberfläche der Erde nur kleines Gebiet, von wenig Meilen in Umfang, mit einer Kette von Bergen umschlosse…. Aber wenige Lachter unter der urbaren Erdrinde hebt seine Alleinherrschaft an, die kein Partagetraktat zu schmälern vermag, und erstreckt sich auf achthundert sechzig Meilen in die Tiefe, bis Mittelpunkt der Erde."
[340] Krause, "Sagenhafter Rammelsberg," 29-32.

when he opened his School) and scuttled through the shafts to spy on the workers.[341] A clear breach of miners' moral economy, subterranean spirits set about deceiving officials who "eavesdropped" on the hewers, procuring three ladders in the place of one.[342] Back in the Harz, it was said that the "Mine Monk" once crushed the head of particularly "evil foreman" between his knees.[343] This, at least, was one way to understood structural collapse.

In this tradition, stags of silver and gold can be read as parables. Mining ore, as legend had it, *was like* hunting a stag: only those who were patient and measured in tracking the beast could reap the benefits of its killing. "He who sights the stag, while going unnoticed by him, shall have great happiness so long as he lives," goes one Thuringian legend; "But he who lacks the poise to sit still in the dark forest at dusk, and frightens the animal off, will be pursued by bad luck and all misfortunes of body and soul until the last of his days."[344]

In the industry's official and vernacular landscapes the exploitation of natural resources was conceived as a moral matter, the prerogative of the measured and moderate. Recent scholarship has portrayed mining culture as a system of symbols and expressions that spanned the industry's peasant, bourgeois, and noble estates.[345] So, too, the imperative to regulate the "ransacking" of the earth was integral to its administrative and mythological discourses. For officials of Humboldt's rank, deposits were thought to be inexhaustible but for rash, thief-like practices of investors. In folklore from the period, these riches drew from "an inexhaustible treasure trove" that yielded metals according to Rübezahl's "subterraneous governance."[346]

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[341] Werner, *Bergmannssagen* (1990), 138-39.
[342] Werner, *Bergmannssagen* (1985), 154.
[343] Werner, *Bergmannssagen* (1990), 179, 206.
[344] Dietmar Werner, ed., *Bergmannssagen aus Thüringen* (Leipzig: Deutscher Verlag für Grundstoffindustrie, 1991), 28-29, also 37-38.
[345] Rainer Slotta, "Der (Silber-) Bergbau als Kunst-Katalysator," in *Geschichte des deutschen Bergbaus*, vol. 1, eds. Christoph Bartels and Rainer Slotta (Münster: Aschendorff Verlag, 2012), 591-618.
[346] Musäus, *Volksmärchen*, 100.

Yet the differences, of course, are just as striking. Aside from obvious formal distinctions, these official and vernacular landscapes also differed in their politics. While mining myths frequently express animosity towards state officials, traditional songs reinforced miners' allegiance to investors. Vernacular culture was contested terrain within the mining industry. Songs not only strengthened solidarity amongst the miners, but also served the commercial ends of their lords by "reproducing labor-power."[347] The aggrandizing territorial states of early modern Germany used songs and sermons to pacify miners in times of unrest amongst the peasantry.[348] Moreover, the same power-struggle that placed foremen between states and shareholders reached into the realm of song and lore as well. Here, it appears that the investors had gained the upper hand. This may be due to the fact that *Gewerkschaften* were composed not only of wealthy foreigners but also of familiar townspeople of modest means. "Rejoice now, you investors," begins one song; "and sing the glory of God."[349] Variations abound in compendia sourced from the seventeenth and eighteenth centuries: "Be cheerful, investors…"; "Gratify the enterprising investors…"; "May the investors rejoice…."[350] Some songs were composed by the investors themselves, likely in an effort to encourage further investment. In them, state officials are eclipsed by the "paternal administration" of God, that "High-Lord of Mines."[351]

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[347] Wolfgang Korb, "Bergschöre und Bergkapellen an der Saar," in *Musik und Industrie: Beiträge zur Entwicklung der Werkschöre und Werksorchester*, ed. Monica Steegmann (Regensburg: Bosse, 1978), 129-57, on 130.
[348] Susan C. Karant-Nunn, "From Adventurers to Drones: The Saxon Silver Miners as an Early Proletariat," in *The Workplace before the Factory: Artisans and Proletarians, 1500-1800*, eds. Thomas Max Safley and Leonard N. Rosenband (Ithaca, NY: Cornell University Press, 1993), 73-99, on 96-98.
[349] Johann Engelschalln, *Beschreibung der Exulantend- und Bergstadt Johann Georgen Stadt* (Leipzig, 1723), 190: 'Nun seyd fröhlich ihr Gewercken'.
[350] Köhler, *Bergmannslieder*, 21, 25-26, 135-36: "erfreu den bauenden Gewerken doch"; "Seid frölich, ihr Gewerken"; "G'werkschaft mag sich wol freuen."
[351] Köhler, *Bergmannslieder*, 160.

Mining folklore suggests a skepticism toward investors' sole interest in profit but also conveys an abiding sense of loyalty to them. In some stories, that loyalty is sanctified by the *Berggeist* himself, who tempts a poor laborer to steal the silver he discovered. "I cannot do that," answered the faithful miner Daniel, in spite of his family's desperate want, "for it belongs to the investors." That night, the *Berggeist* visited Daniel in a dream, promising a handsome reward for the "honor" he had shown. Where lightning struck the next day, there the poor man discovered "a rich vein of silver ore."[352]

In the Mining School, by contrast, young foremen were to "imbibe a minerly sense of honor" through the written word. The phrase must be understood within the language of early modern estate society. In Germany's home towns, honor—"the respect of the respected"—was a hallmark of artisanal guildsmen, jealously guarded social capital; and phrases like "*ehrbares Handwerk*" and "*Handwerksehre*" signalled the dignity of their craftsmanship. Honor was thus bound to the artisan caste, an exclusive and inherited virtue denied to peasants, journeymen, women, and all outsiders.[353] "Honor eternal to the miner's estate!" wrote one Prussian mine official, riffing on the mining industry's own traditions of honorable distinction: "honor to you, too, brother smelter!"[354] Humboldt's School sought to cultivate a particular brand of honor bound not to the guild—or the *Gewerkschaft*—but to the state. Thus, the moral of Daniel's story can also be found in Voigt's *Mining State*, which forewarns the *Steiger*, "by punishment of removal from his service, not to attempt theft in the mines."[355] Here, too, miners were to be

[352] Werner, *Bergmannssagen* (1985), 144-45.
[353] Mack Walker, *German Home Towns: Community, State, and General Estate 1648*, 2nd ed. (Ithaca, NY: Cornell University Press, 1998), 102, 105, 179-80. See also Andreas Grießinger, *Das symbolische Kapital der Ehre: Streikbewegungen und kollektives Bewußtsein deutscher Handwerksgesellen im 18. Jahrhundert*, Sozialgeschichtliche Bibliothek (Berlin: Ullstein, 1985).
[354] Carl Friedrich Ludwig Plümicke, "Ehre dem Bergstand," in Moritz Doering, *Sächsische Bergreyhen* (Freiberg, 1845), 75: "Ehre Dir, Bruder *Hüttenmann*! […] Ehre für immer dem Bergmannsstand!"
[355] Voigt, *Bergwerksstaat*, 103-04.

rewarded for the honor they showed.[356] "Love of one's *métier* need not be preached directly," Humboldt wrote, suggesting the instructor make a show of "public examinations and gifts for the diligent."[357]

In cultivating a "minerly sense of honor," Humboldt also drew upon notions of the *bergmännisch* steeped in song and lore. "The minerly wisdom gives me great joy," begins a traditional song, naming the "minerly virtues three": "to be earnest, God-fearing, and diligent." Such a miner possessed "a *bergmännisch* heart," rang the chorus of another, "with metallic luster, white- and red-gold ore."[358] Humboldt did not want to be rid of these oral traditions; he wanted to re-inscribe them in the language of reason and realign them with stately *Direktion*.[359]

In the *Deutsches Wörterbuch* compiled by the brothers Grimm—famous collectors of folklore and fairy tales—*bergmännisch* is defined in all its moral and material valences: first with respect to the miner's underground exploits, "rich yields" harvested from the earth; then as an architectural practice, to "build minerly, carefully"; and finally as a moral virtue, to be "true and faithful."[360] All these meanings were implied in Humboldt's use of the term, as in the industry's widely-held view of resource extraction as a matter of structural and moral integrity.

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[356] Michel Foucault described the bestowal of honor as a typical instrument of social discipline in schools and militaries. See Michel Foucault, *Discipline and Punish: The Birth of the Prison*, trans. Alan Sheridan (New York: Vintage Books, 1995), 181.
[357] Humboldt, "Promemoria," 294.
[358] Köhler, *Bergmannslieder*, 39, 84-85: "*Die bergmännsche Weise gefallt mir sehr wol*, | wenn jeder so lebt wie er billich soll, | aufrichtig, gottfürchtig und fleißig dabei, | dieß sind die bergmännischen Tugenden drei," "Gott kann veredlen und aufthun | Einen Spat- und Morgen-Trum, | wie es sich wünschet ein bergmännisch Herz, | mit Glanz, weiß- und rotgülden Erz."
[359] Compare to Joseph Gosmu, "Humboldts Umgang mit lokalem Wissen," *HiN* 5, no. 8 (2004): 5-17.
[360] *Deutsches Wörterbuch von Jacob und Wilhelm Grimm*, 16 vols (Leipzig, 1854-1961), Online Version, accessed 7 September 2020, http://woerterbuchnetz.de/cgi-bin/WBNetz/wbgui_py?sigle=DWB&mode=Vernetzung&lemid=GB04461#XGB04461: "*nach art der bergleute:* bergmännische anweisung, *guter, reiche ausbeute versprechender ausbruch.* bergmännisch bauen, *vorsichtig. man sagt,* sich auf gut bergmännisch die hände geben, *auf treu und glauben, nach art der bergleute, indem sie die daumen an einander setzen, die hände verschränken und die arme schütteln. s.* bergenzend."

Conclusion: Natural Order as Social Order

When miners of Humboldt's time spoke about resources, they spoke, in fact, about labor. A mine's yield was thought to be determined by the social organization and moral comportment of the miners themselves. This is true not only of the *Raubbau* discourse through which officials waged an administrative campaign against "obstinate investors," but also of folk traditions whose keeper entities similarly shielded the earth from human avarice. "In the early modern as in the postmodern world," Simon Schaffer wrote, "challenges to cultural order were often seen as threats to nature itself."[361] Thus, the environmental alarms sounded by miners of both *Feder* and *Leder* were triggered by transgressions of a social nature. In turn, officials like Humboldt conceived of sustainable resource management as a matter of labor discipline. Challenges to the cultural and social order of mining were met with psychological politics.

The Mining School can be seen within a broader cameralistic effort in eighteenth-century Germany to "stabilize workers' group identities within the State."[362] Mining culture, as Sebastian Felten argues, was not only produced in the mines, but also fashioned in courts and bureaucracies. Rulers, officials, and investors wielded various aspects of the industry's rich material culture to advance their own agendas, donning the dress and axe of the miner in parades for instance. In his own intervention in mining culture, Humboldt's Mining School seized upon miners' mental and spiritual world. This meant supplanting the moral economy of the "mine spirit" with a "spirit of the practical" grounded in administrative protocol. More an act of translation than erasure, Humboldt sought to enroll "minerly virtues" into a statist vision of sustainable resource management. However dismissive towards the "mining folk," Humboldt

[361] Simon Schaffer, "The Earth's Fertility as a Social Fact in Early Modern Britain," in *Nature and Society in Historical Context*, eds. Mikuláš Teich, Roy Porter, and Bo Gustafsson (Cambridge: Cambridge University Press, 1997), 124-47, on 124.
[362] Felten, "Mining culture," 124.

was also keenly aware of their vernacular traditions. Tales of the Golden Stag, he observed, were a "daily phenomenon" for "anyone who works amongst the miners."[363] Noting also how "every foreign manner of speech is incomprehensible to the boys here," Humboldt appointed a local shift boss as the School's first instructor precisely for his Franconian dialect.[364] He himself did not trust "a foreigner" to lecture pupils on Franconian geology and mining law. "Never have I encountered such a thorough knowledge of the region," Humboldt boasted of his appointee.[365]

The early modern state has justly been viewed as the original agent of "sustainable" resource management. But its bureaucracies and administrative cultures were not insulated from, and did not simply impose themselves upon, the vernacular cultures of miners. It may be tempting to view the early modern mine as a "state space," where territorial rulers enforced a severe hegemony over human and natural resources, and to see Humboldt's Mining School essentially as an instrument of discipline and disenchantment.[366] It was this—but not only this. Certainly, as I have argued, sustainable resource management in central Europe around 1800 consisted largely in the strict oversight of labor. But the School's implicit analogy between natural and social order ran through both bureaucratic and folkloric discourses, confounding clear-cut dichotomies one might draw between states and subjects, the learned and the laboring, or official and vernacular landscapes. Here were two social groups—one beholden to the *Berggeist*, the other to the *Bergstaat*—who may indeed have inhabited different ontological worlds, but who nonetheless shared common assumptions about the correlation between moral

[363] Humboldt, "Promemoria," 293.
[364] Ibid., 294; as quoted in Oscar Köhl, *Zur Geschichte des Bergbaues im vormaligen Fürstentume Kulmbach-Bayreuth* (Hof, 1913), 126.
[365] Humboldt to Carl Freiesleben, 14 Dec. 1795, *Jugendbriefe*, 474.
[366] The ambitions of early modern "state space," and modes of resistance to it, are discussed in James C. Scott, *The Art of Not Being Governed: An Anarchist History of Upland Southeast Asia* (New Haven, CT: Yale University Press, 2009), esp. 40-63.

constitution, material practice, and mineral abundance. Rübezahl, after all, who opened the earth to the true and modest, was said to have been a just mine master—just the kind of *Oberbergmeister* Humboldt aspired to be.[367]

[367] Krause, "Sagenhafter Rammelsberg," 32; Werner, *Bergmannssagen* (1990), 146-48.

Part Two

Epistemic Workscapes

Chapter Three

Producing the Geography of Plants

The power of science lies in its ability to abstract and manipulate representations relevant to working world problems.[368]

Jon Agar,
Science in the Twentieth Century and Beyond

And piercing into the bowels of the earth,
Long hidden in Stygian gloom,
They examine its wealth of flora.[369]

Ovid, *Metamorphoses*, I: 139-40
As adapted by Alexander von Humboldt
Freiberg, Saxony, 1793

Natural history, the study of flora, fauna, and mineralia, is conventionally understood as a descriptive science, as opposed to the causal science of natural philosophy. In the second half of the eighteenth century, disciples of the Swedish naturalist Carl Linnaeus traveled throughout Europe and its colonies collecting all manner of naturalia and classifying them according to the artificial taxa prescribed by his *Systema Naturae* (1735). They set out to order the natural world, to catalogue Creation itself.

This chapter expands upon arguments made in Patrick Anthony, "Mining as the Working World of Alexander von Humboldt's Plant Geography and Vertical Cartography," *Isis* 109, no. 1 (2018): 28-55.

[368] Jon Agar, *Science in the Twentieth Century and Beyond* (Cambridge: Polity, 2012), 7.

[369] Fredericus Alexander ab. Humboldt, *Florae fribergensis specimen. Plantas cryptogamicas praesertim subterraneas exhibens* (Berlin: Rottmann, 1793): "itum est in viscera terrae, | quasque recondiderat, Stygiisque admoverat umbris, | explorantur opes florae." Ovid's original is: "sed itum est in viscera terrae, quasque recondiderat Stygiisque admoverat umbris, *effodiuntur opes, inritamenta malorum*" (emphasis mine), which translates to "and piercing to the bowels of the earth, | the wealth long hidden in Stygian gloom | is excavated and induces evil." This and my own rendering of Humboldt's adaptation are from Ovid, *Metamorphoses: A New Translation*, trans. Charles Martin (New York: W. W. Norton, 2004), 20.

But natural history was not merely descriptive or antiquarian. Sharing in the same Enlightened spirit of utility as the so-called "improvers" and "projectors," naturalists also sought to manipulate nature to the ends of empire and political economy. Historians call this "economic botany." In the seventeenth and eighteenth centuries, maritime powers like Spain, Britain, France, and the Dutch Republic effectively re-shaped the global geography of plants, transplanting "green gold"—stimulants, medicines, and cash crops—to slave plantations and botanical gardens throughout their colonies. In the process, colonial gardens in India, the South Pacific, and the Caribbean became laboratories for environmental engineering, as timber-devouring empires first desecrated then attempted to restore local climates.[370]

Within Europe, naturalists promoted imperious designs of their own, attempting to cultivate rugged, unyielding environs in the mountains and moors and the frozen boreal north. Linnaeus's own science was propelled by aspirations of economic self-sufficiency, a cornerstone of cameralist governance in the land empires of central and northern Europe. To that end, he endeavored to acclimatize plants to the Arctic tundra and "teach" saffron and rice to grow in Lapland, speculating even on the prospect of a "pearl plantation" in Sweden.[371] In the Scottish Highlands, cameralism merged with primitive agriculture in the practice of "moss husbandry" as

[370] Richard Grove, *Green Imperialism: Colonial Expansion, Tropical Island Edens, and the Origins of Environmentalism* (Cambridge, UK: University of Cambridge Press, 1995); Londa Schiebinger, *Plants and Empire: Colonial Bioprospecting in the Atlantic World* (Cambridge, MA: Harvard University Press, 2004); Jorge Cañizares-Esguerra, *Nature, Empire, and Nation: Explorations of the History of Science in the Iberian World* (Stanford, CA: Stanford University Press, 2006); Harold J. Cook, *Matters of Exchange: Commerce, Medicine, and Science in the Dutch Golden Age* (New Haven, CT: Yale University Press, 2007); Helen Cowie, *Conquering nature in Spain and its empire, 1750-1850* (New York: Manchester University Press, 2011); J'Nese Williams, "Imperial Intervention: Botanic Gardens, Science, and Colonial Administrations in the British Empire, Late Eighteenth and Early Nineteenth Centuries," (PhD diss., Vanderbilt University, 2018).
[371] Lisbet Koerner, *Linnaeus: Nature and Nation* (Cambridge, MA: Harvard University Press, 2001).

improvers grew barley and flax in peat bogs.[372] To the east, Prussia's Frederick II embarked on a military-like campaign to reclaim, settle, and cultivate the marshes of the River Oder.[373] And throughout Europe physicians urged compatriots to re-discover the wealth of "indigenous" products overlooked by exotic imports from European colonies.[374] Matters of exchange amongst mercantile powers, plants were matters of state to their cameralist counterparts.

This chapter explores a still more subtle feature of the relationship between science and statecraft. For the shaping and exploitation of natural environments also constituted a way of knowing, an extractive epistemology in which economic production and knowledge production cohered in common practices.[375] This is how Alexander von Humboldt viewed his training as a mining official in the early 1790s. "Here I can achieve all the scientific aims to which I am drawn," wrote the twenty-two-year-old upon arriving at the Mining Academy in Freiberg, Saxony in 1791.[376] He later reflected that his decision to serve the mining industry was itself the fulfillment of an "ardent desire ... to live in free nature."[377] The industry's mechanical pumps,

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[372] Frederik Albritton Jonsson, *Enlightenment's Frontier: The Scottish Highlands and the Origins of Environmentalism* (New Haven, CT: Yale University Press, 2013).
[373] David Blackbourn, *The Conquest of Nature: Water, Landscape, and the Making of Modern Germany* (New York: Norton, 2006). On the politics of hydraulic engineering projects in early modern England, see also Eric H. Ash, *The Draining of the Fens: Projectors, Popular Politics and State Building in Early Modern England* (Baltimore, MD: Johns Hopkins University Press, 2017).
[374] Alix Cooper, *Inventing the Indigenous: Local Knowledge and Natural History in Early Modern Europe* (Cambridge, UK: Cambridge University Press, 2007). See also Wolfgang Schivelbusch, *Das Paradies, der Geschmack und die Vernunft: Eine Geschichte der Genußmittel* (Berlin: Fischer, 1990).
[375] This formulation is heavily indebted to Pamela H. Smith, Amy R. W. Meyers, and Harold J. Cook, "Introduction: Making and Knowing," in *Ways of Making and Knowing: The Material Culture of Empirical Knowledge*, eds. Pamela H. Smith et al. (New York City: Bard Graduate School, 2014), 1-16.
[376] Alexander von Humboldt to Johann Leopold Neumann, 23 June 1791, in Ilse Jahn and Fritz G. Lange, eds., *Die Jugendbriefe Alexander von Humboldts, 1787–1799* (Berlin: Akademie Verlag, 1973), 142: "Ich lebe hier in Freiberg sehr, sehr zufrieden…. Ich kann alle die wissenschaftliche Zwekke erfüllen, die mich herzogen. Ich bringe fast alle Morgen von 7-12 Uhr in der Grube zu."
[377] Alexander von Humboldt (1853) in Kurt R. Biermann, ed., *Aus meinem Leben: Autobiographische Bekenntnisse* (Leipzig: Urania Verlag, 1987), 88: "…erlangte ich die Erlaubnis, meine nächste Lebensbestimmung zu verändern und, nach meinem sehnlichsten Wunsche, außerhalb der Städte in der freien Natur zu leben, zum praktischen Bergbau überzugehen."

smoke-belching ovens, and black powder blasting may seem a world apart from *freie Natur*, and further still from the purview of the naturalist. But for Humboldt, hard rock mines doubled as geological dig sites and chemical laboratories, even a new frontier of botanical inquiry.

Humboldt's botany—better known as the science he called plant geography—is famously associated with mountains of the tropics. Tenerife's Pic du Teide and Ecuador's Chimborazo are enshrined in the iconography of his journey through the "equinoctial regions" with Aimé Bonpland from 1799 to 1804 (**Figure 1**). These towering equatorial peaks also served as visual aids, illustrating analogies in plant life between high latitudes and high elevations (poles and peaks), known to historians of geography as the "correspondence principle."[378]

Figure 1. Humboldt's *Naturgemälde der Anden*, after the original "Tableau physique des Andes et pays voisins." The *Naturgemälde* accompanied the *Essay*'s 1807 German translation. Wikimedia Commons.

[378] Michael Reidy, "Oceans through Islands to Mountains: Creating the 'Correspondence Principle'," in *Fluid Frontiers: New Currents in Marine Environmental History*, eds. J. Gillis and F. Toma (Cambridge, UK: White Horse Press, 2015), 192-210. On Humboldt's use of mountains more generally, see Bernard Debarbieux, "The Various Figures of Mountains in Humboldt's Science and Rhetoric," *Cybergeo: European Journal of Geography* (2012), https://journals.openedition.org/cybergeo/25488 and Tobias Kraft, *Figuren des Wissens bei Alexander von Humboldt: Essai, Tableau und Atlas im amerikanischen Reisewerk* (Berlin: De Gruyter, 2014).

But in the decade that preceded his famous voyage, Humboldt also drew biogeographical insights from far more unlikely places: the mining and textile industries of Germany and Britain. Here Humboldt learned to study plants as artefacts of human history, even as instruments of industrial production and political economy. As an aspiring cameralist in the 1790s, commercial routes, industrial practices, and concerns about labor shaped the very conditions of possibility for Humboldt's theorizing about the geographical relations of plants. Insights gleaned from these working worlds—about the primacy of human activity in plant migration and the vertical distribution of plants from mineshafts to mountain summits—would underpin his *Essay on the Geography of Plants*, published in 1805.

Humboldt positioned the *Essay* as a radical departure from the taxonomic efforts of eighteenth-century botanists. Where naturalists had traditionally catalogued plant species in the classificatory schema devised by Linnaeus, the *Essay* offered a climatic study of "vegetational regions" composed of various species.[379] According to Humboldt, each region possessed a distinctive "physiognomy," an aesthetic articulation of the geological and atmospheric relations that shape organic nature at different altitudinal strata and latitudinal bands.[380] "Rather than discovering new, isolated facts I preferred linking already known ones together," begins Humboldt's *Personal Narrative*. "The discovery of a new genus seemed to me far less

[379] The novel aspects of Humboldt's study of "vegetational communities" are discussed in Malcolm Nicolson, "Alexander von Humboldt, Humboldtian Science, and the Origins of the Study of Vegetation," *History of Science* 25 (1987): 167–193. Nicolson argues that the holistic study of "vegetation," which includes its "formative influence on humanity, both materially and spiritually," is what makes Humboldt's plant geography a significant precursor to ecology, even if he himself cannot yet be called an "ecologist." See Malcolm Nicolson, "Humboldtian Plant Geography after Humboldt: The Link to Ecology," *The British Journal for the History of Science* 29, no. 3 (1996): 289-310, on 292.

[380] See also Michael Dettelbach, "The Face of Nature: Precise Measurement, Mapping, and Sensibility in the Work of Alexander von Humboldt," *Studies in the History and Philosophy of Biological and Biomedical Sciences*, 30 (1999): 490-94 and Gernot Böhme, "Die Physiognomie einer Landschaft," *Geographische Zeitschrift* 87, H. 2 (1999): 98-104.

interesting than an observation on the geographical relations of plants, or the migration of social plants, and the heights that different plants reach on the peaks of the cordilleras."[381] Believing the geography of plants existed hitherto "in name only," the *Essay* set out to raise a nominal science of plants to "general physics."[382]

In the process, however, Humboldt also re-cast the economic botany of the eighteenth century as a universal science of the nineteenth. As Miles Ogborn recently argued, Humboldt's "'Global physics' reconceived the horticulturalist's question—what grows where and why?—on a grand scale."[383] Ogborn's brief yet powerfully argued chapter on the subject is supported by more the thoroughgoing studies of Nils Güttler, who sees Humboldt's plant geography as a bricolage of botanical traditions, imperial ventures, and administrative practices. Underscoring Humboldt's studies in statecraft at universities in Frankfurt/Oder and Göttingen, Güttler shows how Humboldt followed French physiocrats and German cameralists in "taking the inventories of states," a debt betrayed by his tendency to naturalize altitudinal borders of crops as vegetational zones.[384] In Latin America, moreover, Humboldt grafted these practices onto local agricultural traditions, which, as Jorge Cañizares-Esguerra has shown, viewed the Andes as a microcosm of global biogeography.[385]

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[381] Alexander von Humboldt, *Personal Narrative of Travels to the Equinoctial Regions of The New Continent*, trans. Jason Wilson (New York: Penguin Books, 1995), 6.
[382] Alexander von Humboldt and Aimé Bonpland, *Essay on the Geography of Plants*, ed. Stephen T. Jackson, trans. Sylvie Romanowski (Chicago: University of Chicago Press, 2009), 64.
[383] Miles Ogborn, "Vegetable empire," in *Worlds of Natural History*, eds. H. Curry, N. Jardine, J. Secord, & E. Spary (Cambridge: Cambridge University Press, 2018), 281.
[384] Nils Güttler, *Das Kosmoskop: Karten und ihre Benutzer in der Pflanzengeographie des 19. Jahrhunderts* (Göttingen: Wallstein, 2014), 126-31, 164; Nils Güttler, "Drawing the Line: Mapping Cultivated Plants and Seeing Nature in Nineteenth-Century Plant Geography," in *New Perspectives on the History of Life Sciences and Agriculture*, eds. Denise Phillips and Sharon Kingsland (Basel: Springer, 2015), 27–52. Cf. Ursula Klein, "The Prussian Mining Official Alexander von Humboldt," *Annals of Science* 69 (2012): 27–68.
[385] Jorge Cañizares-Esguerra, "How Derivative Was Humboldt? Microcosmic Nature Narratives in Early Modern Spanish America and the (Other) Origins of Humboldt's Ecological Sensibilities," in *Colonial*

This chapter expands on these perspectives by showing how cultures of production across Europe informed both practical and theoretical elements of Humboldt's plant geography. Trained to serve the Prussian state in the 1780s and 90s, Humboldt's earliest science of vegetation was animated by the recognition that plants could, by turns, help or hinder industrial production in mills and mines—as dyestuff, wool-carding instruments, or toxic nuisances. Global exchange networks and local industrial imperatives combined to underscore the primacy of human activity in the migration of plants, while "subterraneous vegetation" in the mines of Saxony and Prussia impressed Humboldt with a vertical conception of plant distribution. Gradually, however, the local workscapes that originally stimulated Humboldt's plant geography were eclipsed by his overarching commitment to global patterns and cosmic harmonies. Human agency, once a "primary factor" in Humboldt's plant geography, became a "disturbance" in the Cosmos.

The Nature of Universal History

In the *Essay*, Humboldt conceived of "the great problem of the migration of plants" as a natural history shaped, above all, by human history. Where people went, plants followed. It was an ancient and enduring feedback loop between nature and society. "The impact of food that can be more or less stimulating to the character and strength of the passions, the history of navigations and wars carried out over the products of the plant kingdom; such are the factors that link the geography of plants to the political and intellectual history of mankind."[386] Humboldt thus viewed human and natural history upon a single continuum.

Botany: Science, Commerce, and Politics in the Early Modern World, eds. Londa Schiebinger and Claudia Swan (Philadelphia, PA: University of Pennsylvania Press, 2005), 148–65.

[386] Humboldt and Bonpland, *Essay on the Geography of Plants*, 72-73.

Certainly, natural forces explained a great deal about the distribution of plants across space and time. Humboldt's generation was among the first to view the fossil record as a geo-historical archive, "the tomb of the initial plant life of our planet," as he phrased it in the *Essay*.[387] Vegetation found fossilized in the rock evidenced great upheavals in the earth's ancient history. To explain the "tropical bamboos" and "petrified fruits" buried in the ice-locked north, as well as elephant tusks and fossilized sea creatures in the caves of Germany, contemporaries envisioned dramatic climatic alterations and primordial deluges. Perhaps, Humboldt speculated, the earth's axis had tilted with time.[388]

But living plants—and even some fossilized ones—evidenced another catalyst of plant migration: human enterprise. "Man, being restless and industrious, traveled in all the earth's regions," Humboldt wrote in the *Essay*, "and thereby forced a certain number of plants to live under many climates and in many altitudes." Imagine a world map with arrows depicting the entangled migrations of peoples and plants—the olive tree, for instance, spreading from Asia to Greece, Greece to Sicily, and Sicily to Spain. So reads the *Essay*. The more useful a plant, the more mysterious its provenance. In the tropics, he noted, bananas and maize "have never been found in a wild state," while the provenance of European staples like wheat, barley, oats, and rye remain equally unknown.[389]

Humboldt was not the first to pursue plant distribution as a result of human activity. In 1718, the Jesuit missionary Joseph-François Lafitau published a sensational study of ginseng, in

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[387] Humboldt and Bonpland, *Essay on the Geography of Plants*, 69. See Martin Rudwick, *The Meaning of Fossils: Episodes in the History of Palaeontology* (New York: Elsevier, 1972).
[388] Alexander von Humboldt to Georg August Ebell, 2 Dec. 1793, Staatsbibliothek Bamberg OFS. Autogr. H 2 (urn:nbn:de:bvb:22-ofs.autogr.h2-7): "Daß Elefanten in Deutschland lebten, davon sind Sie gewiß so überzeugt als ich. Das Bette von helix pomatia u[nd] h. nemorosa bei Burgtonna, worin der Elefant lag, bezeugen es. Eben so scheint die Veränderung der Erdaxen durch ältere astronom[ische] Beobachtungen factisch bewiesen zu sein…." Cf. Humboldt to Johann Friedrich Pfaff, 12 Nov. 1794, *Jugendbriefe*, 370.
[389] Humboldt and Bonpland, *Essay on the Geography of Plants*, 71.

which he traced its use as medicine from the "Tartars" of Northern China to the Iroquois of North America.[390] Later in the century, Humboldt's own mentors, Johann Reinhold Forster and Carl Ludwig Wildenow, had pioneered a field they called "*Pflanzengeschichte*," the historical development of plant distribution.[391] Building on these efforts, Humboldt adapted botany's traditional preoccupation with provenance into a synoptic study of the natural and artificial means by which plants migrate. Summarizing Humboldt, one contemporary described the plants that follow people as "true world citizens," and European crops in particular as "the footsteps of the whites," so named by the "first peoples of the Americas."[392]

One tradition of scholarship views this "holistic" conception of nature and society as an expression of German Romanticism.[393] Emphasizing Humboldt's ties to Romantic circles, Aaron Sachs has described his "commitment to include human beings and their civilizations in his

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[390] Joseph-François Lafitau, *Concernant la précieuse Plante du Gin seng de Tartarie, découverte en Canada par le P. Joseph François Lafitau, de la Compagnie de Jesus, Missionnaire des Iroquois du Sault Saint Louis* (Paris, 1718). Humboldt's point that the origins of the most useful plants are the least known seems to be proven by an *Encyclopédie* entry in 1757 that suggests ginseng's provenance remained a matter of dispute. Édition Numérique Collaborative et Critique de l'*Encyclopédie* (1751-1772), vol. VII (1757), 664a, accessed 1 Feb. 2021, http://enccre.academie-sciences.fr/encyclopedie/article/v7-1067-0/.

[391] Nicolson, "Alexander von Humboldt," 172-73.

[392] "38. Brief. Geographie der Pflanzen und Thiere," in Bernhard Cotta, ed., *Briefe über Alexander von Humboldt's Kosmos: Ein Commentar zu diesem Werke für gebildete Laien* (Leipzig: Weigel, 1848), 282: "Vor allem dürfen wir bei Beurtheilung des gegenwärtigen Zustandes nicht die mehr als tausendjährige Cultur des Menschen außer Acht lassen, der auf stolzem Fahrweg nicht nur seine heimathlichen Pflanzen und Hausthiere weit hin über die Erde verbreitet, sondern auch unabsichtlich eine Menge lästiger Insecten und für ihn nutzloser Pflanzen (sogenannter Unkräuter) zu wahren Weltbürgern gemacht hat."

[393] Excellent studies of Humboldt's engagement with German Romanticism, as well as his measured embrace of *Naturphilosophie* in the *Essay on the Geography of Plants*, are Anne Buttimer, "Beyond Humboldtian Science and Goethe's Way of Science: Challenges of Alexander von Humboldt's Geography," *Erdkunde* (Apr.-Jun. 2001): 105-120 and Gabrielle Bersier, "Picturing the Physiognomy of the Equinoctial Landscape: Goethe and Alexander von Humboldt's *Ideen zu einer Geographie der Pflanzen*," in *Forster – Humboldt – Chamisso: Weltreisende im Spannungsfeld der Kulturen*, eds. Julian Drew, Ottmar Ette, Tobias Kraft, Barbara Schneider-Kempf, and Jutta Weber (Göttingen: Vandenhoeck & Ruprecht, 2017), 335-56. Also consider Robert Richards, *The Romantic Conception of Life* (Chicago: University of Chicago Press, 2002), 518-21 and Anne Margaret Macpherson, *The Human Geography of Alexander von Humboldt,* 2 vols. (PhD diss., University of California, Berkeley, 1971). More recently, consider Heinrich Detering, *Menschen im Weltgarten: Die Entdeckung der Ökologie in der Literatur von Haller bis Humboldt* (Göttingen: Wallstein Verlag, 2020).

portrait of the Americas" as the hallmark of an "environmental revolution."[394] Laura Dassow Walls has similarly described Humboldt's impulse to bridge nature and culture as a veritable "environmental revolution"; yet she locates its origins in an altogether different context than the "organicism" of Goethe and the *Naturphilosophen*. Instead, Walls suggests Humboldt's holistic field of vision drew upon a broad conception of political economy that encompassed "land forms, climatology, and natural history; the culture, languages, and history of indigenous peoples; and the history of European exploration, invasion, and exploitation."[395]

This chapter traces Walls's insight into the working worlds where Humboldt first learned to practice plant geography as political economy. The dialogue between natural and universal history was a common feature of Enlightenment historicism.[396] Naturalists like Georges-Louis Leclerc le Comte de Buffon and Humboldt's own mentor, Georg Forster, believed the development of civil society was, at heart, an environmental history: civilization advanced in proportion as it subdued and cultivated nature, they argued.[397] For Humboldt, the nature of universal history was also a matter of practice. By botanizing amidst commercial and industrial

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[394] Aaron Sachs, "The Ultimate 'Other': Post-Colonialism and Alexander von Humboldt's Ecological Relationship with Nature," *History and Theory* 42 (Dec. 2003): 111-35, on 124.
[395] Laura Dassow Walls, "Rediscovering Humboldt's Environmental Revolution," *Environmental History* 10, no. 4 (Oct. 2005): 758-60, on 758. Compare to Laura Dassow Walls, *The Passage of the Cosmos: Alexander von Humboldt and the Shaping of America* (Chicago: University of Chicago Press, 2009), 122-23. Ecology's roots in the "economy of nature" are thoroughly explored in Donald Worster, *Nature's Economy: A History of Ecological Ideas*, 2nd ed. (Cambridge: Cambridge University Press, 1994). For a linguistic approach, compare Erwin Morgenthaler, *Von der Ökonomie der Natur zur Ökologie. Die Entwicklung ökologischen Denkens und seiner sprachlichen Ausdrucksformen* (Berlin: Erich Schmidt Verlag GmbH & Co., 2000).
[396] Paolo Rossi, *The Dark Abyss of Time: The History of the Earth and the History of Nations from Hooke to Vico*, trans. Lydia G. Cochrane (Chicago: The University of Chicago Press, 1984).
[397] Georges-Louis Leclerc, le Comte de Buffon, *The Epochs of Nature*, trans. and ed. Jan Zalasiewicz, Anne-Sophie Milon, and Mateusz Zalasiewicz (Chicago: The University of Chicago Press, 2018), esp. 119-32; Noah Heringman, "Stadial Environmental History in the Voyage Narratives of George and Johann Reinhold Forster," in *Curious Encounters: Voyaging, Collecting, and Making Knowledge in the Long Eighteenth Century*, eds. Adriana Craciun and Mary Terrall (Toronto: University of Toronto Press, 2019), 206-27.

enterprises, he adopted a particular style of thinking about plants in relation to human activity past and present. Humboldt was both a witness to and participant in the history of plant migration that the *Essay* described.[398]

While composing the *Essay* in Paris in 1805, Humboldt echoed letters penned over a decade earlier in Freiberg: "My course of study in mining and Werner's lessons [in mineralogy] are of great interest to me," a twenty-two-year-old Humboldt wrote to the Swiss botanist Paul Usteri in 1791, "particularly for my Forsterian project [referring here to Johann Reinhold Forster], which requires one to seek out subterraneous vegetation (wood coal, brown coal, etc.) in their tombs."[399] Pursuing the parallel further, we see that fourteen years only bolstered a project originally carried out in the depths of Saxon mines:

To Paul Usteri from Freiberg, Saxony, 1791	*Essay on the Geography of Plants*, 1805
As I always studied geognosy, the history of cultivation etc. together with botany, I came upon the idea two years ago of assembling a history of the migration of plants…. The plants that follow certain peoples, for example the Arabs, Greeks, Persians, and especially the Vandals and Goths, through whom Europe became inundated with Caucasian vegetation, have made me especially mindful of this idea.	These are the topics by which the geography of plants is related to geology. […] Winds, currents, and birds are not the only ones that help plants migrate; the primary factor is man. […] In Europe, the Greeks took with them vines, the Romans, wheat, and the Arabs, cotton. In America, the Toltecs carried maize with them: potatoes and quinoa are found wherever went the inhabitants of the ancient Cundinamarca.[400]

Not only do these passages show how mines served as venues for scientific inquiry; they also exhibit Humboldt's nearly self-evident sense that plant migration belonged, as he told Usteri, to "universal history."[401]

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[398] Humboldt and Bonpland, *Essay on the Geography of Plants*, 72-73.
[399] Humboldt to Paul Usteri, Autumn 1791, *Jugendbriefe*, 164: "Mein bergmän[nisches] Studium und Werners Unterricht interessiren mich sehr, selbst für mein Forstersches Projekt, denn die untergegangene Vegetation muß man in ihren Gräbern (Bitumin[öses] Holz, Braunkohle, p.) suchen."
[400] Humboldt and Bonpland, *Essay on the Geography of Plants*, 69-70.
[401] Humboldt to Paul Usteri, Autumn 1791, *Jugendbriefe*, 163-64: "Da ich Geognosie, Geschichte des Feldbaus p. mit Botanik immer zusammen studirte, so fiel ich schon vor 2 Jahren darauf, auf eine Geschichte der Pflanzenwanderungen zu samlen…. Die Pflanzen, welche gewissen Völkern folgten, z. B.

Assumptions about the unity of human and natural history were embedded in the very title Humboldt gave this inquiry, which carried over to the *Essay*'s German translation, *Ideen zu einer Geographie der Pflanzen* (1807). Writing to Friedrich Schiller in August 1794, Humboldt described his "history and geography of plants" as an "underappreciated aspect of general world history." By November he had devised a full title: "Ideas on a future history and geography of plants," he called it, "or historical report on the gradual proliferation of vegetation over the surface of the earth and their universal geognostic relations."[402] Yet it was the title's first two words—the German "*Ideen zu*"—that then registered a genre of political philosophy, echoing Immanuel Kant's *Idee zu einer allgemeinen Geschichte in weltbürgerlicher Absicht* (*Idea for a Universal History with Cosmopolitan Intent*, 1784). In fact, his elder brother Wilhelm von Humboldt had drafted a manuscript titled *Ideen zu einem Versuch, die Gränzen der Wirksamkeit des Staates zu bestimmen*, portions of which censors allowed Schiller to publish in his journal *Neue Thalia* in 1792.[403] As Enlightenment philosophers like Hume and d'Holbach had written "natural histories" of human culture and spirituality, Humboldt undertook a "political and intellectual history" of nature itself.[404]

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den Arabern, Griechen, Persen, und vornehmlich den Vandalen und Gothen, durch welche Europa mit Caucasischen Gewächsen überschwemmt wurde, machten mich besonders aufmerksam darauf. …dieses so vernachlässigten Theils der Universalgeschichte…."

[402] Humboldt to Friedrich Schiller, 6 Aug. 1794, *Jugendbriefe*, 346: "…Geschichte und Geographie der Pflanzen oder historische Darstellung der allgemeinen Ausbreitung der Kräuter über den Erdboden, ein unbearbeiteter Teil der allgemeinen Weltgeschichte, Aufsuchung der ältesten Vegetation in ihren Grabmälern (Versteinerungen, Steinkohlen, Torf etc.), allmähliche Bewohnbarkeit des Erdbodens, Wanderungen und Züge der Pflanzen, der geselligen und isolierten, Karten darüber, welche Pflanzen gewissen Völkern gefolgt sind, allgemeine Geschichte des Ackerbaus ... —das scheinen mir Objekte, die des Nachdenkens wert und fast ganz unberührt sind." Humboldt to Johann Friedrich Pfaff, 12 Nov. 1794, *Jugendbriefe*, 370: "'Ideen zu einer künftigen Geschichte und Geographie der Pflanzen oder historische Nachricht von der allmählichen Ausbreitung der Gewächse über den Erdboden und ihren allgemeinsten geognostischen Verhältnissen'."

[403] Hanno Beck, "Hinweise zu den einzelnen Essays des Werkes," in *Alexander von Humboldt Werke*, vol. v, Ansichten zur Natur, ed. Hanno Beck (Darmstadt: WBG, 2008), 371.

[404] E.g. David Hume, *Natural History of Religion* (1757) and Paul Henri Thiry d'Holbach, *La Contagion Sacrée, ou Histoire naturelle de la superstition* (1768).

To understand the fluidity between human and natural history in Humboldt's plant geography, we return to the utilitarian culture of his youth in Prussia. Viewed from the 1790s, Humboldt appears destined not for a life of worldly travel but rather for a spot in Germany's administrative elite. Born into the Prussian *Dienstadel*, a noble rank earned through royal service, Humboldt wrote of a "youthful inclination" to follow his father into Frederick II's military.[405] Even as he inclined towards the study of nature, Humboldt's aspirations remained firmly embedded within state service. To practice science in the service of the state, as Humboldt would as in the mines of Prussian Franconia, was perfectly in keeping with the German Enlightenment, whose spirit of top-down reform took on "an almost millenarian temper" after the economic upheaval of the Seven Years War.[406] Unlike the French Enlightenment, which galvanized in opposition to ruling powers, the *Aufklärung* took place within existing institutions, particularly the Holy Roman Empire's nearly fifty universities.[407] Among its primary vectors were the "Cameral Sciences," from *Kammer* or court.[408] Outside princely courts and university classrooms, early Romantic ideals of *Bildung* began to communicate a still broader sense of civic cultivation. Meanwhile German notions of "cosmopolitanism" (*Weltbürgertum*) reconciled Enlightened humanism with devotion to one's Fatherland.[409]

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[405] Alexander von Humboldt, 4 Aug. 1801, in *Aus meinem Leben*, 33: "Meine jugendliche Neigung war von jeher der Soldatenstand gewesen."
[406] David Blackbourn, *History of Germany, 1780-1918: The Long Nineteenth Century*, 2nd ed. (Malden, MA: Blackwell Publishing, 2003), 11-15.
[407] Timothy Blanning, *Reform and Revolution in Mainz, 1743-1803* (Cambridge: Cambridge University Press, 1974), 11-12. The political fragmentation of the Holy Roman Empire, with its some 300 *Reichsstände*, created a high demand for administrators and universities in which to train them.
[408] David. F. Lindenfeld, *The Practical Imagination: The German Sciences of State in the Nineteenth Century* (Chicago: University of Chicago Press, 1997); Andre Wakefield, *The Disordered Police State: German Cameralism as Science and Practice* (Chicago: University of Chicago Press, 2009); Ere Nokkala and Nicholas B. Miller, eds., *Cameralism and the Enlightenment: Happiness, Governance, and Reform in Transnational Perspective* (London: Routledge, 2019).
[409] Theodore Ziolkowski, *German Romanticism and its Institutions* (Princeton, NJ: Princeton University Press, 1990); Frederick C. Beiser, *The Romantic Imperative: The Concept of Early German Romanticism* (Cambridge, MA: Harvard University Press, 2003); Franz Filafer and Jürgen Osterhammel,

It was in this context that Humboldt developed a passion for botany, and with it, an understanding of plants as products. Though he would later present the *Essay* as the first fruits of his disinterested travels through the "New World," Humboldt also hinted at its origins in the Old, recalling in the Preface a "first sketch" he had shared with Georg Forster in 1790. Recall, too, that in 1791 Humboldt said he had conceived of a history of his geography of plants "two years ago," placing him at the University of Göttingen in 1789. In the same years, Göttingen professor Johann Friedrich Blumenbach placed plant and animal fossils at the forefront of debate about the "earth's revolutions."[410] Students like Humboldt thus learned to see fossilized plants as geo-historical records in the archive of the earth. At the same time, Humboldt developed an interest in the utility of living plants, in keeping with a broader patriotic effort to catalogue "indigenous" naturalia that might serve the Fatherland(s) as medicine, nourishment, or dyestuff.[411] Reflecting on his studies of cameralism in Frankfurt/Oder in 1787-88, Humboldt later wrote that "without a thorough knowledge of plants" he "could not have understood" classic works on statecraft like *Contributions to Oeconomy*, written by another Göttingen professor Johann Beckmann.[412]

After Frankfurt, Humboldt had returned to Berlin, where he devoted himself to *Technologie*, a new "science" devised by the same Johann Beckmann. This also when he began

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"Cosmopolitanism and the German Enlightenment," in *The Oxford Handbook of Modern German History*, ed. Helmut Walser Smith (Cambridge, MA: Cambridge University Press, 2011), 199-243.

[410] John H. Zammito, *The Gestation of German Biology: Philosophy and Physiology from Stahl to Schelling* (Chicago: University of Chicago Press, 2018), 216-24.

[411] Ursula Klein, *Humboldts Preußen: Wissenschaft und Technik im Aufbruch* (Darmstadt: Wissenschaftliche Buchgesellschaft, 2015), 13-20; Cooper, *Inventing the Indigenous*; Wolfgang-Hagen Hein, *Alexander von Humboldt und die Pharmazie*, Veröffentlichungen der Internationalen Gesellschaft für Geschichte der Pharmacie e.V., Neue Folge, Band 56 (Stuttgart: Wissenschaftliche Verlagsgesellschaft, 1988).

[412] Humboldt, 4 Aug. 1801, in *Aus meinem Leben*, 33: "doch sah ich ein, daß ich ohne Pflanzenkenntnis ein so vortreffliches Buch als Beckmanns Ökonomie nicht verstehen könne." Humboldt referred here to Johann Beckmann's *Beiträge zur Oekonomie, Technologie, Polizei- und Cameralwissenschaft*, 12 vols. (Göttingen, 1777-91).

to investigate cryptogams, a class of plants that then included mosses, lichens, and fungi, alongside Wildenow in Berlin's Tiergarten.[413] Moss and manufacturing would be a fateful pairing. "I have determined to serve my fatherland in the manufacturing arts [*Fabrikfache*]," Humboldt wrote from Göttingen in '89, as he turned his attention to cryptogams that could be harvested for dyes in the tanning and textile industries.[414] To Göttingen classmates like the young Dutch physician Steven Jan van Geuns, Humboldt was known equally for his prowess "in botany, mineralogy, oeconomy, and the manufacturing arts [*Fabrikkunde*]," a list that bespeaks the fusion of science and statecraft from which his plant geography emerged.[415] This was especially characteristic of Göttingen, where Humboldt took courses from both Blumenbach and Beckmann. Lecture transcripts show Beckmann taking students of "Agriculture" and "Oeconomy" on regular excursions to track down "oeconomic plants" and observe the refinement of natural products in local manufactories.[416]

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[413] Alexander von Humboldt (1853) in *Aus meinem Leben*, 85-86: "Herbst und Winter 1787-88 brachte ich auf der Universität Frankfurt a. O., den folgenden Sommer und Winter wieder in Berlin zu, um Technologie, auf das Fabrikwesen angewandt, zu studieren. […] In dieser Zeit schloß ich mich mit warmer Freundschaft an den jungen, aber schon berühmten Botaniker Wildenow an, und zeigte besondere Vorliebe für das Studium der Kryptogamen…." Beckmann, a Göttingen professor, coined "*Technologie*" in 1772, defining it more fully in *Anleitung zur Technologie, oder zur Kentniß der Handwerke, Fabriken und Manufacturen, vornehmlich derer, die mit der Landwirthschaft, Polizey und Cameralwissenschaft in nächsten Verbindungen stehn* (Göttingen: Vandenhoeck, 1777), xv: "Technologie ist die Wissenschaft, welche die Verarbeitung der Naturalien, oder die Kentniß der Handwerke lehrt."

[414] Humboldt to Johann Friedrich Pfaff, 11 May 1789, *Jugendbriefe*, 58: "Da ich bestimmt bin, meinem Vaterland im Fabrikfache zu dienen, so kann ich die Mathematik nur als Hülfswissenshcaft treiben. […] Bei meinen so geringen mathematischen Kenntnissen habe ich genug erfahren, wie wichtig jenes Studium dem Kameralisten sei."

[415] Steven Jan van Geuns, *Tagebuch einer Reise mit Alexander von Humboldt durch Hessen, die Pfalz, längs des Rheins und durch Westfalen im Herbst 1789*, Beiträge zur Alexander-von-Humboldt-Forschung, eds. Bernd Kölbel and Lucie Terken (Berlin: Akademie, 2007), 23: "Hofrat Blum[en]bach hat mich bekannt gemacht mit einem Herrn von Humboldt, einem jungen Berlinischen Edelmann, der ein sehr vortrefflicher junger Mensch zu sein scheint und sehr viele Kenntnisse in der Botanik, Mineralogie, Ökonomie und Fabrikkunde hat."

[416] *Verzeichniß der Vorlesungen, welche in dem nächsten Sommer vom 26ten April 1784 an, sowohl von den ordentlichen und ausserordentlichen Herren Professoren, als von Privat-Lehrern auf der Universität zu Göttingen gehalten* werden (1789-91). SUB Gö Digitalisierungszentrum, accessed 28 Jan. 2021, https://gdz.sub.uni-goettingen.de/volumes/id/PPN654655340.

Steeped in the spirit of "useful knowledge," Humboldt and Geuns embarked on an oeconomic journey of their own, up the Rhine through Hessen and the Pfalz, in 1789.[417] The journey yielded Humboldt's first book, a well-known study of Rhenish basalts.[418] Less well known is a review Humboldt wrote of Geuns's 1789 work on local "dyeing-, tanning-, salt- and weaving-plants" (*Färbe-*, *Gerber-*, *Salz und Weberpflanzen*). Printed in Paul Usteri's *Magazin für Botanik*, the review reads rather as a manifesto on the relationship between natural sciences and political economy. "The study of the utility of plants," Humboldt wrote,

> appears promising to a degree that corresponds with the general needs of men. The rise in population, the political relations of the states—everything stimulates us to make use of the natural treasures of our soil. And yet there are only a few statesmen who recognize the value of these treasures, and who have dreamt of such a thing as precious dyestuff hidden among the lowly lichens, of the many tanning plants besides the oak, and of utilizing domestic plants to reduce the importation of Asiatic and West Indian ones.

"Domestic" nature appeared "inexhaustible" to Humboldt, not yet alive to the mining industry's anxieties about the exhaustion of wood resources, which later prompted him to join in the call for "sustainable" reforms. In 1790, nature's utility knew no bounds: "Organic Creation continually regenerates new life," he rejoiced in closing, "new and useful powers!"[419]

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[417] On the German culture of "useful science" and its institutional grounding in universities like Göttingen, see Ursula Klein, *Nützliches Wissen: Die Erfindung der Technikwissenschaften* (Göttingen: Wallstein, 2016) and Dominik Hünniger, "What is a useful university? Knowledge economies and higher education in late eighteenth-century Denmark and central Europe," *Notes and Records* 72, no. 2 (2018): 173-94.

[418] Alexander von Humboldt, *Mineralogische Beobachtungen über einige Basalte am Rhein* (Braunschweig: 1790). Humboldt mailed a copy of the book to Saxon mining luminary, Abraham Gottlob Werner, with whom he would soon study in Freiberg.

[419] Alexander von Humboldt, Review of Steven Jan van Geuns, *Verhandeling over de inlandsche Plantgewassen, omtrent vvelker nuttige eigenschappen men met grond vervvagten kan, dat, ten nutte van het vaderland*…. (Matth. Z. Haarlem 1789), *Magazin für die Botanik* 4, no. 10 (1790): 150-51: "Die Lehre von dem Nutzen der Pflanzen schien sich, dem allgemeinen Bedürfniss der Menschen gemäss, mehrere Liebhaber versprechen zu dürfen. Die zunehmende Volksmenge, das politische Verhältnisse der Staaten, alles reizt uns an, die natürlichen Schätze unseres Bodens zu benutzen. Dennoch sind nur wenige Politiker, die den Werth dieser Schätze erkennen, die sich träumen liessen, dass unter den elenden Flechten manches kostbare Farbematerial versteckt ist, dass es ausser der Eiche noch manche Gerbepflanzen giebt, dass man durch inländische Pflanzenvollen den Import der asiatichen und westindischen vermindern könne, u. s. f. […] Die Natur, und scheint sie auch noch so kärglich ihre Güter

Of Teasels, Lichens, and Breadfruit

Harnessing nature's "useful powers" was a primary concern of Humboldt's next journey, down the Rhine, this time, through the Low Countries to England and back by way of Paris. It was then that Humboldt gave the *Essay*'s "first sketch" to his travel companion Georg Forster. Though the 1790 draft has never been found, scholars have recently uncovered a surrogate of sorts: the journal he kept that year.[420] In it, Humboldt compiled detailed notes on a history of plant migration that unfolded before his eyes. Where the *Essay* traced the migration of plants through the agrarian peoples of antiquity, the 1790 journal described their movement amongst the industrializing societies of his present. England, both the seat of a global empire and the world's leading textile manufacturer, exhibited the botanical agency of humankind in real time.

Forster shared Humboldt's commitment to indigenous products: "their application in mechanical arts and handcrafts, dying, manufacturing and trade" had been the very aim of Forster's earlier position as Professor of Natural History at the Polish university in Vilnius.[421] And on their three-month journey together, Forster and Humboldt toured dye manufactories throughout the Rhineland and discussed the latest chemical methods of bleaching and coloring cloth.[422] Their letters and diaries show human industry as a facet of natural inquiry: they queried coal miners in the Rhineland, calc-burners in Derbyshire, and mill-owners in Aachen and

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ausgespendet zu haben, ist immer unerschöpflich; die Werke des menschlichen Kunstfleisses vergehen, aber die organische Schöpfung entwickelt immerdar aus sich selbst neues Leben, neue nutzbare Kräfte!"

[420] Dominik Erdmann and Christian Thomas, eds., "Alexander von Humboldts Englisches Reisejournal," in *Edition Humboldt Digital*, ed. Ottmar Ette (Berlin: Berlin-Brandenburgische Akademie der Wissenschaften), https://edition-humboldt.de/reisetagebuecher/detail.xql?id=H0017682&view=l&l=de.

[421] Georg Forster to Johann Reinhold Forster, 3 March 1784, AA XIV, 25: "Die Hauptabsicht der Erziehungscommission, indem sie die Stelle eines Professors der Naturgeschichte errichtet, ist die Anwendung der inländischen Producte bekannter und allgemeiner zu machen. Ich werde mich, wie sich versteht, bemühen, die Producte des Landes, ihren ökonomischen, landwirtschaftlichen und medicinischen Nutzen, ihre Anwendung für Künste und Handwerke, Färberei, Manufacturen und Handel, ihre Verbesserung, leichteste Culturmethode, Erhaltung und dergleichen zu studiren."

[422] Forster, *Ansichten vom Niederrhein*, 163, 364.

Manchester. Indeed, Dominik Erdmann has observed that Humboldt's journal was composed less as a travelogue than a "cameralistic protocol."[423] All manner of economic activity fell within their purview as naturalists, from the cheese trade between Bristol and the Caribbean and the price of wool in Wiltshire to the "exact chem[ical] investigations" that might one day explain the "supremacy of Engl[ish] beer."[424]

Teasels in particular captured the peculiar relationship between botany and *Technologie* in eighteenth-century Europe. Under the heading "Somersetshire," in Southwest England, Humboldt collected notes on *Dipsacus fullonum*, a teasel "so important for the woolen cloth industry." Commonly known as the "fuller's teasel," its Latin binomial recalls the process of "fulling"—cleansing and compacting—the threads of newly-woven fabric. The German *Weberskarde,* or "weaver's card," refers to an earlier stage in the cloth manufacturing process: the carding of wool after shearing, which aligns the fibers now ready to be spun into yarn.[425] In fact, teasel itself comes from the act of teasing, or disentangling, fibers before being carded. Yet teasels were also used to finish woolen products, as illustrated in George Walker's *The Costume of Yorkshire* (**Figure 2**), where workers are pictured raising the "nap" of already-dyed cloth with

[423] Dominik Erdmann, "'Wenn ich Zeit und Ruhe hätte etwas vernünftiges zu schreiben'—Anmerkungen zu Alexander von Humboldts Journal der Englandreise 1790," in *Forster – Humboldt – Chamisso: Weltreisende im Spannungsfeld der Kulturen*, eds. Julian Drews, Ottmar Ette, Tobias Kraft, Barbara Schneider-Kempf, and Jutta Weber (Göttingen: Vandenhoeck & Ruprecht, 2017), 205-26, on 222.
[424] Humboldt, "Englisches Reisejournal," 2: "Es fehlt noch immer an genauen chem. Untersuchungen über den Einfluß verschiedener Wasserarten beim Färben, Bierbrauung. Es ist eben so unverständig, den Vorzug des engl. Biers, der engl. Färbereien p. dem engl. Wasser zuzuschreiben, als es voreilig ist den Einfluß des Wassers, der Athmosphäre bei so schweren chem. Prozessen, da Gährungen für die es keine Messer giebt, im Spiel sind, abzuleugnen."
[425] On the practice of carding wool in the eighteenth century, see Walter Endrei and Rachel P. Maines, "On Two-Handed Spinning," in *European Women and Preindustrial Craft*, ed. Daryl M. Hafter (Bloomington and Indianapolis: Indiana University Press, 1995), 31-41, on 33. Endrei and Maines do not note the teasel's application in carding but describe how laborers—almost always women—poked "sturdy bent wires" through flaps of leather attached to wooden paddles, which could be handled like "modern brushes used for grooming pets."

the plant's prickly, curved bracts. To do this, they have assembled handheld combs known as "teasel crosses" (**Figure 3**).

Employed in these various tasks since at least the medieval period, the fuller's teasel was actively cultivated by wool manufacturers in Humboldt's time, who sometimes fastened its sharp bulbs onto mill-powered "gig" machines.[426] In the Rhineland, too, teasels were readily integrated into large-scale woolen cloth manufacturing, as at "House Clermont" in Vaals, just outside of Aachen, which Humboldt and Forster visited en route to England. After inspecting the "fulling mill" (*Walkmühlen*) where woven cloth was cleansed and pounded into a thick fabric, they studied the dying manufactory (*Färberei*), which produced greens and "exquisite" reds of cochineal. Circling around to the start of the process, they then entered "several large rooms [where] shearers and cloth-preparers sat." As Forster noted in his *Views of the Lower Rhine*, "The teasels, which are used here, are taken from the area of Aachen."[427] Humboldt's own account cites several recent works on the use of *Weberskarde* in cloth manufacturing published in Germany, suggesting that the teasel's industrial utility was common knowledge among manufacturers and naturalists alike.[428]

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[426] P. N. Topham, "The Fuller's Teasel," *Proceedings of the Botanical Society of the British Isles* 7, no. 3 (1968): 377-81. Other modern accounts suggest the fuller's teasel also yields a blue dye similar to indigo and was once used to soothe sore eyes and even to remove freckles. See Richard Mabey, *Flora Britannica* (London: Sinclair-Stevenson, 1996), 480.

[427] Georg Forster, *Ansichten vom Niederrhein von Brabant, Flandern, Holland, England und Frankreich im April, Mai und Junius 1790* (Leipzig: Dieterich'sche Verlagsbuchhandlung, 1971), 165: "In mehreren großen Zimmern sitzen die Scherer und Tuchbereiter. Die Karden, deren man sich hier bedient, werden in der Gegend von Aachen gezogen."

[428] E.g. William Lewis, *Der Zusammenhang der Künste philosophisch-practisch abgehandelt: ein Versuch für die Beförderung der Künste, Gewerbe und Manufacturen*, vol. 2 (Zürich: Heidegger und Compagnie, 1766), 76; Albrecht Wilhelm Roth, *Botanische Abhandlungen und Beobachtungen* (Nürnberg: Johann Jacob Winterschmidt, 1787), 18; Albrecht Wilhelm Roth, *Tentamen florae Germanicae; continens enumerationem plantarum in Germania sponte nascentium*, vol. 2 (Leipzig: Bibliopolio Mülleriano, 1789), 162.

Figure 2. Raising the nap of woolen cloth with teasel combs in Yorkshire, whose wool manufacturers were known to have cultivated teasels for this purpose. "Illustration of the preemer boy" from George Walker, *The Costume of Yorkshire* (London, 1814). Wikimedia Commons.

Figure 3. Traditional teasel cross for carding wool, at the "Clothworker's Exhibition" in Lavenham, Suffolk in 2005. © National Trust Collections, Photo: Sue James, CMS_LAV317_14.

Humboldt, in fact, possessed a thorough knowledge of weaving instruments, the subject of what he called his "oldest, never-published work on 'The Weaving of Antiquity'."[429] He originally composed the project in Göttingen under the direction of philology professor Christian Gottlob Heyne, with whom he consulted Vatican manuscripts and "copper" artefacts from the Mediterranean. It focused on the development of the upright ("*haute lisse*") weaving loom, which the "the Saracens" had first introduced it to Europe.[430] Returning to the project again after his travels to England, Humboldt served as an authority on the history of ancient textile production through the correspondence of his brother, who was an avid philologist. In the margins of a letter Wilhelm wrote to classicist Friedrich August Wolf in 1794, for instance, Alexander included a sketch of the "weaver's comb" (*Pecten*) used by the "*Weberinnen*" of Ancient Greece. "They took the comb and beat the weft together," he wrote, describing the very process of compacting newly spun yarn for which the fuller's teasel earned its name.[431]

The fuller's teasel also prompted some of Humboldt's earliest meditations on human agency in the geographical distribution of plants. "Whether D[ipsacus] fullonum is indigenous to England, or only scattered about from the gardens of woolen cloth manufactories, I cannot

[429] Humboldt to Carl Friedrich Gauss, 22 Feb. 1851, in *Briefe zwischen A. v. Humboldt und Gauss*, ed. Karl Bruhns (Leipzig: Engelmann, 1877), 58: "…meine älteste nie erschienene Schrift 'über die Webereien der Alten'."

[430] Humboldt to W. G. Wegener, 17 Aug. 1789, *Jugendbriefe*, 70: "Ich habe die Entdekkung gemacht, daß der Weberstuhl der Alten gerade der *Hautelisse*-stuhl sei, den die Sarazenen nach Frankreich gebracht habe. Das läßt sich aus Kupfern aus dem Herkulanum, aus dem Onomastikon des Pollux, aus dem Isidor, aus den Vatikanischen *MSS* des Vergil, aus dem Homer & erweisen. Der Beweis ist sehr lang." See also Humboldt to Carl Freiesleben, 20 Jan. 1794, *Jugendbriefe*, 313 and *Wilhelm von Humboldt Briefe*, vol. 2, *Juli 1791 bis Juni 1795*, ed. Philip Mattson (Berlin: De Gruyter, 2015), 432, n. 18.

[431] Humboldt to Friedrich August Wolf, 8 Mar. 1794 (addendum to the margin of a letter from Wilhelm von Humboldt), *Jugendbriefe*, 325: "Der Pecten scheint so ausgesehen zu haben. Wenn die Weberinnen bei ihren stehenden [Ancient Greek for Webstühlen] besonders beim [Ancient Greek for Stäbchen] um den Stuhl herumgingen und den Radius (ein bloßer Stab mit umwickelten Fäden) sakkartig einflochten, so ergriffen sie den Pecten und schlugen den Einschlag damit zusammen."

decide," he wrote, noting that its provenance was equally unknown in Germany.[432] As with bananas and barley, so with the fuller's teasel: its natural history had become so entwined in human history that the two could hardly be distinguished. Images from the period offer an impression of teasel cultivation from the standpoint of educated travelers (**Figure 4**). George Walker, who had shown well-muscled men wielding teasel crosses in a workshop setting, depicted women harvesting teasels in the fields. Large stores of surplus bracts, like the bundle carried by a boy, suggest the yield is to be sold to local manufactories. Humboldt's *Essay* would later turn the notion that *plants follow people* into a general biogeographical insight. First, though, it was an everyday practice of production. Still today, botanists speculate that the now-wild "Somerset teasel" might have first arrived in the British Isles with Huguenot refugees who reinvigorated the English cloth industry in the sixteenth and seventeenth centuries.[433]

Figure 4. Working-class women and a boy bundling their yield in a "teasel field" in George Walker's *The Costume of Yorkshire* (1814). Wikimedia Commons.

[432] Humboldt, "Englisches Reisejournal," 3-4: "Dipsacus sylvestris, D. fullonum und wenn ich recht gesehen, auch D. laciniatus wachsen in Sommersetsh. und Glocestersh. wild. Linne hielt gewiß mit Unrecht D. fullonum, der für d. Tuchmanufakt. so wichtig ist, für eine bloße Abart von D. sylvestris. S. Roths Bot. Abhandl. P 18. Ob aber D. Fullon in England einheimisch od. nur aus den Gärten der Tuchmanufakt. verstreut sei, entscheide ich nicht. In Deutschland ist das eben so zweifelhaft Roth Flor. german. II p 162."

[433] Topham, "The Fuller's Teasel," 378. Topham also notes that the natural teasel was replaced by a "metal teasel" only in the course of the twentieth century.

But it was the "lowly lichens"—the subject of another manuscript Humboldt titled "*Mater*[*ia*] *technologica plantae tinctor*"—that took centerstage in his natural history of manufacturing. Alongside roots, barks, berries, and onion peels, lichens were a traditional source of dye in the artisanal workshops of early modern Europe. By the turn of the nineteenth century, however, these "cottage industries" faced a dual threat: the importation of colonial dyes like cochineal, indigo, and logwood (an insect, a flower, and a tree, respectively) alongside the rise of large-scale dyeing factories. In response, advocates of cameralist economics like Humboldt, who championed "indigenous" products over colonial imports, leapt to the defense of local lichen economies.[434] "The crÿptogam[atic] study is not so insignificant as one is accustomed to believing," Humboldt wrote while botanizing in the Derbyshire countryside, whose inhabitants rendered reds and purples from *Lichen tartareus* (**Figure 5**); for "in a good political economy, stone mosses should contribute to national prosperity."[435]

In England, Humboldt again lamented the underappreciated status of cryptogams amongst "statesmen," echoing his earlier review of Geuns. Yet the journal's extensive references to Latin-, German-, Danish-, French-, and English-language works speak to a lively international discourse on the practical utility of lichens in the second half of the eighteenth century.[436]

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[434] See Agustí Nieto-Galan, *Colouring Textiles: A History of Natural Dyestuffs in Industrial Europe*, Boston Studies in the Philosophy of Science, 217 (Dordrecht: Kluwer Academic Publishers, 2001).
[435] Humboldt, "Englisches Reisejournal," 5: "Das crÿptogam. Studium ist nicht so unwichtig als man es gewöhnlich glaubt. Bei einer Staatswirthschaft muß auch das Steinmooß mit zum Nationalreichthum beitragen."
[436] E.g. Johann Jacob Ferber, *Neue Beyträge zur Mineralgeschichte verschiedener Länder. Erster band, der zugleich Nachrichten von einigen Chymischen Fabriken enthält* (Mietau: Hinz, 1778); Johann Christian Fabricius, *Reise nach Norwegen: mit Bemerkungen aus der Naturhistorie und Oekonomie* (Hamburg: Bohn 1779), 64; Johann Karl Gottfried Jacobsson, *Johann Karl Gottfried Jacobssons technologisches Wörterbuch, oder, Alphabetische Erklärung aller nützlichen mechanischen Künste, Manufakturen, Fabriken….* (Berlin: Nicolai, 1781); Jacques-François and Henri Struve Demachy, *Herrn Demachy's Laborant im Grossen oder Kunst die chemischen Produkte fabrikmässig zu verfertigen*, vol. 2 (Leipzig: Crusius, Siegfried Leberecht, 1784); Nicolai Mohr, *Forsøg til en islandsk naturhistorie, med adskillige oekonomiske samt andre anmærkninger* (Kopenhagen: Christian Friderik Holm, 1786); Louis-Alexandre Dambourney, *Recueil de procédés et d'expériences sur les teintures solides que nos végétaux*

Figure 5. (Left) *Lichen tartareus*, among the lichens commonly known as "liverwort," is now called *Ochrolechia tartarea*. Around 1800, it was commonly known as "cudbear" after Cuthbert Gordon (1730-1820), a Scottish coppersmith who patented a method of obtaining red and purple dyes from lichens in 1758 and established a manufactory in Leith thereafter. As illustrated in James Sowerby, *English Botany*, vol. 3 (1794), 156. Harvard University. (Right) *Lichen saxatilis*, later called *Parmelia saxatilis*, was originally described by Linnaeus in 1753. As illustrated in Joh. P. Westring, *Svenska Lafvarnas Färghistoria, eller Sättet att använda dem till färgning och annan hushållsnytta* (Stockholm: Carl Delén, 1805), 11. New York Botanical Garden, LuEsther T. Mertz Library.

indigènes communiquent aux laines et aux lainages (Paris: Imprimerie de Ph.-D. Pierres, 1786); James Pilkington, *A view of the present state of Derbyshire; with an account of its most remarkable antiquities. Illustrated by an accurate Map and Plates* (Derby: Drewry, 1789).

So, too, state-run dye manufactories in France and Germany, prize competitions amongst scientific societies in England and the Netherlands, and efforts everywhere to safeguard "secret" dyeing recipes reveal the great economic value accorded to natural dyestuff.[437] Humboldt himself would later carry out experiments to enhance the enamel of multi-colored ceramics at the Royal Porcelain Manufactory in Berlin in the early 1790s. And in Franconia, he used his position as a high-ranking mining official to promote local manufactories that utilized mineral agents like vitriol in dyeing and bleaching.[438]

If the 1805 *Essay* reads as a world map of the great migrations of peoples and plants, the journal of 1790 catalogues the global exchange of lichens and their dyes. In the Scottish Highlands, Humboldt noted, some "200 people are engaged in the collection" of *Lichen saxatilis* (**Figure 5**), from which red, blue, and purple powders were rendered in baths of alum and alkali at the "litmus manufactories" of Leith and Manchester. A contemporary account adds that the "gatherers carefully choose such specimens as are of a firm dense texture, and they never scrape the same rock oftener than once in five years."[439] Ready to be boiled with woolen yarn, the lichenous dyes were then shipped throughout Britain, as to Holland and Germany, where merchants competed with colonial imports—from "the Canary, Cape Verde, and Greek Islands," Humboldt noted. Meanwhile, the slave plantation economy of indigo, taken from the East to the

[437] Klein, *Humboldts Preußen*, 138-45; Agustí Nieto-Galan, "Between Craft Routines and Academic Rules: Natural Dyestuffs and the 'Art' of Dyeing in the Eighteenth Century," in *Materials and Expertise in Early Modern Europe*, eds. Ursula Klein and E. C. Spary (Chicago: University of Chicago Press, 2010), esp. 323-26.
[438] Frank Holl and Eberhard Schulz-Lüpertz, *"Ich habe so große Pläne dort geschmiedet…": Alexander von Humboldt in Franken* (Gunzenhausen: Schrenk-Verlag, 2012), 53-58; Klein, *Humboldts Preußen*, 268-72. Specifically, as *Oberbergmeister* in Bayreuth, Humboldt worked to rehabilitate a state-run porcelain manufactory in Bruckberg, reserve sufficient timber to fuel another, privately-owned manufactory in Tettau, and promote the founding of a Royal Alum- and Vitriol-Works in Crailsheim, vitriol being crucial to dyeing and bleaching processes in the eighteenth-century textile industry.
[439] James Sowerby, *English Botany; or, Coloured figures of British plants, with their essential characters, synonyms, and places of growth*, vol. 3 (London: Davis, 1794), 156.

West Indies, had all but crushed the traditional harvest of greens, browns, and blues from the *Lichen tartareus* growing upon the rocks of Norway, Sweden, and the Faroe Islands. "In 1785 just two shiploads of this Lich[en] Tartareus from Norway to England," notes the journal.[440] These exchanges can be viewed within a larger, global market of natural dyestuffs, from the Prussian Blue and Turkey Red produced from potash and plant roots in Glasgow to the "mourning" black of logwood harvested in Caribbean colonies and the red of cochineal in Mexico, which the British East India Company tried to reproduce in South Asian cactus farms.[441]

As local cryptogam commerce struggled against imperial trade networks, Humboldt took recourse to the mercantilist policies he had learnt as a student of the Cameral Sciences. He speculated that the "beautiful red-purple" of *Lichen tartareus*, for instance, which was "prepared with urine" in Derbyshire, might stem the "expensive" importation of *Lichen roccella*, known for its Royal Purple. Humboldt's *Mater*[*ia*] *technologica plantae* even contained a chemical method he had devised to replace the 500-year-old practices by which the *Roccella tinctoria*'s dyes were,

[440] Humboldt, "Englisches Reisejournal," 5: "Wir kaufen Lakmus von Holländer und Engländer und vergessen daß dieser ihn von L. saxatilis macht, das bei uns jed. Baum, jeder Pfahl, jeder Stein trägt. S. von den Lakmusfabriken bei Leith in Schottland zu der 200 Menschen sich mit d. Sammeln des L. saxatilis beschäftigen Ferbers neue Beiträge zur Mineralgesch. I. p 455." Ibid., 6: "Hviddblik od. K orke. Dies Moos ist seit den ältesten Zeiten in Norwegen, Schweden und den Farörinseln und Island zum Färben gebraucht worden. Der Indigo und andere ausländ. Farbstoffe haben jetzt den Gebrauch desselben fast ganz verdrängt. Der Vorwurf, daß die Farbe daraus nicht so hoch, glänzend und haltbar als die aus ostindischen Materialien sei, ist ungegründet da auch bei der elendsten Bereitung ohne Anwendung von Salzen und anderen Bindemitteln dieselbe oft so überaus prächtig ausfällt. Prof. Strom versichert in der Maanedsskrivt fra Christiania daß der Hviddblik od. Lich. tartar. von Norwegen nach England gehe, wo man ihn zu einer rothen und blauen Farbe auf Wolle und Kattun veredle. 1785 gingen allein 2 Schifladungen von diesem Lich. tartareus von Norwegen nach England."

[441] Robert G. W. Anderson, "Relations between Industry and Academe in Scotland, and the Case of Dyeing: 1760 to 1840," in *Compound Histories: Materials, Governance and Production, 1760-1860*, eds. Lissa L. Roberts and Simon Werrett (Leiden: Brill, 2018), 333-53; Alicia Weisberg-Roberts, "Between Trade and Science: Dyeing and Knowing in the Long Eighteenth Century," in *Ways of Making and Knowing: The Material Culture of Empirical Knowledge*, eds. Pamela H. Smith, Amy R. W. Meyers, and Harold J. Cook (New York City: Bard Graduate School, 2014), 86-112; Deirdre Moore, "Cochineal Husbandry in Eighteenth-Century Mexico and India," paper delivered at the Annual Meeting of the History of Science Society, Utrecht, the Netherlands, July 2019.

he wrote, first rendered "in the Levant." Finding also many of the same "oeconomic plants" as he had encountered on Beckmann's tours in Göttingen, Humboldt echoed calls to re-discover the hidden wealth of Germany's "indigenous" products. "We purchase litmus from the Dutch and English," Humboldt wrote, "but forget that they make this from L[ichen] saxitilis, which grows on every one of our trees, posts, and stones."[442] Like Linnaeus before him, Humboldt saw the science of plants as a science of state.

But in spite of his redoubled commitment to protectionist policies, Humboldt's journey to England, and particularly his encounter with London's scientific circles, also stirred colonial fantasies.[443] Indeed, the amalgamation of cameralist and imperialist aspirations formed in 1790 would underpin Humboldt's science for decades to come. From Prussia's metallurgic industry and Spain's silver-rich colonies to mineral prospecting in the Ural Mountains of Russian Siberia, Humboldt served autocratic rulers who saw his science as an instrument in the making of domestic and overseas empires. Some four decades before serving the Tsar in 1829, the England journey marked Humboldt's first trip across open waters—at the side of the "Circumnavigator" no less. "Forster's name" ushered Humboldt into the home of Royal Society President Sir Joseph Banks, who preceded him and his father as naturalist aboard Cook's first voyage.[444] Banks's

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[442] Humboldt, "Englisches Reisejournal," 4: "Es giebt mit Urin präparirt (wie L. saxitilis L. calcar. und Verruc. pertusa) eine schöne purporrothe Farbe, bei der man den theuren Erd- und Kräuterorseillen (L. Roccella und L. Parell.) entbehren kann."

[443] Many of Humboldt's German contemporaries hailed him as a "second Columbus." See Suzanne Zantop, *Colonial Fantasies: Conquest, Family, and Nation in Precolonial Germany, 1770-1870* (Durham, NC: Duke University Press, 1997), 165-69.

[444] Humboldt to Wilhelm Gabriel Wegener, 20 Jun. 1790: "Forsters Name, der allgemeines Interesse erwekt, Empfehlungen p. verschaften uns überall Zugang zu den handelnden Personen." Humboldt to Friedrich Heinrich Jacobi, 3 Jan. 1791, *Jugendbriefe*, 117: "So schnell auch unsere Reise war, so war sie doch äußerst lehrreich für mich. Besonders hab' ich an naturhistorischen Kenntnissen, theils durch die übergroße Gesälligkeit von Banks, theils durch eine mineralogische Tour nach dem Peak von Derbyshire, viel gewonnen. Forsters Name verschafte mir überall Eingang, und ich wurde in wenigen Wochen mit so viel vorzüglichen Menschen bekannt, als ich vielleicht allein in eben so viel Jahren nicht hätte kennen gelernt."

home famously functioned as a gathering place for naturalists and rare specimens alike, the center of a "learned empire."[445] Enamored of "Banks's magnificent society," Humboldt described the "beneficence" with which he introduced him to "the Indian world that was his home." With these words Humboldt described the enormous archive of colonial specimens and artefacts at 32 Soho Square, a "world" at once "material and human."[446]

Captain William Bligh of H.M.S. Bounty infamy appeared to Humboldt as a sort of living travel narrative. Bligh's command of the Bounty, which sailed for the Polynesian Islands in 1787, is remembered best for the munity led by Acting Lieutenant Christian Fletcher. But the ship's mission, to transport over a thousand breadfruit trees from Tahiti to the Caribbean (**Figure 6**), also typified imperial efforts to re-shape the global geography of plants.[447] Having emerged victorious from the Seven Years War, the British Empire was now moving plants of commercial value throughout a global network of botanical gardens and slave plantations, from Calcutta to Jamaica and St. Helena to London. The Bounty's voyage was part of a long-running project, begun in the 1770s, to cultivate the Tahitian staple as cheap foodstuff for enslaved laborers on Caribbean plantations, an enterprise backed by Banks himself. "I have spoken to Bligh frequently at Banks's," Humboldt boasted in a letter to Usteri, describing the captain's "miraculous rescue."

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[445] Edwin D. Rose, "Publishing Nature in the Age of Revolutions: Joseph Banks, Georg Forster, and the Plants of the Pacific," *The Historical Journal* 63, no. 5 (December 2020): 1132-1159. See discussion of the so-called "Banksian learned empire" in David Phillip Miller, "Joseph Banks, empire, and 'centers of calculation' in late Hanoverian London," in *Visions of Empire: Voyages, Botany, and Representations of Nature*, eds. David Phillip Miller and Peter Hans Reill (Cambridge: Cambridge University Press, 1996), 21-37, esp. 22.

[446] Humboldt, 4 Aug. 1801, in *Aus meinem Leben*, 39: "Die auszeichnende Nachsicht, mit der Sir Joseph Banks mich behandelte, der Anblick seiner Sammlungen, die indianische Sach- und Menschenwelt, dieser Umgang bestärkte meinen naturhistor[ischen] Eifer." After returning to Germany, Humboldt continued to correspond with Banks until at least 1798. See *Jugendbriefe*, 110-11, 584-85, 614, 636-37.

[447] Ogborn, "Vegetable empire," 272-77.

Figure 6. The breadfruit tree as depicted in John Hawkesworth's 1773 account of Cook's first voyage around the world. SUB Gö, HSD:4 NAT II, 955:2 RARA.

But it was the economic endeavor, for which the Bounty's botanist David Nelson died a "martyr," that most captured Humboldt's imagination. Humboldt ostensibly opposed slavery. But he was willfully ignorant of the history of forced human migration coupled with that of the breadfruit. "It seemed the Bounty would accomplish a more benevolent undertaking than had ever been attempted," he wrote to Usteri.[448] These attitudes serve as a stark reminder that in Humboldt's Europe botany's vaunted role as an agent of social "Improvement" entailed efforts to ameliorate—and continue—the violent regime of plantation slavery. Natural history was

[448] Humboldt to Paul Usteri, 27 Jun. 1790, *Jugendbriefe*, 97-98. "Die Bounty wurde ausgeschickt, um Brodbäume in der Südsee zu sammeln und sie nach Westindien zu bringen. Nie schien eine wohlthätige Absicht glücklicher erfüllt zu werden als diese. […] Ein Leichenstein für Nelsons Grab war nicht zu finden. – Wenn auch der Ort vergessen ist, wo die heilige Asche der Märtyrer ruht, so haben sie ein bleibenderes Denkmahl doch in dem Mitgefühle der Edlen! […] Ich habe den Bligh hier öfters bei Banks gesprochen." The breadfruit did not reach the Caribbean until Bligh's second attempt in 1793.

practiced through, and in the service of, the slave plantation economy.[449] Forster, who studied breadfruit cultivation on-site in Tahiti and authored an essay on its utility in 1784, also noted its intended use as foodstuff for "negro slaves." Like Humboldt, Forster railed against the cruelty of slavery. Yet he too considered the plant "one of the most benevolent of natural products."[450] Notably, Forster's essay also described how the breadfruit spread throughout the South Pacific in the hands of the Polynesians, long before Europeans attempted to co-opt its migrations.

Everywhere Humboldt looked in England, plants and people were on the move. Inside his London lodgings he found the walls "decorated with copper plates of East India ships." Outside, he marveled at "a land whose inhabitants visited both Indies 4-5 times in their lives, and where one is equally well acquainted with the products from the most distant parts of the world as with those of his own country." Humboldt's "favorite walk" took him by a placard that advertised seafaring work "for young people who wish to try their luck outside Europe," aboard a ship "set to sail for Bengal." Enchanted by the offer, fantasies of global commerce saturated his imagination. "I lived in a conceptual world [*Ideenwelt*]," Humboldt reflected from Bogotá in 1801, "which drew me away from the real one."[451] A half century later, Humboldt would recall the 1790 journey as a "former world" (*Vorwelt*), petrified like the "primitive plants" (*Pflanzen der Vorwelt*) to which he turned as a student of mining in 1791.[452]

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[449] J'Nese Williams, "Plantation Slavery and Government Science in the St. Vincent Botanic Garden, 1765-1820s," forthcoming in *Berichte zur Wissenschaftsgeschichte* (June 2021).
[450] Georg Forster, "Der Brodbaum," in AA VI, Pt. 1, 63-64.
[451] Humboldt, 4 Aug. 1801, *Aus meinem Leben*, 38-40: "Die Hügel von Highgate und Hemptsteat waren mein Lieblingsspaziergang in London, an dem Wege las ich Anschlagzettel nach engl[ischer] Sitte: 'Junge Leute, welche ihr Glück außerhalb Europas suchen wollen, melden sich dort und dort, als Matrose, Schreiber ... finden sie Aufnahme. Das Schiff ist segelfertig nach Bengalen'. Mit welchen Empfindungen las ich diese Einladung […] Ich lebte in einer Ideenwelt, die mich von der wirklichen abzog."
[452] Humboldt to Carl Bunsun, 28 Sept. 1851, *Briefe von Alexander von Humboldt an Christian Carl Josias Bunsen*, ed., Ingo Schwarz (Berlin: Rohrwall Verlag, 2006), 139: "so weit ist es her, als Georg Forster mich in die Vorwelt zu Sir Joseph Banks, Cavendish, William Herschel führte…."

Gardens in the Mines

The Mining Academy in Freiberg may seem worlds away from the Banksian intellectual milieu, an altogether different industry than that to which lichens and teasels belonged. But the mines of Saxony not only proved a significant site for further botanical inquiries; they also impressed Humboldt's nascent geography of plants with a deeper temporal dimension. In England, the migrations of plants like *Dipsacus fullonum*, *Lichen tartareus*, and the breadfruit were routed through manufactory gardens, global dye industries, and the Atlantic slave plantation economy. But by expanding the scope of this inquiry into the earth—shifting from a horizontal gaze across states and empires to vertical perception into coal seams and fossil beds—Humboldt began to study the historical migrations of plants.

Humboldt's plant geography crystallized as a truly historical science during Werner's lessons at the Mining Academy, as he told Usteri in 1791. Werner's new earth science, "geognosy," classified rocks according to the age of their formation (rather than by composition and location), making *time* their very essence.[453] Extending this framework to the study of "submerged vegetation" (*untergegangene Vegetation*) found fossilized in Saxon mineshafts Humboldt began to view rock formations and plant fossils as mutually informing bodies of evidence. Some fossils, like the tropical plants unearthed in German mines and caves, seemed to evidence climatic change in nature.[454] The gradual cooling of the earth, many speculated, had forced plants and animals alike to migrate from northern to equatorial climates. Drawing upon

[453] Rachel Laudan, *From Mineralogy to Geology: The Foundations of a Science, 1650–1830* (Chicago: University of Chicago Press, 1987), 87-96, 106-09.
[454] Humboldt to Johann Friedrich Pfaff, 12 Nov. 1794, *Jugendbriefe*, 36: "Ich fange von der untergegangenen Vegetation, den Grabstätten der Pflanzen der Vorwelt (Phytolithen, Steinkohlen usw.) an. Hier sehen wir Produkte heißer Zonen unter 60-70° n. Br., und zwar (von Blumenbach und anderen erwiesen) zahllos nicht hingeschwemmt, sondern in einer Lage, welche beweist, daß sie in ihrer Heimat liegen." See also Humboldt and Bonpland, *Essay on the Geography of Plants*, 69.

fossil evidence, naturalists began to establish unfathomably deep timescales of geo-history, relegating human history to a mere "recent phase."[455] Yet the line the divided the primordial world from the present remained blurry, and there was as yet no clear-cut distinction between geological time and species time.[456] This helps to explain why Humboldt wrote of his commitment to the study of "geognosy [and] the history of cultivation etc. together with botany," supposing that even some fossilized plants registered evidence of human migrations.[457]

But as fossils receded into a deeper, pre-human past, it was the study of living plants in the mines that underscored the interplay of human and natural phenomena in Humboldt's early science. First in Saxony and then in Prussian Franconia, Humboldt took his "cryptogamatic study" underground, studying mosses, lichens, and fungi that grew there. Natural resources above ground, Humboldt believed them toxic nuisances below—the source of "wicked airs" (*böse Wetter*) that plagued miners with respiratory illnesses traditionally known in the industry as "mine-maladies," or *Bergkrankheiten*. "No sooner does the miner begin his underground work," Humboldt wrote in a 350-page book on the subject of "subterraneous airs" in 1799, "no sooner does he bore an adit of 20 leagues, or dig a shaft of 8 to 10 leagues, than he confronts the daunting afflictions caused by a shortage of respirable air."[458] As an antidote, Humboldt called

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[455] Martin J. S. Rudwick, *Bursting the Limits of Time: The Reconstruction of Geohistory in the Age of Revolution* (Chicago: University of Chicago Press, 2005), 261, 279, 1-2.
[456] Heringman, "Stadial Environmental History," 206-27.
[457] Humboldt to Paul Usteri, Autumn 1791, *Jugendbriefe*, 163-64. Humboldt went so far as to claim that the fossilized "cave bears" recently unearthed in Franconia had lived alongside primitive humans. Where others, like Georges Cuvier, relegated strange fossilized beasts like the mammoth and "megatherium" to a pre-human world, violently severed from the present by revolutions of the earth, Humboldt believed Franconia's "cave bear" had experienced the same "great planetary catastrophes" as its human neighbors had. See Humboldt to Carl Freiesleben, 20 Jan. 1794, *Jugendbriefe*, 316, n. 10. Humboldt did not return to the speculation that plant fossils evidenced human migrations.
[458] Alexander von Humboldt, *Ueber die unterirdischen Gasarten und die Mittel, ihren Nachtheil zu vermindern: Ein Beytrag zur Physik der praktischen Bergbaukunde* (Braunschweig: Vieweg, 1799), 201-02: "Kaum fängt der Bergmann seine unterirdische Arbeit an, kaum ist ein Stollen an 20 Lr. in das Gebirge gebracht, ein Schacht 8 bis 10 Lr. abgesunken, so treten die ängstlichen Beschwerden des Wettermangels ein."

for a broad administrative effort to transform underground ecologies, beginning with the "extermination" of all cryptogams from the mines.[459]

Humboldt's position as a mining official afforded him unique access to a "phenomenon already well known to the common miner": mosses and lichens that grow green in utter darkness (**Figures 7-8**).[460] "Perhaps no one before me has had so many opportunities to observe them as I," he boasted to the Göttingen natural philosopher Georg Christoph Lichtenberg. He described collecting "the most exquisite fungi and lichen from depths of 900 to 1,000 [Prussian] feet" (287 to 314 meters)—"an entire subterraneous Creation."[461] Arriving at the Mining Academy in the summer of 1791, Humboldt had sent a draft of his dissertation on "cryptogram[matic] flora" to Usteri by November. *Florae fribergensis specimen*, as it was published in 1793, catalogued 258 plants known to grow in the Saxon subterranean. The prodigious *Byssus clavata* and *Lichen verticillatus* in particular captured Humboldt's "rapt attention"—not only for their "colossal" size, but also their green color.[462] The *Lichen verticillatus*, he reported in the *Journal der Physik*

[459] See Humboldt, *Ueber die unterirdischen Gasarten*, 233: "Vertilgung unterirdischer Pflanzen."
[460] Humboldt to Usteri, 7/10 Jan. 1792, *Jugendbriefe*, 166: "Diese dem gemeinen Bergmann sehr bekannte Erscheinung machte mich noch aufmerksamer, als ich auf Kurprinz Friedrich August zu Großschirma denselben, riesenmässigen Lich[en] verticillatus, von welchem das Exemplar durch den Herrn Bergrath von Charpentier an den Kurfürsten (einen tiefen Kenner und Beschüzer der Pflanzenkunde) geschikt ist, mit lichte graßgrünen Keimen fand."
[461] Humboldt to Georg Christoph Lichtenberg, 21 Apr. 1792, *Jugendbriefe*, 184: "und vielleicht hat nie jemand so viel Gelegenheit sie zu beobachten als ich, der ich ¾ Jahr alle Tage 4—5 Stunden regelmäßig in der Grube zubrachte. Ich habe Schwämme und Lichenes in einer Teufe vom 900 bis 1000 Fuß aufs feinste organisirt, ja Ellen lang gefunden und in ihnen eine ganze unterirdische Thierschöpfung."
[462] Humboldt to Paul Usteri, Autumn 1791, *Jugendbriefe*, 163: "Ich sende Ihnen hier eine Probe meiner kleinen cryptogam[atischen] Flora…. Ich habe alle meine Pflanzen selbst gezeichnet und denke sie den Winter stechen zu lassen. Die Abbildungen von L. verticillat, B. clavate & folgen daher in meiner Flora nach." Humboldt to Dietrich Ludwig Gustav Karsten, 26 Nov. 1791, *Jugendbriefe*, 160-61: "Ich bin unter Werner's Anweisung beinah 3 Woche bloß in dieser Rüksicht täglich auf verschiedenen Gruben gefahren bin und habe manches sonderbarer gefunden…. Ich habe ein 3 Platten Zeichnungen selbst dazu entworfen, besonders ein 14—18 neue *Species*. Eine neue Pflanzengattung habe ich auf dem Kurprinz und vor dem Moritzer Stollort entdeckt. Es ist das größte Cryptogamische Gewächs, das bisher bekannt geworden ist, 4—6 Fuß lang. Ich nenne es Usnea verticillata." In the *Essay*, Humboldt notes that plants like the *Lichen verticillatus* could be found growing "in the mines of Germany, England, and Italy, as in

in 1792, "coats the walls" and spans some "7—8 feet in three of the local (Freiberg) mines," its "young swirling tips, initially moist and *light grass-green*, soon *harden* and *change their color* to the *blackish-brown* of the rest of the plant."[463] Determined to find a chemical explanation for the green growth of underground vegetation, Humboldt cultivated a garden ("*Akkerbau treibe*") in the mines "at a depth of 60 toises" (117 meters).[464]

Figure 7. Copper plate of the *Lichen verticillatus* (16), *Byssus clavata* (17), *Byssus speciosa* (18), and *Bolet. Striatus* (19), from sketches Humboldt made in Autumn 1791. Engraved the following year, the images appeared as Plate 4 of Humboldt's *Florae fribergensis specimen* in 1793. New York Botanical Garden, LuEsther T. Mertz Library.

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those of New Grenada and Mexico, and, in the southern hemisphere, in the mines of Hualgayoc in Peru." (Humboldt and Bonpland, *Essay on the Geography of Plants*, 88.)

[463] F. A. Humboldt, "Versuche und Beobachtungen über die grüne Farbe unterirdischer Vegetabilien," *Journal der Physik* 2, no. 1 (1792): 195-205, on 196-97: "so wurde meine Aufmerksamkeit doppelt gespannt, als ich eine *Flechtenart* (der das Innere des Erdkörpers zum *ausschliessenden* Wohnplatz bestimmt scheint) mit *grünen Keimen* fand. Dieses riesenmässige Gewächs, das ich *Lichen verticillatus* nenne, und welches bey einer sehr zarten inner Structur bisweilen eine Länge von 7—8 Fuss erlangt, ist wenigstens auf drey der hiesigen (Freiberger) Gruben ... einheimlich. An dem letztern Orte, wo es das Gestein überzieht, sind die jungen Spitzen der quirlförmigen Aeste anfangs *weich* und *lichte gras-grün*, *erhärten* aber bald und *verändern ihre Farbe* in die *schwärzlichbraune* des übrigen Plfanzenkörpers."

[464] Humboldt to Karsten, 26 Nov. 1791, *Jugendbriefe*, 161.

Figure 8. Moss found by the author growing at a depth of 150 meters in a Freiberg mine called Fürstenstollen Fundgruben. This coated the walls of a gallery completed in 1791 (as chiselled onto the rock), during Humboldt's studies at the *Bergakademie*. In 1792, Humboldt described the *Lichen verticillatus* he found "in at least three of the local (Freiberg) mines" in the *Journal der Physik*.

Humboldt effectively re-orientated the industrial and imperial horticulture of which learnt in England, working now on the vertical plane. As amongst horticulturalists and manufacturers, moreover, Humboldt's garden played a significant economic role, offering new insights into the "airs" that wreaked havoc on miners' lungs. Transplanting weeds and flowers that grew above ground into his subterranean garden, Humboldt found that they, too, "grow again as green as before." The reason for this, he surmised to Lichtenberg, was that plants thrive in the very "irrespirable airs" in which miners suffer.[465] "Nitrogen and hydrogen, which corrupt the atmosphere of our mines," Humboldt concluded in a letter to another chemist, "generally act on subterraneous vegetation as light acts on those found on the surface of the earth."[466]

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[465] Humboldt to Lichtenberg, 21 Apr. 1792, *Jugendbriefe*, 184: "Ich habe gefunden, daß Pflanzen in irrespirablen Luftarten ohne je einem Sonnenstrahl ausgesezt zu sein, grün gefärbt sein können."
[466] Humboldt to Jean-Claude Delamétherie, 10 Jan. 1792, *Jugendbriefe*, 167-68: "J'ai observé que la *poa annua*, *P. compressa, plantago lanceolata*, *trifolium arvense*, *cheiranthus cheiri*, &c. &c. placés dans les galeries d'écoulement à une profondeur de 60 toises, ne perdent souvent pas leurs feuilles, & qu'il leur en croît de nouvelles aussi vertes que le premières. […] L'azote, l'hydrogène, dont l'atmosphère de nos

These findings not only challenged conventional wisdom about the effect of sunlight on plant physiology; they also prompted a far more expansive inquiry into what Humboldt called "subterraneous meteorology." Measuring airs with a eudiometer—a glass tube he had fashioned to detect subtle changes in volume—Humboldt came to believe that underground plants not only thrive in "irrespirable air"; they produce it, too. "White fungi" and "various species of *byssus*" in particular, which proliferate on the wooden framing of the mines, "assimilate" oxygen from water and "perpetually exhale hydrogen gas."[467] "Whereas the green plants in sunlight exhale oxygen [*Lebensluft*]," he wrote, "thereby contributing to the enhancement of the atmosphere above ground, we find the opposite is true for subterraneous plants, which grow in mines."[468]

The "subterranean meteorology" Humboldt developed in these years marked plant geography's first step towards "general physics." In its synoptic view of plant life, geological relations, meteorological phenomena, and human activity, this study laid the groundwork for an instrumentalized science of plants that spanned nature's vertical axis, from mineshafts to mountain summits. Six years after publishing on his *Ueber die unterirdischen Gasarten*, cryptogams would again figure centrally into the *Essay*. Here Humboldt argued for two types of correspondence in plant distribution: the first between mountaintops and poles and the second between mountaintops and mines. "The opposite limits of plant life," Humboldt believed,

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mines est généralement empestée, agissent sur les végétaux souterrains, comme la lumière agit sur ceux qui se trouvent sur la surface de la terre. Ils ont de l'affinité avec l'oxigène qui se combine avec eux, &c."

[467] Alexander von Humboldt, "Ueber Grubenwetter und die Verbreitung des Kohlenstoffs in geognostischer Hinsicht," *Chemische Annalen für die Freunde der Naturlehre, Arzneygelahrtheit, Haushaltungskunst und Manufakturen* 2 (1795): 99-119, on 101-02: "Viele von ihnen [hauchen] ununterbrochen Wasserstoffgas aus. Sie zersetzen das Wasser unendlich schnell, assimiliren vielleicht den einen Bestandtheil desselben, das Oxygen ihrer durch diese Anhäufung *weißen* Fiber, und geben den andern Bestandtheil von sich."

[468] Humboldt, *Ueber die unterirdischen Gasarten*, 158-59: "So wie die grünen Pflanzen im Sonnenlichte Lebensluft aushauchen, so wie sie über Tage zur Verbesserung der Atmosphäre viel beytragen, so finden wir von alle dem das Gegentheil, bey den unterirdischen Pflanzen, die in der Grube wachsen." See also ibid., 233-35.

"produce beings with a similar structure and a physiology equally unknown to us." For "the rocky and icy peaks above the clouds … are covered only with mosses and lichenous plants," just as "cryptogams, sometimes pale, sometimes colorful, branch out on the roofs of mines and underground caves."[469]

Humboldt's inclusion of subterranean flora in the *Essay* was not merely descriptive. Rather, these cryptogams had a theoretical importance, illustrating the analogies in plant life between nature's "opposite limits"—alpine summits and polar extremes, mountaintops and mineshafts. In the *Essay*'s "Tableau physique" (**Figure 9**), Humboldt emphasizes this analogy by placing the "Région des Plantes Souterraines" at sea level. As such, we encounter subterranean vegetation not in crags, caverns, and mines at various elevations but rather as a region held in vertical juxtaposition to the mountainous "Région des Lichens" at 4,600 to 4,900 meters. So Humboldt idealized nature's opposite and analogous extremes.

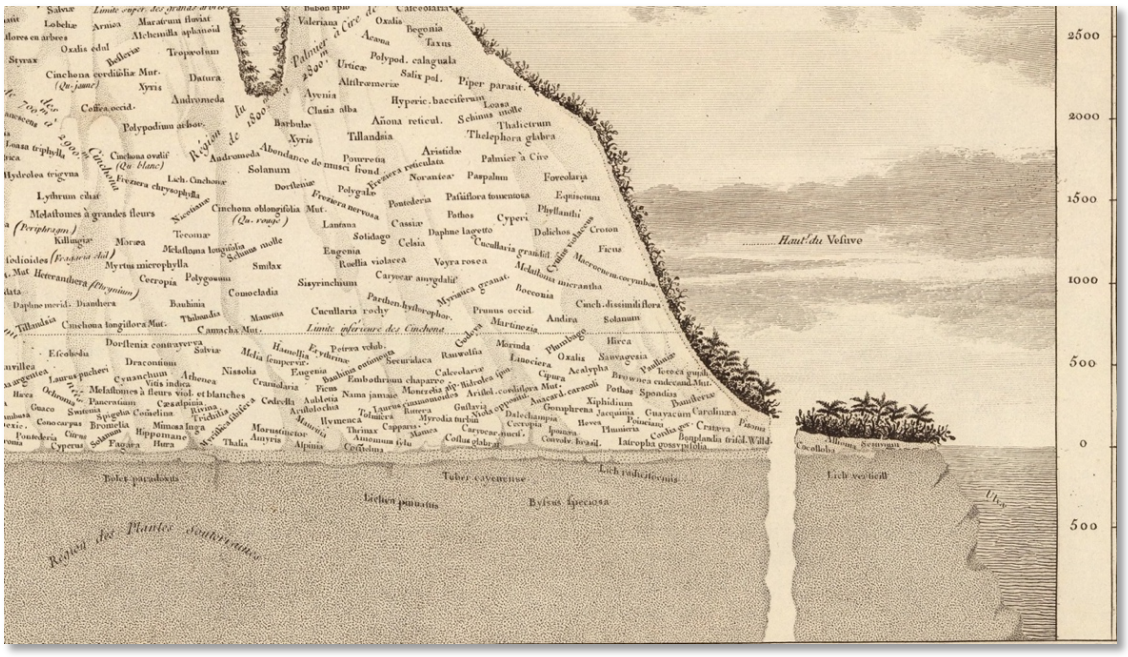

Figure 9. Detail of the "Région des Plantes Souterraines" in Humboldt's "Tableau physique des Andes" (Paris, 1805). David Rumsey Historical Map Collection, Image No: 11083000.

[469] Humboldt and Bonpland, *Essay on the Geography of Plants*, 64.

The notion of correspondence in plant geography was emblematic of the "cosmic" worldview Humboldt developed in the first half of the nineteenth century: a confluence of interweaving natural forces that tend toward steady-state equilibrium, oscillating around mean values.[470] It is tempting to view Humboldt's Cosmos as the epitome of a proto-ecological perspective in which humans were embedded in the fabric of nature.[471] Yet this interpretation of Humboldt, striving towards a holism that spanned nature and society, must also be reckoned with the fissure between natural and universal history in the early nineteenth century. In the following section I suggest that Humboldt's plant geography, first born of the union between natural history and political economy, gradually came to reflect the widening gulf between nature and (European) society.[472]

A New Disturbance in the Cosmos

Humboldt lived to see a drastic shift in European views of nature, from the Enlightened imperative to subdue and improve "rude Nature," as captured in the works of Buffon, to the Romantic fantasy of "pristine" nature devoid of human intervention, born of a reaction to

[470] In this way, Cosmos also drew upon Enlightenment cosmologies, especially Laplacian celestial mechanics. See Michael Dettelbach, "The Face of Nature: Precise Measurement, Mapping, and Sensibility in the Work of Alexander von Humboldt," *Studies in the History and Philosophy of Biology and Biomedical Sciences* 30, no. 4 (1999): 473-504, on 486, n. 24.
[471] See the link between *Kosmos* and ecology discussed in Aaron Sachs, *The Humboldt Current: Nineteenth-Century Exploration and the Roots of American Environmentalism* (New York: Penguin, 2006), 77-79. Nicolson finds ecology's roots specifically in Humboldt's plant geography: Nicolson "Humboldtian Plant Geography after Humboldt: The Link to Ecology."
[472] Joppe van Driel and Lissa Roberts, "Circulating Salts: Chemical Governance and the Bifurcation of 'Nature' and 'Society'," *Eighteenth-Century Studies* 49, nr. 2 (2016): 233-63. It is important to note how the same nineteenth-century sciences that delineated nature and European culture also tended to naturalize "other" cultures, ascribing alternative temporalities to non-Western civilizations and landscapes. Consider Pratik Chakrabarti, "Gondwana and the Politics of Deep Past," *Past and Present* 242, no 1 (2019): 119-53; Pratik Chakrabarti, *Inscriptions of Nature: Geology and the Naturalization of Antiquity* (Baltimore, MD: Johns Hopkins University Press, 2020).

industrialization and urbanization in western and central Europe.[473] Undergirding this shift was the invention of "deep time," with its vast pre-human timescales, which began to sever the bonds of natural and universal history.[474] A "temporal and ontological divide" opened between earth and climate, on the one hand, and society and culture on the other; and human action began to appear "microscopic compared to the vast cycles of nature."[475] Where eighteenth-century natural history spanned strata, fossils, flora, and fauna, the nineteenth century saw a deliberate distinction between the biological and the geological, the living and non-living. Humans, long viewed as a primary force in nature, were increasingly viewed in opposition to it.

Humboldt's plant geography was not insulated from this sea-change: the "externalization of nature" that accompanied the compartmentalization of natural and social economies.[476] Ultimately, Humboldt's over-arching commitment to universal harmonies would supersede his earlier zeal for the practical utility of plants and the integrated view of nature and society that it inspired. Botany itself underwent a significant reorganization in Humboldt's lifetime. Coming of age amidst the Enlightened project of "economic botany," which touted the commercial and medicinal value of plants, the nineteenth century saw the rise of self-described "philosophical" or "professed botanists," who eschewed material interest. Jim Endersby has described this transformation as part of a self-conscious effort to elevate plant geography, as a causal science,

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[473] Jan Zalasiewicz et al., "Introduction: Buffon and the History of the Earth," in Georges-Louis Leclerc, le Comte de Buffon, *The Epochs of Nature*, trans. and ed. Jan Zalasiewicz, Anne-Sophie Milon, and Mateusz Zalasiewicz (Chicago: The University of Chicago Press, 2018), xiii-xxxiv and Keith Thomas, *Man and the Natural World: Changing Attitudes in England, 1500-1800* (London: Penguin, 1991).
[474] Rudwick, *Bursting the Limits of Time*, 1-2; Lydia Barnett, *After the Flood: Imagining the Global Environment in Early Modern Europe* (Baltimore: Johns Hopkins University Press, 2019), 194.
[475] Christophe Bonneuil and Jean-Baptiste Fressoz, *The Shock of the Anthropocene: The Earth, History and Us*, trans. David Fernbach (London: Verso, 2017), 29, 205; Adam Bobbette and Amy Donovan, "Political Geology: An Introduction," in *Political Geology: Active Stratigraphies and the Making of Life*, eds. Adam Bobbette and Amy Donovan (Palgrave Macmillan, 2019), 5-6.
[476] Bonneuil and Fressoz, *The Shock of the Anthropocene*, 206-15.

above the allegedly descriptive pursuits of "amateur" naturalists.[477] Humboldt followed suit, describing his own geography of plants as a "philosophical natural inquiry" superior to "mere natural description."[478] As Humboldt communicated lessons from the botany he practiced as an aspiring cameralist to learned, cosmopolitan audiences, he began to distance his plant geography from its origins in political economy. By mid-century, his geography of plants consolidated around a worldview that saw local variations—whether human or natural—as "disturbances" in nature's essential equilibrium and order. Human activity was no longer constitutive of natural environments but reconceived as a force that acts upon them.

This can be read in the "Cosmos Lectures" that Humboldt delivered in Berlin's Sing-Academy between 1827 and 1828 and the five-volumes that followed. Here, the human activity he once described as a "primary factor" in the global distribution of plants began to appear as an anomaly in an otherwise harmonious order. Indeed, this strain of Humboldt's writings informed a founding myth of modern ecology: that nature tends towards a steady-state equilibrium, and that human activity upsets the balance.[479] In notes compiled for his Cosmos lectures (**Figure 10**), Humboldt planned to speak on "Disturbances" in "the historical distribution of plant species," among them the "effects of humans, cultivation of plants."[480] Yet the lecture transcripts, copied

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[477] Jim Endersby, *Imperial Nature: Joseph Hooker and the Practices of Victorian Science* (Chicago: University of Chicago Press, 2008), 1-12. More generally, historians have pointed to a conscious effort in the nineteenth century to separate practical from philosophical pursuits that were once united in the Enlightenment's utilitarian culture. On the eighteenth century, see Celina Fox, *The Arts of Industry in the Age of Enlightenment* (New Haven, CT: Yale University Press, 2010); for the nineteenth: Thomas Gieryn, *Cultural Boundaries of Science: Credibility on the Line* (Chicago: University of Chicago Press, 1999).
[478] Alexander von Humboldt, "Über den Bau und die Wirkungsart der Vulkane" (1823), in *Ansichten der Natur*, ed. Adolf Meyer-Abich (Ditzingen: Reclam, 1969), 110: "Die philosophische Naturkunde erhebt sich über die Bedürfnisse einer bloßen Naturbeschreibung."
[479] Gregory T. Cushman, "Humboldtian Science, Creole Meteorology, and the Discovery of Human-Caused Climate Change in South America," *Osiris* 26 (2011): 16-44.
[480] SBB, Nachl. Alexander von Humboldt, gr. K. 13, Nr. 29, Bl. 13, Vorlesungsmanuskript: "Geographie der Pflanzen." Under the heading "6 versch[iendene] Verbreitungsverhältnisse," Humboldt links "VI. Stohrungen der Verbreitung" to "Wirkung des Menschen, Cultivation."

by Henriette Kohlrausch, present a world governed by natural law alone. Harmonious juxtapositions abound in Kohlrausch's transcript—"contrasts" between "microscopic" and "monstrous" life forms, as between climatic extremes. Human activity—"agriculture, the trade relations of peoples"—is present, but marginal. "The geographical distribution of plants," Humboldt neatly stated before a Berlin audience, "is dependent upon the climates."[481]

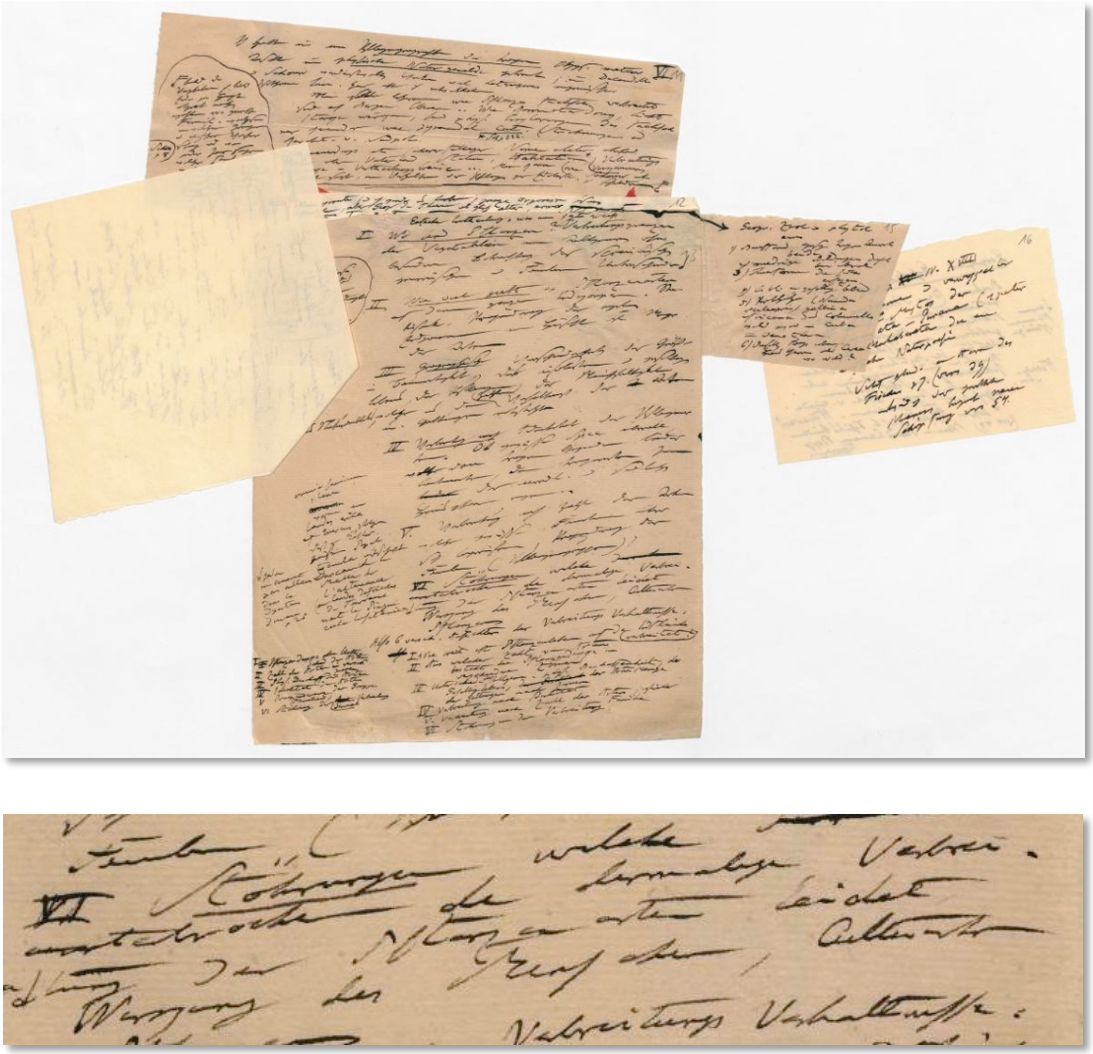

Figure 10. Lecture notes titled "Geographie der Pflanzen." They include "Disturbances" in the "distribution of plant species," among them "the effect of humans, cultivation of plants." Digitalisierte Sammlungen SBB, Nachl. Alexander von Humboldt, gr. K. 13, Nr. 29, Bl. 13.

[481] Alexander von Humboldt and Henriette Kohlrausch, *Die Kosmos-Vorlesung an der Berliner Sing-Akademie*, eds. Christian Kassung and Christian Thomas (Berlin: Insel Verlag, 2019), 153, 158: "Die geographische Verbreitung der Pflanzen ist abhängig von den Klimaten." On contrasts, see 160-62.

The first volume of *Kosmos* that followed in 1845 portrays a "reciprocal" relationship between the "forces of the earth" and "the human race." But it is nature who has the upper hand, by turns stimulating or stifling the migrations and productivity of peoples, and humankind who exerts the "weaker" influence.[482] Also in 1845, Humboldt filed a report to the Prussian Ministry of Commerce warning that deforestation had resulted in decreased humidity in Germany and falling water-levels in its major rivers.[483] In *Kosmos*, however, Humboldt gave priority to nature's "physiognomic" powers over humankind. In the volume's section on plant geography, the influence of a region's "*physiognomic character*" upon the mental and physical capacities of human cultures appears in juxtaposition with the "uniformity" that "agricultural peoples" impose through artifice. In temperate climates, Humboldt wrote, human enterprise had largely subdued nature, sapping its "physiognomic" powers. Yet the tropics "powerfully resist the coercive transformation of organic nature."[484] There, in the equinoctial regions, the intellectual and aesthetic influence of nature is strongest. Humankind is certainly a force in *Kosmos*; but its industry is no longer the "primary factor" it was in the *Essay*.

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[482] Humboldt, *Kosmos*, *1*, 378: "Es würde das allgemeine Naturbild, das ich zu entwerfen strebe, unvollständig bleiben, wenn ich hier nicht auch den Muth hätte das *Menschengeschlecht* in seinen physischen Abstufungen, in der geographischen Verbreitung seiner gleichzeitig vorhandenen Typen; in dem Einfluß, welchen es von den Kräften der Erde empfangen und wechselseitig, wenn gleich schwächer, auf sie ausgeübt hat: mit wenigen Zügen zu schildern." See also Debarbieux, "The Various Figures of Mountains in Humboldt's Science and Rhetoric," esp. "Partition: a proto-ecology of the earth's fragmentation" and "Dwellings: the role of mountains in the making of human diversity."

[483] K. H. Bernhardt, "Alexander von Humboldts Auffassung vom Klima und sein Beitrag zur Einrichtung von meteorologischen Stationsnetzen," *Zeitschrift für Meteorologie* 34 (1984): 213-17.

[484] Humboldt, *Kosmos*, *1*, 374: "Diese Art der geographischen Vertheilung bestimmt: neben der individuellen Form der Pflanzengestalt, neben ihrer Größe, Blatt- und Blüthenform, hauptsächlich den *physiognomischen Charakter* einer Gegend. Das bewegliche Bild des Thierlebens: so mannigfaltig und reizend, so mehr angeeignet es unseren Gefühlen der Zuneigung oder des Abscheues ist; bleibt fast demselben fremd, wirkt wenigstens minder mächtig auf ihn. Die ackerbauenden Völker vermehren künstlich die Herrschaft geselliger Pflanzen, und so an vielen Punkten der gemäßigten und nördlichen Zone den Anblick der Einförmigkeit der Natur; auch bereiten sie den Untergang wildwachsenden Pflanzungen und siedeln andere, die dem Menschen auf fernen Wanderungen folgen, absichtslos an. Die üppige Zone der Tropenwelt widersteht kräftiger diesen gewaltsamen Umwandlungen der Schöpfung."

Consciously or not, Humboldt's botanical equations, isolinear cartography, and vegetational zones invested plant geography with aesthetic and quantitative values that effectively obscured the *human* production of plant geography—both as a physical reality and as a field of study. In the 1820s, he had dreamt of a plant geography that quantified and calculated vegetational mass and organic diversity across the globe: "Eventually," Michael Dettelbach has written, "Humboldt envisioned the development of a grand botanical equation, with constants to be fixed empirically, which would describe the vegetational composition of a certain region over time."[485] Isolines, Dettelbach concludes, imbued the geography of plants with a unity that befit a harmonious Cosmos. Meanwhile, Humboldt's tableaux naturalized the altitudinal bands at which various crops grew. Horticultural projects plotted by European physiocrats and slave-owning planters could be viewed, in Humboldt's maps, as demarcated not by imperious designs but by natural vegetational zones.[486] By the 1830s and 40s, the geography of plants appeared to Humboldt determined by "the curvature of the isothermal lines" that he used to chart annual mean temperatures across the globe.[487] Were it not for "disturbances" in physical geography (the uneven shape of continents, the rise and fall of topographical relief) global climates would be

[485] Michael Dettelbach, "Global physics and aesthetic empire: Humboldt's physical portrait of the tropics," in *Visions of Empire: Voyages, Botany, and Representations of Nature*, eds. David Philip Miller and Hanns Reill (Cambridge: Cambridge University Press, 1996). 258-92, on 287. As Dettelbach notes, Humboldt also used equations and universal symbolic languages (pasigraphies) to express geognostic relations. See Hanno Beck, "Alexander von Humboldt's 'Essay de Pasigraphie' (Mexiko 1803/04)," *Forschungen und Fortschritte* XXXII, no. 2 (Berlin: Akademie Verlag, 1958): 33-39, originally titled *Pasigraphica geognóstica al uso de los Jóvenes de Colegio de Minería de México* (Mexico 1803), and Alexandre de Humboldt, *A Geognostical Essay on the Superposition of Rocks, in both Hemispheres* (London, 1823).
[486] Güttler, "Drawing the Line."
[487] Humboldt, *Kosmos*, *1*, 376: "Die Krümmungen der Isothermen, besonders die der isochimenen [lines of analogous winter temperature], offenbaren sich in den Grenzen, welche gewisse Pflanzen- und nicht weit wandernde Thierarten gegen die Pole zu, wie gegen den Gipfel schneebedeckter Gebirge, selten übersteigen."

arranged according to a "normal parallelism of lines," each climate a "type" unto itself delineated by "a homogenous and uniformly curved" isotherms.[488]

So strong was Humboldt's commitment to uniformity and equilibrium that he sometimes repudiated the very idea of plant migration, if only in private conversation. In August of 1845, Charles Darwin asked the geologist Charles Lyell if he had gotten his hands on the recently-published *Kosmos*: "I think you w[d] probably find the subject of multiple & single Creations there discussed," he wrote, referring to the prominent Enlightenment doctrine that life generates spontaneously under certain conditions; "at least H. discussed [the] subject with [Joseph Dalton] Hooker and & Humbolt is a multiple man."[489] To be a "multiple man," as Darwin called Humboldt, was to believe that the presence of common flora and fauna in different but analogous climates is not the result of species migration, but of multiple creation.[490] This was a stunning blow to Darwin, whose theory of evolution by natural selection hinged on migration as a cause of speciation.[491] Earlier that year, in Paris, Hooker had heard out "Humboldts strong arguments

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[488] Alexander von Humboldt, "Von den isothermen Linien und der Verteilung der Wärme auf dem Erdkörper," in *Alexander von Humboldt Werke*, vol. vii, Schriften zur Physikalischen Geographie, ed. Hanno Beck (Darmstadt: Wissenschaftliche Buchgesellschaft, 2008), 97-99: "Störende Ursachen verschiedener Ordnungen, welche den normalen Parallelismus der Linien gleicher Wärme verändern […] Die erste von allen Perturbations[Störungs]-Ursachen, welche den Parallelismus der Isothermen affizieren, ist die Ausdehnung und die Gestalt der Kontinente, ihre Verlängerung und ihre Verengung in verschiedenem Sinn […] Abweichung von dem Typus, welchen eine homogene und gleichmäßig gekrümmte Oberfläche darbietet…."

[489] Charles Darwin to Charles Lyell, 12 Aug. 1845, Darwin Correspondence Project, "Letter no. 905," accessed on 16 June 2020, https://www.darwinproject.ac.uk/letter/DCP-LETT-905.xml.

[490] See Peter J. Bowler, *Evolution: The History of an Idea*, 25th Anniversary Edition (Berkeley: University of California Press, 2009), 79-81. On the question of evolution, Bowler places in the Romantic vein of "philosophical naturalists" who believed nature "built according to a rational and harmonious pattern."

[491] See, for instance, Joseph Dalton Hooker to Charles Darwin, 2-6 Apr. 1845, DCP, "Letter no. 850," accessed on 16 June 2020, https://www.darwinproject.ac.uk/letter/DCP-LETT-850.xml: "Except Brown & Humboldt, no one has attempted this, all seem to dread the making Bot. Geog. too exact a science, they find it far easier to speculate than to employ the inductive process. The first steps to tracing the progress of the creation of vegetation is to know the proportions in which the groups appear in different localities, & more particularly the relation which exists between the floras of the localities, a relation which must be expressed in numbers to be at all tangible…."

against the *migration of species*, a doctrine he had most studiously & repeatedly warned me against, as wholly untenable."[492] How, Humboldt asked Hooker, could the same plants be found on either side of the Andes, while rivers in Central Asia seemed to act as natural barriers to the migration of rhododendrons, oaks, and other species? In answering these questions, Darwin and Hooker took recourse to Lyell's arguments about gradual geological activity. While sunken land bridges explained ancient migrations, mountain barriers helped solve the problem of divergence amongst species.[493] Humboldt's insistence on multiple creation underscores the essential stasis he sought in nature, shown in stark relief against the backdrop of Darwin's evolutionism.

Where Hooker and Darwin saw life proceed directionally in manifold variations—no two species alike, all with common ancestry—Humboldt's Cosmos was inhabited by analogous organic forms that sprang up along fixed isothermal lines, as though the result of universal formulae.[494] Privately, Humboldt remained devoted to his own active role in shaping the geography of plants. Scheming a return to Mexico in 1822, he dreamt of "how many plants we might introduce to the culture of our own forests!"[495] Publicly, though, Humboldt maintained his "philosophical" aims: Cosmos subordinated humankind to natural forces and viewed human agency as disturbance in natural order.

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[492] Joseph Dalton Hooker to Charles Darwin, late Feb. 1845, DCP, "Letter no. 832," accessed on 16 June 2020, https://www.darwinproject.ac.uk/letter/DCP-LETT-832.xml.

[493] Janet Browne, *The Secular Ark: Studies in the History of Biogeography* (New Haven, CT: Yale University Press, 1983), 196-202.

[494] In *Kosmos*, Humboldt referred to the origin of species as "die geheimnißvollen und ungelösten Probleme des *Werdens*." (Humboldt, *Kosmos*, *1*, 367.) Though he offered no answers to this "unsolved problem of *being*," his discussion of the subject is consistent with Darwin's description of him as a "multiple man."

[495] Alexander von Humboldt to Wilhelm von Humboldt, 17 Oct. 1822, in *Briefe Alexander's von Humboldts an seinen Bruder Wilhelm herausgegeben von der Familie von Humboldt in Ottmachau* (Stuttgart: Cotta, 1880), 99: "Je pourrai immensément enrichir dans ce voyage les cabinets de Roi, la zoologie du Mexique est toute inconnue et combien de plantes dont on peut introduire la culture en plein air dans nos forêts!"

Conclusion: When *Wissenschaft* was Statecraft

Cosmos has long obscured the working worlds that originally animated Humboldt's science. For this, we must return to Humboldt's youth in Europe, when he practiced botany in the service of states. This chapter has examined the origins of Humboldt's plant geography within the industrial cultures of its making, revisiting the link between natural and cameral sciences. Writing in 1850 to Prussia's consul to the United States, Humboldt expressed his "amazement" at the "rapid progress" of science in the young Republic: "Yes, one was inclined to doubt, and certainly not without reason, whether republican governments from their very nature were not hostile to the active promotion of scientific undertakings."[496] Conversely, the passage betrays Humboldt's own faith in the scientific patronage of absolutist governments.

This perspective flips the script on the development of Humboldt's "ecological" perspective. Humboldt did not strive towards an increasingly holistic conception of nature and society; he drifted away from a union of universal and natural history, which reflected botany's central role in eighteenth-century political economy. From England to the *Essay*, Humboldt's science of plant geography described a world he was busily engaged in making. Efforts to harness, utilize, and re-shape environments constituted a way of knowing for Humboldt. As a practitioner of economic botany, Humboldt witnessed the botanical agency of humankind in real time; and as an agent of cameralism in Europe—and of colonialism in the Americas—Humboldt's science actively participated in re-shaping the global geography of plants. What can, in retrospect, be called ecological in Humboldt's plant geography was, in origin, a reflection of the dynamic relationship between *Wissenschaft* and statecraft around 1800.

[496] Humboldt to Johann G. Flügel, 19 June 1850, in *Alexander von Humboldt und die Vereinigten Staaten von Amerika. Beiträge zur Alexander-von-Humboldt-Forschung, 19. Briefwechsel*, ed. Ingo Schwarz (Berlin: Akademie Verlag, 2004), 269-70.

Chapter Four

Mines, Mountains, and the Making of Vertical Nature

There is a sense in which all knowing is like travelling….[497]

David Turnbull,
Masons, Tricksters and Cartographers

Up, up, to the mines, I call you
I, who stands above
So often as you go into the depths
Think up to the heights.[498]

The Miner's Bell in St. Peter Church
Freiberg, Saxony

Church bells sounded the rhythms of life and death in early modern Europe. In mining towns, like Freiberg, Saxony, they choreographed a daily transhumance. The *Bergglöcklein* (**Figure 1**) aloft in Freiberg's St. Peter Church rang "by ancient decree" in eight-hour intervals, at 3:00, 11:00, and 19:00, harmonizing the descent that began one miner's shift and the ascent that ended another's.[499] In 1756, the bell was re-cast with the inscription above: "Up, up, to the mines, I call you, | I, who stands above…." At mid-century, miners in the Harz Mountains of central Germany and the Ore Mountains sprawling along the Saxon-Bohemian border spent as many as three hours of each workday in vertical transit. In the deepest pits, miners sometimes covered over a

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This chapter expands upon the article Patrick Anthony, "Mines, mountains, and the making of a vertical consciousness in Germany ca. 1800," Special Issue: "Verticality in the History of Science," *Centaurus* 62, no. 4 (2020): 612-30.

[497] David Turnbull, *Masons, Tricksters and Cartographers: Comparative Studies in the Sociology of Scientific and Indigenous Knowledge* (Amsterdam: Harwood, 2000), 153.

[498] "Auf auf zur Grube ruff ich Euch | ich die ich oben steh | so offt ihr in die Tiefe fahrt | so denket in die Höh," Stadt- und Bergbaumuseum Freiberg, Inv.-Nr. 50/210.

[499] Gustav Eduard Benseler, *Geschichte Freibergs und seines Bergbaues,* Pt. 2 (Freiberg: J. G. Engelhardt, 1853), 1132.

thousand meters on wooden ladders in a single day, down and back up again.[500] The bell's inscription put a pious gloss on the treachery of that ascent/descent. Like the theatrics of the mining parade, its lyrics sanctified the work-time discipline of a well-ordered silver mine. In doing so, the *Bergglöcklein* also expressed a particular way of thinking borne of these working rhythms—"So often as you go into the depths, | Think up to the heights"—a vertical spatial consciousness embedded in the very language of hard rock mining.

Figure 1. The bronze miner's bell ("Häuerglöckchen" or "Bergglöcklein") formerly in the Petrikirche in Freiberg, Saxony. First produced in 1509, the bell was recast by Johann Gottfried Weinhold in 1756. Stadt- und Bergbaumuseum Freiberg, Inv.-Nr. 50/210.

[500] On the daily labor rhythms of miners and depths of the mines in Freiberg and the Harz, see Otfried Wagenbreth and Eberhard Wächtler, *Der Freiberger Bergbau: Technische Denkmale und Geschichte* (Leipzig: Verlag für Grundstoffindustrie, 1986); Wilfried Liessmann, *Historischer Bergbau im Harz: Kurzführer*, 3rd ed. (Berlin & Heidelberg: Springer, 2010). Early modern miners in these regions often made a one-hour descent into and two-hour ascent out of shafts that plunged as far as 600 meters below the surface of the earth (though most mines in Freiberg ranged from 200-300 meters). This meant climbing up from the deepest mine at about five meters per minute. These rhythms accelerated in the mid-nineteenth century with the invention of the water-powered "Fahrkunst" (or "man engine," first installed in the Harz in 1833 and in Freiberg in 1853), whose two ladders drove continually up- and downwards, allowing miners to hop from one to the other according to their destination.

The language spoken within an eighteenth-century mine can be compared to that heard aboard sailing vessels of the period. "[T]he force of a seamen's language lay in its capacity to relate actions to a precisely named environment," Greg Dening observed: "To a sailor the text of life was in knowing every degree of the relationship of his wooden world to the wind and sea and land outside it and the relationship of every place, role and action within it to himself."[501] So it was for miners, whose nomenclature coordinated human action with the gases, groundwater, and geological strata that encompassed—and endangered—their own "wooden world." What distinguishes miners' language, however, is its peculiar ability to articulate the verticality of their environs: the deadly threat of "rising weather" (poisonous vapors), the orientation of an ore vein that "falls into the depths" (perpendicular to the surface), the command to "run a mountain" (process the surface spoils), or the many expressions of descent—*einfahren*, *niederfahren*, *absincken*, *abteuffen*, *ablörschen*, *auf der Teuffe seyn*, or *auf einem Gang sinken*, to name a few.[502] Working vertically meant thinking vertically.

The insight that scientific theories are "practice-laden" has animated scholarship in the history of science for nearly three decades.[503] This chapter presents a new variation on that theme, examining a style of geographical thought that was, like the miner's language, *movement*-laden. The thought style in question has been described as a "vertical consciousness that

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[501] Greg Dening, *Mr Bligh's Bad Language: Passion, Power and Theatre on the Bounty,* 2nd ed. (Cambridge, UK: Cambridge University Press, 1994), 56–57.
[502] Fribergensi Minerophilo, *Mineral- und Bergwerks-Lexicon*, 3rd ed. (Chemnitz: Stößel, 1784), 487, 82, 9, 44; Johann Gottfried Jugel, *Geometria Subterranea, oder Unterirdische Meßkunst der Berg- und Grubengebäude, insgemein die Markscheidekunst genannt* (Leipzig: J. P. Kraus, 1773), 16, 14.
[503] On the "practice-ladenness of theory," see Andrew C. Warwick, "Cambridge Mathematics and Cavendish Physics: Cunningham, Campbell, and Einstein's Relativity, 1905-1911. Part I: The Uses of Theory," *Studies in History and Philosophy of Science* 23 (1992): 625–56; Andrew C. Warwick, "Cambridge Mathematics and Cavendish Physics: Cunningham, Campbell, and Einstein's Relativity, 1905-1911. Part II: Comparing Traditions in Cambridge Physics," *Studies in History and Philosophy of Science* 24 (1993): 1–25.

engulfed science in the early nineteenth century," and is closely associated with the geographical imaginary of Alexander von Humboldt.[504] Humboldt's science spanned nature's horizontal and vertical axes, from subterranean flora to the vegetational regions he plotted on the slopes of the Andes, and from the currents of the ocean to those of the "aerial ocean." But while Humboldt's profound influence on his Victorian successors has been well documented, the origins of his era's vertical consciousness remain obscure.

Returning to mineshafts hewn by generations of laborers and mountain caverns curated by local artisan families, this chapter locates the roots of vertical thinking in the routes of vertical travel. Humboldt's *physique du monde*, or "global physics," first emerged in a time and place—central Europe around 1800—when patterns of travel up and into mountains flourished amongst a wide range of administrators, artists, and savants.[505] These actors traced miners' rhythms, first with their bodies, then with their pens. The embodied experience of vertical mobility was constitutive of a spatial imaginary that spanned mineshafts and mountain summits. Mediated in print and visual culture, this experience circulated Europe's educated classes through paintings and poems of the Romantic era.

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[504] Michael S. Reidy, *Tides of History: Ocean Science and Her Majesty's Navy* (Chicago: University of Chicago Press, 2008), 280. Scholarship on "verticality" was largely spurred by the work of geographers and architectural scholars who have analyzed the political dimension of vertical space in the colonial past and the geopolitical present. Consider Bruce Braun, "Producing vertical territory: Geology and governmentality in late Victorian Canada," *Ecumene* 7, no. 1 (2000): 7-46. Similar approaches have been taken up by historians of science who have aimed to correct spatial history's horizontal bias and illuminate the ways in which scientific knowledge production takes place in vertical space, e.g. Michael Reidy, "From Oceans to Mountains: Spatial Science in an Age of Empire," in *Knowing Global Environments: New Historical Perspectives on the Field Sciences*, ed. Jeremy Vetter (New Brunswick, N.J.: Rutgers University Press, 2010), 17–38 and Gabrielle Hecht, *Being Nuclear: Africans and the Global Uranium Trade* (Cambridge, MA: MIT Press, 2012).

[505] On cultures of underground travel and science in central Europe, see E. P. Hamm, "Knowledge from Underground: Leibniz Mines the Enlightenment," *Earth Sciences History*, 16, no. 2 (1997): 84–91 and Johannes Mattes, *Reisen ins Unterirdische: Eine Kulturgeschichte der Höhlenforschung in Österreich bis in die Zwischenkriegszeit* (Vienna: Böhlau, 2015).

Mines, mountains, and caverns were not only sites of scientific imagination and Romantic allure, but spaces where men and women of diverse backgrounds established—and sometimes challenged—vertical hierarchies of a social nature.[506] A useful guide here is James Clifford's essay "Traveling Cultures," which outlines a comparative framework for the study of travel. Clifford seeks a dialogue between the economic compulsions that move some and the material privileges that enable others. He asks us to consider a comparison between Humboldt's American travels and those of a hypothetical migrant laborer arriving in the "New World" under very different circumstances. Not only does Clifford draw the laborer's experience of mobility under the rubric of "travel," a term typically reserved for the affluent and socially mobile; he also reminds us that Humboldt himself "moved within highly determined circuits."[507]

Following Clifford, this study delves into the construction of the highly determined circuits that Humboldt moved through in the mountains and mines of Germany. It calls attention to the many vertical imaginaries at play, from the map-making of mining technicians and songs of salvation sung by laboring miners to cave guides' choreography of underground travel and poems penned by women writers excluded from the Romantic canon. Like Caspar David Friedrich's iconic "Wanderer above the Sea of Fog" (**Figure 11**), Humboldt's grand geographical vision may appear to express a sort of *Bergeinsamkeit*, a communion between Man

[506] Geographers have drawn attention to the ways in power operates through vertical space, as in Eyal Weizman, *Hollow Land: Israel's Architecture of Occupation* (New York: Verso, 2007); Heidi V. Scott "Colonialism, Landscape and the Subterranean," *Geography Compass* 2, no. 6 (2008): 1853-869; and Stuart Elden, "Secure the volume: Vertical geopolitics and the depth of power," *Political Geography* 34 (2013): 35-51.

[507] James Clifford, "Travel Cultures," in *Routes: Travel and Translation in the Late Twentieth Century* (Cambridge, MA: Harvard University Press, 1997), 34-36. See also Susan Stanford Friedman's application of Clifford's "Traveling Cultures" in her chapter "'Routes/Roots': Boundaries, Borderlands, and Geopolitical Narratives of Identity," in *Mappings: Feminism and the Cultural Geographies of Encounter* (Princeton, NJ: Princeton University Press, 1998), 151-78.

and Nature in the unpeopled solitude of the mountains.[508] But the consciousness shared by Friedrich and Humboldt was grounded in working worlds of industrial activity (mines) and well-trodden sites of aesthetic education (mountains).[509] This chapter thus emphasizes the networks and cultures, people and practices, long masked by tropes of the solitary "wanderer."

To play on a quotation from Susan Faye Cannon: if Humboldt was revolutionary, as I think he was, it was not in inventing a style of vertical thinking, but in elevating it to a global scientific enterprise.[510] In Latin America, too, Humboldt's vertical spatial imagination continued to reflect the influence of local scientific cultures that he often erased in his writings. Humboldt's famed "Tableau physique des Andes," for instance, drew inspiration from a project already undertaken by Francisco José de Caldas (1768–1816) when the two met in Columbia in 1801. Moreover, both men incurred a heavy debt to indigenous and Creole traditions that had long viewed the Andes as "providentially designed" to the host a global array of natural products.[511] In mapping South American biogeography as a "vertical archipelago," Caldas and Humboldt worked in a cartographic tradition rooted in the very organization of Andean life.[512]

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[508] Mary Louise Pratt, "Alexander von Humboldt and the Reinvention of América," in *Imperial Eyes: Travel Writing and Transculturation* (New York: Routledge, 1992), 109–140.

[509] Alternatively, Sean Franzel has studied movement, or *Bewegung*, as a conceptual feature of the "mountain sublime." (Sean Franzel, "Time and Narrative in the Mountain Sublime around 1800," in *Heights of Reflection: Mountains in the German Imagination from the Middle Ages to the Twenty-First Century*, eds. Sean Ireton and Caroline Schaumann (Rochester, NY: Camden House, 2012), 98-115.)

[510] Susan Faye Cannon, *Science in Culture: The Early Victorian Period* (New York: Dawson/Science History Publications, 1978), 77: "If Humboldt was a revolutionary (as I think perhaps he was), it was not in inventing all the parts of Humboldtian science. It was in elevating the whole complex into the major concern of professional science for some forty years or so."

[511] Pablo Vila, "Caldas y los orígenes eurocriollos de la geobotánica," *Revista de la Academia Colombiana de Ciencias* 11 (1960): 16-20; Jorge Cañizares-Esguerra, "How Derivative Was Humboldt? Microcosmic Nature Narratives in Early Modern Spanish America and the (Other) Origins of Humboldt's Ecological Sensibilities," in *Colonial Botany: Science, Commerce, and Politics in the Early Modern World*, eds. Londa Schiebinger and Claudia Swan (Philadelphia: University of Pennsylvania Press, 2005), 148–65, on 152.

[512] John Murra, "Limits and limitations of the 'vertical archipelago' in the Andes," in *Andean ecology and civilization*, eds. Shozo Masuda, Izumi Shimada, and Craig Morris (Tokyo: University of Tokyo Press), 15-20.

This chapter, while focused on central European actors, joins in a larger at reappraisal of Humboldt's science as an adaptation of existing traditions, many of which were obscured in proportion as the Humboldtian mythology took shape. It begins with a case study of the movement-laden cartography practiced by mining technicians like Heinrich von Trebra (1740–1819). If the naturalist Georg Forster learned from Trebra how to "unfold" nature's verticality, Humboldt's innovation was to fold the geological profile right-side up again, from the mine to the mountain. The following section shifts the focus from mines to caverns, focusing on the labor that quite literally produced vertical space in the Fränkische Schweiz and the Harz Mountains. Here I reconstruct the workscapes of artisan cave guides like Johann Georg Wunder (1726-99) and Christian Friedrich Becker (dates unknown). With the help of their daughters and sons, Wunder and Becker used their expertise in underground travel and highland geography to negotiate a certain degree of recognition amongst the scientific and learned elites they guided. The chapter's third section then sets Humboldt's geographic imaginary within a heterogeneous culture of vertical travel. In this culture, actors of diverse backgrounds commonly linked subterranean depths and mountain heights, yielding a shared understanding of nature as a set of vertically corresponding spaces. This over-and-under motif found expression in the poems and paintings of artists like Julie von Bechtolsheim (1751–1847), Caspar Wolf (1735–1783), Elisabeth Kulmann (1808–1825), and many more. Finally, by the mid-nineteenth century, the practice of vertical movement had become one of vertical measurement. Scientists across a range of emergent disciplines used mountains and mines as measuring rods with which to comprehend and communicate the very shape of the globe.

Unfolding the Earth

Eighteenth-century savants were well aware of the unique opportunities afforded by the mining industry. Mines made it possible to move through the earth and view nature from within. Reflecting on his tenure as a mining official in Ilmenau, Johann Wolfgang von Goethe (1749–1832) said that the undertaking, though financially disastrous, "earned me a view of nature [*Naturanschauung*]."[513] In a speech he delivered at the re-opening of a silver mine in February of 1784, Goethe stressed the link between moving, seeing, and knowing. "Let us not look upon this humble opening ... in the surface of the earth with indifferent eyes," Goethe implored; for it is in this mineshaft "where men will ascend and descend, and where we will behold before our eyes with the greatest joy what we now see only in the mind."[514] Later that year, after completing his own apprenticeship in mining, Forster was convinced that "the practical mining expert sees what the theorist never experiences, nor could ever believe."[515] What was this *Naturanschauung* drawn from the mines? What did the technician see that the theorist could not?

An image of this comes from the works of Trebra, who mentored both Goethe and Forster in the 1780s and was a leading architect of the cartographic blueprint Humboldt later followed in the Americas. First graduate of the Mining Academy in Freiberg, Trebra now served the Electorate of Braunschweig-Lüneburg as officer of the mines in Clausthal-Zellerfeld, the

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[513] Goethe to F. T. A. Müller and F. J. Soret, 16 Mar. 1824, *Goethes Werke. Herausgegeben im Auftrage der Großherzogin Sophie von Sachsen*, Pt. IV, vol. 5 (Weimar: Hermann Böhlau, 1887-1919), 50-51.
[514] "Reden bey Eröffnung des neuen Bergbaus zu Ilmenau am 24 Feb. 1784," GSA 25/W 2776: "Lassen sie uns also die geringe Oeffnung, die wir heute in die Oberfläche der Erde machen werden, nicht mit gleichgültigen Augen ansehen…. […] Wir selbst können noch, wenn es uns Gott bestimmt hat, da auf- und niederfahren, und das was wir uns jetzt nur im Geiste vorstellen, mit der größten Freude vor uns sehen und betrachten." On Goethe's mining and its influence on his science, see Ernst Peter Hamm, "Goethe on Granite" (PhD diss., University of Toronto, 1990).
[515] Georg Forster, Tagebuch, 12 July 1784, AA XII, 77: "Der praktische Bergkundige sieht, was Theoretiker nie erfahren, neu glauben können; er sieht Gänge, die sich gegen die Oberfläche der Erde hin ganz verlieren, Gänge wo ~~das Gestein~~ die Gangart ordentliche Ablösungen bildet, andere wo ~~es~~ sie sich ganz ins Nebengestein vertuscht."

center of the Harz mining industry. There, he called upon technicians to hone their ability to pair aerial ground plans (*Grundrisse* or *Situations-Charten*) with vertical profiles (*Saigerrisse* or *Durchschnitte*), collating the two perspectives into one. These maps did not merely represent a new way of depicting mineshafts and mineral deposits; they encouraged a new way of thinking about nature, one rooted in miner's routes.[516] Such was Forster's experience in 1784.

Already hailed as the "Circumnavigator" thanks to his celebrated account of James Cook's second voyage, Forster now wished to become a practitioner of useful science. Hoping to advance his knowledge of "the utilization of domestic products" en route from Kassel (Hessen) to his new post as professor of natural history in Vilnius (Poland), Forster made his first stop in the Clausthal, lodging in Trebra's own home.[517] By day, Forster learnt mineralogy in the mines and caverns of the Upper Harz, while by night he discussed vein-formation with his host, rising early to study "Trebra's manuscript," published the following year as *Erfahrungen vom Innern der Gebirge* (*Experiences from the Interior of the Earth*).[518]

Trebra's use of "experiences," rather than "observations" or "considerations" (*Beobachtungen* or *Betrachtungen*), expresses the central idea of the work: advancing knowledge of the subterranean meant moving through it.[519] Composed of a series of letters and reports, *Erfahrungen* begins with Trebra's wish that others will join him in "gathering experiences" from which to "envision the miner within a wider environment." To this end, *Erfahrungen* modeled the practice of combining multiple visuals into "a total and correct image of the whole, from

[516] See also Martin J.S., *Bursting the Limits of Time: The Reconstruction of Geohistory in the Age of Revolution* (Chicago: University of Chicago Press, 2005), 85–90, which draws upon the cartography of Trebra to show how geognosy, a science that studied "three-dimensional structures" in the earth, took shape in the German mining industry.
[517] Forster to Johann Reinhold Forster, 3 Mar. 1784, AA XIV, 26.
[518] Forster, Tagebuch, 26 Apr. 1784, AA XII, 25.
[519] The verb *erfahren* means both "to experience" and "to learn."

various and of various aspects."[520] The primary instrument here is the multi-dimensional map, which coordinated aerial and cross-sectional views. The "Situational map of Clausthal and Zellerfeld" in **Figure 2**, for instance, offers a bird's-eye view of the area's primary ore veins, while the adjoining profile invites viewers to unfold the subterranean geography of its southeastern-most terrain. On the morning of April 27th, Forster woke at 6:30 to study *Erfahrungen* at Trebra's side, then followed his host into the mines to "learn how the strike of a veins typically occurs on the slope of a hill," and how, according to Trebra, "the noblest veins are those where two valleys intersect."[521]

[520] F. W. H. Trebra, *Erfahrungen vom Innern der Gebirge, nach Beobachtungen gesammlet* (Dessau & Leipzig, 1785), ii, 234: "Ich wünschte also, dass mehrere mit mir auf gleichem Wege beobachten, Erfahrungen machen, prüfen, und daraus nach und nach, wenigstens hohe Grade der Wahrscheinlichkeit den vorgesetzten Zweck zu erreichen, in einem weitern Kreise dem Bergmann vorzeichnen möchten." "…ein vollständiges und richtiges Bild vom Ganzen, aus verschiedenen, auf verschiedenen Seiten."
[521] Forster, Tagebuch, 27 Apr. 1784, AA XII, 25–26.

Figure 2a. Tafel V^A-V^B from Trebra's *Erfahrungen vom Innern der Gebirge* (1785). The wide view in Tafel V^A, a "Situations-Charte der Gegend um Clausthal und Zellerfeld," is adjoined in Tafel V^B by "three cross-sections of this area." SUB Gö, GR 2° H. N. Mineral. III, 1700 Rara.

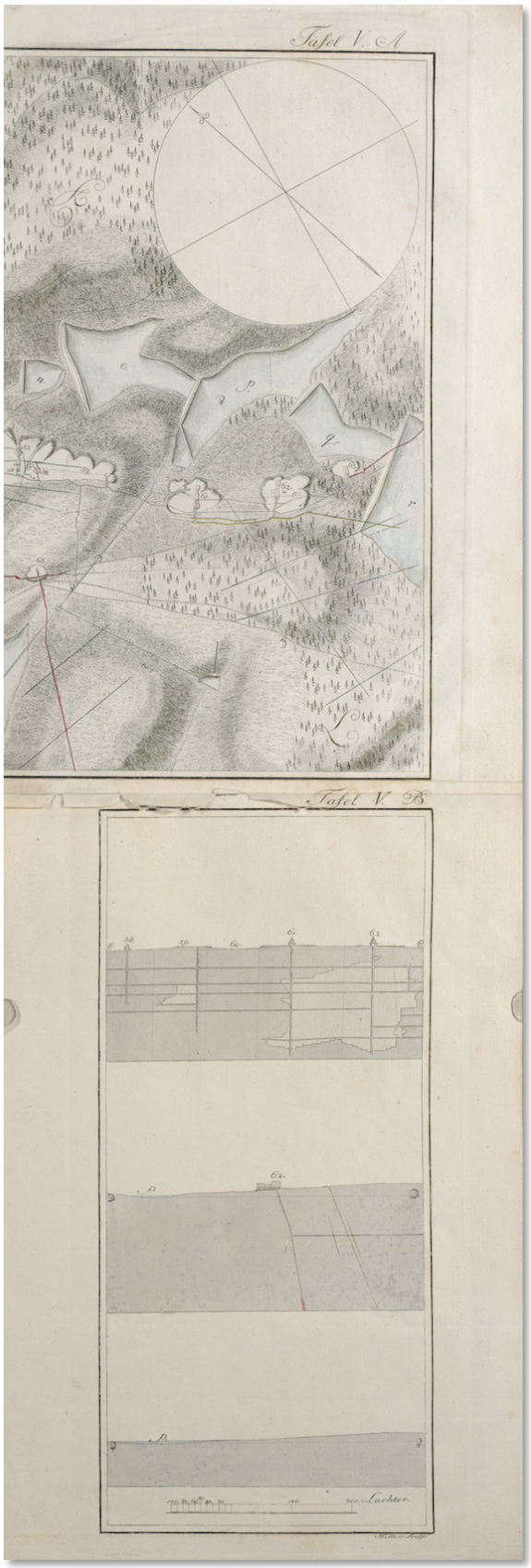

Figure 2b. Detail from Tafel V^A-V^B. The three cross-sections that unfold in V^B depict the area around the Dorothea and Caroline Mines from various aspects. Their contents correspond to the mineshafts, mineral deposits, ore veins, and reservoirs shown in V^A.

A gaze that unfurled the earth as such could be also performed remotely, by the mere flip of a page. To unfold **Figure 2** is to lay bare the Harz's most lucrative silver mines, the Dorothea and Caroline (numbered 61 and 62), shown here in relation to known ore deposits (in light grey), unexploited mineral veins (in red and yellow), and the nearby Elisabeth Reservoir ("p."). The idea was to collate profiles of three different perspectives into a single three-dimensional view. "In order to ascertain the entirety of a major ore deposit in its three dimensions of *length* [x-], *depth* [z-] and *breadth* [y-axes], *as it really exists*," Trebra wrote, "one must consider all images of the veins against each other."[522]

So intent was Trebra on giving readers a three-dimensional "experience" that some of *Erfahrungen*'s plates literally invite participation. **Figure 3** sets mineralogical phenomena within the wooden framing of the local adits where they were observed. To the right is a hollow cut-out: peel back the page—enter the adit—and encounter an ore-bearing specimen of "natural size" from the adit called Old Glücksrad, such as one might find within the vein shown on the left.

Trebra's case for a three-dimensional view that collated "*length*, *depth* and *breadth*" also mirrored his argument for the coordinated use of vertical shafts and horizontal adits. Whereas coal typically lies in horizontal beds, mineral deposits tend to have a more vertical orientation, hence the bell-shaped pits and vertical shafts that then characterized hard rock mining. And yet, as improved water-pumping technologies enabled miners to exploit new depths in the late eighteenth century, Trebra also believed horizontal adits (*Entwässerungsstollen*) remained invaluable, particularly for draining shafts and galleries below the reach of the pumps.[523]

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[522] Trebra, *Erfahrungen*, 234: "So halte man, um das Ganze eines Hauptzuges nach seinen drey Dimensionen der *Länge*, *Teufe* und *Mächtigkeit*, *so wie es ist* in den Blick zu fassen, die hier vorgelegten sämmtlichen Bilder von den Gängen gegen einander…."
[523] Ibid., 142–43.

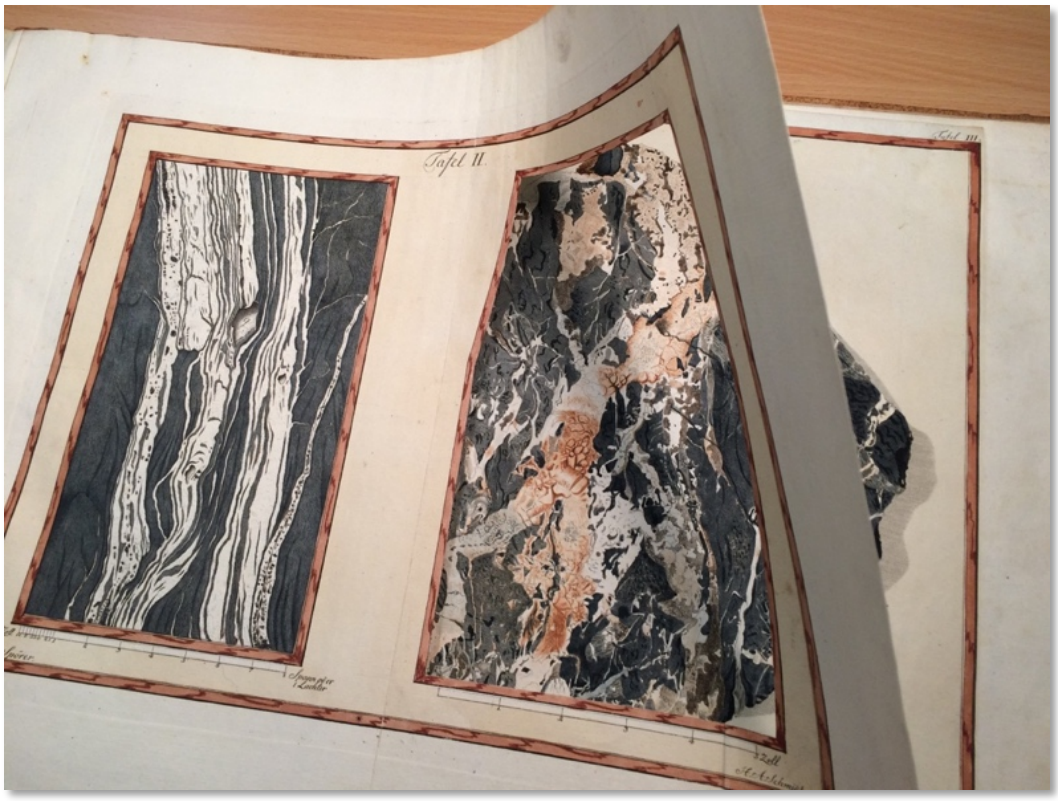

Figure 3. Tafel II from Trebra's *Efahrungen vom Innern der Gebirge* (1785). Designed to appear like the wooden framing of an adit, the hollow cut-out on the right of Tafel II invites readers to peer into, or open up, Tafel III for closer inspection of ore-bearing rock from Altes Glücksrad Stolln. SUB Gö, GR 2° H. N. Mineral. III, 1700 Rara. Photo by the author.

In this way, the Dorothea and Caroline mines featured in **Figure 2** underwent a hundred-year descent into unfathomed depths, from 73 and 190 meters, respectively, in the first decades of the eighteenth century to 576 and 489 meters in the first half of the nineteenth. They were so deep, Heinrich Heine joked in 1826, that "you can hear the people in America shouting 'Hurrah for Lafayette!'"[524] For a somewhat more reliable sense of scale, imagine the two mines inverted on a profile map, soaring amongst the tallest skyscrapers of our own time (the Dorothea amounts to some 175 stories), and challenging even the highest peak in the Harz, the Brocken, with its

[524] The joke was recounted by Heinrich Heine in his *Harzreise* (published in 1826) after touring the Caroline and Dorothea Mines in 1824. Marquis de Lafayette had recently made a triumphant return to the United States in whose War of Independence he had earned a heroic reputation. (See "The Harz Journey," in *Heinrich Heine: Selected Prose*, trans. and ed. Ritchie Robertson (New York: Penguin, 1993), 44.)

topographical prominence of 856 meters. Humboldt himself used similar measuring rods when communicating the profound depths reached by miners of the period. In volume one of *Kosmos* (1845) he noted that the depth of the "Old Kuttenberger Mine" (today Kutná Hora, Czech Republic) was not only "greater than the height of our Brocken" but also eight times larger than "the tallest man-made structures," the Pyramids of Giza and the Strasbourg Cathedral.[525] Mining at such depths meant carefully coordinating the flow of air, water, ore, and men through vertical and horizontal nature, just as Trebra's maps coordinated nature's x-, y-, and z-axes.

By pairing Trebra's *Erfahrungen* with his own "experiences," Forster learned to unfold—or, as he wrote, "open"—the earth. After studying Trebra's manuscript, he donned the miner's habit and followed his host into the nearby New Glücksrad Adit (the lower, hence "newer," portion of the same mine that one encounters in *Erfahrungen*'s interactive plate, **Figure 3**). In his journal, Forster studiously recorded "the strike, crisscrossing and shattering of the vein in the slate and greywacke," and restated *Erfahrungen*'s argument about the primacy of aqueous (rather than thermal) forces in the "generation of a vein"—a hypothesis that "the steady dripping of water in all the mines naturally impresses upon us." Putting Trebra's theory in a language more familiar to his previous travels, Forster likened mineral veins to "islands formed within the mountains." Fittingly, Forster re-traced his and Cook's "entire voyage on a world map" for Trebra that evening.[526]

But it was Trebra's cartography that now gave a new dimension to the Circumnavigator's worldview. When Forster continued his practical education in Freiberg that summer, he saw the Saxon subterranean through Trebra's eyes. After noting how the veins there "confirmed the

[525] Alexander von Humboldt, *Kosmos: Entwurf einer physischen Weltbeschreibung*, vol. 1 (Stuttgart: Cotta, 1845), 418.
[526] Forster, Tagebuch, 27 Apr. 1784, AA XII, 25–26.

observations of Trebra" about the location of the richest ore deposits, Forster went one step further, envisioning a three-dimensional cartographic project:

> But one should still identify and chart all veins throughout the entire Ore Mountains, and perhaps draw from this something important and, for theory, applicable and reliable. Such a map, which designated all converging veins, would make for a rare sight, especially if one were to include a profile that indicated the ~~heights of mountains~~ form of mountains, and in this way determine the richer bodies of ore.

Earlier that day, Forster had observed to the east of Freiberg, as to the south, vast tracts of land "still entirely unopened [*noch gar nicht geöffnet*]." Yet Forster's cartographic vision did just that—it opened the mountains. Beginning, like Trebra, with the aerial view, Forster's imaginary map then unfolded into a profile. Initially, that profile portrayed the "heights of mountains." True to his training, though, Forster dashed his pen through those two-dimensional "~~heights~~." In their stead, he re-imagined the three-dimensional "form of mountains." This, as Forster concluded at the end of the journal entry, is what the "practical mining expert sees."[527]

In their ambitious geographical scale and immense vertical reach, the "Tableaux" that Humboldt drafted in Latin America bear a striking resemblance to that which Forster imagined in Freiberg. This is no coincidence. The training Forster underwent in a matter of months Humboldt experienced over the course of five years, studying first at Freiberg's Mining Academy from 1791–92, then serving the Prussian Mining Administration in Franconia's Fichtel Mountains through 1796. The cartographic practices Humboldt learned in these years, he extended into the Americas—vertical movement chief among them. If in Freiberg Humboldt "regularly spent 4 to 5 hours of every day in the mines" while making comparative geognostic and meteorological

[527] Forster, Tagebuch, 12 July 1784, AA XII, 76–77: "Man sollte doch billig überall durchs ganze Erzgebirge alle Gänge aufsuchen, und aufzeichnen, so käme vielleicht etwas wichtiges, und für die Theorie anwendbares, sicheres, heraus. Eine solche Charte mit der Angabe aller sich durch kreuzenden Gänge, würde curios anzusehen seyn, zumal, wenn man überall Profile beyfügte, um die ~~Höhe der Berge~~ Form der Berge anzuzeigen, und dadurch die reichern Erzpunkte zu bestimmen."

inquiries aboveground, his American journey took him up mountains and volcanoes and into mineshafts and craters.[528] In this, Humboldt did indeed move through highly determined circuits, tracing the routes of Freiberg-educated mine engineers like Baron von Nordenpflycht, who attempted to introduce German amalgamation practices to the silver mines of Potosí in 1789, or the brothers Elhuyar—Juan José, who directed mines in New Grenada, and Fausto, who ran the Royal School of Mines in Mexico City at the time of Humboldt's journey.[529]

The cartographic undertaking that culminated in Humboldt's *Atlas géographique et physique du royaume de la Nouvelle-Espagne* (1811) bears the stamp of this ascent-descent rhythm of natural inquiry, and of his collaboration with surveyors and draftsmen at the School of Mines in Mexico City. This much Humboldt made clear when he pronounced, from the School of Mines, that he had "conceived of the idea of representing entire countries as one would a mine."[530] The result: a three-part, continent-spanning profile (**Figure 4**). Shorn of mineralogical information, Humboldt's Mexican tableaux depict an entire landmass in what he understood as a set of inverted mine profiles. Flipped upright, as it were, and spread across the eastern third of New Spain, **Figure 4** displays the territory's hypsometric form above sea-level, as determined by barometric and trigonometrical measurements that Humboldt grafted onto surveys made by Mexican mining technicians.[531]

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[528] Humboldt to Georg Christoph Lichtenberg, 21 Apr. 1792, *Die Jugendbriefe Alexander von Humboldts, 1787–1799*, eds. Ilse Jahn and Fritz G. Lange (Berlin: Akademie, 1973), 184.
[529] Kendall W. Brown, *A History of Mining in Latin America from the Colonial Era to the Present* (Albuquerque: University of New Mexico Press, 2012), 27, 34-35.
[530] As quoted in Hanno Beck, ed., "Alexander von Humboldt's 'Essay de Pasigraphie' (Mexiko 1803/04)," *Forschungen und Fortschritte* 32, no. 2 (1958): 33-39, on 37: "J'ai conçu l'idée de figurer des pays entiers comme on représente une mine."
[531] This connection is thoroughly explored in Chapter 5 of this dissertation. See also Myron Echenberg, *Humboldt's Mexico: In the Footsteps of the Illustrious German Scientific Traveller* (Montreal, Ontario: McGill-Queen's University Press, 2017).

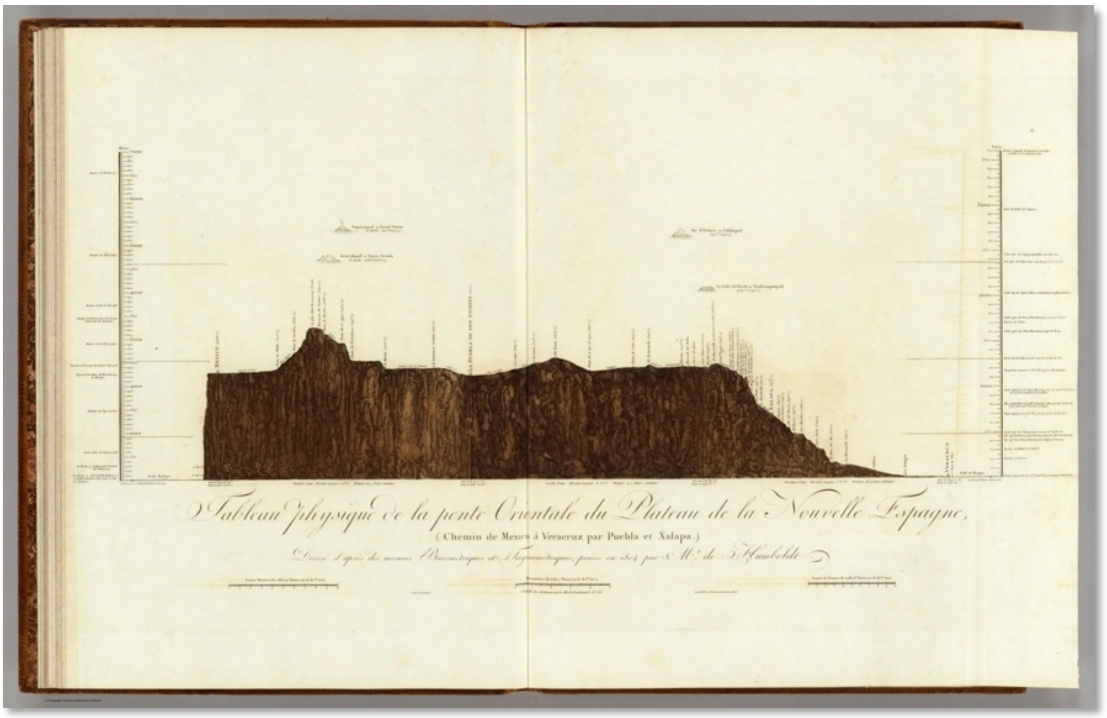

Figure 4. Humboldt's "Tableau physique de la pente Orientale du Plateau de la Nouvelle Espagne," drafted by Humboldt in collaboration with students at the School of Mines in Mexico City in 1804, engraved in 1807, and published in the *Atlas géographique* (1811). The middle profile indicates the elevation (1,186 toises, roughly 2,312 meters) and greatest depth (264 toises, or 513 meters) of the mines of Valenciana (in Guanajuato). David Rumsey Historical Map Collection, Image No: 0328012.

Humboldt's maps thus declare, with Trebra and Forster, that what can be unfolded into mines can be folded up again into the mountains. This is illustrated by the fact Humboldt's more famous "Tableau physique des Andes," commonly thought to be inspired by the Ecuadorian volcano he and his porters nearly summitted in 1802, Mt. Chimborazo, also belongs to a whole family of "Tableaux physiques" that he himself attributed to mining.[532] Both attributions are true, and truer still when taken together. For Humboldt saw nature as a set of corresponding spaces—over and under, mountain and mine, summit and sea—to be studied and mapped with corresponding methods.

[532] Alexander von Humboldt, *Versuch über den politischen Zustand des Königreichs Neu-Spanien*, 5 vols. (Tübingen: Cotta, 1809-14), *1*, 43: "Ich habe den Versuch gewagt, ganze Länder nach einer Methode darzustellen, welche bis jetzt nur für Bergwerke oder bei Canalprojecten angewendet wurde."

That sense of geographical analogy, as we will see in the following sections, was the unifying idea behind a far-reaching culture of verticality whose most famous interpreter was Humboldt himself. But before such a conception of nature's verticality could be transposed from mine to mountain, popularized in print, and mapped across entire continents, it had to be produced—in the most literal sense. It is to the making of vertical space that we now turn.

Earth Workers and Cave Guides

The cartography practiced by Trebra and Humboldt was borne of working rhythms in mineshafts as well as travel routes into mountains. Their maps, I have argued, are movement-laden. From another perspective, however, these maps are also haltingly still. Implicit in these tableaux are "cartographic silences"—power structures, political agendas, and labor relations mystified by the authoritative neutrality of the cartographer's gaze.[533] Mountains, mines, and mineral veins abound, but the work that produced these spaces is largely obscured. Gone are the various technicians—hewers, surveyors, and draftsmen—who made the mines and facilitated their inscription in maps credited to the likes of Trebra and Humboldt.[534]

Often, the passive sentences penned by officials and naturalists served to silence such actors. Sometimes officials wrote of how the mines themselves "furnished" knowledge. Consider a plan to drain flooded galleries near Freiberg with an adit dug into the mountainside (a project backed by Humboldt himself), which cited "the teachings it will furnish us about the nature of unknown strata and unknown depths." The report's authors continued to pledge that the project would not only employ "many thousands of people for ages to come," but also "increase their

[533] J. B. Harley, "Silences and Secrecy: The Hidden Agenda of Cartography in Early Modern Europe," *Imago Mundi* 40 (1988): 57-76.
[534] Steven Shapin, "The Invisible Technician," *American Scientist* 77, no. 6 (1989): 554-63.

intellectual powers."[535] Recent studies have made it possible to more accurately re-imagine the communication of knowledge amongst Saxon miners and among other eighteenth-century "earth workers."[536] Geognostic observations for maps like Trebra's were *furnished*, in fact, by hewers, foremen, and inspectors, then passed up a vertical chain of command.[537]

This section joins those studies in exploring the social dimension of vertical nature and the division of labor behind its production in central Europe around 1800. Verticality was a way of working as much as it was a way of thinking. For two artisan men in particular—the Franconian "*Höhleninspektor*" Johann Georg Wunder and the Harz Mountain "*Führer*" Christian Friedrich Becker—vertical travel was a source of income, a personal point of pride, and even a means of aspiring for credibility. Wunder, a wainwright by trade, and Becker, a mine foreman, saw an opportunity in the allure of the underground *au courant* amongst the educated classes in the last decades of the eighteenth century. They turned cave-guiding into a family-run business of sorts. Employing their sons and daughters in trade family trade, Wunder and Becker leveraged their unique knowledge of and access to subterranean nature to occasionally transgress the confines of their social station, circulating naturalia through high scientific circles and finding some defenders amongst the educated and mobile. In doing so, the sometimes spurned, sometimes celebrated guides of Franconia and the Harz helped produce a collective thought style in the mountains of Germany.

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[535] "Freyberg, den 6ten Januar 1830. Königlich Sächsisches Ober-Bergamt," GSA 26 LXVI, 2, 85, "Freyberger Bergwerks-Angelegenheiten," Bestand Goethe, Naturwissenschaftliche Schriften, Material zur Mineralogie und Geologie: "…eine Ausführung, wie der Meißner Stolln, die, außer den Belehrung, die sie uns über die Natur unbekannter Gebirgstheile und unbekannter Tiefen zuführen wird, auch vor vielen andern auf mehrern Menschenalter hinaus vielleicht Tausende von Menschen mittel- oder unmittelbar beschäftigt, ihren Wohlstand vermehrt, ihre intellectuelle Kraft erhöht."

[536] Lydia Barnett, "Showing and hiding: The flickering visibility of earth workers in the archives of earth science," *History of Science* 58, no. 3 (2019): 245-74.

[537] Sebastian Felten, "The history of science and the history of bureaucratic knowledge: Saxon mining, circa 1770," *History of Science 56*, no. 4 (2018): 403-31, esp. 412-14, 418-19.

The Wunder and Becker families faced significant prejudices against highland peoples. At a time when naturalists were re-imagining the earth as a historical entity, reading its "primitive" strata as a record of the planet's immensely deep past, travelers regularly essentialized "mountain folk" (*Gebirgsvolk*) as the nearest descendants of a hearty primordial stock, a sort of "noble savage" or *Naturkind*.[538] In naturalizing mountain dwellers as a fixture of the landscape, they denied "mountain folk" a coeval social and political existence, even while celebrating their "primitive virtues."[539] Aesthetic conventions compounded the marginalization faced by highlanders. Educated travelers commonly viewed "natural" caverns as just that—spaces devoid of artifice. Visiting Switzerland's Beatus Cave, Wilhelm von Humboldt described it as "near to the most beautiful productions of nature, far from the pathetic efforts of art."[540]

But Humboldt is betrayed by a contemporary painting of the Beatus Cave (**Figure 5a**). The scene, depicted by Caspar Wolf in 1784, is peopled by a range of actors: an artist at work in the distance; servants gathering wood, setting a fire, and pouring wine; two women in repose outside the cavern juxtaposed with their male counterparts seen emerging from within it. Closer

[538] Rudwick, *Bursting the Limits of Time*, 1-2. Savants who investigated the large mammal fossils found in the caverns of Franconia and the Harz (resembling bears, elephants, wales, and, Leibniz speculated, unicorns) frequently mentioned the "groundless nonsense" of "the old inhabitants" who took the bones for the "remains of their ancestors, for giants' bones." And yet the same travelers often regarded highland inhabitant like Wunder and Becker as a reserve of "primitive" strength not yet corrupted by the "culture and luxury" of their age. See J. C. Rosenmüller, *Die Merkwürdigkeiten der Gegend um Muggendorf* (Berlin: Unger, 1804), 52 and Samuel Christian Wagener, *Reise durch den Harz* (Braunschweig: 1797), 33-34, 97-98. This is discussed in Patrick Anthony, "Making Historicity: Paleontology and the Proximity of the Past in Germany, 1770-1820," *Journal of the History of Ideas* 82, no. 2 (April 2021): 31-55.

[539] Londa Schiebinger, *Nature's Body: Gender in the Making of Modern Science* (New Jersey: Rutgers University Press, 2013).

[540] As quoted in Sabine Röder, *Höhlenfaszination in der Kunst um 1800: Ein Beitrag zur Ikonographie von Klassizismus und Romantik in Deutschland* (Remscheid: Arns, 1985), 86: "In solchen Gegenden, den schönsten Werken der Natur nah, fern von allem Machwerk der Kunst, würde man erst Homer, und Ossian verstehn." The poet Elisabeth Kulmann echoed him, finding in the subterranean sublime "not a trace of human art[ifice]." Elisabeth Kulmann, "Die Grotte," in *Sämmtliche Gedichte von Elisabeth Kulmann. Mit dem Leben, Bildniß und Denkmal der Dichterin*, 5th ed., ed. Karl Friedrich von Großheinrich (Leipzig: Wigand, 1847), 182: "O wunderschöne Grotte! […] Von Kunst nicht eine Spur."

inspection reveals the blocky outcroppings of stonemasonry at the cave's entrance (**Figure 5b**). As in Franconia and the Harz, these "most beautiful productions of nature" involved considerable artifice: blasting and boring, ropes and ladders, hand-crafted doors and steps hewn into the rock, artificially polished stalagmites and elaborate lighting schemes.

So complex was the social topography of highland travel that a wainwright and a mine foreman met poetic tribute one day only to encounter condescension and mimicry the next.[541] Visitors who did appreciate the production of these underground spaces were often careful to delineate between manual and mental labor.[542] In the Harz, for instance, those who boasted of Becker's physical feats often mocked his interest in sublime aesthetics. Still, some expressed genuine admiration for their guides. A student of the Painting Academy in Leipzig, who traveled through Biel's Cave in 1795, praised "the honorable and well-mannered foreman," placing him in the highest of company. "Every friend of Nature" should visit the cave, he wrote, "partly to treasure the arduous and dangerous works of this active man, and partly to bear witness to the works of the great Being in Nature."[543]

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[541] One traveler signed the Biel's Cave Logbook, kept by Becker, with the signature "Hermit from the Valley." Others, as we will see, expected Becker to conjure gnomes and "little earth-men," mythical figures from mining folklore. See "Der Eremit aus dem Thale" in July 1790, in *Die Jahrbücher*, 159-60.

[542] Some naturalists consciously emphasized the physical labor of working-class collectors in order to elevate their own intellectual labor. See Barnett, "Showing and hiding," 245-74. Other scholars have observed similar patterns amongst naturalists in colonial contexts, where Indigenous and African knowledges are presented as "raw materials" to be refined into knowledge by European savants. See Kathleen S. Murphy, "Translating the vernacular: Indigenous and African knowledge in the eighteenth-century British Atlantic," *Atlantic Studies* 8, no. 1 (2011): 29-48.

[543] Christian Jacob Schwarz, 7 Aug. 1795, in *Die Jahrbücher der Bielshöhle oder Verzeichniß derer, welche die Bekkerbielsteinhöhle befahren haben. Erster Theil vom Jahr 1788 bis 1795. Besorgt von Christian Friedrich Bekker, Steiger auf den Marmorbrüchen und Entdecker der obbenannten Höhle* (Rübeland, an dem Tage, da die Höhle zuerst fahrbar gemacht ist, im Monat August 1787), 217: "Den 7ten befuhr ich Christ. Jacob Schwarz Schüler der Churfürstl. Sächs. Maler-Akademie in Leipzig unter der Leitung des ehrlichen braven Steigers, mit Nahmen Becker, die berühmte Bielshöle, die jedem Freunde der Natur gewiß bewundernswürdig ist, theils die mühsamen und gefährlichen Arbeiten eines thätigen Mannes zu schätzen, theils des großen Wesens Wirken in der Natur zu vernehmen." The *Jahrbücher* were edited by Christian Friedrich Schröder and printed in his *Naturgeschichte und Beschreibung der Baumanns und Bielshöhle...* (Berlin, 1796).

Figure 5a. Caspar Wolf, *Beatushöhle, mit einer Reisegesellschaft* (*Beatus Cave, with a group of travelers*), 1784, oil on canvas, 54 cm x 82 cm. Aarauische Kunstsammlung, Kunsthaus. Wikimedia Commons.

Figure 5b. Detail from Wolf's *Beatushöhle*, highlighting the division of labor in cave travel and the artifice evidenced by the stonemasonry at the cave's entrance. Wikimedia Commons.

From such accounts, we can begin to reconstruct the workscape of a late eighteenth-century cave-guide.[544] No sooner had the two secured princely *Privilegium* to guide visitors in the 1780s than origin stories began to spread about the discovery of the caves. Wunder, the wainwright of Muggendorf, was said to have found the cave that bore his name (*Wundershöhle*) while seeking refuge from thunder and lightning in the autumn of 1772.[545] In the Harz, one chronicler ascribed to Becker an innate "thirst for inquiry" (*Forschungsbegierde*), which drew him into the Biel's Cave "already as a boy of 12 years."[546] The tales promoted by learned writers are tempered somewhat by the fact that caves were not curiosities for rural peasants and artisans, but well-trafficked sites of practical significance: cold cellars used in the making of beer, cured meats, and cheese, safehouses for livestock in times of war, and refuge for poachers evading princely foresters in times of hunger.[547] In the case of Wunder and Becker, the truth lay somewhere in between. Both men were compelled by economic necessity, to be sure. But Wunder, Becker, and their children also appear to have shared in a passion for natural history and nature aesthetics typically associated with those they guided.

Family formed the core of their enterprise. It was "with the help of his two daughters," Christian Friedrich Schröder wrote in 1796, that Becker employed the skills he developed as foreman of the nearby marble quarry. Together, they used black powder to blast passageways from one chamber to another, sculpting steps of stone and stalagmite. Schröder's account also suggests Becker drew inspiration from his cousin, "Guide Gottlieb Bekker" of the nearby

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[544] Thomas G. Andrews, *Killing for Coal: America's Deadliest Labor War* (Cambridge, MA: Harvard University Press, 2008), 123-25.
[545] Popular in Wunder's day, this origin story continues to persist in online travel guides from our own time: "Wundershöhle bei Muggendorf," *Krafvolle Orte*, accessed 2 Feb. 2021, http://www.kraftvolle-orte.de/uebersicht-der-kraftvollen-orte/hoehlen/wundershoehle-bei-muggendorf/.
[546] Schröder, *Naturgeschichte*, 57-58.
[547] Mattes, *Reisen ins Unterirdische*, 95-103.

Baumann's Cave.[548] In a later account taken from Schröder, the labor performed by the Becker sisters is obscured in proportion as their father's masculine strength and bravery is emphasized.[549] Yet the sisters Becker also participated in the guided tours. In December 1792, one "Moser from Berlin" thanked "*Führer* Herr Becker, and his daughter, the first for his good ladders and the second for the charming song she sang in the 5th chamber of the cavern."[550] The Becker home was itself an integral part of the traveler's itinerary and the guide's practice. They lived "across the street from *Schinnemann*'s lodge," in a house distinguished from the other "huts of the village Rübeland" by a "sign for travelers who wish to visit the cave." Here travelers would register, pay, and be outfitted with a "miner's lamp" and "black linen smock" before walking "not a quarter of an hour" to the cave. After the tour, the company would return to the Becker home to document their names, thanks, and, in some cases, their criticisms in the "Logbook" that was kept there.[551]

In the Fränkische Schweiz, too, travelers' journeys up to the dozen or so caverns above Muggendorf began in the home of Johann Georg Wunder, a "rickety hut in the market," one traveler wrote, among the village's 53 houses.[552] From here, Wunder and his two sons led clients

[548] Schröder, *Naturgeschichte*, 57-59.
[549] Wagener, *Reise durch den Harz*, 79. Where Schröder said "und so fuhr er mit Hülfe seiner beiden Töchter so lange fort," Wagener wrote "Lange fuhr *Becker* so mit unermüdeten Fleiße fort."
[550] 28 Dec. 1792, in *Die Jahrbücher*, 182: "Den 28 August befuhr ich die Bielshöhle, staunte über dessen Bau und Anordnung und danke dem Führer Herrn Becker, wie auch dessen Tochter, Ersterem wegen seiner guten Fahrten, und Letzterer für den anmuthigen Gesang, den dieselbe in der 5ten Höhle anstimmte. Moser aus Berlin."
[551] Instructions for travelers are found in "Die Bielshöhle," *Neues Hannöversches Magazin* 22tes Stück (März 1807), 341-44 and "Für Reisende," *Der Anzeiger. Ein Tagblatt zum Behuf der Justiz, der Polizey und aller bürgerlichen Gewerbe* (Gotha, 1792), 1017-18. That Becker kept the Logbook in his home is evident from the editor's (Christian Friedrich Schröder's) note that an entry in June of 1795, though signed from "Biel's Cave," had in fact been penned "here in the guide's house, not in the cave ... when his mining clothes [*Berghabit*] was returned." (A[nmerkung] d[es] H[erausgebers], *Die Jahrbücher*, 211).
[552] Johann Gottfried Köppel, *Malerische Reise durch die beiden fränkischen Fürstenthümer Baireuth und Anspach* (Erlangen, 1816), 67.

into the mountains, earning the title "Cave Inspector."[553] A *Handbook for Travelers* in Franconia published in 1841 lists multiple Inspectors in the area, alongside foresters, a pair of "farmers," and a *Höhleninspektor*'s wife, all willing to guide paid tours.[554] The Wunder "hut" doubled as a trading post for all manner of naturalia—an overlooked "cottage industry" of early modern natural history operated by artisans and their families.[555] "In a small room his treasures are spread about," reads an 1816 account of the home kept by second generation *Höhleninspektor* Ludwig Wunder (1771-1819)—"fossilized bones, teeth, jawbones, whole heads of unknown animals and other petrified artifacts." Conflating father and son, the account claims that "he"—"our Cicerone"—has "provided nearly all natural history cabinets in and outside of Germany with fossilized bones of strange animals that he collected from the local underground treasure trove."[556] Though largely unrecognized by taxonomists, the Wunders had indeed ushered into the

[553] The title *Höhleninspektor* was itself the object of some derision, though the following account jests equally at the German tendency to bureaucratize even its natural caverns: "Natürlich konnten wir Deutschen die hübsche Gelegenheit der Entdeckung dieser Höhlen unmöglich vorübergehen lassen, ohne dabei ein neues Amt, eine neue Würde und einen neuen Titel zu erfinden. …ich weiß nicht einmal, ob der von Muggendorf, der von der Regierung angestellt wird, nicht gar 'Ober-Höhlen-Inspector' oder 'Königlich Bairischer Stalaktitenhöhlen-Ober-Inspector' ist…." (J. G. Kohl, *Skizzen aus Natur- und Völkerleben*, Pt. 1 (Dresden: Rudolf Kunze, 1851), 58.)

[554] Julius von Plänckner, *Die Fränkische Schweiz. Taschenbuch für Reisende* (Coburg & Leipzig, 1841), 20, 25, 104-05.

[555] In recent years, historians of science have shown how domestic spaces, and conceptions of domesticity itself, have shaped scientific thought and practice. See Alix Cooper, "Homes and Households," in *The Cambridge History of Science*, vol. 3, eds. Katherine Park and Lorraine Daston (Cambridge: Cambridge University Press, 2006), 224-237; Mary Terrall, "Masculine Knowledge, the Public Good, and the Scientific Household of Réaumur," *Osiris* 30 (2015): 182-201; Simon Werrett, *Thrifty Science: Making the Most of Materials in the History of Experiment* (Chicago: The University of Chicago Press, 2019); Valentina Pugliano, "Natural history in the apothecary's shop," in *Worlds of Natural History*, eds. H. Curry, N. Jardine, J. Secord, and E. Spary (Cambridge: Cambridge University Press, 2018), 44-60.

[556] Köppel, *Malerische Reise*, 67: "Und nun Freund! lassen Sie uns unsern Cicerone, den Höhleninspektor *Wunder* aufsuchen, der seit dreißig Jahren so viele unterirdische Entdeckungen gemacht, der beinahe alle Naturalienkabinette in und ausser Deutschland mit Petrefakten und versteinerten Knochen fremder Thiere, welche er aus den hiesigen unterirdischen Schatzkammern hervorsucht…. […] Dieser Mann wohnt in einer gebrechlichen Hütte auf dem Markt, und so wie diese von außen sich zeigt, so harmonirt auch alles innere mit ihr. In einer kleinen Kammer sind seine Schätze, welche aus versteinerten Knochen, Zähnen, Kinnbacken, ganzen Köpfen unbekannter Thiere und andern Petrefakten bestehen, ausgestreut."

scientific mainstream one of the period's most spectacular discoveries of large mammal fossils. Franconia's "cave bear," which was similar to, yet distinct from, existing species, stood alongside the recently unearthed "Ohio unknown," Mammoth, and *Megatherium americanum* in the era's great debate about earth history.[557]

The case of Wunder and Becker opens up the intricate relationship between the vertical orientation of life and labor in the mountains and mines of central Europe and the production of vertical space there. In the mining tradition, this dynamic is captured in songs and sagas. From above, authorities viewed mining songs and sermons as an instrument with which to placate laborers by valorizing the dangers of their daily toil. From below, songs passed down through generations of miners spoke to the pious hope that God might help them survive those dangers.[558] "Glory, Glory, God in the Heights," began a Saxon carol sung during Christmas parades, marching through the streets by torchlight while bearing the industry's signature axe, the *Bergmannsbarte*. Inscribed on the wooden handle of many an axe were the words: "JESUS SHALL BE MY MINE LAMP"—*with him I climb down and back up again*, goes the rest of the popular miner's prayer.[559]

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[557] Rudwick, *Bursting the Limits of Time*, 264-74, 349-75; Anthony, "Making Historicity."
[558] Wolfgang Korb, "Bergschöre und Bergkapellen an der Saar," in *Musik und Industrie: Beiträge zur Entwicklung der Werkschöre und Werksorchester*, ed. Monica Steegmann (Regensburg: Gustav Bosse Verlag, 1978), 129-30; Susan C. Karant-Nunn, "From Adventurers to Drones: The Saxon Silver Miners as an Early Proletariat," in *The Workplace before the Factory: Artisans and Proletarians, 1500-1800*, eds. Thomas Max Safley and Leonard N. Rosenband (Ithaca & London: Cornell University Press, 1993), 73-99, esp. 96-98.
[559] "Gloria, Gloria, Gott in der Höh!" in Harmut Rau, ed., *Arzgebirg, mei Arzgebirg: Erzgebirgische Weihnachts- und Bergmannslieder,* vol. 2 (Leipzig: Friedrich Hofmeister, 2017), 18. Several *Bergbarten* (or *Berg-häckchen*) of seventeenth- and eighteenth-century origin can be found in the Stadt- und Bergbaumuseum Freiberg with the inscription "MEIN GRUBENLICHT SOLL JESUS SEIN." The miner's prayer continues: "mit ihm fahr' ich aus und ein!" (Herbert Pforr, *Freiberg: Stadt auf silbernem Boden* (Erfurt: Sutton Verlag, 2012), 147.) As Pamela Smith writes of the physical-spiritual experience of vertical travel in the mines: "Their bodily striving underground brought the materials to the earth's surface and then drew out the metals from the matrix of their ores, but in this process, the spirits and humours of the metals and minerals mixed with those of the metalworkers, and they affected and shaped each other in distinctive ways." (Pamela H. Smith, "Itineraries of Materials and Knowledge in the Early

The division of labor in early modern mining was itself vertically oriented. In the Harz, the age of 17 or 18 marked a harrowing rite of passage, the descent of "miners' sons" from unskilled over-ground tasks (e.g. winching rock out of the shafts or crushing ore en route to the smelting huts) to more specialized, and far more dangerous, underground labor: blasting, hewing, carpentry, and masonry in the mines. One study of the Upper Harz lists 1,190 mining deaths between 1751 and 1863, most of them caused by collapsing tunnels and accidental explosions of black powder—precisely the kind of risks to which Becker and his daughters exposed themselves in Biel's Cave. Hewers and borers alone (*Gedinghäuer* and *Bohrhäuer*) accounted for nearly half of these deaths (457), as compared to the 52 ore-crushers (*Pocharbeiter*), 21 smelting operators (*Hüttenleute*), and 5 administrators (*Bergbeamte*) who died in over-ground accidents.[560]

A vertical geography of risk emerges from these numbers, one that informed the spatial orientation of miners' spirituality and even their sense of justice. The subterranean sublime popular amongst Europe's educated classes had no place here in the ranks of common miners, where mortal danger was so imminent—in the "wicked mine air" (*böse Wetter*), the open flame of the miner's lamp so near the stores of black powder, and the perpetual threat of structural collapse. For them, as for well-to-do travelers, transit through vertical space was both a physical and spiritual experience, no less enchanted for the miner than the Romantic. But if educated enthusiasts found in the subterranean evidence of the Creator's awe-inspiring artifice (as can be read on nearly every page of the Biel's Cave logbook), miners drew divinity into the depths as a matter of life and death. Miners, in short, did not have the luxury of enjoying fear.

Modern World," in *The Global Lives of Things: The Material Culture of Connections in the Early Modern World*, eds. Anne Gerritsen and Giorgio Riello (New York: Routledge, 2015), 30.)

[560] Liessmann, *Historischer Bergbau im Harz*, 41, 46-50.

The miner's bell soaring above the gables of Freiberg commanded those who "go into the depths" to "Think up to the heights." So, too, mining songs appealed to "*Berg-Rath Jesum Christ*" for angels to guard them from the evil wrought by the "*Bergteuffel*" and the "*Daemon metallicus*."[561] "You safeguard the miners | the young with the old | that they remain tranquil | deep in the pits," began one miner's song, addressing the divine "*Ober-Berg-Herr*" directly:

> when they mine the ore
> you grant them your angel
> to mercifully protect them
> from danger and harm….[562]

"We miners hidden in the deep," goes a similar rendition sourced from Joachimsthal (Jáchymov) in the Ore Mountains, whose deepest mines Humboldt recorded some 650 meters beneath the surface of the earth:

> God wishes to send us angels
> when we climb down and back up.
> Wager with our lives we must
> down into the noble mine….[563]

But if such songs can be characterized by their pious pleas, miners' vernacular traditions also convey a degree of contempt towards those who worked above them, physically and socially.

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[561] Theophilus Drechßler (1681) as quoted in Johann Christian Engelschalln, *Beschreibung der Exulantend- und Bergstadt Johann Georgen Stadt, in vier Theilen vorstellende* (Leipzig: Friedrich Lanckischens Erben, 1723), 191-93; Ortrud Krause, "Sagenhafter Rammelsberg: Historie, Berggeister und zauberhafte Kräfte in der bergmännischen Erlebniswelt und Volksdichtung," in *Der Rammelsberg: Tausend Jahre Mensch-Natur-Technik*, ed. Reinhard Roseneck (Goslar: Goslarsche Zeitung, 2001), 25-26.

[562] Gerhard Heilfurth, *Neuvermehrtes vollständiges Bergliederbüchlein: Eine buntgemischte Singgut-Sammlung aus Mitteldeutschland um 1700* (Hildesheim: Georg Olms Verlag, 1988), 253: "Wollst die Bergleut erhalten | die Jungen mit den Alten | daß sie bleiben mit Ruh | tief in der Grube drinnen | wenn sie das Ertz gewinnen | gieb ihnn dein Engel zu | daß er sie gnädiglich bewahr | für Gefahr und Schmerzen | das wünsch ich ihnn von Herzen | jetzt und immerdar." "Ober-Berg-Herr" comes from ibid., 39, which dates to 1688.

[563] Heilfurth, *Bergliederbüchlein*, 84: "Gott woll uns sein Engel senden | wenn wir fahren aus und ein. | Wagen müssn wir unser Leben | in das edle Bergwerck nein." Humboldt's recording of the "Jung Häuer Zechen- und Andreasgang" in Joachimsthal comes from *Kosmos*, *1*, 418. As Humboldt used Prussian feet, I have used an English translation's "2120 feet" to convert into meters.

Earth workers chided their over-ground counterparts as "miners who accustom themselves to the day-air"—fresh "*Tage-Lufft*," as opposed to the suffocating "carbon-seas" (*Kohlensäureseen*) looming in the pits below.[564] In tales and sagas, moreover, miners voiced grievances about the despotism of their superiors, wielding folklore to right the wrongs of mine officials.[565]

Wunder and Becker occupied a space between laboring miners and educated travelers. They were skilled laborers of the artisan class who contributed to a geographic thought style ultimately claimed as the domain of artists and savants. For Wunder, the caverns of Muggendorf opened the door to the study of natural history, which was, by all accounts, the wagon maker's true passion. Wunder had been employed as "guide" and "handyman" (*Handlanger*) to the Erlangen pastor Johann Friedrich Esper, a well-known figure amongst European naturalists thanks to "his" discoveries in Muggendorf. Wunder was said to have learned from Esper to classify "nearly all fossils and plants" in Linnaean taxonomy, albeit, one chronicler added, "in rather corrupt Latin."[566] Notwithstanding the classist slight, Wunder earned a certain celebrity for his prowess in natural history, posing a significant challenge to boundaries that still separated the learned and Latinate from the laboring and "low-born."[567] As one of Wunder's earliest

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[564] Mineralophilo Freibergensi, *Neues und Curieuses Bergwerks-Lexicon Worinnen nicht nur Alle und jede beym Bergwerck, Schmelzten, Brenn-Hause, Saiger-Hütten, Blau-Farben enthalten….* (Chemnitz, 1730), 96: "Bergleute gewöhnen sich an die Tage-Lufft"; Liessmann, *Historischer Bergbau im Harz*, 48.

[565] Krause, "Sagenhafter Rammelsberg," 15.

[566] Köppel, *Malerische Reise*, 67: "…nachdem ihn seine Wagner-Profeßion nicht genug beschäftigte, sich unter Anleitung des seel. Hrn. Superintend. *Espers*, und blos als Führer in dem Umgange des Herrn Präsidenten von *Schreber*, des großen Naturforschers, ziemliche Kenntnisse in der Botanik und in dem Naturreiche gesammelt hat, so daß er nunmehr beinahe alle Petrefakten und Kräuter nach den Linneischen Namen, obschon in ziemlich corruptem Latein, benennt."

[567] These boundaries were in flux at this precise moment. In her study of natural history societies in Germany, Denise Phillips described this as a period of transition from a "learned estate," grounded in the corporate order of the early modern period, to a "learned world," which came of age during the Napoleonic Wars and the era of state reform that ensued. "By 1800," Phillips writes, "witty enlightened satirists had more or less mocked the learned man, the *Gelehrte*, out of existence. The figure that replaced him was the modern *Bildungsbürger*, the educated middle-class man." But while natural history societies ostensibly adopted a "democratic" model open to contributions from artisans, gardeners, and other men of

champions wrote, the *Höhleninspektor*'s "life deserves to be pragmatically described and publicly known."[568]

Middle-class writers with an upward-striving social agenda of their own were particularly fond of Wunder, "one of the most remarkable people in the whole of the region." In 1789, as Revolution broke out in France, a tutor-turned-*Universalgelehrter* elevated Wunder to a place of theoretical prominence, believing the professors at the University in Erlangen were indebted to him for collections of naturalia "once thought to be the peculiar rarities of far-away lands." "What a pity," Wunder's champion wrote, "that his limitless thirst for knowledge is not supported by a sufficient salary," a point echoed again and again by enamored travelers.[569] But such high praise evidently fell on deaf ears. Later, in 1797, another traveler lamented that in spite of the economy of naturalia that Wunder and his sons generated from their mountain village, the guide "sometimes endured the customary fate of meritorious men—to starve."[570]

practical knowledge, learned members retained the corporate assumption that people ought to work "within their allotted sphere." See Denise Phillips, *Acolytes of Nature: Defining Natural Science in Germany, 1770–1850* (Chicago: University of Chicago Press, 2012), 15-16, 70-71.

[568] Hirschung, *Nachrichten*, 142: "[S]ein Leben verdiente, pragmatisch beschrieben, öffentlich bekannt gemacht zu werden…."

[569] Friedrich Karl Gottlob Hirschung, *Nachrichten von sehenswürdigen Gemälde- und Kupferstichsammlungen, Münz- Gemmen- Kunst- und Naturalienkabinetten ... in Teutschland*, vol. 3 (Erlangen: Johann Jakob Palm, 1789), 142: "Der Höhleninspektor Wunder ist in der That eine der merkwürdigsten Personen in der ganzen dasigen Gegend…. […] Nur Schade, daß man seine gränzenlose Wißbegierde nicht durch eine hinlängliche Besoldung unterstüzt…." Compare Wunder's "Wißbegierde" to Becker's "Forschungsbegierde" in Schröder, *Naturgeschichte*, 57-58.

[570] Klement Alois Baader, *Reisen durch verschiedene Gegenden Deutschlands in Briefen*, vol. 2 (Augsburg: Johann Melchior Lotter, 1797), 135: "Man hat die ersten hiesigen Entdeckungen besondrer Naturseltenheiten dem Höhleninspektor *Wunder* zu danken, der aber bisher weder die Unterstützung, noch die Belohnungen erhielt, die er verdiente, und der bey all seinem Fleiße manchmal das gewöhnliche Schicksal vieler verdienstvoller Männer erfährt—darben zu müßen."

Figure 6. Detail from *Die Rosenmüllershöhle von Innen*, illustrated by Rosenmüller in *Die Merkwürdigkeiten der Gegend um Muggendorf* (1804). Wikimedia Commons.

Though the extent of Wunder's tribulations may never be known, it is clear that he positioned himself at the center of an industry that dealt flora, fossils, and minerals across Europe, and that he passed this craft down to his son Ludwig.[571] To urban writers and naturalists, Wunder offered on-site observation in the fossil-filled caverns of an otherwise peripheral Franconian hinterland. Romantics like Wilhelm Heinrich Wackenroder, paleontologists like Johann Christian Rosenmüller, and savants like Alexander von Humboldt flocked to Muggendorf, returning to cities like Berlin, Nürnberg, and Leipzig to put their experience in

[571] Alix Cooper, *Inventing the Indigenous: Local Knowledge and Natural History in Early Modern Europe* (Cambridge, UK: Cambridge University Press, 2007), 109-15.

print—sometimes citing, sometimes erasing the *Höhleninspektor*.[572] When visitors did make Wunder visible, they tended to emphasize the division of labor in natural-historical travel. Rosenmüller's own engravings of the caverns in Muggendorf (**Figures 6-7**) consistently depict a cloaked savant overlooking the manual activities of his guide—the one upright, a scroll of illustrations or a torch in hand, the other with an arched back, his hands busy at work in the stone and stalagmite.

Figure 7. Detail from *Eingang zur Gailenreuther Höhle*, illustrated by Rosenmüller in *Die Merkwürdigkeiten der Gegend um Muggendorf* (1804). Wikimedia Commons.

[572] Wilhelm Heinrich Wackenroder, *Reisebriefe*, ed., Heinrich Höhn (Berlin, 1938), 66-67. Wackenroder purchased "heathen urns," fossilized seashells, and "a pair of red stalagmites" from Wunder, who led him into the caves with the help of his son Ludwig. The Wunders are given more credit in Rosenmüller's work, though they go unmentioned in Humboldt's various references to the caves of Muggendorf, which he visited while serving as a mining official in nearby Prussian Franconia. Notably, it was Wunder who discovered the cave that bears Rosenmüller's name. See Johann Christian Rosenmüller and Wilhelm Gottlieb Tilesius, eds., *Beschreibung merkwürdiger Höhlen: Ein Beitrag zur physikalischen Geschichte der Erde*, 2 vols. (Leipzig: Breitkopf und Härtel, 1799/1805), *2*, 363, 370, 390-91. Humboldt referenced the Rosenmüllershöhle in Alexander von Humboldt, *Ueber die unterirdischen Gasarten und die Mittel, ihren Nachtheil zu vermindern: Ein Beytrag zur Physik der praktischen Bergbaukunde* (Braunschweig: Vieweg, 1799), 42-43, 197, and again, privately, in *Die Jugendbriefe*, 316, n. 10.

Becker's case is similarly fraught. An official post as keeper of the Biel's Cave gave Becker unique authority over its comings and goings. When Becker received permission from the Ducal Chamber of Blankenburg in 1788 to guide "both high and low persons, foreigners and locals," he was instructed to maintain the cavern's physical *and* moral integrity. Specifically, Becker was to ensure that no one entered the cave without first registering with him, "and to see that the loose rabble does not smash or destroy anything in it."[573] Becker took these orders to heart, asserting his moral governance over "the rabble." As Schröder noted while editing Becker's Logbooks, the erstwhile foreman had, "out of a just zeal for respectability, morality, and chastity," torn out an entire page whose "disgusting and wanton inscriptions" would have mired the many "venerable names" in the cave's records.[574] In the cave, and perhaps only in the cave, could social order be so inverted that a foreman or a wainwright might justly "command" his elite clients—among them dukes, barons, and, Becker added in the Logbook, "the Princess of Sweden."[575]

When Becker ventured to engage in aesthetics, however, transgressing a cultural boundary, many educated travelers took issue. Like the natural history earth sciences to which Wunder contributed, the aesthetic judgment of nature was a well-policed domain—even in an era when intellectuals like Herder and Goethe looked to folk traditions and "primitive genius" for

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[573] Schröder, *Naturgeschichte*, 59: "…auch dahin zu sehen, daß niemand, der sich nicht zuvor bey ihm gemeldet, die Höhle befahren, und von losem Gesindel etwas darin zerschlagen oder zernichtet werde; widrigenfalls davon sofort Anzeige zu thun!"

[574] A[nmerkung] d[es] H[erausgebers], *Die Jahrbücher*, 222: "Aus gerechtem Eifer für Ehrbarkeit, Sittlichkeit und Züchtigkeit, hat der Führer zur Bielshöhle, Steiger Becker, ein Blatt mit einem Theil einer Inschrift vom 26sten September 1795 selbst ausgerissen. Der Herausgeber dieser Jahrbücher beläßt es um so mehr bey dem Ostrazismus dieser witzig seyn sollenden, seichten, ekelhaften und muthwilligen Inschrift, die inzwischen weder auf die Höhle, noch auf eine andre Person als den Einschreiber selbst zu sehr kompromittiren würde, wenn man in der Reihe und Gesellschaft ihrer Ehrfurcht verdienenden Nahmen und Beifügungen solchen Schmutz stehen lassen wollte."

[575] On placing artisanal science, see the classic study Anne Secord, "Science in the Pub: Artisan Botanists in Early Nineteenth-Century Lancashire," *History of Science* 32, no. 3 (1994): 269-315.

inspiration.[576] In June of 1789, the writer August Wilhelm Schlegel (soon to join Goethe in Jena) described Becker in English—a reference to the Anglophilic fad for "primitivity" strongly associated with caverns in England and Scotland.[577] "An excellent old Man!" Schlegel wrote in the primitivist vein, "I should go to Hell with him for an hour or two, without being frightened." Then, however, Schlegel added a revealing caveat, lamenting how Becker "spoils his very reasonable talking, by pointing out soned [sic.] resemblances [of the stalagmites]."[578] As another group complained, Becker identified a series of "resemblances" in the stalagmitic features: "the veiled nun," the "spinning maid," the "string of pearls," the "Jewish Temple," and the "Glockenspiel," as he called them.[579] "Were I the Duke," Schlegel chided, "I should prohibit the finding out of them by a peculiar law."[580] Little did he know, the Duke *already had* attempted to curtail Becker's aesthetic judgments, instructing him "not to spoil the cave by describing its curiosities to the point of impropriety."[581] Wunder's "corrupt" Latin had its counterpart in Becker's "spoilt" reason.[582]

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[576] Most famous in this genre is Johann Gottfried Herder, *Von Deutscher Art und Kunst* (Hamburg, 1773), especially the essay "Auszug aus einem Briefwechsel über Ossian und die Lieder alter Völker."
[577] James Macpherson's revival (though some said fabrication) of the Poems of Ossian, a third-century Celtic bard, immortalized a great seaside cavern on the Isle of Staffa, called Fingal's Cave after the warrior-hero who dwelt there. Fingal's Cave became a celebrated icon in Germany, and a cultural touchstone for German travelers.
[578] August Wilhelm Schlegel, 8 June 1789, in *Die Jahrbücher*, 152. On "primitive genius" as a literary and cultural fad in Germany, and especially the *Stürmer und Dränger*'s embrace of the Poems of Ossian, see M. H. Abrams, *The Mirror and the Lamp: Romantic Theory and the Critical Tradition* (New York: W. W. Norton & Company, 1958), 79-88; Fania Oz-Salzberger, *Translating the Enlightenment: Scottish Civic Discourse in Eighteenth-Century Germany* (Oxford: Clarendon Press, 1995), 69-73.
[579] Anon., "Etwas über die Bielshöhle," in *Der Freimüthige und Ernst und Schertz* (Berlin, 1804), 283: "Eine betende verschleierte Nonne, eine Spinnjungfer, zwei Kinder, eine Leber, Gedärme, Schnüren Perlen, einige Säulen, die harmonisch tönen, und die unser Führer das Glockenspiel nannte, noch ein Heer andere klingende Säulen, Eiszapfen, Bänder, ein Judentempel, der aus einigen glocken- und keilförmigen Figuren besteht, und von unserm Cicerone so getauft worden ist."
[580] August Wilhelm Schlegel, 8 June 1789, in *Die Jahrbücher*, 152.
[581] Schröder, *Naturgeschichte*, 58-59: "…und die Höhle von ihren Seltenheiten zum Ungebühr nicht spoliiret werde…."
[582] The naming of stalagmites and other subterranean phenomena was, in fact, a common practice amongst educated travelers and mine officials. Traveling into the caves of Franconia, the Harz, Italy,

As in Wunder's case, Becker's intellectual contributions were rebuffed by some and defended by others. One group of travelers initially expected the "foreman" to "conjure gnomes and little earth men" (*Erdmännchen*, common creatures in mining folklore alongside *Bergmännlein*). Ultimately, though, they conceded that Becker had spoken with practiced "oratory talent" and constructed the cave itself "*con amore*."[583] In the face of critiques like Schlegel's, Becker's trusted Logbook-editor Schröder leapt to his defense, carving out a space for the foreman's aesthetic participation. Nature's features are so manifold and human impressions so various, Schröder wrote in the Logbook, that the "naming [of stalagmites] ought to be left a free realm of play [*freien Spielplatz lassen*]."[584] "[L]ike the conservator of paintings," Schröder concluded his apologia, "the guide ... produces his rarities according to the impressions

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Spain, and Great Britain, German travelers regularly described the fantastical apparitions called to mind by shadows and shapes. In the caves of Muggendorf, Rosenmüller confessed to being enchanted by the play of torchlight against the "gigantic stalagmites," which "awaken images of fantasy." Arriving at Pool's Hole in Derbyshire, England with Alexander von Humboldt, Georg Forster encountered "three old women" bearing torches, and "thought vividly of the three witches in Macbeth; and the Stygian subterranean vault, into which they led us, animates this impression in the most vivid manner." Elsewhere, in an article on the bioluminescent quality of a "white fungus" growing in the mines of Saxony, the mining officer Carl Friedrich Freiesleben wrote (quoting a fellow mining official) that these fungi transformed a shaft into a "magic castle" (*Zauberschloss*) bathed in "faint moonlight." In Becker's case, therefore, it was not the practice of naming stalagmites that social elites regarded as transgressive, but the fact that a commoner engaged in their aesthetic project. (Rosenmüller, *Die Merkwürdigkeiten der Gegend um Muggendorf*, 49; Georg Forster, *Ansichten vom Niederrhein von Brabant, Flandern, Holland, England und Frankreich, im April, Mai und Junius 1790*, Pt. 3 (Leipzig: Dieterich'sche Verlagsbuchhandlung, 1979), 617; as quoted in J. C. Freiesleben, "Lichterscheinungen, I: Leuchten der Rhizomorphen," *Journal der Chemie und Physik* 44 (1825), 66.)

[583] Anon., "Etwas über die Bielshöhle," 283: "Wir alle, seinem ernsten Befehl gemäß, standen voll Erwartung der Dinge, die da kommen sollten, und ob er etwas erst die Gnomen und Erdmännchen vertreiben wollte…."

[584] A[nmerkung] d[es] H[erausgebers], *Die Jahrbücher*, 185: "Die Natur hat hier nicht Nahmen geben, nicht mahlen, sie hat nicht nachahmen wollen. Ihre Schnörkel sind Zufall, und genau das minder wichtigste der Höhle, wobey man eines jeden Einbildungskraft und Reverien in der Vergleichung und Benennung freien Spielplatz lassen und sich damit recht gut begnügen kann, wie der Führer, der hier gleichsam wie ein Bilderküster seine Raritäten produzirt, nach den Eindrükken, die sie auf ihn selbst gemacht haben, sein: Schaun Sie her, hier kommt ein u. s. w! über sie ausrufen will."

they make on him." Schröder himself assertively re-named the "*Becker's*-Biel's Cave" after the guiding family he so admired.[585]

The naming of curiosities was just one aspect of Wunder and Becker's craft. Again like a "conservator of paintings," the cave guides carefully curated their chambers, orchestrating the visual, acoustic, and embodied experience of vertical travel. The result was a particular impression of nature's vertical arrangement, above and below the threshold space of the cave's entrance. In Muggendorf, the naturalist Rosenmüller described how the "entirely vertical" arrangement of "some twenty" ladders, which allowed one to descend through a "narrow opening" in the craggy rock, produced the sensation of "hovering between the Over- and Underworld, while searching with one's feet for the first rung of the next ladder."[586] In a neighboring cave, Wunder and his sons combined the physical experience of vertical space with a visual performance. "The *Höhleninspektor* regularly illuminated the lower part of the cave when one stood atop the summit of Parnassus," Rosenmüller wrote, referring to the "subterranean mountain" that Wunder styled after Greek mythology:

> so that one could overlook from this prominence the entire expanse of the cave. From here, the depths can be ascertained in which the lights flicker below. One can also see here the opening of the cave's entrance, through which the daylight dawns and contrasts in a special way with the shine of the lanterns.[587]

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[585] A[nmerkung] d[es] H[erausgebers], *Die Jahrbücher*, 185.

[586] Rosenmüller and Tilesius, *Beschreibung merkwürdiger Höhlen*, *2*, 390-91: "Jetzt kann man auf einer Leiter von einigen zwanzig Stufen hinabsteigen, allein es ist sehr beschwerlich sich durch die enge Oefnung durchzuzwängen, und gleichsam zwischen der Ober- und Unterwelt schwebend, mit den Füßen so lange zu suchen, bis man die erste Sproße der nicht ganz in die Höhe reichenden Leiter gefunden hat, die noch obendrein ganz perpindicular steht."

[587] Rosenmüller and Tilesius, *Beschreibung merkwürdiger Höhlen*, *2*, 370: "Gewöhnlich erleuchtet der Höhleninspektor den untern Theil der Höhle, wenn man auf der Spitze des Parnasses steht, so daß man von dieser Stelle aus den ganzen Raum der Höhle übersehen kann. Wenigstens läßt sich hier die Höhle des Parnasses aus der Tiefe, in welcher man die Lichter unter sich flimmern sieht, beurtheilen. Auch sieht man hier der Oefnung des Eingangs entgegen, durch welche das Tageslicht dämmert, das auf eine besondere Weise mit dem Scheine der Lichter kontrastirt."

In Rübeland, Becker had a Parnassus of his own. Inverting Wunder's performance, Becker positioned himself atop a prominence. Having reached "these heights," one traveler recalled, "he cleared his throat and thundered down to us suddenly a little speech in verse, in which he described the wonders of nature that awaited us." Gazing down at those who looked down upon him, Becker switched to a "hushed tone" and gave his "command—to ascend."[588]

We may not have Becker's lyrics, but we do have the access to the geographical imaginary he and Wunder helped produce: a cross-sectional conception of nature illustrated by the poems, paintings, and maps of those they led into the depths. In what follows, I show how the kind of movement through vertical space that these cave-guiding families choreographed in Muggendorf and Rübeland occurred also on a grand scale. After the turn of the century, the embodied experience of vertical travel was increasingly mediated through art and science. Sedentary actors began to think with the travels of others, perceiving mountains, mines, and caves virtually, much as Trebra had instructed.

Corresponding Spaces

A common logic of correspondence underlay the many ways in which people represented vertical space in central Europe around 1800. In the oral culture of mining, it was said that one ought to look to the heights for salvation in the depths. Likewise, the industry's visual culture showed that what can be unfolded may be folded up again. Steeped in this style of thinking,

[588] Anon., "Etwas über die Bielshöhle," 283: "Bald hatte er seine Höhe erreicht; faßte nun einen festen Standpunkt, räusperte sich ein wenig, und donnerte nun mit einemmahl so überraschend zu uns in die Tiefe eine kleine Rede in Versen herab, in welcher er uns vorzüglich auf die Naturwunder, die unserer warteten, im voraus aufmerksam machte. Als er gesprochen, erhielt wir von unserm Redner, der sich auf seine Rede und sein Rednertalent nicht wenig zu Gute zu thun, und die Bewunderung des Ganzen, als unsern besten Dank zu fordern schien, in einem sehr selbst zufriednen und gedämpften Tone, den Befehl—aufzusteigen."

Humboldt constructed nature as a system of corresponding spaces, an arrangement of "contrasts and analogies" between the strata of earth, ocean, and atmosphere.[589] Indeed, as Kären Wigen has written, the related "notion of a correspondence between latitude and altitude," popularized by Humboldt, "was in fact a central principle of nineteenth-century geography," from the Andes to the Japanese Alps.[590] But this logic of correspondence was also rooted in routes of vertical travel plotted long before Humboldt.

On the eve of his journey through the Americas, in 1799, Humboldt published a 350-page study of the airs in mines, which sought to mitigate the effects of noxious gases (or "*böse Wetter*") on miners' lungs. In it, he declared: "Nature knows no over- and underground. All that is contained in fluid elements is counteractive, *mixed*."[591] Inverting the physical sciences of his contemporaries, Humboldt called this study "subterraneous meteorology." "I wish to draw downwards what [Jean-André] Deluc, [Horace-Bénédict de] Saussure and [Georg Christoph] Lichtenberg have drawn up toward the region of the clouds," he wrote. Humboldt had in mind Lichtenberg's studies of electrical discharge and Saussure's use of new instrumentation on Europe's highest summits, like the hygrometer he built to measure atmospheric humidity atop Mont Blanc (**Figures 8**).[592] Deluc, "the century's foremost hypsometer," had already transposed

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[589] Alexander von Humboldt, *Kosmos: Entwurf einer physischen Weltbeschreibung*, vol. 2 (Stuttgart: Cotta, 1847), 529.

[590] Kären Wigen, "Discovering the Japanese Alps: Meiji Mountaineering and the Quest for Geographical Enlightenment," *The Journal of Japanese Studies*, 31, no. 1 (2005): 1-26, on 25. Michael Reidy explores the critical role of islands and equatorial peaks in the making of Humboldt's "correspondence principle." See Michael Reidy, "Oceans through Islands to Mountains: Creating the 'Correspondence Principle'," in *Fluid Frontiers: New Currents in Marine Environmental History*, eds. J. Gillis and F. Toma (Cambridge, UK: White Horse Press, 2015), 192-210.

[591] Humboldt, *Ueber die unterirdischen Gasarten*, 201: "Möchte ich doch durch diese geringfügigen Betrachtungen die Aufmerksamkeit arbeitender Physiker auf die Culture eines so unterhaltenden, für Wohlstand und Leben einer der nützlichsten, arbeitsamsten Menschenklassen, so unendlich wichtigen Feldes heften können; möchte ich sie herabziehen wie *Deluc*, *Saussure* und *Lichtenberg* sie aufwärts in die Region der Wolken zogen. Die Natur kennt kein Oben und Unten. Alles im beweglichen Element ist gegenwirkend, ist *mischend*."

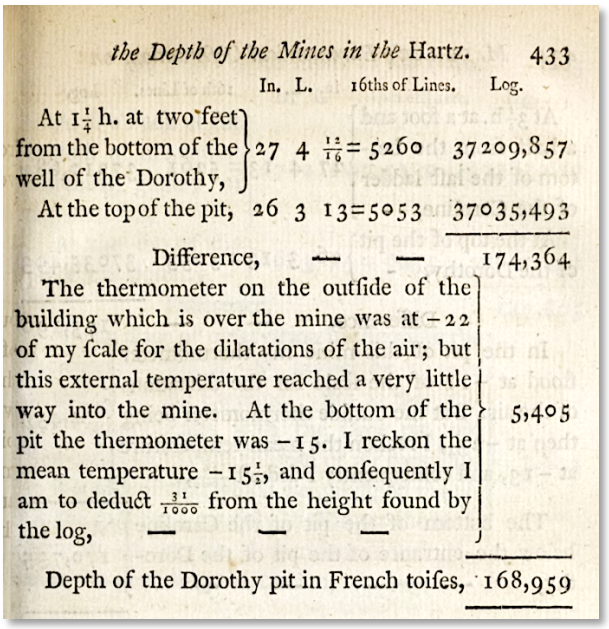
[592] Rudwick, *Bursting the Limits of Time*, 15-22.

physical experiments from mountains to mines (**Figure 9**). Having pioneered a method of measuring mountain heights according to the ratio by which barometric pressure falls during an ascent, he took a portable barometer he had designed around 1770 into the mines of Clausthal-Zellerfeld to use the same "pressure-height rules" in determining depths.[593] Humboldt followed suit, first in the mines of Franconia, then in the mountains of South America, where be brought barometers designed by Deluc and Saussure, along with the hygrometer shown in **Figure 8**.[594]

Figure 8. Horace Bénédict de Saussure after a painting by Jean-Pierre Saint-Ours (1796), shown here with a hygrometer he designed for measuring atmospheric humidity. SBB, Inventar-Nr. Portr. Slg, Nat. gr, Saussure, Horace Bénédict de, Nr. 5.

[593] Theodore S. Feldman, "Applied Mathematics and the Quantification of Experimental Physics: The Example of Barometric Hypsometry," *Historical Studies in the Physical Sciences* 15, no. 2 (1985): 127-195, on 137, 177. Jean-André Deluc, "XXI. Barometrical Observations on the Depth of the Mines in the Hartz. By John Andrew de Luc, F.R.S. In a letter to Sir John Pringle, P.R.S.," *Phil. Trans. R. Soc.* 67 (1777): 401-49.

[594] See Humboldt's discussion of "the barometric scale," the "hygrometric scale," and "the chemical composition of the atmosphere," in Humboldt and Bonpland, *Essay on the Geography of Plants*, 103-09, 110-11, 116-18.



the Depth of the Mines in the Hartz. 433

	In.	L.	16ths of Lines.	Log.
At $1\frac{1}{4}$ h. at two feet from the bottom of the well of the Dorothy,	27	4	$\frac{12}{16}$ = 5260	37209,857
At the top of the pit,	26	3	13=5053	37035,493
Difference,	—	—	—	174,364
The thermometer on the outside of the building which is over the mine was at −22 of my scale for the dilatations of the air; but this external temperature reached a very little way into the mine. At the bottom of the pit the thermometer was −15. I reckon the mean temperature $-15\frac{1}{2}$, and consequently I am to deduct $\frac{31}{1000}$ from the height found by the log,	—	—	—	5,405
Depth of the Dorothy pit in French toises,				168,959

Figure 9. Jean-André Deluc's logarithmic calculation of the depth of the Dorothea Mine outside Clausthal Zellerfeld, based on barometric pressure readings, as published in the *Philosophical Transactions of the Royal Society* in 1777. © 2017, Royal Society.

Correspondence was practice before it was principle.[595] Subterraneous meteorology, though named for inquiries made underground, was in fact the result of comparative measurements taken atop mountains and in mines. Humboldt's rhythmic, Deluc-like practice of ascending mountains and descending mines spanned the five years of his book's gestation. In fact, Humboldt met Deluc and Saussure during a journey through the Tyrolean Alps in 1795, where he brought with him the eudiometer he used to measure the "virtue" of the air in the mines.[596] Returning to Franconia in the winter of 1795/96, Humboldt later described being

[595] In a review Humboldt wrote for Usteri's journal in 1791, Humboldt described Thaddäus Haenke's practice of ordering plants of the Sudeten Mountains "in the order in which he found them" (rather than according to Linnaean taxonomy) as being preferred by the vertically mobile naturalist. By the time Humboldt arrived in Freiberg, then, he had already conceived of vertical travel as a critical practice in the geography of plants. See *Annalen der Botanik* (1791): 78-83: "Da er sich, von der Ebene, also von der wärmeren und dichteren Luftregion in die kältere und dünnere der Bergkuppen begab, so ist diese Methode der systematischen gewiß vorzuziehen."

[596] Karl Bruhns, *Alexander von Humboldt. Eine wissenschaftliche Bibliographie in drei Bänden*, vol. 1 (Leipzig: Brockhaus, 1872), 169-70. The Alpine journey took him into mines as well. See Humboldt to Christiane von Waldenfels, Oct. 1795, *Jugendbriefe*, 462: "Wir gingen immer zu Fuß den ewigen alten Weg über Thun, Interlachen, Lauterbrunn, das Bergwerk, Grindelwald (wo ich Reinhards Freund, den Wirth leider! nicht zu Hause traf),…"

"engaged in taking corresponding eudiometric measurements on high mountains and in the lowlands," as, of course, in the mines.[597] Though he quit his post as a mine official in early 1797, Humboldt continued to develop his work on mine airs during further Alpine travels. It was in Salzburg in 1798, after "testing out my great collection of instruments atop the summits of the neighboring peaks," that Humboldt completed his "great eudiometric work."[598]

For Humboldt, the underground was not a space apart but one that corresponded, in ways familiar and unfamiliar, to the world above. The expression that nature knows no over- and under-ground was not meant to equate or confound terrestrial and sub-terrestrial spaces. Rather, it may be read as a methodological statement, suggesting that the same scientific practices and instruments may be applied above as below the surface of the earth. In fact, Humboldt's theory of mine airs rested upon a fundamental distinction between meteorological phenomena above and below the earth's surface. Whereas "the *over-ground* aerial regions are differentiated in regular stratified increments (decreasing in oxygen and carbon dioxide, strengthening electrical charge and so on)," Humboldt believed that "*underground* aerial regions" are primarily "modified by local-conditions"—e.g. the amount and rate of airflow, the size and shape of the shafts and galleries, and the presence of water, wood, and subterranean plants.[599] Analogous methods yielded contrasting results.

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[597] Humboldt to Carl Freiesleben, 2 Oct. 1796, *Jugenbriefe*, 529-30: "Ich habe nun ein großes Eudiometerisches Werk vor. Ich stelle nicht bloß hier zu bestimmen Stunden mit 2—3 correspondirenden Eudiometern auf hohem Gebirge, in der Ebene p. alle Tage Versuche an, sondern ich analysire besonders die Winde."

[598] Alexander von Humboldt (1806), *Aus meinem Leben*, 56: "Ich verbrachte den Winter mit nutzlosem Warten in Salzburg, wo ich mich mit Meteorologie beschäftigte und wo ich Gelegenheit nahm, die große, von mir zusammengestellte Instrumentensammlung an den benachbarten Berghöhen zu erproben. In Salzburg beendete ich auch ein Werk über die matten Wetter in Bergwerken und die Mittel, ihre Schädlichkeit für die menschliche Natur herabzusetzen."

[599] Humboldt, *Ueber die unterirdischen Gasarten*, 57: "In der *überirdischen* Luftregion unterscheiden sich die höhern Schichten wesentlich (durch mindern Sauerstoff und Kohlensäure-Gehalt, stärkere elektrische Ladung u. s. f.) von den untern, der Erdfläche näheren Schichten. In der *unterirdischen*

This general conception of vertical space was already decades in the making by the time Humboldt set foot in the mines of Freiberg and Franconia. Fixed within a set of poetic tropes and aesthetic motifs, vertical correspondence unified an otherwise heterogenous travel culture. In 1767, the Hessian miner Franz Ludwig von Cancrin published a description of mining operations throughout central Europe "in order to give dilettantes and travelers a taste of the mines" before venturing in themselves.[600] The work heralded a new era in which the travel routes of the educated classes drew inspiration from the revitalization of Germany's mining industry after the Seven Years War (1756–63). This period saw the establishment of mining academies in Schemnitz (1762-1770) and Freiberg (1765). A series of lectures followed in Berlin around 1770, along with a mining school in Clausthal-Zellerfeld in 1775. From this "underground enlightenment" arose a culture of travel that combined scientific inquiry and sublime aesthetics in the subterranean.[601]

In the second half of the eighteenth century, shifting sensibilities were documented by travelers' entries in the logbooks kept atop mountain summits and in the homes of cave guides. In the same year as Cancrin's underground travel guide, a telling exchange can be read between

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Luftregion lassen sich ähnliche Unterschiede nicht angeben. Hier wird alles durch Lokal-Verhältnisse modificirt."

[600] Franz Ludwig von Cancrinus, *Beschreibung der vorzüglichsten Bergwerke* (Frankfurth an dem Main: Andreäischen Buchhandlung, 1767), Vorrede: "Ich habe dieses Werk um deswillen in den Druk gegeben, damit ich den Anfängern und den Reisenden der Bergwerkskunde einen Vorgeschmak von denen Bergwerken ... machen mögte."

[601] See Nicolaas A. Rupke, "The Study of Fossils in the Romantic Philosophy of History and Nature," *History of Science*, *21* (1983): 389-413; Jakob Vogel, "Aufklärung untertage: Wissenswelten des europäischen Bergbaus im ausgehenden 18. und frühen 19. Jahrhundert," in *Staat, Bergbau und Bergakademie: Montanexperten im 18. und frühen 19. Jahrhundert*, eds. H. Schleiff and P. Konečny (Stuttgart: Steiner, 2013), 13–31. As Albrecht Classen observed, it was not mountains themselves but the treasures within them that gave alpine peaks their allure in the late medieval and early modern literature that anticipated the eighteenth-century's aesthetic embrace of elevation. Albrecht Classen, "Terra Incognita? Mountains in Medieval and Early Modern German Literature," in *Heights of Reflection: Mountains in the German Imagination from the Middle Ages to the Twenty-First Century*, eds. S. Ireton and C. Schaumann (Rochester, NY: Camden House, 2012), 35-56, on 46.

two parties who climbed the Harz's highest peak, the Brocken, some 30 kilometers east of Clausthal-Zellerfeld. Speaking for a group of seven middle-class men (identified variously as "preacher" and "magister"), one traveler noted the party's preference for the Brocken's summit over its underground counterpart, the nearby Baumann's Cave. The judgment elicited a defense not of the cave itself, but of a vision that beheld summit and subterranean together. One Logbook entry, signed by "Hans Sachs reincarnate" (the sixteenth-century artisan-poet) observed that:

> Of the Brocken one can say
> That it has already borne those,
> Who spurn the Baumann's Cave
> And rejoice only in the Brocken…

But a change was underfoot, and the Baumann's Cave could now be counted "amongst the landmarks of our time." The poem concludes:

> Happy is the wise man,
> Who esteems both.[602]

Logbooks like the *Brocken-Stammbuch* (beginning in 1753), or the *Jahrbuch* kept at the Baumann's neighboring Biel's Cave (beginning in 1788), help re-trace the travel patterns that took shape in the second half of the eighteenth century. The most well-trodden route connected the depths of Biel's and Baumann's Caves, notched in the valley of Elbingerode, with the heights of the Brocken, which rises some 680 meters above the caverns—an ascent (or descent, depending) just greater than the era's deepest mines. "It is an unforgettable thing," wrote a

[602] It is very possible that the cave's guide, Christian Friedrich Becker, penned this entry. Hans Sachs was known as a "shoemaker intellectual," a cobbler turned *Meistersinger*. Perhaps Becker knew of this mythology when he, a mine foreman, composed his own verses about the cavern. (See Joan W. Scott and Eric Hobsbawm, "Political Shoemakers," in *Worlds of labour: further studies in the history of labour*, ed. Eric Hobsbawm (London: Orion Books, 1984), 103-30, on 111.) The entry follows as in Aug. 1767, *Jahrbücher des Brockens von 1753 bis 1790* (Magdeburg: Johann Adam Creutz, 1791), 95: "Die Baumannshöhle auch wohl ist | Ein Sehenswürdig Ding zu dieser Frist, | Doch von dem Brocken kann man sagen, | Daß er schon manchen hat getragen, | Der verachtet die Baumannshöhle | Und freut sich des Brockens mitt Leib und Seele | Zufrieden ist der weise Mann,| Der beides hat gesehen an. (Hans Sachs redivivus.)"

Nürnberg baron in 1780, "to inspect the famous Baumann's Cave and climb the Brocken, and to have beheld both on a single day."[603] That same year, Goethe made a request of his mentor Trebra, namely that he produce a geognostic map that proceeds "from the summit of the Brocken ... to the deepest shafts of the Harz mines" in order to "see such various rock formations with a single set of eyes."[604] Three years later, Goethe attained such a view with his own eyes, making a Baumann-to-Brocken tour with Trebra himself. At the end of the decade, a twenty-year-old Alexander von Humboldt signed his own name in Becker's Logbook, two days after summitting the Brocken with Göttingen University classmates. Inverting Humboldt's route, three students from Halle wrote in June of 1793 that having "climbed and crawled through Biel's Cave" they would carry on "to the higher regions and climb the old Brocken."[605]

Humboldt was one of over a thousand visitors who recorded their names in Biel's Cave between '88 and '95. From its Logbook we know that an astonishingly wide range of people participated in the rhythms he made so famous—men and women, noble and bourgeois, miners, lawyers, rectors, philologists, musicians, whole families, groups of university students, and many more. Where bodies wandered minds followed: the juxtaposition of height and depth pervades both logbooks. "Seize my hand, brother," waxed one Swiss traveler in 1784, "and feel joy upon

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[603] K. Welser, 1780, in C. E. Nehse, *Brocken-Stammbuch mit Scherz und Ernst, Witz und Laune, Weisheit und Einfalt in Gedichten und Prosa vom Mai 1753 bis Mai 1850* (Sondershausen: Eupel, 1850), 46: "mir unvergeßlich, an Einem Tage die berühmte Baumannshöhle befahren und den Brocken bestiegen und beydes besehen zu haben."

[604] Goethe to Herzog Ernst von Gotha, 27 Dec. 1780, in Walther Herrmann, "Goethe und Trebra: Freundschaft und Austausch zwischen Weimar und Freiberg," *Freiberger Forschungshefte: Kultur und Technik* D9 (Akademie-Verlag: Berlin, 1955), 50: "Wie ich denn alle Aufsätze hiervon an Trebra zu kommuniziren im Begriff stehe, mit der inständigen Bitte, daß er auf eben die Weise vom Gipfel des Brockens, der aus Granitfelsen besteht, bis in die tiefsten Schachten der Harzer Bergwerke, wie ich es gethan, die Schichten stufenweise verfolgen möge. Wenn wir nun gegen einander zurücken, uns über die Namen der Gesteinarten vergleichen und so verschiedene Gebirge mit einerlei Augen sehen, können wir wohl ein hübsches Stück Land für die Naturgeschichte erobern."

[605] 3 June 1789, in *Die Jahrbücher*, 152; 5 June 1793, ibid., 188: "Wir 3 hallische Studenten befuhren den 5ten Jun. früh die Bielshöhle und fanden uns hinlänglich für das Herumklettern und Herumkriechen belohnt; nun werden wir uns in die höhern Regionen begeben und den alten brocken besteigen."

the high mountain summits, as in the valley's depths." "[I] rose out of the depths and up to the heights," wrote a Saxon miner atop the Brocken in 1818, describing his ascent from the mines of Clausthal-Zellerfeld.[606]

A vertical Romanticism thus took hold in the Harz, linking physical descent and spiritual elevation.[607] "Great is the architect of worlds!" wrote a Berlin statesman in August of 1788, having found the works of his god "High in the airs of heaven [and] Deep in the chasms of the earth." Similar verses echoed again and again through Biel's Cave, as in April of 1791 when a traveler from Hamburg found the "rich blessings" of God "Atop the Biel-Stone's green heights, | As in its abysmal depths."[608] The following winter, Eisenach salonnière and poet Julie von Bechtolsheim climbed through the eleven chambers of Biel's Cave alongside her two sisters and her two nieces. "With deep admiration," she wrote in the Logbook, "three sisters navigated the remarkable Biel's Cave on 20 February"—a month that seldom saw visitors.[609]

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[606] J. Ronca, 31 May 1784, in Nehse, *Brocken-Stammbuch*, 67: "Nimm Bruder, unser Lebewohl, und reise, wie man reisen soll, durchs schöne Alpenland; Schlag Bruder Hand in Hand, fühl auf der Berge hohen Spitze, der tiefen Thäler Glück"; F. A. Kramer, 21 Aug. 1818, in ibid., 143–44: "Und stieg aus der Tiefe zur Höhe heran."

[607] On caves, mines, and depth in German Romanticism, see Brigitte Peucker, *Lyrical Descent in the German Romantic Tradition* (New Haven: Yale University Press, 1987); Theodore Ziolkowski, "The Mine: Image of the Soul," in *German Romanticism and its Institutions* (Princeton, New Jersey: University of Princeton Press, 1990), 18-26; Kate Rigby, "Up and under Mountains," in *Topographies of the Sacred: The Poetics of Place in European Romanticism* (Charlottesville and London: University of Virginia Press, 2004), 131-172; Holly Watkins, *Metaphors of Depth in German Musical Thought: From E.T.A. Hoffmann to Arnold Schoenberg* (Cambridge: Cambridge University Press, 2014).

[608] J. F. Gedike, 4 Aug. 1788, in *Die Jahrbücher*, 147: "Groß ist der Weltenerbauer! | Mit ehrfurchtsvollen Schauer | hab ich auch hier sein Werk gesehn. | Hoch in des Himmels Lüften, | Tief in der Erde Klüften…"; D. R. Hudtwalcker, 2 Apr. 1791, in ibid., 162: "Auf des Bielsteins grünen Höhen, | Wie in seiner Felsenklüfte tiefen, | Fühlt ich einer hohen Allmacht leises Wehen, | Sah ich ihren reichen Seegen triefen."

[609] 20 Feb. 1792, in ibid., 169: "Mit tiefer Bewunderung befuhren drey Schwestern die merkwürdige Bielshöhle den 20ten Febr. Julie F. F. von Bechtolsheim geb. von Keller, August F. F. von Bechtolsheim geb. von Keller, Luise R. Fr. Fr. Grote geb. von Keller, Sophie Bechtolsheim, Julie Bechtolsheim, Töchter der zweiten Schwester."

One of 46 women counted amongst the Logbook's 1,130 visitors, Bechtolsheim's entry struck a defiant tone. The same tone resonates through much of her poetry, where mountains, subterranean springs, and craggy cliffs form the topography of her verse. Bechtolsheim wrote at a time when Romantics emphasized nature's essential femininity, especially the trope of the "womb of the earth," and sometimes fetishized mineral extraction as an act of rape. "Kindly permit that your womb | Be ransacked by the diligent hand | Of the unquenchable thirst of man | Seeking gold and silver-ore that lay in waste…."[610] So wrote Friedrich von Hardenberg (Novalis) in a perverse ode to the "Mother Mountains" of the Harz. Bechtolsheim shared Novalis's assumption about nature's femininity; but she wielded it towards a different end. Her Harz-inspired poetry can be read within a growing movement of men and women who renegotiated tropes about women's proximity to "Mother Earth" to argue for privileged insight into the natural world.[611] Defying the Weimar literary elite who, two years after her tour through Biel's Cave, said she lacked the requisite "interior matter" for "the depiction of scenes of Nature," Bechtolsheim instead spoke *through* nature.[612] She anthropomorphized the mountains, grottos,

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[610] Friedrich von Hardenberg, "Der Harz," in *Novalis. Werke und Briefe*, ed. Alfred Kelletat (München: Winkler-Verlag, 1962), 14: "Gütig ließest du zu, daß dir dein Eingeweid | Mit der emsigen Hand durchwühlt | Nach verderbendem Gold und nach dem Silbererz | Unersättlicher Menschendurst…."

[611] Consider the "Allgemeine einleitende Bemerkungen" in Christian Friedrich Harleß, *Die Verdienste der Frauen um Naturwissenschaft…* (Bonn, 1830). Denise Phillips notes that around a hundred women belonged to learned societies in Germany at the end of the eighteenth century. Indeed, in caverns as in natural history societies throughout Germany, women's presence was increasingly viewed as a marker of learned sociability. In the "Safety Rules" with which Rosenmüller began his 1804 *Die Merkwürdigkeiten der Gegend um Muggend*, for instance, he points to women's presence in the Rosenmüller Cave to prove the *Höhleninspektor*'s safe guidance. (Phillips, *Acolytes of Nature*, 69, 156.)

[612] Julie von Bechtolsheim to Christoph Martin Wieland, 2 Jan. 1794, in SLUB, H.43, Bd.9, Bl. 13: "Mangel an innerem Gehalt. Also ... Gedanken-Leere!" Bechtolsheim conceded: "My subject is not depictions of scenes of Nature, but rather ... an epistle tone blended with a superficial philosophy of life." ("Allein mein Fach ist nicht Darstellungen von Scenen der Natur, sondern die leichtere flüchtige Poesie von der ich obenhin sprach, und der Epistel Ton mit einem bisher oberflächlichen Philosophie des Lebens vermischt.") Alix Cooper has described "a gendered politics of description" in eighteenth-century natural sciences, which allowed for female participation in poetic, rather than naturalistic, descriptions. See Alix Cooper, "Picturing Nature: Gender and the Politics of Natural-Historical Description in Eighteenth-Century Gdańsk/Danzig," *Journal for Eighteenth-Century Studies* 36, no. 4 (2013): 519-29.

springs, and streams of the Thuringian Forest, published under the pseudonym "a mountain-dweller" (*eine Bergbewohnerin*), and described the spring seeds "wrested from the earthly womb" as her "sisterly soul."[613] When words failed her, Bechtolsheim told a friend to read her writing "in every autumn flower."[614] "Do you hear them echoing over the shelves of the mountains?" she asked in another poem.[615]

Bechtolsheim's poetic navigation of vertical nature exhibits a gloomy sense of suffering and a yearning for salvation, reminiscent of miners' oral traditions. For while Bechtolsheim—a baroness—moved through high circles of the Weimar intelligentsia, she also engaged mountains and caverns from a gendered subject position that marginalized her intellectual contribution. Nature's vertical extremes became imagined sites of respite for the embattled poet (told that she was, in fact, "no poet"), who wished to demarcate a "powerful, tender" sentimental realm that belonged exclusively to the "female paintbrush."[616] "In my grotto you hide yourself away to frolic," she wrote to a newly-betrothed friend, "Free upon the heights | you'll see me presiding | Shepard of the ancient | the holy forest."[617] In another ballad, she chronicled the fate of a woman who, having been cheated by "the false man," scaled a treacherous path to a high cliff. There she

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[613] [Julie von Bechtolsheim], "Abschiedsworte einer Bergbewohnerin an DIE NEU-VERMÄHLTE im Julius 1810," in GSA 20/129 Bestand Jakob Friedrich von Fritsch; "Frühlingslied," in THsaW Großherzogliches Hausarchiv A XXV, Nr. 1067, Bl. 90-91: "Heimlich entwunden der Erde Schooß, | Drängen hervor sich die Keime; […] Also erkennen sich schwesterlich | Seelen mit zarten Gemüthe…."

[614] Bechtolsheim to Friedrich von Müller, 14 Dec. 1825, in GSA 68/38 Bestand Friedrich von Müller, Bl. 9-10: "Worte, wie gesagt, können meinen Dank nicht fassen; möchten Sie ihn in jeder Herbstblume, in den schon wiederkehrenden Primeln und Veilchen und in den freundlichen Strahlen lesen die uns eine milde Sonne fast noch täglich gewährt!"

[615] Bechtolsheim, "Abschiedsworte einer Bergbewohnerin" (1810), GSA 20/129: "Hörst Du das Echo durch der Berge Stufen | *Vergiss mein nicht* ausharrend Dir noch rufen?"

[616] A decade after Bechtolsheim's correspondence with Wieland, she turned to Friedrich Schiller for support, seeking affirmation and publication opportunities: Bechtolsheim to Schiller, 27 March 1805, GSA 83/194. It was in this letter that Bechtolsheim made her case for the "weiblicher Pinsel."

[617] "Abschied und Empfang im Julius 1810," GSA 20/129 Bestand Jakob Friedrich von Fritsch: "In meinen Grotten bargst Du Dich mit Scherzen | Vor der Gespielen suchend muntrer Schaar"; "Frei auf den Höhen | Siehst Du mich walten, | Hüten den alten | Den heiligen Wald."

"leapt from the precipice" "down into the kingdom of shadows!" that she may "rise up" again "in the form of an angel."[618] For Bechtolsheim, verticality was a language of solace.

Stepping out beyond the Harz and its logbooks, we find the same aesthetics of correspondence and contrast in visual art. Consider the Swiss painter Caspar Wolf, whose fascination with grottos earned him the name "*Höhlenwolf*" (cave-wolf). In his 1778 painting "The Interior of the Bear Cave at Welschenrohr" (**Figure 10**), Wolf depicted his subject on a rocky pedestal, gazing out through the threshold-space that divides nature's "over- and underground." To be underground, Wolf seems to say, is to look above.

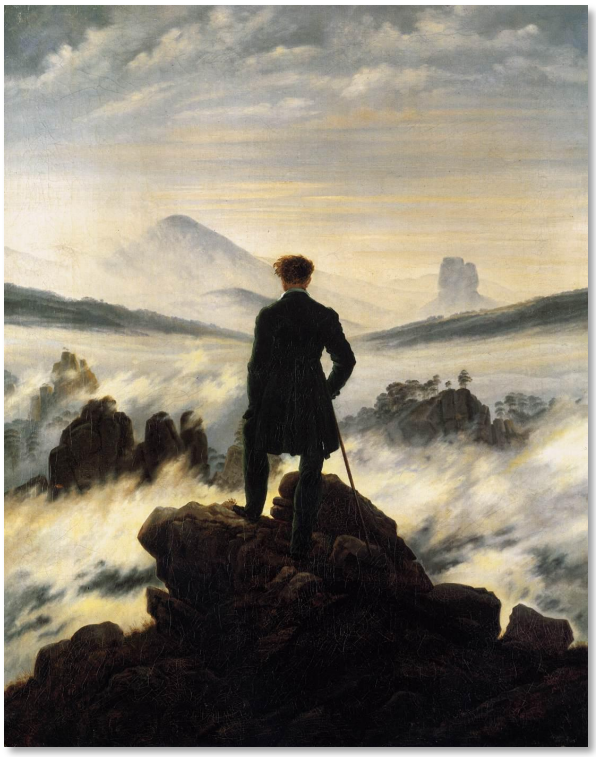

Figure 10. (Left) Caspar Wolf, *Das Innere der Bärenhöhle bei Welschenrohr* (*The Interior of the Bear Cave at Welschenrohr*), 1778, oil on canvas, 42.5 cm. x 34.5 cm. Kunstmuseum Solothurn.
Figure 11. (Right) Caspar David Friedrich, *Der Wanderer über dem Nebelmeer* (*Wanderer above the Sea of Fog*), 1817-18, oil on canvas, 74.8 cm x 94.8 cm. Wikimedia Commons.

[618] Bechtolsheim to Schiller, 27 March 1805, GSA 83/194: "Da sprang sie vom jähen Felsenhang | Hinab in die rauschenden Fluthen […] Hinab! hinab in's Schattenreich! […] Da hebt sich ihr Geist, da webet und wallt | Er freundlich in schimmernder Engelgestalt." The ballad "Der Sprung von Felsen" was first published in the *Journal für deutsche Frauen* that he edited (Heft 2 (February 1806), pp. 61–67.

In Friedrich's "Wanderer above the Sea of Fog" (**Figure 11**) an analogous figure stands atop a Saxon peak pondering the abyss below him. The one inverts the other, much as Humboldt's maps inverted the mine profile. Six years before beginning his famous "Wanderer above the Sea of Fog" in 1817, Friedrich himself wandered into the Harz, where he illustrated mountains and caverns alike. Among his subjects was the grotto-feature "Krochstein," not two kilometers from Biel's Cave, and a "stalagmitic cavern" thought to be Baumann's Cave.[619]

Through paintings and poems, the motifs of the Harz logbooks spread far and wide, increasingly untethered from the travel routes that inspired them. And as Romantics like Hardenberg and E. T. A. Hoffmann sourced tales from mining folklore, ideas about vertical correspondence entered mainstream literary culture. In his novel *Heinrich von Ofterdingen* (1802), Hardenberg described miners as "inverted astrologers": As the astronomer "beholds the heavens, and wanders through its immeasurable firmament," spoke a hermit to a miner,

> so you turn your gaze to the earth and fathom its structure. They study the force and influence of the stars, and you investigate the force of rocks and mountains, and the manifold effects of the layers of the earth and its rock bedding. To them, heaven is the book of the future, while to you the earth reveals the monuments of the former world.[620]

The same cosmological order, which paired the earthly with the astral, is found in Hoffmann's "The Mines of Falun" (1818). Hoffmann drew from existing legends of the great copper pits in

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[619] Herrmann Zschoche, *Caspar David Friedrich im Harz* (Dresden: Verlag der Kunst, 2008), 35–40.
[620] [Friedrich von Hardenberg], "Heinrich von Ofterdingen," in *Novalis Schriften*, 5th ed., Pt. 1, eds. Ludwig Tieck and Friedrich Schlegel (Berlin: Verlag von G. Reimer, 1837), 115: "Ihr seid beinah verkehrte Astrologen, sagte der Einsiedler. Wenn diese den Himmel unverwandt betrachten, und seine unermeßlichen Räume durchirren: so wendet ihr euren Blick auf den Erdboden, und erforscht seinen Bau. Jene studiren die Kräfte und Einflüsse der Gestirne, und ihr untersucht die Kräfte der Felsen und Berge, und die mannichfaltigen Wirkungen der Erd- und Steinschichten. Jenen ist Himmel das Buch der Zukunft, während euch die Erde Denkmale der Urwelt zeigt." Novalis adapted earlier cosmologies based upon correspondence between the earth and the heaves: "As above, so below," reads the Emerald Tablet or Tabula Smaragdina, produced by Arab scholars in early medieval period. Later associated with the philosopher's stone in early modern Europe, the Tablet is known for its analogy between alchemy and astrology, the earthly and the astral.

Sweden.[621] In Hoffmann's rendering, an old miner says that "if the blind mole burrows by blind instinct, it may be that the eyes of man acquire more penetrating sight in the deepest depths of the earth, until they can recognize in the wonderful stones … a reflection of that which is hidden above the clouds."[622] That Hoffmann did not, like Hardenberg or Humboldt, work in mines suggests that by about 1820 writers no longer relied on the embodied experience of vertical travel, but on a cultural consciousness of it.

A striking example of this comes from Elisabeth Kulmann (1808–1825). Despite styling herself as a poet of the underground—"a child of the depths," as she wrote—Kulmann had seen neither mountains nor mines nor caves with her own eyes. The daughter of a German family that emigrated to Russia and fell upon financial straits, Kulmann's short life was largely confined to their home in St. Petersburg. There, Kulmann wandered nature's vertical limits in the mind, extrapolating like Trebra from an array of visuals—paintings, ceiling frescos, copper engravings. "She seemed to have taken great pleasure in arranging all these mountain scenes alongside one another," her tutor recalled, "and began to work on a grotto with a special passion."[623]

In Kulmann we find verticality at a distance. And in her posthumously published poems and letters, we see how she conceived of the earth-system, like Humboldt, as a set of vertically complementary domains. For her, nature was composed of two elemental spheres, which envelope the solid earth: the "overworld" or "aerial kingdom" and the "underworld" or "water-

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[621] Just a year before Hoffmann wrote "The Mines of Falun" in 1817, the third volume of a German-language work on Scandinavia was published in Göttingen, featuring the mines of Falun in its frontispiece and detailing the working lives of the miners there: Johann Friedrich Ludwig Hausmann, *Reise durch Scandinavien in den Jahren 1806 und 1807*, vol. 3 (Göttingen: Röwer, 1816).
[622] E. T. A. Hoffmann, "The Mines of Falun," in *Tales of Hoffman*, trans. R. J. Hollingdale, Stella and Vernon Humphries, and Sally Hayward (New York: Penguin Books, 2004), 316-18.
[623] Kulmann, *Sämmtliche Gedichte*, 53, 94: "Sie scheint mit Wohlgefallen alle Bergscenen in diesem Gedichte aneinander gereiht zu haben, und wenn wir uns nicht irren, mit vorzüglicher Liebe an einer Grotte gearbeitet zu haben…."

kingdom." Humboldt made a similar tripartite distinction: "The solid surface of the earth has two envelopes [*zweierlei Umhüllungen*]," he wrote, "the liquid and the aeriform."[624] For him, islands were submarine mountains and mountains, "green forested shoals" rising through the "aerial ocean."[625] Kulmann viewed subterranean aquifers as inverted clouds and clouds as floating aquifers. Astonished by this last feature of Kulmann's cosmos, her tutor reflected that "with respect to underwater phenomena, everything appeared inverted by her estimation, all heads flipped under, all feet turned up."[626] But this, of course, was just the point.

Nature's Measuring Rods

By the mid-nineteenth century, as imperial projects sounded new depths in the Atlantic and triangulated new heights in the Himalayas, savants began using mountains and mines as measuring rods to convey this new scale. Mountains proved particularly useful while converting between a dizzying array of units—Paris feet and English feet, meters and toises, the seaman's fathoms and the miner's *Lachter*—to say nothing of what contemporaries called "absolute depth"

[624] Humboldt, *Kosmos*, *2*, 529: "Die starre Oberfläche der Erde hat zweierlei Umhüllungen, tropfbar-flüssig und luftförmige. Contraste und Analogien, welche diese Umhüllungen, das Meer und die Atmosphäre, darbeiten in Aggregat- und Electricitäts-Zuständen, Strömungen und Temperatur-Verhältnissen. Tiefen des Oceans und des Luftmeeres, dessen Untiefen unsere Hochländer und Bergketten sind." Cf. Humboldt, *Kosmos*, *1*, 303-04.

[625] Humboldt, *Kosmos*, *1*, 321: "Das Luftmeer ruht theils auf der festen Erde, deren *Bergketten* und Hochebenen, wie wir schon oben bemerkt, als grüne, waldbewachsense *Untiefen* aufsteigen; theils auf dem Ocean, dessen Oberfläche den beweglichen Boden bildet, auf dem die unteren dichteren, wassergetränkten Luftschichten gelagert sind."

[626] Kulmann, *Sämmtliche Gedichte*, 14: "…alles auf der Erde sich befinde war für sie belebt; sondern auch alles, was den beiden andern Welten angehörte, in ihrer Sprache der Ober- und Unterwelt. […] Alles im Reiche der Luft sich Darstellende machte die Oberwelt, und alles im Wasserreiche Webende die Unterwelt aus. […] Jedes Wölkchen und jede Wolkenmasse war für sie ein belebtes Wesen; und jeden Wiederschein von Erd- und Luftkörpern im Wasserspiegel sah sie als die wunderbaren Bewohner der staunenswurdigsten aller drei Welten, der Unterwelt an. Denn die Gegenstände des Luftreichs stellten sich ihrer Einbildungskraft doch immer noch, gleich denen der Erde, in ihrer natürlichen Lage, d. i. das Haupt nach oben und die Füße nach untern, dar; dies war aber nicht mehr der Fall mit den Gegenständen des Wasserreichs, wo alles in einer ihren Erwartungen widersprechenden Lage erschien, alle Häupter nach unten und alle Füße nach oben gekehrt."

(below the surface of the earth) and "relative depth" (below the surface of the sea).[627] For Humboldt, the instrumentalization of mountains and mines followed directly from his understanding of nature's vertical architecture.

Humboldt saw the interplay of disparate natural phenomena above and below the surface of the Earth and its oceans as characterized by principles of correspondence, ratios written into nature. As studies in mines had shown Humboldt that nature knows no over- and underground, so his *Essay on the Geography of Plants* (1805) argued that "the opposite limits of plant life produce beings with a similar structure."[628] He found a similar relationship in temperature changes above and below sea-level. His famous isothermal maps charted mean annual temperatures across the globe, their "iso-lines" linking diverse regions with common climates. These maps already accounted for the prominence of continents and their mountain chains. Yet this perspective, too, could be unfolded into a cross-sectional view of the aqueous and aerial oceans. "So wonderful is the distribution of heat across the globe," Humboldt wrote in his *Political Essay on the Kingdom of New Spain*,

> that we find colder strata as we ascend through the aerial ocean, while in the depths of the sea the temperature decreases in proportion as we descend below its surface. In both elements the same latitudes, so to speak, indeed all climates, are unified. At different distances from the surface of the ocean, but upon the same vertical plane, we encounter air- and water-strata of the same temperature.[629]

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[627] 1 English foot = 0.9383 Paris feet; 1 meter = 0.5131 toises; and 1 Freiberger Berglachter = 1.9490 meters, while 1 English fathom is 1.8293 meters. Some sources list as many as 27 regionally differentiated *Lachter* in German mining regions.

[628] Alexander von Humboldt and Aimé Bonpland, *Essay on the Geography of Plants*, ed. Stephen T. Jackson, trans. Sylvie Romanowski (Chicago: University of Chicago Press, 2009), 65.

[629] Humboldt, *Neu-Spanien*, *3*, 2: "So wunderbar ist die Hitze über die Erdkugel vertheilt, dass je höher man sich im Luft-Ozean erhebt, man auch immer kältere Striche findet; da sich hingegen Temperatur in der Tiefe des Meers in dem Maas, wie man sich von der Wasserfläche entfernt, vermindert. In beiden Elementen vereinigt dieselbe Breite, so zu sagen, alle Klimate, und in ungleichen Entfernungen von dem Spiegel des Ozeans, aber auf gleicher Vertikal-Fläche, trift man Luft- und Wasser-Lagen von derselben Temperatur an."

In other words, the climatic characteristics of the earth typically associated with latitudinal change could also be read in profile, mapped onto alpine heights and oceanic depths. "Strata" is the word on which this view hinges, hearkening to the subterranean roots of Humboldt's global physics. Recall Humboldt's Kulmann-like conception of nature: the two "envelopes" (liquid and aeriform) that encompass the solid earth. In each of these three domains, Humboldt saw stratigraphy. By the time he wrote his five-volume *Kosmos* (1845–62), Humboldt regularly employed the phrase "superimposed strata" to describe earth, ocean, and atmosphere alike.[630]

The vertical architecture of Humboldt's cosmos shows how, by the mid-nineteenth century, a way of working and traveling had become a way of knowing and thinking. The sedentary life Humboldt led in his later years meant perceiving the natural world virtually, much as Kulmann had. Humboldt's private notes and letters show the Cosmos years as a moment in which the observable world seemed to expand ever more along the y-axis.[631] Massive commercial and colonial enterprises, like the surveying of the Indian subcontinent and the laying of a transatlantic telegraph, opened up staggering new heights and depths.[632] In the same years

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[630] See variations of "über einander gelagerten Schichten" in Humboldt, *Kosmos*, *1*, 64, 84, 335; Humboldt, *Kosmos*, *2*, 146, 378; SBB, Nachl. Alexander von Humboldt, gr. K. 11, Nr. 59a.

[631] Knowledge of the globe's figure altered dramatically in Humboldt's lifetime. As the Italian mathematician Guglielmo Libri reminded him in 1825, it was in antiquity that the Greek geometer Xenagoras argued that no mountain is higher and no sea deeper than ten stadia (roughly 1,850 meters)—a hypothesis that Forster reiterated in his lecture notes from Kassel, "presuming" that the surface of the earth expanded some 19,000 Paris feet (6,172 meters) above and below that of the sea. Forster took Chimborazo to be the world's highest peak at 19,302 Paris feet, as compared to Humboldt's measurement of 20,100 Paris feet. (SBB, Nachl. Alexander von Humboldt, gr. K. 11, Nr. 22. Libri pointed Humboldt to "une citation d'un passage de Plutarque [Plutarch's *Lives of the Noble Greeks and Romans*] dont je vous avoirs . . . sur la relation qui existe entre la hauteur des montagnes, et la profondeur de la mer…." Forster, AA VI, *2*, 905, 908: "Wie tief die größte Tiefe des Meeres sey, weiß man nicht, doch ist zu vermuthen, daß es höher nicht, als die höchste Berge, d.i. 19000 Fuß oder 3000 Toisen tief seyn könne.")

[632] On sea-soundings and Himalayan surveying around mid-century, see Michael Reidy and Helen Rozwadowski, "The Spaces in Between: Science, Ocean, Empire," *Isis* 105 no. 2 (2014): 338–51; Lachlan Fleetwood, "'No former travellers having attained such a height on the earth's surface': Instruments, inscriptions, and bodies in the Himalaya, 1800-1830," *History of Science* 56, no. 1 (2018): 3-34; Lachlan Fleetwood, "Bodies in High Places: Exploration, Altitude Sickness and the Problem of Bodily Comparison in the Himalaya, 1800-50," *Itinerario* 43, no. 3 (2019): 489-515.

that the deepest point sounded in the ocean descended from 4,600 to 7,706 fathoms (in 1840 and 1852, respectively), the roof of the world grew from the Andean volcano Chimborazo, measured by Humboldt himself at 20,100 Paris feet (about 6,529 meters), to the Himalayan peak Kanchenjunga, recorded at 26,438 (or 8,588 meters) in 1849. Enmeshed in a network of British astronomers, American oceanographers, and German miners, Humboldt compiled notes on the morphing physiognomy of the earth. Often, he used the mines of Guanajuato in New Spain and Freiberg in Saxony as vertical reference points.

Humboldt thus used nature to understand nature, transposing the features of one domain into another. Nature's ablest measuring rods were the mountains and mines that he consistently recorded throughout his life. In the first volume of *Kosmos*, for example, he calculated "[f]rom the highest pinnacles of the Himalayas" to the "depth of the coal basin in Liege"—which "lay as deep below the surface of the sea as Chimborazo rises above it"—"a vertical distance of 45,000 feet, that is, 1/435 of the Earth's radius."[633] Here Humboldt drew upon estimates made by Prussian mining officers, who sent him reports and manuscripts throughout the 1840s and 50s.[634] Tellingly, Humboldt often grouped these reports in a folder titled "Ocean & Depths" (*Meer u. Tiefe*). In that folder, we see how mountains were equally useful in fathoming the depths of the ocean. On one note (**Figure 12, left**), Humboldt observed how British naval officer James Clark Ross described a depression in the South Atlantic, just below the Tropic of Capricorn, as "very little short of the elevation of Mount Blanc above it."[635]

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[633] Humboldt, *Kosmos*, *1*, 419–20, n. 95.
[634] SBB, Nachl. Alexander von Humboldt, gr. K. 11, nr. 60; gr. K. 11, nr. 42; gr. K. 11, nr. 14; gr. K. 11, nr. 116-17; kl. K. 14, nr. 10.
[635] SBB, Nachl. Alexander von Humboldt, gr. K. 11, nr. 72, Blatt 7r. Humboldt cited J. C. Ross, *A Voyage of Discovery and Research in the Southern and Antarctic Regions, During the Years 1839–43*, vol. 1 (London: John Murray, 1847), 26.

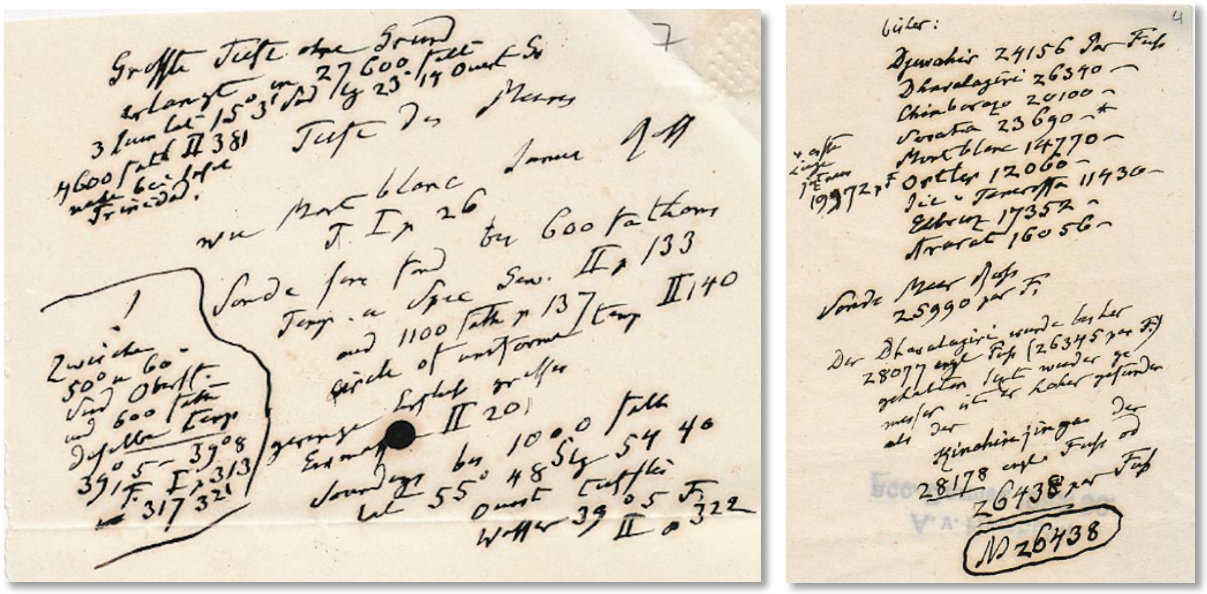

Figure 12. (Left) Humboldt's notes on James Ross's *A Voyage of Discovery and Research in the Southern and Antarctic Regions* (1847). Note especially: "Tiefe des Meeres wie Montblanc James Ross T. I p. 26." (Right) Humboldt's notes on the world's most prominent peaks, as reported to him in the late 1840s by Joseph Dalton Hooker. In the center of the page, below Mt. Ararat, are the words "Sonde Meer Roß 25990 par[iser] F[uss]." Digitalisierte Sammlungen SBB, Nachl. Alexander von Humboldt, gr. K. 11, Nr. 72, Bl. 7r and ibid., gr. K. 8, Nr. 48a, Bl. 4r.

Beside this note lay a letter from the Irish astronomer Edward Sabine, who wrote to Humboldt in 1853 "of a successful attempt which has been made by Captain Denham of the Royal Navy … to reach the bottom of the sea at a depth much exceeding that of the highest summits of the Himalaya."[636] Humboldt's notes on the summits of the Himalaya illustrate the same method in reverse, now using the depths of the ocean to take stock of mountain heights (**Figure 12, right)**. When Hooker sent him the latest measurements of Tibet's tallest peaks, Humboldt compared them not only with Montblanc and Chimborazo, but also with "ocean soundings [by] Ross."[637]

[636] Edward Sabine to Humboldt, 21 Jan. 1853, SBB, Nachl. Alexander von Humboldt, gr. K. 11, Nr. 65.
[637] SBB, Nachl. Alexander von Humboldt, gr. K. 8, nr. 48a, Blatt 4r.

What began as a practice of vertical movement had evolved into a practice of vertical measurement. By 1856, Humboldt read in Washington's *National Intelligencer* that American oceanographer Matthew Fontaine Maury had "discovered" a "telegraphic plateau" in the North Atlantic. Two years later, the first telegraphic communication was made between Ireland and Newfoundland.[638] Earlier, in 1853, Maury told Humboldt of a vertical profile that spanned the Atlantic from continent to continent, just as Humboldt had mapped Mexico from coast to coast. "The 'Ino Adams' on her way from the Capes of Virginia to the Coast of Africa," Maury wrote, "will I hope, give us a line of deep sea soundings entirely across the Atlantic, and so enable us to present a vertical section of the Atlantic basin and compare it with a vertical section of this continent between the same parallels."[639] In Maury's mind, the Atlantic basin completed a great hypsometric profile that spanned America and Europe. When he unveiled his "Vertical Section [of the] North Atlantic" in *Physical Geography of the Sea* (1855), he began with a telling nod to the geographic imaginary he associated with Humboldt, recording a distance of nine miles "in a vertical line" "[f]rom the top of Chimborazo to the bottom of the Atlantic."[640]

Conclusion: Re-Routing Humboldt's Science

Long before its association with Humboldt, Chimborazo appeared as a vertical reference point in the Logbook of Biel's Cave. When one visitor expressed disappointment in the cavern as compared to the nearby Baumann's Cave, the Logbook's editor, Schröder, retorted: "To deny nature the splendor and grandeur it shows in Baumann's Cave … is to go so far as to say the

[638] SBB, Nachl. Alexander von Humboldt, gr. K. 11, nr. 70, Blatt 3r.
[639] Friedrich von Gerolt to Humboldt, in *Alexander von Humboldt und die Vereinigten Staaten von Amerika. Beiträge zur Alexander-von-Humboldt-Forschung, 19. Briefwechsel*, ed. Ingo Schwarz (Berlin: Akademie Verlag, 2004), 327.
[640] Matthew Fontaine Maury, *Physical Geography of the Sea* (New York: Harper & Brothers Publishers, 1855), 208.

Brocken is not a mountain because it is not so high as Chimborasso."[641] The logic of Schröder's rebuttal is revealing of the way travelers drew local geographical features into conversation with distant ones, pairing Andean summits with German peaks and caverns. A little over a decade later, Humboldt himself noted the Brocken's comparatively modest height on his "Tableau physique des Andes," crowned by Chimborazo.

A nineteenth-century biographer once asked: "in what epoch of history has a man wandered through air and sea and land, over the summits and into the shafts of the mountains [*Gipfel und Schachte der Berge so durchwandert*], like our Alexander von Humboldt?" His patriotic answer was, of course, that "He is the only one!"[642] But Humboldt, as I have shown, was just the tip of the *Berg*. This wide-angle approach to Humboldt, which situates his geographical vision amongst miners, cave guides, and mountain-goers, reveals the multidimensionality of vertical thinking in his time. Beginning with the cartography of Trebra, I have shown how a three-dimensional visualization of the subsoil derived from working worlds, while stimulating cultures of travel and art. For the poets and painters of the Harz, vertical travel offered communion with God and sublime aesthetic education. Transit through vertical space defined the spiritual geography of miners' folk traditions, much as cliffs and grottos offered Harz traveler Julie von Bechtolsheim a language of solace. Yet amidst the diverse aspirations that gained expression on the vertical plane, a strikingly consistent logic undergirded this way of moving and thinking. The *Bergglöcklein* aloft in Freiberg said it best: "So often as you go into the depths, | Think up to the heights."

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[641] A[nmkerung] d[es] H[erausgebers], 18 July 1793, *Die Jahrbücher*, 202: "Der Natur aber in der Baumannshöhle Größe und Würde ganz absprechen, sie ganz verächtlich machen wollen, heiße eben so zu weit gehen, als wenn man den Brocken deswegen keinen Berg nennen wollte, weil er so hoch ist als der Chimborasso."

[642] Hermann Klencke, *Alexander von Humboldt's Leben und Wirken, Reisen und Wissen. Ein biographisches Denkmal*, 7th ed. (Leipzig: Spamer, 1876), 485–86.

The following chapter pivots from vertical nature to vertical territory, showing how the division of labor in Humboldt's global physics drew upon the cameralist and colonial infrastructures within which he worked. Indeed, the vertical scope of that science, spanning mountains and mines, is largely a reflection of the range of the mining technicians and colonial surveyors who carried out "Humboldtian" projects. Here, as elsewhere in the dissertation, it becomes clear that Humboldt's stratified worldview was not merely meant to describe nature, but to shape nature, too. In New Spain especially, vertical consciousness implied vertical colonization.

Chapter Five

Managerial Science from Prussia to Mexico and Back

> *When a government undertakes one of those maritime expeditions that contribute to the exact knowledge of the globe and the advancement of the sciences nothing obstructs the execution of its designs.* […] *Far different is the situation of a private individual who undertakes, at his own expense, a voyage into the interior of a continent over which Europe has extended its system of colonization.*[643]
>
> Alexander von Humboldt, 1812

> *Every schoolboy is familiar with his methods now, but he does not know that Humboldt is his teacher. The fertilizing power of a great mind is truly wonderful; but as we travel farther from the source, it is hidden from us by the very abundance and productiveness it has caused*.[644]
>
> Louis Agassiz, 1869

So great was Humboldt's influence over the science of his age that it seemed, to admirers like Agassiz, he had dissolved into his own ubiquity. This vanishing act is one of the conceits of modern science as it was constituted around the time of Humboldt's death. It was then that "objectivity" took a familiar form, as the ascetic virtue of those who produced self-*less* knowledge, allowing nature to "speak for itself." This new epistemic ethos may have subverted the values of Humboldt's age, when the properly cultivated savant claimed to speak for nature.[645]

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[643] Al. de Humboldt et A. Bonpland, *Voyage aux régions équinoxiales du Nouveau Continent: fait en 1799, 1800, 1801, 1803 et 1804. Tome 1* (Paris, 1814), 39-40: "Lorsqu'un gouvernement ordonne une de ces expéditions maritimes qui contribuent à la connaissance exacte du globe et à l'avancement des sciences physiques, rien ne s'oppose à l'exécution de ses desseins. […] Il n'en est pas de même lorsqu'un simple particulier entreprend à ses frais un voyage dans l'intérieur d'un continent sur lequel l'Europe a étendu son système de colonisation."

[644] Louis Agassiz, *Address delivered on the Centennial Anniversary of the birth of Alexander von Humboldt, under the auspices of the Boston Society of Natural History, by Louis Agassiz, with an account of the evening reception* (Boston, MA: Boston Society of Natural History, 1869). Cf. T. H. Huxley and Louis Agassiz, *Darwin and Humboldt: their lives and work* (New York: Fitzgerald, 1883), 28.

[645] Lorraine Daston and Peter Galison, *Objectivity* (Cambridge, MA: Zone Books, 2007). John Tresch has shown how, well into the nineteenth century, Humboldt's notion of objectivity saw machines and

But to Humboldt's admirers, omniscient ubiquity seemed only fitting for a man whose final act was to present a "physical description of the universe."

This mythology has its origins in Humboldt's own self-portrayal, as a "private individual" who, it is so often repeated, undertook his great American voyage "at his own expense."[646] If Humboldt was not self-less, he sometimes made himself out to be state-less—the credo of the *Weltbürger*, or "world-citizen." A disinterested voyager, allegedly distinct from those who traveled in the name of aggrandizing states and belligerent empires, Humboldt's aims were, as he put it later in life, "purely scientific."[647] A stunning paradox arises: the very man who headed a school of geographic science, a style of spatial thinking, also embodied a sort of placelessness. "His presence everywhere meant that he was nowhere in particular," one scholar has written, "leaving behind no field or school to bear his name."[648] Modern historiography has, in many ways, contributed to this mystification. The school that now does bear his name, "Humboldtian science," is said to characterize such a range of endeavors—from Herschel's global system of observatories and Sabine's studies in terrestrial magnetism to Darwin's theorizing on speciation and Maury's physical geography of the sea—that it too is obscured by the "very abundance and productiveness it has caused."[649]

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instruments as extensions of sensitive knowers and emphasized the collective labor of observation—a thesis taken up in the course of this chapter. See John Tresch, *The Romantic Machine: Utopian Science and Technology after Napoleon* (Chicago: The University of Chicago Press, 2012), 62-87.

[646] Humboldt emphasized this point throughout the first chapter of his *Voyage aux régions équinoxiales du Nouveau Continent*, translated to English as the *Personal Narrative*. Here Humboldt explains how he sought "to obtain permission to visit, at my own expense, the interior of Spanish America" and boasts that "Never had so extensive a permission been granted to any traveller." Alexander de Humboldt, *Personal Narrative of Travels to the Equinoctial Regions of the New Continent, During the Years 1799-1804…*, trans. Helen Maria Williams (London, 1818), 13-14.

[647] Humboldt (1859) in Kurt R. Biermann, ed., *Aus meinem Leben: Autobiographische Bekenntnisse* (Leipzig: Urania Verlag, 1987), 71.

[648] Laura Dassow Walls, "'Hero of knowledge, be our tribute thine': Alexander von Humboldt in Victorian America," *Northeastern Naturalist* (2001): 121-34, on 129.

[649] Susan Faye Cannon, *Science in Culture: The Early Victorian Period* (New York: Dawson/Science History Publications, 1978), 73-110.

This chapter aims to *place* the "school of Humboldt" and *people* the specific institutions that shaped and sustained his science. It seeks to explain how a way of working became a way of knowing, first in Prussian Franconia, then in New Spain, and finally in Berlin. And it argues that the history of Humboldt's science is the history of the labor force involved in its production. When contemporaries spoke of those "formed in the school of Humboldt," they referred to a set of practices and even a certain scientific persona, which combined the affective and aesthetic sensibilities of romanticism with a dedication to instrumentation, precise measurement, and quantification.[650] But this "school" implied nothing of actual institutions.[651] By contrast, this chapter shows how Humboldt's approach to natural inquiry—as a manager of natural and social economies—developed through educational institutes like the *Bergakademie* in Freiberg, the *Bergschule* in Franconia, and the *Real Seminario de Minería* in Mexico City, as through the cameralist and colonial systems of governance that these institutions served. Humboldt may have financed his own journey through the Americas, but the science he practiced there was often financed by the colonial state. The Mining Administration of the Viceroyalty of New Spain in particular, the *Tribunal de Minería*, provided Humboldt access to the same human and instrumental resources he was already accustomed to working with, having made an experimental community of the miners under his charge in Franconia.

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[650] Roderick Murchison as quoted in D. Graham Burnett, *Masters of All They Surveyed: Exploration, Geography and a British El Dorado* (Chicago: The University of Chicago Press, 2001), 98-99.

[651] Notably, Humboldt did belong to informal "research groups." Agassiz himself studied under Humboldt in Paris. Also in Paris, Humboldt was part of a small community of physicists and chemists known as the Society of Arcueil, which gathered in the private homes of Claude Louis Berthollet and Pierre-Simon Laplace and fostered in its younger, student-like members a common "Newtonian" approach to problems across the sciences, "a world of particles governed by forces of attraction." As Maurice Crosland wrote in his history of the society, "Humboldt was perhaps the perfect member of the Arcueil group," being younger than Berthollet and Laplace yet older and already more accomplished that younger members whom he could mentor. (Maurice P. Crosland, *The Society of Arcueil: A View of French Science at the Time of Napoleon I* (Cambridge, MA: Harvard University Press, 1967), 301, 110.)

Few scholars have recognized the "essential continuity" between Humboldt's activities as a state administrator and as an agent of empire.[652] Focusing exclusively on his travel writings, Mary Louise Pratt identified Humboldt as the harbinger of a self-aggrandizing "planetary consciousness," which presented European readers an image of the Americas as a pristine land ripe for the taking.[653] Michael Dettelbach gave form and texture to Pratt's critique, suggesting a "direct line" between the kind of territorial administration he exercised in central Europe and Spanish America. "[A]t the very roots," Dettelbach wrote,

> in the glass tubes of Humboldt's barometer, the needle of his dip circle, and the delicate spring of his chronometer, the 'beginning of scientific travel' and the 'rediscovery of the New World' were means of opening large swathes of America to such large capital ventures as road- and canal-building and mining.[654]

Here Humboldt's science appears an essentially hybrid enterprise, which aimed to orchestrate the "confluence of forces" at work in nature and society. This way of knowing was romantic, administrative, and imperial all at once. For the kind of "aesthetic empire" that Humboldt mapped over the earth—drawing disparate forces into autocratic oversight—implied the calibration of the self and of others.[655]

This chapter pursues the social history of Humboldt's empire of observation, focusing on his sustained engagement with mining administrations. Scholars have long used a political language to describe the collective of savants whose observations Humboldt synthesized from

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[652] Michael Dettelbach, "Romanticism and Administration: Mining, Galvanism and Oversight in Alexander von Humboldt's global physics" (PhD diss., University of Cambridge, 1992), 9.
[653] Mary Louise Pratt, "Alexander von Humboldt and the Reinvention of América," in *Imperial Eyes: Travel Writing and Transculturation* (New York: Routledge, 1992), 109–40. Cf. Mauricio Nieto Olarte, "Alexander von Humboldt y Francisco José de Caldas: americanismo y eurocentricsmo en el Nuevo Reino de Granada," in *Alexander von Humboldt: Estancia en España y viaje americano*, eds., Mariano Cuesta Domingo and Sandra Rebok (Madrid: Real Sociedad Geográfica, 2008), 127-42.
[654] Dettelbach, "Romanticism and Administration," 155, 164.
[655] Michael Dettelbach, "Global physics and aesthetic empire: Humboldt's physical portrait of the tropics," in *Visions of Empire: Voyages, Botany, and Representations of Nature*, eds. David Philip Miller and Hanns Reill (Cambridge: Cambridge University Press, 1996), 258-92.

afar, a "republic of instruments," as Marie-Noëlle Bourguet has written.[656] In Dettelbach's formulation, this was a polity "populated by measurers": "His voyager, bristling with apparatus, cut the figure of the general individual, a representative citizen in the polity described by isothermal, isodynamic, and plant geographic lines."[657] More recently, John Tresch has shown how Humboldt invested "objectivity" with a republicanism that bound observers and instruments alike in an interdependent community that relied upon "shared labor."[658] "For Humboldt the best way to know the world was to multiply mediations and observers," Tresch writes, "not eliminate them."[659] This chapter shows how, in doing so, the Humboldtian polity also drew directly from existing political orders, taking the form of the cameralist and colonial regimes in which he operated. Before Humboldt governed a republic of savants, he managed a more localized program of observation in the mines, where he equipped subordinates with the means of chemical experimentation and geognostic investigation. The learned voyager was preceded by the laboring miner, similarly employed in the measurement and description of the earth.

This was the context in which Humboldt first "conceived of the idea of a *physique du monde*," as he wrote to the Genevan natural philosopher Marc-Auguste Pictet in January of 1796.[660] The letter was penned from the Franconian city of Bayreuth, where Humboldt was *Oberbergrat*, amidst letters to experimentalists and administrators alike. In them, he moved

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[656] Marie-Noëlle Bourguet, "La république des instruments. Voyage, mesure et science de la nature chez Alexandre de Humboldt," in *Marianne-Germania: Deutsch-französischer Kulturtransfer im europäischen Kontext – Les transferts culturels France-Allemagne et leur contexte européen, 1789-1914*, Étienne François et al. eds., vol. 2 (Leipzig: Universitätsverlag, 1998), 405-35.
[657] Dettelbach, "Global physics and aesthetic empire," 283.
[658] Tresch, *The Romantic Machine*, 65.
[659] John Tresch, "Even the Tools will be Free: Humboldt's Romantic Technologies," in *The Heavens on Earth: Observatories and Astronomy in Nineteenth-Century Science and Culture*, eds. David Aubin, Charlotte Bigg, and H. Otto Sibum (Durham, NH: Duke University Press, 2010), 251-84, on 257.
[660] Humboldt to Marc-Auguste Pictet, 24 Jan. 1796, *Die Jugendbriefe Alexander von Humboldts, 1787–1799*, eds. Ilse Jahn and Fritz G. Lange (Berlin: Akademie, 1973), 487: "Je conçus l'idée d'une physique du monde." Cf. Alexander von Humboldt, "Lettre à M. Pictet," *Magasin encyclopédique* 6 (1796): 463.

seamlessly between geognostic observations made on a recent trip through the Alps and physiological studies of the "vital force" that animates organic matter. Such was the scale of this new global physics, from muscle fibers to mountain chains, which Humboldt claimed to have developed in the six years since his journey to England with Georg Forster in 1790.

These six years also mark the duration of Humboldt's training and service as a miner, having decided in England to study in Freiberg.[661] *Physique du monde* has long been associated with the international network of well-equipped observers that Humboldt coordinated from Paris (and later Berlin) after his American travels. But even in the 1820s—which culminated in the Cosmos Lectures of 1827-28—Humboldt's vision for global physics still drew on the model of *Bergstädte* (mining cities) and *Bergakademien* (mining academies).[662] In 1822, Humboldt recruited Jean-Baptiste Boussingault, a recent graduate of the *Ecole des Mines*, to help his friend Simón Bolívar engineer a newly liberated Columbia. Humboldt assured Boussingault that he would one day join him at "an institute [*établissement*] in a large city in the Cordilleras" complete with:

> a superb collection of instruments, meteorological, magnetic apparatus, placed at great distances; a centralization of observations…; an assembly of young, educated people, courageous, active, suited for employment by the state and for acting from the same views; plenty of independence; the resources of powerful men, some influence in Europe for procuring every improvement—this cannot remain a dream.[663]

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[661] It was in Hamburg in 1791, while studying at the Commercial Academy, that Humboldt fixed his plans to go to Freiberg. But in those plans he identified the journey to England in 1790 as the inspiration for his application to Freiberg. Humboldt to Abraham Gottlob Werner, 13 Dec. 1790, *Jugendbriefe*, 112: "Mein Aufenthalt in Göttingen, meine botanischen Wanderungen in deutschen Gebirgen, meine angenehme, aber viel zu schnelle Reisen ach dem *Peak* von *Derbyshire* (in Begleitung Ihres Freundes *Georg Forster*) – weckten meinen Eifer für dies Studium immer mehr. […] Das heiße Begierde, nach Freiberg zu gehen, und Ihr Schüler zu werden, lag schon lange in mir…."

[662] Consider Humboldt's emphasis on the list of Andean cities that made possible the high-altitude precision measurements crucial for the establishment of isothermal lines: Alexander von Humboldt, "Von den isothermen Linien und der Verteilung der Wärme auf dem Erdkörper," in *Alexander von Humboldt Werke*, vol. vii, Schriften zur Physikalischen Geographie, ed. Hanno Beck (Darmstadt: Wissenschaftliche Buchgesellschaft, 2008), 85-89.

[663] Humboldt to Boussingault, 5 Aug. 1822, in *Lettres américaines d'Alexandre de Humboldt*, ed. E. T. Hamy (Paris: Librarie Orientale et Américaine, 1905), 287, as translated in Dettelbach, "Romanticism and

But it was less a dream than a memory, a memory of the human and instrumental resources Humboldt had at his disposal at centralized mining operations in Freiberg in the Ore Mountains, Bayreuth near to the Franconian Alps, Mexico City notched in the trans-Mexican volcanic belt, and the silver-city of Guanajuato, which likewise sits well over a mile high in the Cordilleras.

Humboldt's letter to Boussingault was presaged by an earlier plan for a continental system of "*Stationen*" similarly equipped with instruments and observers. This plan was conceived, like *physique du monde* itself, in 1796. "I already make observations with the *eud*[iometer], *bar*[ometer], and *thermom*[eter]," he wrote to erstwhile Freiberg classmate Carl Freiesleben, referring to his studies of the composition, pressure, and temperature of mine airs:

> But I now wish to establish stations, with [Marc-Auguste] *Pictet's* help, upon *St. Bernhard Pass*, in *Geneva*, here (also when I am away), *Hamburg*, *Freyberg* or *Marienberg* [in Saxony, where Freiesleben then served as Mining Assessor], *Berlin*, *Paris* and *Venice*. Besides, think how wonderful it would be when I make observations atop Vesuvius to know *correspond*ing observations in Germany.[664]

Spanning Europe from the Adriatic to the North Sea, Humboldt's "eudiometric stations" also rose up from sea-level, through the mines of Franconia and Saxony, to an elevation of nearly 2,500 meters in the Swiss Alps. Further, Humboldt's (imagined) observational network entwined the instrumental resources of Europe's cities with the manpower of its mining centers.

Administration," 163. Boussingault, who in 1822 operated a lignite mine in Alsace, was placed at the Escuela Nacional de Mineros en Bogotá and employed as part of a team of technical experts that did indeed establish experimental stations to assess the mineral and agricultural potential of Columbia.

[664] Humboldt to Carl Freiesleben, 2 Oct. 1796, *Jugenbriefe*, 530: "Ich will nun, sobald mit mehr Instrumenten zu Stande bin, Eudiometr[ische] *Stationen* anlegen. So *observire* ich jezt schon *Eud*[iometer], *Bar*[ometer] und *Thermom*[eter] mit H. Schmeißer (dem Chemisten in Hamburg). Aber ich will Stationen zu Stande bringen durch *Pictet* auf dem *St. Bernhard, Genf,* hier (auch wenn ich weg bin), *Hamburg, Freyberg* oder *Marienberg, Berlin, Paris* und *Venedig*. Dazu wie schön ist es, daß, wenn ich auf dem *Vesuv observiere*, ich immer *correspond*irende Beobachtungen in Deutschland weiß. Ich denke in der Litt[eratur]-Zeit[ung] eine Anzeige zu machen wenn ich nur erst ein 4-5 Menschen zusammen habe."

Mining, long seen as a hindrance to Humboldt's scientific ambitions, did in fact supply the personnel, and even a rationale, for *physique du monde*. The environmental challenges posed by underground labor, as well as the institutional resources Humboldt commanded there, combined in the first iteration of global physics. Humboldt initially sought to realize this science through a caste of administrator-experimenters, and to popularize it by schooling an army of worker-observers. In Franconia as in New Spain, Humboldt's capacity to depict disparate natural forces within a synoptic field of vision depended upon the managerial position he assumed over social economies. After the turn of the century, Humboldt adapted his metropolitan homes in Paris and Berlin into bureaus of a sort, *Ämter* in which he and his assistant Johann Buschmann worked to collate reports from astronomers, surveyors, mariners, and miners in far-flung regions of the world. This was a familiar role for Humboldt who, as high-ranking mine administrator, once commanded a corps of subordinates to extend his omniscience over the three districts (*Berg-Reviere*) under his charge. It is there, in Franconia, that this chapter begins.

An Experiment in Global Physics

Mines were, in a word, instrumental to Humboldt's science. After describing his *physique du monde* to Pictet in the winter of '96, Humboldt told another correspondent of his plan to use a layer of limestone that stretched from central Germany "to the foot of Mont Blanc" as an "*horizont géognostique*"—much as a surveyor establishes a level line of sight—to determine the superposition of mines in the Tyrolean Alps relative to pits in the Harz.[665] This turned mines into

[665] Humboldt to Friedrich Wilhelm Graf von Reden, 6 Feb. 1796, *Jugendbriefe*, 490: "J'espère de mettre la dernière main pendant cet été à mon ouvrage: Considération zur la Structure de la terre dans l'Europe moyenne. […] J'ai découvert une couche calcaire, qui se prolonge depuis Darmstadt ou Coburg jusqu'au pieds du Montblanc, qui recommence aux environs de Padoue et de Gênes. Elle me sert *d'horizont géognostique* et c'est par cette idée que je suis parvenu à déterminer dans cet ouvrage, si une mine dans le Tyrol est au-dessus ou au-dessous d'une couche dans le Mansfeld." Cf. Humboldt to D. L. G. Karsten, 12

optical instruments—inverted theodolites—with which to gaze through the earth, yielding a geognostic profile of continental dimensions. Already in 1796, then, Humboldt had begun scaling up the practical science known as "subterranean surveying" to encompass the very "structure of the earth in central Europe." Humboldt's instrumental language was particularly strong in his chemical inquiries. Earlier, in 1795, he had described the mineshafts in which he recorded the effects of various gases on vegetable fibers and human respiration as the "bottom of the great retort"—the great distillation vessel that is the atmosphere—"which rises up to the receiving flask!"[666] The mine as an optical or experimental apparatus: these might be read as metaphors for the way in which mining provided both the impetus and the infrastructure for Humboldt's earliest study of the "confluence" of natural forces.

We, too, can borrow from the language of experimental science around 1800 to think of Humboldt's mining activities as a first *Versuch* or experiment in global physics. *Versuch* was a common term in scientific discourse, often used in the plural as "experiments on…" or "ideas toward…." But the term is all the more apt for the humanistic connotations it carried. Humboldt employed *Versuch* while translating his own political *Essai* on New Spain, which first appeared in German in 1809.[667] That same year, Goethe made *Versuch*'s double meaning a central motif in

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Feb. 1796, ibid., 498. Texts on "subterranean surveying" from the period reference the importance of a "*Horizontallinie*"—what would later be called the *Instrumentenhorizont* or *Gerätehorizont* in modern surveying—which can be established either with a weighted line attached to a 180° semi-circle (*Gradwage*) or even with reference to the level plane of still water (as in a *Wasserwage*). (Johann Gottfried Jugel, *Geometria Subterranea, oder Unterirdische Meßkunst der Berg- und Grubengebäude* (Leipzig: J. P. Kraus., 1773), 56, 241; August Beyer, *Gründlicher Unterricht vom Bergbau nach Anleitung der Markscheidekunst* (Altenburg: Richter, 1785), 405-12, 432, 627.)

[666] Alexander von Humboldt, "Ueber Grubenwetter und die Verbreitung des Kohlenstoffs in geognostischer Hinsicht," *Chemische Annalen für die Freunde der Naturlehre, Arzneygelahrtheit, Haushaltungskunst und Manufakturen* 2 (1795): 99-119, on 104.

[667] E.g. Alexander von Humboldt, "Versuche und Beobachtungen über die grüne Farbe unterirdischer Vegetabilien," *Journal der Physik* 2, no. 1 (1792): 195-205; Alexander von Humboldt, *Versuch über den politischen Zustand des Königreichs Neu-Spanien*, 5 vols. (Tübingen: Cotta, 1809-1814). A classic geognostic text in Humboldt's time was Johann Gottlob Lehmann, *Versuch einer Geschichte von Flötz-Gebürgen* (Berlin, 1756).

his novel *Elective Affinities* (*Wahlverwandschaften*).[668] Goethe, who carried out chemical experiments with Humboldt in the mines of Ilmenau, used the novel as a laboratory for experiments of a social nature. In it, he suggested that human passions, like chemical bonds, were guided by inexorable laws of attraction. Humboldt's *physique du monde* was charged with a similar affinity. As Dettelbach has observed, the newly acquired Franconian territories were seen by Humboldt's superior, Karl August von Hardenberg, "as a testing ground for his ideas of political and economic reform…, a small-scale version of his plan for a reformed aggrandized Prussia."[669] For Humboldt, too, mining operations in the Fichtel Mountains became a testing ground for the managerial practices that would long characterize his science.

The labor force in German mining was not only a means of establishing "eudiometric stations" but also a primary motivation for them. With his self-made eudiometer, a graduated glass cylinder fashioned to register subtle changes in the volume of a gas based upon its reaction to phosphorous, Humboldt studied the so-called "wicked air" (*böse Wetter*) that had long wreaked havoc on miners' lungs. In this, he worked in the tradition of pneumatic chemistry, an experimental science based upon the phlogiston theory of combustion popularized by Joseph Priestley in the 1770s. By submerging candles, mice, and plants in different "airs" under bell jars, Priestley differentiated "phlogisticated" (or "fixed") air, which is produced by combustion and respiration, from "dephlogisticated air", which is fit for breathing. Plants, unlike mice, could "restore" the air, Priestley found. Indeed, pneumatic chemistry aimed to measure the very "virtue" of air; and Priestley's followers saw the eudiometer as an instrument capable of

[668] Johann Wolfgang von Goethe, *Die Wahlverwandtschaften* (Tübingen: Cotta, 1809).
[669] Dettelbach, "Global physics and aesthetic empire," 260.

improving the human condition. They set about detecting dangerous miasmata that might account for various respiratory maladies.[670]

Humboldt shared Priestley's commitment to "the analogy between natural improvement and moral reformation," even as he adopted aspects of Antoine Lavoisier's new chemical nomenclature, using "oxygen" interchangeably with "dephlogisticated air" for instance.[671] In practice, too, Humboldt drew directly from the experiments on human respiration and work that Lavoisier, his wife, and his assistants carried out in 1790. In Madame Lavoisier's illustrations of the experiments, a man is shown wearing a respiration mask as fellow assistants measure his pulse and oxygen consumption, first "in repose" then "while performing work."[672] More broadly, chemists in the 1790s commonly understood experimental methods, and especially self-experimentation, as a democratic means of diffusing knowledge to all classes and promoting the

[670] Joseph Priestley, *Experiments and Observations on Different Kinds of Air* (Birmingham: Thompson, 1790), 255-56. Humboldt's eudiometry is discussed extensively in Dettelbach, "Romanticism and Administration," 99-119. On the practice of eudiometry generally, see Simon Schaffer, "Measuring virtue: Eudiometry, enlightenment and pneumatic medicine," in *The Medical Enlightenment of the Eighteenth Century*, eds. Andrew Cunningham and Roger French (Cambridge, UK: Cambridge University Press, 1999), 281-318. Humboldt's eudiometer took its design from Louis Bernard Guyton de Morveau, who also practiced eudiometric chemistry towards the social and political ends of Enlightenment. See Elena Serrano, "Spreading the Revolution: Guyton's Fumigating Machine in Spain: Politics, Technology, and Material Culture (1796-1808)," in *Compound Histories: Materials, Governance and Production, 1760-1860*, eds. Lissa L. Roberts and Simon Werrett (Leiden: Brill, 2018), 106-30.

[671] Schaffer, "Measuring virtue," 283. Humboldt's Priestleyan practices were not at odds with his advocacy for the new chemical nomenclature of Antoine Laurent de Lavoisier. He adopted "oxygen" rather than "dephlogisticated air," for instance. Phlogiston was thought to be an imponderable, subtle fluid contained by combustible bodies, which is released when a substance burns. Lavoisier's self-proclaimed revolution in nomenclature thus replaced a theory of phlogiston, a substance that is *lost* during combustion, with one of oxygen, which is *gained* during combustion. (Frederic L. Holmes, "The 'Revolution in Chemistry and Physics': Overthrow of a Reigning Paradigm or Competition between Contemporary Research Programs?" *Isis* 91 (2000): 735-753, esp. 743–746; Klein, "The Prussian Mining Official Alexander von Humboldt," 57.)

[672] Frederic Lawrence Holmes, *Lavoisier and the Chemistry of Life: An Exploration of Scientific Creativity* (Madison, WI: The University of Wisconsin Press, 1985), on 443. See illustrations in ibid., 444-45.

"general good"—whether by advancing the Enlightened spirit of Revolution in France or tempering the upheaval it threatened across Europe.[673]

Humboldt dedicated his own science of "subterranean meteorology" to "the industry of men at war with superior elements," that is, to what he saw as Enlightened reforms in labor conditions in the mines. He found that while ventilation adits and running water replenished the mines with respirable air, lichens, fungi, rotting wood, and carboniferous deposits all contributed to the "injury" (*Verderbniss* or *empestement*) of the air and the miners who breathed it.[674] In the industry, the respiratory illnesses from which miners and smelters suffered were known, since the fifteenth century, as "mine maladies" (or *Bergkrankheiten*).[675] The ecological reformation of the mines thus became a top priority of Humboldt's administrative program, a "war against the elements," as he called it.[676] The mine itself became a bell jar of unprecedented proportions: a vessel in which Humboldt could submerge plants, birds, lamps—even humans—in various airs.

It was clear to Humboldt that the great challenge of his pneumatic chemistry lay not so much in measuring specific gases as substantiating those readings with useful technologies based

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[673] Larry Stewart, "Pneumatic Chemistry: Self-Experimentation and the Burden of Revolution, 1780-1805," in *The Uses of Humans in Experiment: Perspective from the 17th to the 20th Century*, eds. Erika Dyck and Larry Stewart (Leiden: Brill, 2016), 139-69.

[674] Wilhelm von Humboldt, "Vorrede," in Humboldt, *Ueber die unterirdischen Gasarten*, vi: "…den Kunstfleuss des Menschen im Kampfe mit überlegenen Elementen zu sehen, so wird noch die menschenfreundliche Theilnahme für eine arbeitsame und achtungswürdige Menschenklasse erweckt."

[675] Early modern miners often used the term *Bergkrankheiten* (alternatively *Hütten-Katze*, *Bergsucht*, or even the *Schneeberger Krankheit*) to refer to respiratory illnesses associated with the smelting process. Concerns about toxicity inspired a medical literature beginning with Theophrastus Paracelsus von Hohenheim, *Von der Bergsucht oder Bergkranckheiten drey Bücher, inn dreyzehn Tractat verfast unnd beschriben worden* (Dillingen, 1567). A subsequent study, written by a Saxon mining official, is Johann Friedrich Henkels, *Von der Bergsucht und Hütten-Katze, auch einigen andern, Denen Bergleuten und Hütten-Arbeitern zustoßenden Krankheiten* (Dresden, 1745). Far less attention was devoted to the "mine maladies" contracted underground, however, despite widespread knowledge about *böse Wetter*.

[676] Humboldt to Carl Freiesleben, 25 Nov. 1796, *Jugendbriefe*, 553: "Der ganze Bergbau ist ein Kampf mit den Elementen, wir lernen mit ihnen zu fechten oder ihnen geschickt zu entfliehen."

upon them.[677] In the winter of 1795/96, he devised a mine lamp (the so-called *Rettungslampe*) to burn even in oxygen-depleted shafts and began distributing plans for its replication amongst close friends. That the project's main benefactor was the Prussian King made experimentation a delicate business, for the lamp had yet to function consistently in *böse Wetter*. Designed to draw upon its own reservoir of respirable air, the lamp was nonetheless easily extinguished with rapid movement. As such, the apparatus was a "dormant threat" to Humboldt's efforts to unite theory and practice.[678] After sending a model to Freiesleben, Humboldt "begged" his friend "to make the first experiment alone or with *one* or *two discrete* miners or one discreet friend. […] It would be infinitely fatal to me," he continued, "if the lamp went out the first time it left my hands."[679]

No simple feat of technical ingenuity, Humboldt's subterranean meteorology meant managing the hierarchy of "hands" involved in its realization.[680] In a later publication, written partly as an instruction manual for the lamp's manufacture, Humboldt claimed it was "infinitely more difficult" to place such a "contrivance" "in the hands of common miners" than it was to

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[677] It was only in the course of his travels through the Americas, where Humboldt brought two eudiometers, that he realized just how imprecise his instruments were. His main eudiometric objective in Spanish America was to determine the "purity of the air" at various elevations. Ultimately, though, Humboldt used measurements taken in Europe for his "Tableau physique" of the Andes. See Dettelbach, "The Face of Nature," 478-79 and Stephen T. Jackson, "Instruments Utilized in Developing the *Tableau physique*," in Alexander von Humboldt and Aimé Bonpland, *Essay on the Geography of Plants*, ed. Stephen T. Jackson, trans. Sylvie Romanowski (Chicago: University of Chicago Press, 2009), 221-26.

[678] Martin J. S. Rudwick, *The Great Devonian Controversy: The Shaping of Scientific Knowledge among Gentlemanly Specialists* (Chicago: The University of Chicago Press, 1985), 126.

[679] Humboldt to Carl Freiesleben, 5/18 Oct. 1796, *Jugendbriefe*, 534: "Der König bezahlt alles, was auf die Rettungslampe Bezug hat! Nur bitte ich Dich, alter Junge, a) die ersten Versuche in der Grube ja allein mit *einem* oder *zwei verschwiegenen* Bergleuten oder 1 verschwiegenen Freunde zu machen. […] Nun wäre was mir aber unendlich fatal, wenn die Lampe das erste Mal, daß ich sie außer meinen Händen gebe, ausginge."

[680] As we will see, Humboldt's subterranean meteorology, with its reliance upon miners' involvement and self-experimentation, served as a sort of public performance that lent legitimacy to its chief experimenter. At the same time, this science anticipates the link between highly disciplined precision instrumentation and the calibration of docile bodies—of "social technologies"—that would characterize nineteenth-century experimentation and observation practices. See Simon Schaffer, "Self-Evidence," *Critical Inquiry* 18, no. 2 (Winter 1992): 327-62, esp. 359-62 and Simon Schaffer, "Astronomers Mark Time: Discipline and the Personal Equation," *Science in Context* 1, no. 1 (1988): 115-45.

construct the instruments themselves.[681] And so, he mobilized the industry's entire chain of command in the creation and validation of his instruments. This began, in Humboldt's earliest inquiries, by extracting knowledge from "common" miners themselves. Miners, wary of the so-called "carbon-seas," knew that running water replenished "flat air" with "life-air."[682] Sometimes, Humboldt noted, they held urine-soaked handkerchiefs before their mouths to forge through the "*böse Wetter* that accumulated during their shift."[683] As laborers looked to mice and birds as indicators of air quality, Humboldt looked to laborers. A fallen miner beside a burning lamp would, perversely, be the ultimate proof of its durability. "Write to me of cases where men fall ill or suffocate and the lamp burns bright," he told Freiesleben.[684]

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[681] Humboldt, *Ueber die unterirdischen Gasarten*, 260: "Wie diese künstliche Ersetzung auf die einfachste, wohlfeilste Weise geschehen, wie sie durch eine Vorrichtung bewirkt werden könne, die man auch dem gemeinen Bergmanne in die Hände geben, von der man auch in engen krüplichen Grubenbauen Gebrauch machen könne? Dies ist die praktische Aufgabe, deren zweckmässige Lösung unendlich schwerer ist, als die Zusammensetzung eines physikalischen Instruments, wie ich es bey meinen Thermometerversuchen gebrachte." On Humboldt's intent to place instruments "in the hands of the common miner," compare to ibid., 10, 327.

[682] See Wilfried Liessmann, *Historischer Bergbau im Harz: Kurzführer*, 3rd ed. (Berlin: Springer, 2010), 48-49. Liessmann notes that of 1190 miners who died in the Oberharz region between 1751 and 1848, 37 men were described as having "suffocated in wicked air" (*Erstickt sind in bösen Wetter*). But by counting fatalities alone, this data, compiled by the Mining Administration, obscures the true scope of suffering caused by the long-lasting effects of noxious gases. In New Spain, Humboldt noted how miners employed in blasting (the *barrenadores*, or in German *Bohr- und Sprengmeister*) "rarely pass the age of 35 if from a thirst of gain they continue their labor for a whole week. They generally pass no more than five or six years at this occupation and then move to other employment less injurious to health." (As quoted in Myron Echenberg, *Humboldt's Mexico: In the Footsteps of the Illustrious German Scientific Traveller* (Montreal, Ontario: McGill-Queen's University Press, 2017), 129.) Cf. Humboldt, *Neu-Spanien*, *1*, 103-04, where he urges Spanish American technicians to emulate German methods of air circulation.

[683] Humboldt, "Ueber Grubenwetter," 103-04: "Jedem unsrer gemeinsten Bergleute ist bekannt, daß, wo Wasserklüfte angehauen werden, meist frischere Wetter erfolgen. […] Sie hauchen Lebensluft aus, und eben diese wohlthätige Wassersetzung ist es, welche der *vegetationsarmen* Meeresfläche eine so reine, den *vegetationsarmen* Sandwüsten eine so irrespirable Luft giebt." Ibid., 206: "In England haben mir alte verständige Bergleute erzählt, daß es in Kohlengruben oft ihr Rettungsmittel sey, wenn böse Wetter sich während der Schicht vor den Streb oder die Strecke gelagert haben, und ihnen das Ausfahren erschweren, Urin auf's Schnupftuch zu lassen, und dieses vor den Mund zu halten."

[684] Humboldt to Carl Freiesleben, 15 Sept. 1796, *Jugendbriefe*, 525: "*Ueber Wetter* – Schreibe doch Fälle, wo Menschen erkrankten oder erstikten und die Lichter brennen bleiben. […] Vögel starben darin in 14 Sek. und Lichter brennen treflich. […] Fast alle unterirdischen Schwämme geben Phosphorsäuere."

Freiesleben belonged to a stratum of practically employed bureaucrats amongst whom Humboldt circulated model lamps, plans for his eudiometer, and detailed instructions for testing them out, particularly in pits beset by *böse Wetter*.[685] At the highest levels of state bureaucracy, Humboldt secured the Prussian War Department's interest in his respiration device, or *Rettungsmaschine* (**Figure 1**). Military officers tested the apparatus in the fog of war emitted by volleys of cannon and musket fire. Beyond Prussian ranks, Humboldt used his many Freiberg connections to enlist the Saxon Mining Department in the manufacture of his lamps.[686]

Figure 1. Humboldt's self-made respiration device, or *Rettungsmaschine*, for miners caught in *böse Wetter*, as illustrated in *Ueber die unterirdischen Gasarten* (1799). SUB Gö, 8 Metall 2933.

[685] E.g. Humboldt to Carl Freiesleben, 15 Sept. 1796, *Jugendbriefe*, 525: "Könntest Du nicht einen recht *deutlichen* Versuch auf einer Strekke machen, durch Abkehren der Schwämme in 1-2 Monathen die Wetter daselbst zu verbessern, für mein Buch über die Wetter!" Cf. Carl Freiesleben to Humboldt, 20 Dec. 1796, ibid., 558: "Für das Abkehren der Schwämme auf diesem, so wie auf allen andern gangbaren Stollnflügeln wird *möglichst* gesorgt, allein da sie innerhalb weniger Tage *immer* wieder kommen, so ist es bey vieler Zimmerung und in groser Distanz nicht möglich, sie durchgehends auszurotten, sodaß einzelne Thürstöcke wohl damit befleckt sind; aber das ist evident, daß die Qualität der Wetter sehr von ihnen abhängt…." Humboldt also wrote to Freiesleben of his plan for an "*Abhandlung über Construktion der Eudiometer*," which was never published. (Humboldt to Carl Freiesleben, 5 Oct. 1796, ibid., 532).
[686] Humboldt to Carl Freiesleben, 7 Apr. 1796, ibid., 504. Humboldt's efforts to enlist Saxon *Bergamt* in the lamp's manufacture are evidenced in ibid., 504, 507, 549, 561.

But the linchpin of Humboldt's experimental enterprise was the corps of lower officials—mine inspectors, deputies, and foremen—whose work combined *Feder* and *Leder*. When Humboldt rose from Chief Mine Master (*Oberbergmeister*) to Chief Mine Counselor (*Oberbergrat*) in 1795, he was charged with coordinating the actions of officials across the Principalities of Ansbach-Bayreuth, each of whom were responsible for the extraction of minerals and the management of labor in individual mines. Training in chemical experimentation was just one aspect of the discipline Humboldt exercised over and through them. His most trusted "hands" were Eberhard Friedrich Killinger (1770-1826), a fellow graduate of the Mining Academy, and Heinrich Ludwig Sievert (1772-1818).[687]

Throughout 1794 and 95, Humboldt regularly dispatched Killinger and Sievert, both of whom then carried the rank of *Berggeschworener*, with "elaborate instructions" to drill "boreholes" into the earth in search of coal. Such tasks were, as Humboldt put it, "experiments" in the practical utility of the new earth sciences developing in Freiberg, which saw the geognist's map rather than the dowser's rod as the primary guide to subterranean spoils.[688] In other words, Killinger and Sievert were well prepared to serve Humboldt as trusty experimentalists. By the summer of 1796, Humboldt boasted to Freiesleben that the two had successfully "conducted experiments [on the lamp] without me"—something of an addendum to his earlier plan for eudiometric stations that would function "also when I am away."[689] By proving the lamp's

[687] Sievert ultimately rose from *Berggeschworener* in the district of Wunsiedel to *Bergmeister*. Killinger, *Bergeschworener* in Goldkronach, became Vize-Oberbergmeister in 1796.
[688] Humboldt to Ober-Berg-Department Bayreuth, 22 Oct. 1794, *Jugendbriefe*, 369: "Versuche auf Steinkohlen betr[effend]. […] Ich schickte daher den B[erg]-Geschwornen *Sievert*, der um das Bohren an hiesigem Gebirge reele Verdienste hat … und gab ihm in den *P*[*ro*] *M*[*emoria*] d.d. Cleve 1. Aug. eine ausführliche Anweisung, alle Punkte, wo nur Sage oder Hofnung auf Steinkohlen wäre, einzeln zu untersuchen und ein Verzeichniß davon anzufertigen." Cf. ibid., 289-90, 407-08, 415.
[689] Humboldt to Carl Freiesleben, 17 July 1796, *Jugendbriefe*, 514-15: "Ich halte die Sache für vollendet. *Killinger* und *Sievert* haben ohne mich Versuche damit gemacht und die Lampe (wenn sie auch mit bloßer atmosphär. Luft gefüllt ist) nie zum Verlöschen bringen können."

durability, Killinger and Sievert were, at the same time, proving their own capability as experimenters.

This corps of officials reveals a striking correlation between intellectual authority and physical risk in Humboldt's experimental administration. In early modern Europe, the lived experience of tradesmen, seamen, and other manual workers sometimes provided an avenue to intellectual authority, even amongst affluent men of science who tended to equate credibility with status.[690] This was particularly true of Humboldt's mining lamp, a technology whose success in poor air could be measured by the injury done to its handlers—himself included. Cautioning Freiesleben not to linger long in miasmatic mines, Humboldt described how Killinger's "successful" experiments rendered him unfit for underground travel.[691] It was for this reason that Killinger, waiting outside a pit, was able to rescue Humboldt from "becoming the victim of my own experiment." "The lamp burned bright in *bösen Wettern*," he wrote to Freiesleben. "I was curious and wanted to continue to the place with the rotten wood where we had burnt Sulphur. I crawled further…." But no sooner did Humboldt rejoice in seeing the flame persist than he sunk to his knees. That was all he remembered, having been dragged out unconscious by Killinger. Humboldt was bedridden, "as though drunk," for two days. But the lamp's validation was "worth the unconsciousness," he wrote—"a victory for mining."[692]

[690] Philippa Hellawell, "'The best and most practical philosophers': Seamen and the authority of experience in early modern science," *History of Science* 58, no. 1 (2020): 28-50.
[691] Humboldt to Carl Freiesleben, 25 Nov. 1796, *Jugendbriefe*, 551.
[692] Humboldt to Carl Freiesleben, 5/18 Oct. 1796, *Jugendbriefe*, 532-33: "Fast wäre ich vorgestern ein Opfer meiner Versuche geworden. […] Die Rettungs-lampe brannte hell in den bösen Wettern. Ich war neugierig, wollte bis an das faule Holz vor Ort fahren, wo wir den Schwefel verbrannt haben. Ich kroch hinein. Killinger mußte zurük bleiben, weil er noch von einem ähnlichen Versuch krank ist, den er in der Nailaer Refier machte. Ich kam bis vor Ort, sezte meine Lampe hin und freute mich unendlich ihres Lichtes. Mir wurde müde, sehr wohl, betaumelt, ich sank in die Knie neben die Lampe. Ich soll Killinger gerufen haben, ich weiß nichts davon. […] Mir war wie besoffen und matt, 2 Tage matt."

Foremen in the Republic of Instruments

Humboldt famously instrumentalized his own body. In Jena's circle of experimentalists, he fixed galvanic stimuli to his own back and even licked electrified frog legs, all in the Frankensteinian quest for the elusive "vital force," or *Lebenskraft*.[693] In the Americas, he described his body as a "kind of gauge" with which to measure the rarefication of the air on the slopes of Chimborazo.[694] And by the mid-nineteenth century, Humboldt's account of the "*Bergkrankheit*" he experienced atop the Andes—which caused "blood to ooze from the lips, gums, and eyes"—appeared in early studies of what would be later called altitude sickness.[695]

Less well known is the way in which Humboldt instrumentalized others' bodies. In his experimental administration, low ranking officials and even mine foremen gained a striking degree of intellectual authority—but only at the cost of their personal health. Foremen (or *Steiger*, highest ranking of "common" miners) worked six days a week underground and were particularly vulnerable to the airs that, Freiesleben reported, "cripple the body, causing seizures, stomach pain, dryness of the throat, and simmering pain in the eyes."[696] Both Humboldt and Freiesleben relied on mine foremen to validate their own knowledge claims. Observations on the vitiation of mine air caused by rotting wood or the bioluminescence of subterranean vegetation

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[693] Stuart Walker Strickland, "The Ideology of Self-Knowledge and the Practice of Self-Experimentation," in Special Issue: "The Mind/Body Problem," *Eighteenth-Century Studies* 31 (1998): 453-71; Stanley Finger et al., "Alexander von Humboldt: Galvanism, Animal Electricity, and Self-Experimentation Part 1: Formative Years, Naturphilosophie, and Galvanism," *Journal of the History of the Neurosciences: Basic and Clinical Perspectives* 22, no. 3 (2013): 225-60.
[694] David Livingstone, *Putting Science in Its Place: Geographies of Scientific Knowledge* (Chicago: University Chicago Press, 2003), 75.
[695] Conrad Meyers-Ahrens, *Die Bergkrankheit, oder der Einfluß des Ersteigens großer Höhen auf den thierischen Organismus* (Leipzig: Brockhaus, 1854), 84; Franz-Josef Brüggemeier, *Das unendliche Meer der Lüfte: Luftverschmutzung, Industrialisierung und Risikodebatten im 19. Jahrhundert* (Essen: Klartext Verlag, 1996), 115, n. 85; Lachlan Fleetwood, "Bodies in High Places: Exploration, Altitude Sickness and the Problem of Bodily Comparison in the Himalaya, 1800-50," *Itinerario* 43, no. 3 (2019): 489-515.
[696] Carl Freiesleben to Humboldt, 17 Nov. 1796, *Jugendbriefe*, 547: "die Wetter sind so stockend, daß in wenig Wochen ganz frisches Holz schon fault. [...] seine Wetter … ermatten den Körper, verursachen Stocken, Magenkrampf, Trockenheit im Hals, gelinden Schmerz in Augen u.s.f."

were all substantiated by the weighty word of the foreman—"*Steiger* Schulze" in Marienberg, "*Steiger* Papf and Fischer" in Freiberg, "*Steiger* Bauer" in Franconia, or sometimes just "the *Steiger*."[697] Rarely is a figure so fleetingly visible accorded such intellectual authority.

Eighteenth-century records suggest a view of mine foremen as highly skilled artisans of the underground. Aside from personally directing the blasting, hewing, and exploitation of mines, some foremen contributed to the design of elaborate hydraulic pumps and hoisting mechanisms. In Saxony, for instance, one "*Steiger* Schönherr" was paid by the administration to construct model machinery, a task typically reserved for Mining Academy graduates specially trained in mechanical engineering.[698] Such skills would translate well into helping Humboldt tinker with their many different models of the lamp, as when *Steiger* Schulze was present for the "prudent manipulation" of the oil-to-wick ratio in Freiesleben's "Lamp No. 5."[699] It was not only Killinger and Sievert, but also "all the foremen" who, Humboldt said, were "convinced by experiments in 3 districts that my lamp has been fully perfected for practical application."[700]

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[697] E.g. *Jugendbriefe*, 531, 547, 557. In Humboldt's publications, too, he consistently evoked the figure of the foreman as testimony to the lamp's utility. See Humboldt, *Ueber die unterirdischen Gasarten*, 187, 190, 304, 312, 381.

[698] SächsBergAFG 40169 Grubenakten des Bergreviers Schwarzenberg, 247 includes "Gratifikation für den Steiger Schönherr für die Fertigung eines Modells der auf der Grube erbauten Förder- und Wasserhaltungsmaschine für die Sammlung der Bergakademie." Another document (40168 Grubenakten des Bergreviers Marienberg, 911) described a "Steiger Schönherr" who made suggestions on the "improvement of a *Wassersäulenmaschine*," the most advanced work of hydraulic machinery in central European mining at the time.

[699] Carl Freiesleben to Humboldt, 17 Nov. 1796, *Jugendbriefe*, 547: "Völlig bestärkt bin ich in der Ueberzeugung, und der bey mir gewesene Oberstgr. Schulze von Jung Sebastian F[undgrube] überzeugte sich ebenfalls, daß die Lampe völlig helle in den verderbtesten Wettern brennt, und daß sie alle ihre Zwecke erfüllen *kann*, denn wenn sie mir verlöschte, war es aus Ursachen, die nicht im Wesentlichen der Lampe, sondern in Manipulation oder Nebenumständen lagen…."

[700] Humboldt to Carl Freiesleben, 5/18 Oct. 1796, *Jugendbriefe*, 533: "Seit vorgestern sind wir, ich, Killinger, Sievert, alle Steiger und Bergleuthe, die bei den Versuchen in den 3 Revieren waren, überzeugt, daß meine Lampe völlig zum Praktischen Gebrauch vollendet ist und daß es Zeit sei, zum Verschikken und Verfertigen der großen Lampen zu schreiten."

Humboldt's efforts to illuminate the underground—"the antipode of light, long denied *Aufklärung*," as one official wrote—was symbolic of his broader plan of reform in Franconia.[701] The problem of irrespirable air was also a problem of poor administration. In fact, a "dearth of air ventilation" was included in contemporary definitions of *Raubbau*, alongside flooded pits, negligent construction, and other forms of "un-minerly" practice deemed antithetical to statist visions of "sustainable" resource extraction.[702] Humboldt therefore approached *böse Wetter* much as he did *Raubbau*: by carefully disciplining laborers, especially mine foremen, to carry out the ecological reformation of the underground.

This meant disciplining nature, too. For the chemical composition of Franconia's mines defied the regularity and order Humboldt sought in all realms, natural and social. Nature's "over- and underground" were analogous in certain respects but contrasting in others. "While there is no hail or snow, there are yet clouds, dew, and winds," Humboldt wrote, "I have indeed witnessed even deadly *sheet lightening* in the underground!"[703] Yet there was, of course, a striking distinction between over- and underground weather systems. Humboldt understood atmospheric weather to be arranged in patterned strata (*Schichten* or *niveau*, he wrote) that decrease in oxygen

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[701] A common trope amongst mining elites and earth scientists, this quote comes from Ignatz von Born and Heinrich von Trebra's *Bergbaukunde* (Leipzig: Georg Joachim Goeschen, 1789), Vorwort: "Durch ihre eingeschickten Aufsätze ermunterten sie dazu den Versuch weiter fortzusetzen, und wir unterziehen uns demselben gern auch noch in der Folge, da wir sehen, dass seine lang vernachlässigte, von den Antipoden des Lichts ängstlich verhinderte Aufklärung, auch in den Regionen unter der Oberfläche der Erde wirklich für so wichtig geachtet zu werden anfängt, als sie geachtet zu seyn schon längst verdient hätte." See discussion of the trope in Hartmut Böhme, "Montan-Bau und Berg-Geheimnis. Zum Verhältnis von Bergbauwissenschaft und hermetischer Natur-ästhetik bei Novalis," in *Idealismus und Aufklärung: Kontinuität und Kritik der Aufklärung in Philosophie und Poesie um 1800*, eds. Christoph Jamme und Gerhard Kurz (Stuttgart: Cotta, 1988), 62-64.

[702] E.g. Joseph Tausch, *Das Bergrecht des österreichischen Kaisserreiches* (Wien, 1834), 290: "Man nennt einen Bau Raubbau, wenn … die gehörigen Stollen und Strecken nicht getrieben werden, daß man daher wegen der aufsteigenden Wässer und wegen Mangels des Wetterwechsels in die Tiefe nicht kommen kann."

[703] Humboldt, "Ueber Grubenwetter," 104: "Wenn es in diesem auch nicht hagelt und schneit, so können wir doch Nebel, Thau und Winde, (*Wetterwechsel*, der *schlechterdings nicht* vom Drucke der äußern Atmosphäre anhängen kann,) ja selbst ein tödtendes *Wetterleuchten* in ihm wahrnehmen!"

and increase in electrical charge in proportion with altitude. Various airs appeared to him "uniformly distributed": "Here is carbon dioxide, there hydrogen gas," he explained, "everything in *niveau*."[704] Subterranean climate, by contrast, was not neatly stratified but "modified by local-conditions": "Every subterraneous stratum presents its own unique phenomena."[705]

Humboldt understood these local conditions not simply as anomalous natural phenomena, but rather as the result of negligent administration. The same architectural flaws and regulatory neglect that officials decried as *Raubbau* were also the source of dangerous miasmata. It all came back to the construction of the mines, particularly the wood framing of the shafts. Rotten wood, besieged by mosses and fungi, appeared to produce, "and be enveloped by, its own atmosphere." "Every mine supervisor must therefore be all the more attentive to fresh carpentry," Humboldt wrote, calling on foremen to "exterminate" "the first trace of fungus embedding itself in the framing."[706] These "envelopes" of *böse Wetter* were particularly stubborn in shafts dug upward into the rock from below (what miners called *Firstenbauen*), which buckled and decayed with time.[707] As Humboldt patrolled the mines, eudiometer in hand, for "vitiated" wood and

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[704] Humboldt, "Ueber Grubenwetter," 104: "…hier ist Kohlensäuere, dort Wasserstoffgas; alles ist im *niveau*, alles gleichmäßig vertheilt. Ganz anders ist es im Innern der Erde."
[705] Humboldt, *Ueber die unterirdischen Gasarten*, 57: "In der *überirdischen* Luftregion unterscheiden sich die höhern Schichten wesentlich (durch mindern Sauerstoff und Kohlensäure-Gehalt, stärkere elektrische Ladung u. s. f.) von den untern, der Erdfläche näheren Schichten. In der *unterirdischen* Luftregion lassen sich ähnliche Unterschiede nicht angeben. Hier wird alles durch Lokal-Verhältnisse modificirt." Ibid., 29: "Die Zusammensetzung des äussern Luftkreises ist ziemlich gleichförmig auf der ganzen Oberfläche der Erde. Wo er aber in das Innere des Erdkörpers eindringt, verändert er mannigfaltig seine Mischung. Jede unterirdische Schicht bietet eigene Erscheinungen dar, und ohne die Hindernisse zu betrachten, welche das Lokale den Beobachtungen entgegensetzt, würde das Leben eines einzelnen Menschen doch zu kurz seyn, um irgend etwas Vollständiges über die Grubenwetter zu liefern."
[706] Humboldt, *Ueber die unterirdischen Gasarten*, 234-35: "Desto aufmerksamer sollte jeder Grubenvorsteher auf frische Zimmerung seyn, und die erste Spur, mit der sich an einem Thürstock Schwämme ansetzen wollen, unverzüglich und nicht bloss (wie es gewöhnlich geschieht) durch oberflächliches, geschwindes Abwischen vertilgen."
[707] The Grimm *Wörterbuch* quotes directly from Humboldt in defining the term, noting how "*alte krüppeliche Firsten*" accumulate the "strangest quantity of air." Humboldt urges "regelmässige" construction in Humboldt, *Ueber die unterirdischen Gasarten*, 206-07, contrasted with 322.

miasmatic fungi, Killinger reported on shafts where the "old crippled *Firstenbauen*" signaled the negligence of private investors and the foremen allegedly under their sway.[708]

Humboldt countered these challenges to the socio-environmental order of the mines with training in "regulated" practice. The Mining School (*Bergschule*) in Bad Steben, established in the winter of 1793/94 to promote the education of young foremen, provided a venue for this project. Here, practical training in the "general regulations" of mining was bolstered by a view of nature itself as governed by regular laws. The School's curriculum reads as a legal code of mining "*Regeln*": the "regulations to observe" while describing the "strike of an ore vein," using a "mallet and hammer," "exploiting a deposit," drilling "boreholes," or assembling the "framing of a shaft."[709] The schoolbook Humboldt drafted presented a corresponding image of nature as a well-ordered, precisely measured realm. Distant mountains soared to astonishing heights while the depths of the sea and the interior of the earth tested the limits of human inquiry. "The highest mountain in the world is … called Schimborasso," students learned, "and measures 19,320 feet"; "the earth is 5,400 miles in circumference, 1700 miles in diameter"; and sounding leads "dropped 250 leagues without finding the bottom of the sea."[710] But even that which cannot be

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[708] StABa, KDK, Nr. 7124, "Generalbefahrungsprotokolle für das Revier Lichtenberg-Lauenstein" (unnumbered). The document, signed by "Bergbeschworener Killinger," contrasts "regelmäsiger Firstenbau" with "verkrippelte Firsten," and generally illustrates his and Humboldt's concern about investors and foremen whose "unruly" construction "defiled" the mines and prohibited their longevity.
[709] StABa, KDK, Nr. 7114, vol. 1, Bl. 39-41 (Plan Ueber den Unterricht in der Bergschule zu Untersteben pro 1800/1): "Ueber die Arbeit mit Schlegel und Eisen; und die Regeln die man bei dieser Arbeit zubeobachten hat"; "Vom Abbau der Lager; was für Regeln dabei zu besichtigen sind"; "Regeln die bei denselben zu beobachten sind, in Hinsicht der Bührlöcher und Anfälle nach der Festigkeit des Gesteins"; "Von der Zimmerung auf Streken, mit Hinsicht auf die Regeln, die dabei zu beobachten sind." Compare to the "rules" observed in Humboldt's schoolbook on Bl. 98.
[710] StABa, KDK, Nr. 7114, vol. 1, Bl. 88: "Der höchste Berg in der Welt ist in Amerika. Er heist Schimborasso und mißt 19320 Fuß. Er ist also 6 mal so hoch als unser Fichtelgebirge." Ibid., 92: "Unsere Erdkugel hat 5400 Meilen im Umfang und über 1700 Meilen im Durchmeßer, die Leute, welche die ganze Erde durchgereiset sind, haben 5400 Meilen zurück gelegt." Ibid., Bl. 93: "Auch das Meer hat seinen Boden, wie unsere Flüßen. Nur liegt er oft sehr tief. An einigen Orten hat man Seile mit Eisen belaßt 250 Lachter hiereingelaßen und noch keinen Grund gefunden." All measurements are in Prussian

seen or summited, Humboldt suggested, may yet be measured and comprehended. "The children must not be tormented into remembering these numbers," he told the School's first instructor.[711] Instead, lessons were to impress upon them a sense of nature's proportions and instill a metrological spirit.

Here Humboldt tested out various metaphors and thought experiments that would persist in the phraseology of his cosmos. Often, this meant speaking a language already familiar to the children, describing Chimborazo, for instance, as "six times as high as our own Fichtel Mountains." After imagining a shaft dug through the earth's diameter, he reminded pupils of how shallow real mineshafts were by comparison: "the crust of the earth in which we travel is not even so thick as the oil varnish on a table." Viewed from the same perspective, Chimborazo itself would appear "as though a single hair upon a sphere that is two feet in diameter." Even the unfathomed depths of the sea, Humboldt assured his students, would "appear as our solid land, with mountains and valleys," asking them to imagine a dehydrated globe.[712] Such was the *Weltbild* Humboldt impressed upon his future foremen, viewed as if by a cosmic cartographer.

Before *physische Weltbeschreibung*—the subtitle of *Kosmos*—was *physikal*[ische] *Erdbeschreibung*—the title of his schoolbook.[713] The schoolbook made measurers of miners.

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metrics. The Prussian mile was then equivalent to 7.5 km, meaning Humboldt's measure of the earth's diameter comes within 8 km of the now generally accepted 12,742 km.

[711] StABa, KDK, Nr. 7114, vol. 1, Bl. 100: "Die Kinder brauchen nicht gequält zu werden, die Zahlen zu behalten. Wenn sie nur in Allgemeinen einsehen, wie gering die Teufe unserer Schächte gegen den Erddurchmeßer ist."

[712] StABa, KDK, Nr. 7114, vol. 1, Bl. 93: "Die Erdrinde in der wir auffahren, ist noch nicht so dick, als die Oelfarbe auf einen angestrichenen Tisch." Ibid., Bl. 88: "Wenn man auf eine 2 Fuß dicke Kugel ein Haar legt, so ist das Haar doch höher als der hochste Berg in Vergleich mit der ganzen Erde." Ibid., Bl. 93: "Wenn man den Meeresboden ohne Waßer sehen könnte, so müßte er wie unser festes Land aussehen, mit Berg und Thal. Oft findet man ihn schon in 5 bis 30 Lachter Grund, und die Sandbänke und Inseln sind nur aus dem Wasser hervorstehende Berge."

[713] In fact, the Cosmos lectures were first called "*Physikalische Geographie*," as transcribed by Henriette Kohlrausch in 1827-28 and now archived in SBB, Ms. Germ. Qu. 2124.

Mindful not to "kill spirit of the practical" by overwhelming the youngest pupils with "principles and terminology," Humboldt began with what he called "entertainment" (*Unterhaltung*). In doing so, he greatly expanded the realm of what is considered "useful to the common miner." The ideal foreman's field of vision now spanned "a sort of physical description of the earth," which "he will record without even knowing it."[714] Thus Humboldt described the geo-physical journey students took into mines, across oceans, up the Andes, and back. Aside from the identification of useful metals, pupils were schooled in the latest "geognostic" theories from the Academy in Freiberg, particularly Abraham Gottlob Werner's ideas about the genesis of mineral veins within the historical formation of the earth's strata.[715] Humboldt did not merely wish for pupils to properly identify an ore vein; he wanted them to understand that vein's historical relation to contiguous strata, describe its orientation within a mountain chain, and conceive of local mineralogical phenomena as patterned "formations" in the structure of the earth's crust.[716]

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[714] Humboldt to Carl Freiesleben, 20 Jan. 1794, *Jugendbriefe*, 311: "Er schreibt sich also, ohne es zu wissen, sein Heft. 3) eine Art Physikal. Erdbeschreibung oder Geognosie, als von den Gebirgen, von der Luft, Wettern, Wasser, von den Kennzeichen der Erzführenden Lagerstädten." See also Alexander von Humboldt, "Ganz gehorsamstes Promemoria, die Errichtung einer königlichen freien Bergschule zu Steben betreffend," in Karl Bruhns, *Alexander von Humboldt: Eine wissenschaftliche Biographie*, vol. 1 (Leipzig: Brockhaus, 1872), 292-97. "Unterhaltung" comes from Humboldt's notes to the instructor in the schoolbook itself, StABa, KDK, Nr. 7114, vol. 1, Bl. 101.

[715] On Werner's theory of mineral veins, see Abraham Gottlob Werner, *Neue Theorie von der Entstehung der Gänge…* (Freiberg, 1791), 54-55 and Rachel Laudan, *From Mineralogy to Geology: The Foundations of a Science, 1650–1830* (Chicago: University of Chicago Press, 1987), 87-96, 106-09.

[716] StABa, KDK, Nr. 7114, vol. 1, Bl. 85-100. Cf. Alexander von Humboldt, *Asie Centrale: Recherches sur les chaînes du montagnes et la climatologie compare* (Paris: Gide, 1843), *1*, xxxii-xxxiii. Also observe how his effort to turn geognosy into a science of universal patterns in the superposition of strata, Humboldt complained of the local "prejudice" in miners' observations: "Wherever the working of a mine was directed on a mass of salt, coal, or clay ironstone, covered by successive beds of a different nature, it gave rise to ideas more or less precise, on the arrangement of the rocks peculiar to a formation of small extent. Possessed of this local knowledge, but influenced by prejudices having their source in habit, miners spread themselves over contiguous countries, and, as geognists have often done in our days, they decided upon the positions of rocks, of the nature of which they were ignorant, according to incomplete analogies, and the confined ideas they had originally acquired." They have (wrongly) "imagined that each portion of the globe differed in its geological constitution," where Humboldt argued for a "uniformity of position," though not a simultaneity of formation, around the globe. (Alexandre de Humboldt, *Geognostical Essay on the Superposition of Rocks in both Hemispheres* (London, 1823), 2-3, 8.)

Mine foremen occupied an unacknowledged place in Humboldt's "republic of instruments." By 1806, Killinger noted how successfully his School had taught pupils to use the compass to produce "elaborate mine profiles."[717] In a "cosmic polity" where the "ability to see, to overview the totality in a single act of vision, marked one's citizenship," foremen's use of cartographic technologies was a most radical act.[718] For miners as for voyagers, instrumentation was social capital, and the semiotic power of a compass in the hands of a "common" miner cannot be overstated. In taking on some of the tasks of Academy-trained surveyors, foremen straddled a division of mental and manual labor in the German mining that generally corresponded to social status.[719] "In a society of orders," Lissa Roberts and Simon Schaffer have argued of the early modern period more generally, "the steeply graded hierarchy of head and hand was vital to defining persons and their social places."[720] But just as the noble *von* Humboldt mingled easily with bourgeois officials, so the borderland between lower officials and manual laborers did not entirely segregate men of middle- and working-class origins. And while the industry's corporate order was codified by its rigid table of ranks, miners also looked to dress and instrumentation to demarcate those who worked with the head, the hand, or both.[721] Aside from the miner's lamp, laborers did not wield the instruments of observation specific to officials and surveyors (**Figure 2**)—the magnetic compass, sighted alidade, level, protractor, and so on.

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[717] StABa, KDK, Nr. 7114, vol. 2, Bl. 14: "Hieher gehörten die unentbehrlichsten Lehren aus der *Geometrico* Berechnung körperlicher Größen, Erklärung des *Compaßes* u. Gebrauch sich damit bey Befahrung jeder Grube *orientiren* zu können, Unterricht in Aufnahme eines ohnegefähren Grubenbildes als *Brouillon*, u. ausgearbeitete GrubenRisse verstehen, u. sich deutlich körperlich drucken zu können."
[718] Dettelbach, "Global physics and aesthetic empire," 274.
[719] Klein, *Nützliches Wissen*, 44.
[720] Lissa Roberts and Simon Schaffer, "Preface," *The mindful hand: Inquiry and invention from the late Renaissance to early industrialization*, eds., Lissa Roberts, Simon Schaffer, and Peter Dear (Amsterdam: Royal Netherlands Academy of Arts and Sciences, 2007), xii.
[721] See Sebastian Felten, "Mining culture, labour, and the state in early modern Saxony," *Renaissance Studies* 34, no. 1 (2019): 125-38. Notably, high ranking officials commonly brandished miner's axes during parades. But the social mobility of mining instruments typically only worked in one direction.

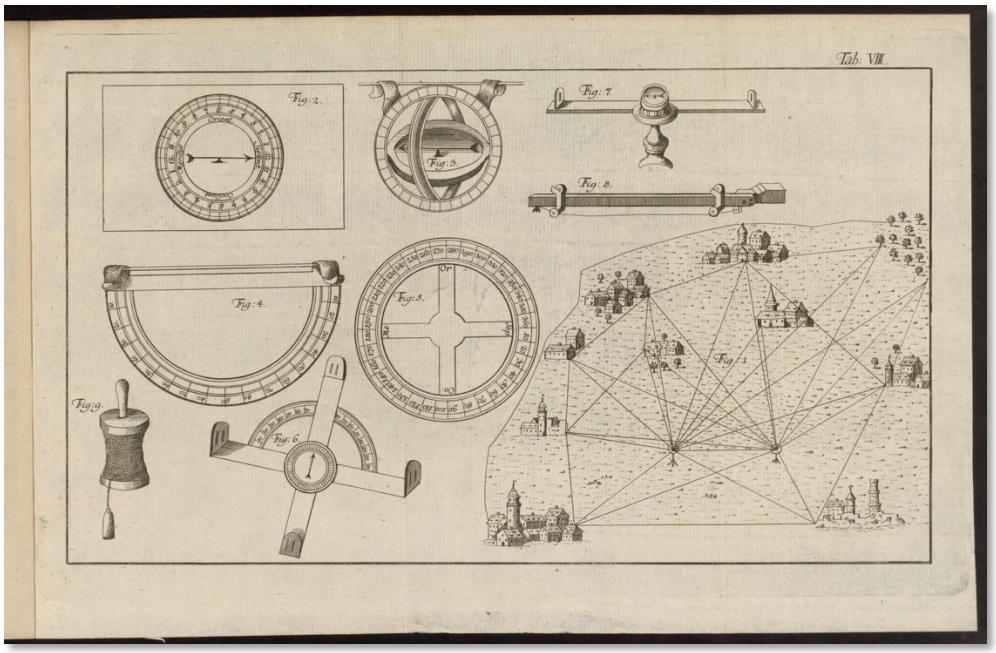

Figure 2. Surveying instruments from Johann Gottfried Jugel's *Geometria Subterranea,* including the *Hängecompass* (in "Fig. 3" above), which was suspended from a cord to determine a mineshaft's declination while drafting a mine profile (*Grubenriss*), as well as a sighting instrument "akin to an astrolabe" (in "Fig. 6") used by miners to record the strike of an ore vein. SUB Gö, 4° met. 2878.

Theirs were instruments of physical rather than intellectual labor: mallet and hammer, axe and saw, black powder and tinder, and the "miner's knife" with which they inspected timber framing, whether *frisch* or *faul*.[722]

The compass in particular bespoke *Wissenschaft*, especially as "the art of surveying" (*Markscheidekunst*) gained a disciplinary coherence in the curricula of Freiberg's Mining Academy after its founding in 1765. Humboldt himself learned cartography from the chief surveyor of Freiberg, Freiesleben's own father, while studying there in 1791.[723] While not directly involved in the extraction of ore, surveyors (or *Markscheider*) played a significant administrative role in the planning and organization of underground operations. Surveyors

[722] This knife, the *Gruben-Tscherper*, is described in Johann Caspar Zeisig, ed., *Neues und wohleingerichtetes Mineral- und Bergwerks-Lexicon,* 3rd ed. (Chemnitz, 1784), 269.
[723] Karl Bruhns, *Alexander von Humboldt: Eine wissenschaftliche Biographie*, vol. 1 (Leipzig: Brockhaus, 1872), 124.

belonged to a group of technical experts that included mechanics, assayers, and smelting operators, all of whom were trained in "theory" at the Mining Academy in Saxony.[724]

The surveyor's confident habitus and elevated stature as a practical mathematician is illustrated in a mid-nineteenth-century atlas of Saxon mining (**Figure 3**), a genre that taxonomized the industry's many trades.[725] Legs crossed in a leisurely pose, the surveyor records the shaft's declination, as indicated by the suspended *Hängecompass*. One assistant looks on—waiting, watching—as another kneels to illuminate the compass with a candle drawn from his lamp. The cord to which the compass is fixed runs down the shaft, where a third assistant has assembled wooden frames specially fixed for the task. Here the *Markscheider*, with pen and paper aglow before his lamp, represents oversight in the most literal sense. Possessed of the requisite data to behold labyrinthine passages in single authoritative gaze, he is charged with the unique task of making visible the dark world below. To bore an adit that would intersect with a vertical shaft hundreds of meters in the earth, for instance, required the precise marksmanship of the surveyor who determined the exact angle and heading at which the foreman would lead his men. As hewers relied upon their foreman, so foremen relied upon their surveyor.

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[724] On *Marksheidekunst*, its development under a "stipend" system in Saxony, as well as the "scientific" status it achieved at the Mining Academy by virtue of its ties to geognosy, see Karl Neubert and Walther Stein, *Plan- und Risskunde*, 2nd ed., vol. 1 (Freiberg: Bergakademie Freiberg, 1958); Michael Ziegenbalg, "Von der Markscheidekunst zur Kunst des Markscheiders," *Berichte der Geologischen Bundesanstalt* 41 (1997): 267-74; Rainer Sennewald, "Die Stipendiatenausbildung von 1702 bis zur Gründung der Bergakademie Freiberg 1765/66," in *Technische Universität Bergakademie Freiberg, Festgabe zum 300. Jahrestag der Gründung der Stipendienkasse für die akademische Ausbildung im Berg- und Hüttenfach zu Freiberg in Sachsen* (Freiberg: TU Bergakademie Freiberg, 2002), 407-29; Christoph Bartels, "Vermessungen, Karten und Pläne im Montanwesen an der Wende zwischen Mittelalter und Neuzeit – Kontinuitätslinien und Entwicklungstendenzen," *Aufsicht – Ansicht – Einsicht: Neue Perspektiven auf die Kartographie an der Schwelle zur Frühen Neuzeit*, eds. Tanja Michalsky, Felicitas Schmieder, Gisela Engel (Berlin: Trafo Wissenschaftsverlag, 2009), 329-50.

[725] Consider G. E. Rost, *Trachten der Berg- und Hüttenleute im Koenigreiche Sachsen* (Freiberg, 1831); Eduard Heuchler, *Album für Freunde des Bergbaus* (Freiberg: Engelhardt, 1855); Eduard Heuchler, *Die Bergknappen in ihren Berufs- und Familienleben bildlich dargestellt und von erläuternden Worten begleitet* (Dresden: Kuntze, 1857), as well as earlier representations of labor in Johann Friedrich Wilhelm von Charpentier, *Mineralogische Geographie der Chursächsische Lande* (Leipzig: Crusius, 1778).

Figure 3. Surveyors at work measuring the mines, recording degrees from the *Hängecompass*. Eduard Heuchler, *Die Bergknappen in ihren Berufs- und Familienleben bildlich dargestellt und von erläuternden Worten begleitet* (Dresden: Kuntze, 1857), Plate 17, with description on p. 7. The author-illustrator was himself a professor at the Mining Academy. Max Planck Institute for the History of Science, Library, Rara H592b.

But a foreman who wielded his own compass might well strike the self-assured pose of the Academy-trained surveyor, taking command of physical and intellectual labor.[726] In parades the *Markscheider* was clearly delineated by the plumage of his hat and the ornate trim of his coat. Underground, however, the foreman might rival him at least in his instrumentation, which simultaneously marked Humboldt's new class of *Steiger* apart from "common" miners. "Rarely does a common miner possess a compass," Humboldt's schoolbook stated.[727] For the compass presumed literacy, distinguishing its possessor as one who knows their craft on paper and in

[726] Historians have studied cartography an instrument and arena of (geo-)political imagination, as in Matthew Edney, *Mapping an Empire: The Geographical Construction of British India, 1765-1843* (Chicago: University of Chicago Press, 1990), 340. On German surveyors, see Klein, *Nützliches Wissen*, 26-27, 38-44; Werner Kroker, "Aspekte der Entwicklung des Markscheidewesens im Oberharz," *Technikgeschichte* 39 (1972): 280-301; Otfried Wagenbreth, "Grubenrisse und geologische Karten als Hilfsmittel der Montanarchäologie," *Berichte der Geologischen Bundesanstalt* 35 (1996): 367-39. Surveyors played a legal role as the arbiters of property disputes. Hence the German appellation *Markscheider*, literally he who determines the lines. See also Felten, "Mining Culture," 128, n. 30.
[727] StABa, KDK, Nr. 7114, vol. 1, Bl. 97.

practice. “Of the *Bergcompasse*,” one standard text on *Subterranean Geometry* said, “The common miner knows little or nothing;”

> for he knows the matter only from hearsay [*Hörensagen*]: but he who wishes to reflect further, to learn the basis of natural insights, scour the mountains for the strike of metal and mineral-rich ore veins, and seek all that is hidden therein, it is for him above all others to behold the *Bergcompaß* and all the advantages to be gained from it.[728]

Humboldt was similarly prejudiced against oral knowledge, just as liable to “kill the sense for the practical.” “The technique itself, the manual methods [*Handgriffe*] of mining must absolutely not become an object of oral instruction,” Humboldt told his first instructor, believing pupils would infer that “one simply learns in the Mining School … as he learns in the mines.”[729]

Humboldt believed it vitally important that his new class of foremen understand their craft first as principle then as practice. He devised lessons in which the students crafted paper compasses that they were to use in determining the declination (or “strike”) of a vein marked out with a “rod” on the classroom floor. “The instructor stands in the middle of the room, naming the four walls after the four cardinal directions”—not north, south, east, and west, as we know them, but *Mitternacht*, *Mittag*, *Morgen*, and *Abend*. Then, the instructor would copy from the schoolbook to the chalkboard an image describing the unique parlance miners used to describe the orientation of mountain chains and ore veins: veins running north and northeast “strike a standing vein [*Stehenden Gang*],” Humboldt wrote, continuing around the *Bergcompass* (as

[728] Jugel, *Geometria Subterranea*, 409-10: “Wer aber weiter nachdenken, den Grund von natürlichen Einsichten erlernen, die Gebürge nach ihren streichenden metallischen und mineralischen Erzgängen erschroten, und das Verborgene darinnen aufsuchen will, dem lieget vor allen Dingen ob, den Bergcompaß und alle dadurch zu erlangende Vortheile zu verstehen.” Description of the surveyor’s instruments precedes this passage in ibid., 406-08.

[729] Humboldt, “Ganz gehorsamstes Promemoria,” 294: “Was das Praktische des Metiers betrifft, so müssen wohl die Gründe angegeben werden, warum man so oder so verfährt; das Verfahren selbst, die Handgriffe müssen aber schlechterdings kein Object der mündlichen Unterweisung sein, weil dadurch der Sinn für das Praktische geschwächt wird und leicht die Meinung entsteht, man lerne in der Bergschule Zimmern, Bohren, Schiessen wie in der Grube.”

shown in **Figure 4**) to describe how the morning vein (*Morgengang*) runs east, spar veins (*Spaatgänge*) to the east and southeast, and flat veins (*Flachengänge*) southeast and south. Some *Bergcompasse* from the period, designed specifically for this purpose, bore these geognostic declinations in addition to the Latinate cardinal directions (typically abbreviated as *septent*, *orient*, *meridies*, and *occident*). "Give this image to the children," Humboldt continued, matching his instructions to corresponding schoolbook figures (**Figure 5**), "which is more valuable to them if they write it down themselves." Paper compass in hand, pupils were to then act like a magnetic needle, maintaining their *Mitternacht* orientation with the front of the classroom, while using "the image to determine for themselves the strike of the vein" already lain on the floor.[730]

Figure 4. A brass *Bergcompass*, 72 mm in diameter, of seventeenth- or eighteenth-century origin. The declination *Spaath* corresponds to *OR*, striking eastward as Humboldt instructed pupils, while *Stehend* aligns with the tail of the magnetic needle pointing to *ME*, or *meridies*. This means "Mittag," the word used in eighteenth-century Germany to designate south (where the sun stands at mid-day). Photo credit: Dorotheum Vienna, auction catalogue 25.09.2019, Lot Nr. 336.

[730] StABa, KDK, Nr. 7114, vol. 1, Bl. 103-03: "*ad.* Sect. 12. Der Lehrer stelle sich mitten in ein 4 eckiges Zimmer, benennen die 4 Wände nach der 4 Weltgegenden und zeige nun, daß ein Gang oder eine Bergkette entweder wie *a. b.* oder wie *e. d.* … sich hinziehen können wie Figur 35 vorgestellet ist…. […] Wenn man daher Mitterbacht vor sich hat; so gehört alles, was in Mitternacht oder zunächst rechts davon streicht zum Stehenden Gang, alles was in Mitternacht Morgen oder zunächst rechts dabey streicht zum Morgengang, alles was in Morgen oder zunächst rechts dabey streicht zum Spaatgänge alles was in Mittag Morgen oder zunächst rechts dabey streicht zum Flachengänge. Man gebe den Kindern das Bild, daß sie selbst schreiben müßen weil es ihnen dadurch mehr werth wird, in die Hand, laßen sie das Bild in den in den wirklichen Mitternacht halten und lebe nun eine Stange auf dem Fusboden, die das Streichen eines Ganges ausdrückt. Dan müssen die Knaben auf dem Bilde selbst aufsuchen, wie der Gang streicht?"

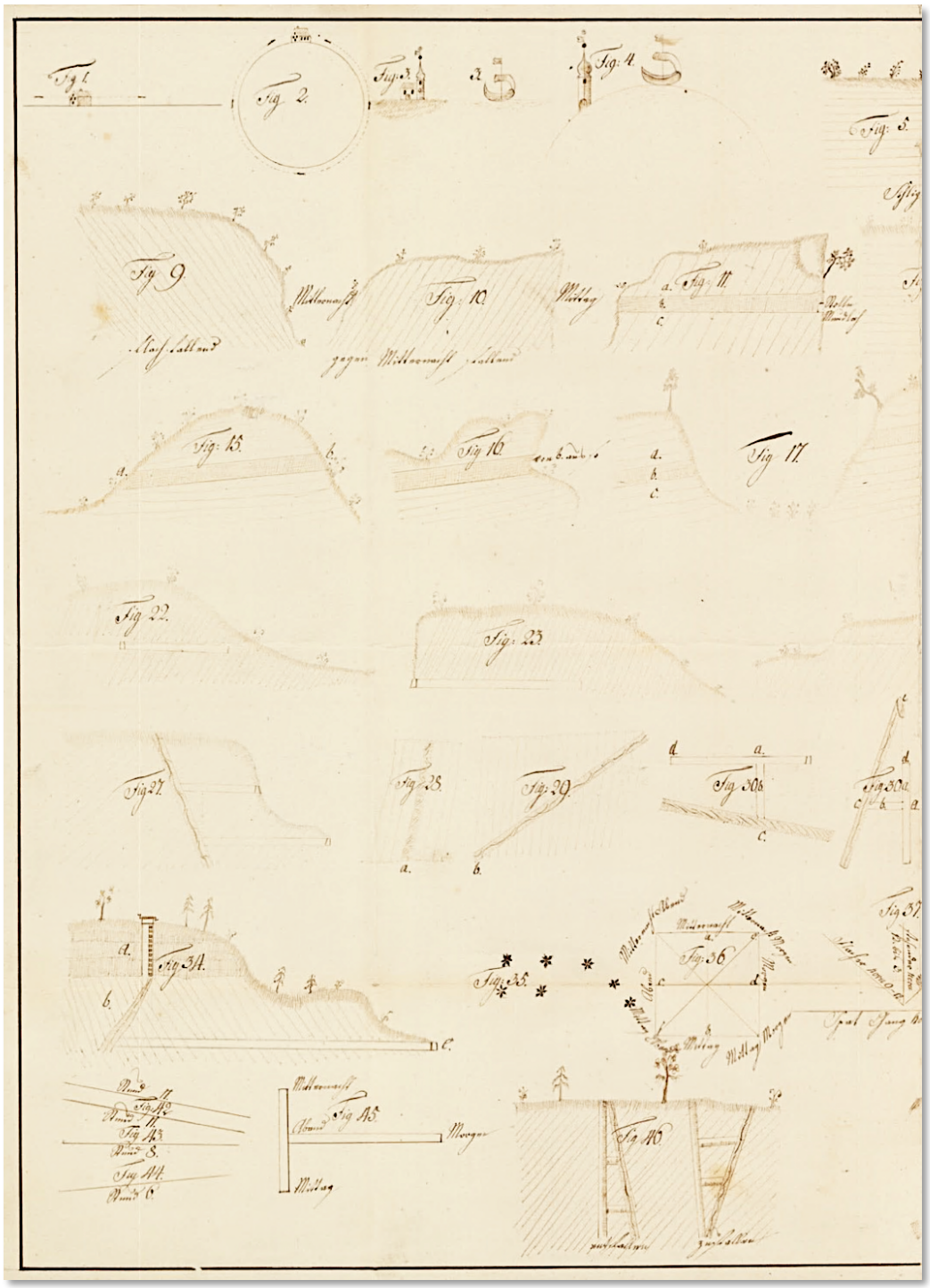

Figure 5. Detail from Humboldt's schoolbook, showing the left half of the forty-eight figures that corresponded to specific lessons. Here we see the progression from lessons in the circumference of the earth the nature of geognostic formations to the orientation of ore veins and plan of mining operations. "Fig. 35" mentioned by Humboldt in the compass exercise likely referred to a page of its own, as indicated by the stars at the bottom of the page. However, the declinations in "Fig. 36" give an impression of the "image" after which the School's pupils drafted their own compasses. StABa, Karten und Pläne (A 240), T 5022.

This brief history of the *Bergcompass* and the mine foremen who learnt to use it shows the social organization of Humboldt's science in the making. Certainly, the compass held a modest rank in Humboldt's "republic of instruments." Eudiometers, as we have seen, were placed in the hands of fellow officials, while savants had shown how barometers could be used to determine the depths of mines. Humboldt took both these instruments with him while voyaging through the mountains and mines of Europe and Spanish America. But by arming foremen with instruments of observation, Humboldt also advanced a tradition of learned technicians who saw mining as a field of scientific inquiry and observation. Around the middle of the eighteenth century, some mine officials composed guidebooks and instructions for well-to-do travelers to record their mineralogical observations in Germany's mining regions. A later generation of officials took to publishing their own correspondence, all in an effort to catalogue mineralogical knowledge drawn from the earth in the extraction process.[731] Humboldt followed suit, publishing the results of what he and his colleagues called "minerly journeys," or *bergmännischen Reisen*.

The catchphrase of a veritable genre that emerged around 1800, "minerly journeys" carry an important lesson for understanding Humboldt's style of scientific travel and inquiry.[732] In the place of *a* voyager, these works presupposed a complex labor-intensive infrastructure of

[731] E.g. J. G. Lehmann, "Ohnmaßgeblicher Vorschlag, auf was Art und Weise man zu einer genauern Entdeckung der unter der Erde verborgenen Dinge, oder kurz zu sagen, zu einer unterirdischen Erdebschreibung gelangen könne," in *Physikalische Belustigungen* 1 (Berlin, 1752): 27-42; Franz Ludwig von Cancrinus, *Beschreibung der vorzüglichsten Bergwerke* (Frankurt, 1767); F. W. H. Trebra, *Erfahrungen vom Innern der Gebirge, nach Beobachtungen gesammlet* (Dessau & Leipzig, 1785).
[732] A selection of works that portray mine inspections as mineralogical "journeys" include: J. G. Jugel, *Entdeckung der verborgenen Schatzkammer der Natur, oder: desselben ober und unterirdischen Reisen durch das Mineralreich* (Berlin, 1789); Böhmer, "Journal einer bergmännischen Reise von Freyberg nach Altenberg," *Lempes Magazin für die Bergbaukunde* VIII (1791); W. G. E. Becker, *Journal einer Bergmännischen Reise durch Ungarn und Siebenbürgen* (Freyberg, 1816); G. G. Pusch, *Geognostisch-bergmännische Reise durch einen Theil der Karpathen, Ober- u. Nieder-Ungarn, angestellt im Jahre 1821* (Leipzig, 1828); S. A. W. Herder, *Bergmännische Reise in Serbien* (Pesth, 1846).

observation that relied upon the administrative oversight of the mining state. So, too, Humboldt's *physique du monde* depended upon larger governing structures in which he himself was an instrument. No mere prelude to global physics, the social structure of mining would remain integral to Humboldt's science through his thirty-four-volume voyage and beyond.

The Surveyor of Mexico

In the racist iconography of the American voyage, Humboldt sometimes appears as a mercurial messenger sent to bestow the gifts of learning and industry to uncivilized peoples (**Figure 6**). This, at least, is how he chose to be allegorized in the frontispiece of his *Atlas géographique*, where Mercury and Minerva are seen helping a fallen Aztec empire to her feet.[733] The scene is reconfigured in Weitsch's oil painting (**Figure 7)**, where one of the "copper-colored Indians," as Humboldt called indigenous people, is depicted as though handing surveying instruments over to his master at the foot of Chimborazo. Behind a large sextant (likely indicating the 10-inch model by Ramsden that Humboldt noted in his *Personal Narrative*) a wooden case can be discerned. Perhaps the case contained the dipping needle Humboldt received from France's Bureau des Longitudes, or the 12-inch magnetic needle he carried, which could be suspended, like the *Hängecompass*, to register subtle latitudinal variations in magnetic intensity. Here again the semiotics of surveying instruments are at work. A burden for indigenous porters and Creole assistants, LeNoir's repeating circle, Ramsden's graphometer, and Hurter's theodolite were transcendent devices for Humboldt, representing oversight in every sense.

[733] The frontispiece belongs to the *Atlas géographique et physique des régions équinoxiales du Nouveau Continent* published as part of his thirty-four-volume *Voyage aux régions équinoxiales du Nouveau Continent* (1808-1834), and dates to 1831. This chapter also analyzes the *Atlas géographique et physique du Royaume de la Nouvelle-Espagne* (Paris, 1814), published in affiliation with the *Political Essay*.

Figure 6 (Left). Mercury and Minerva raising a fallen Aztec Empire in the frontispiece to Humboldt's *Atlas géographique et physique des régions équinoxiales du Nouveau Continent* (Paris, 1831) by Barthélemy Roger, after a drawing by François Gérard. The inscription *humanitas, literæ, fruges* is often translated as humanity, knowledge, and economy (or, literally, agriculture). David Rumsey Historical Map Collection, Image No: 12125006. Figure 7 (Right). Detail from Friedrich Georg Weitsch's "Alexander von Humboldt und Aimé Bonpland im Tal von Tapia am Fuß des Vulkans Chimborazo" (1810). Oil on canvas, 162 x 226 cm. Berlin, Staatliche Schlösser und Gärten, Wikimedia Commons.

Scholars have looked to these very images, and the imperious gaze they represent, as proof that Bolívar's moniker for Humboldt, as a "second Columbus," was all too true. Humboldt's science, some have argued, amounted to an "intellectual annexation" of the world.[734] Mary Louise Pratt described Humboldt as having presented educated European readers (and investors) an image of the Americas as an unpeopled, timeless land "waiting to be known and

[734] Antonello Gerbi, *The Dispute of the New World: The History of a Polemic, 1750-1900*, trans. Jeremy Moyle (Pittsburgh, PA: University of Pittsburgh Press, 1973), 208.

possessed." This required a brutal act of erasure and dispossession on Humboldt's part, a gaze that "archeologized" America's inhabitants as vestiges of antiquity and, in emphasizing nature's sublimity, accomplished a deafening "mystification of social forces."[735]

In many ways, the production of Humboldt's *Atlas* corroborates this interpretation. The "archeologization" of local populations appears embedded in Humboldt's very practice of surveying, as recorded *in situ*. Amidst pages of hastily scribbled coordinates, azimuths, and trigonometric calculations, a curious form emerges: the pyramidal outcropping of Aztec ruins in Cholula where, in January 1804, Humboldt turned a sacred burial site—a "god-dwelling," as he translated the Nahuatl *teocalli*—into a surveying station (**Figure 8**).[736] Fifty-five meters high and "already oriented in exact alignment with the four cardinal directions," Humboldt used this "handmade mountain" to triangulate volcanoes like the "smoking mountain," Popocatépetl.[737]

Humboldt employed a "*hypsometric method*" of surveying developed in the eighteenth century, drawing upon the techniques of surveyors as well as experimental physicists.[738] Having climbed Popocatépetl and measured its prominence (or "absolute height") with a series of barometric readings, he was able to determine the "vertical base" of a right triangle whose adjacent line extended east, horizontally, to Cholula. From there, he measured the angle of

[735] Pratt, *Imperial Eyes*, 118, 138.
[736] "Papiere über die Statistik und Geographie von Mexico und Cuba," in BJK, Berol. Ms. Nachlass von Alexander von Humboldt 1, Bl. 63. A year and a half earlier, Humboldt examined the ruins and other "astronomical relics" left of the pyramidal surveying stations built by French and Spanish operations in Quito in 1735. See Neil Safier, *Measuring the New World: Enlightenment Science and South America* (Chicago: The University of Chicago Press, 2008), 23-24, 55-56. He even encouraged the colonial government there to rebuild the monuments.
[737] Alexander von Humboldt, *Views of the Cordilleras and Monuments of the Indigenous Peoples of the Americas: A Critical Edition,* eds. Vera M. Kutzinski and Ottmar Ette, trans. by F. Ryan Poynter (Chicago: University of Chicago Press, 2012), 42-46.
[738] See Theodore S. Feldman, "Applied Mathematics and the Quantification of Experimental Physics: The Example of Barometric Hypsometry," *Historical Studies in the Physical Sciences* 15, no. 2 (1985): 127-195, esp. 186-95.

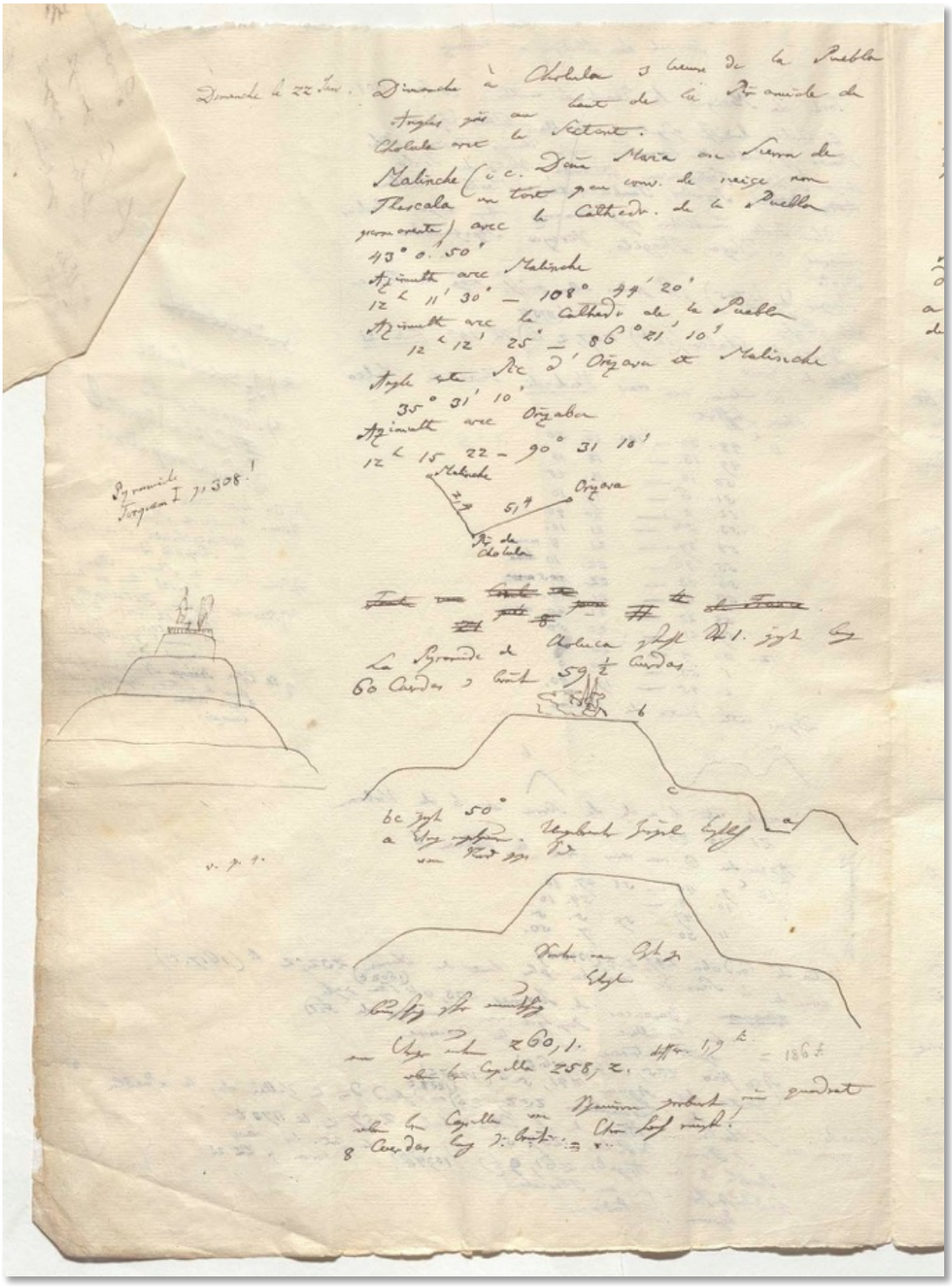

Figure 8. Humboldt's sketches of the Pyramid of Cholula, beneath azimuths determining its position relative to other surveying stations. "Papiere über die Statistik und Geographie von Mexico und Cuba," in BJK, Berol. Ms. Nachlass von Alexander von Humboldt 1, Bl. 63. Spanish conquerors appropriated the site for their own religious practices, as evidenced by the Catholic church built atop the pyramid, hastily included in Humboldt's sketch. The pyramid is illustrated and described at great length in Humboldt's *Vues des Cordillères* (1810).

elevation up to Popocatépetl's summit, allowing him to fill in the triangle, as it were, and determine the distance between the two features in a series of trigonometric calculations. Unsatisfied with existing accounts of the longitudinal distance between Mexico City and Veracruz, the pyramid presented a geographic middle point—and a clear-sighted vantage point—with which to link a series of volcanic beacons that stretch from the Valley of Mexico to its Atlantic seaboard. "With these fire-spitting mountains I have connected two locations separated by some 312 kilometers," Humboldt wrote.[739] It is this very scene that inspired the *Atlas*'s frontispiece. As Popocatépetl towers above, the pyramid of Cholula is faintly visible beneath Athena's olive branch. These ruins mark the engraving's vanishing point—a fitting location, some might say, in a work that sought the "erasure of the human," or at least, of the Other.[740]

Such scenes speak volumes about the hubris of Humboldt's civilizing mission but offer deceptive accounts of his scientific practice. The Humboldtian iconography might be read rather as an inverted reflection of actual social relations. For it was Humboldt who rose to eminence in the hands of Spanish American actors already in possession of advanced surveying instrumentation; and the *Tribunal de Minería* in particular who provided Humboldt an infrastructure uniquely capable of turning his meandering itinerary into a cartographic enterprise of hemispheric proportions.[741] From this perspective, the scene atop Cholula's ancient pyramid is

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[739] Alexander von Humboldt, "Geographische Einleitung," in *Alexander von Humboldt Werke*, vol. iv, Mexico-Werk*,* ed. Hanno Beck (Darmstadt: WBG, 2008), 16: "Zwei große Vulkane, der Vulkan von la Puebla oder Popocatépetl und der Pic von Orizaba sind beide sichtbar von der abgetragenen Spitze der alten Pyramide von Cholula. Mittels dieser feuerspeienden Berge habe ich zwei beinahe 160,000 Toisen voneinander entlegene Orte miteinander verbunden." Cf. Humboldt, *Neu-Spanien*, *5*, 110.
[740] Pratt, *Imperial Eyes*, 125. For critical appraisals of Pratt's position, consider Aaron Sachs, "The Ultimate 'Other': Post-Colonialism and Alexander von Humboldt's Ecological Relationship with Nature," *History and Theory* 42 (Dec. 2003): 111-35 and Laura Dassow Walls, "Rediscovering Humboldt's Environmental Revolution," *Environmental History* 10, no. 4 (Oct. 2005): 758-60.
[741] This argument is indebted to Eduardo Flores Clair and Cuauhtémoc Velasco Ávila, "Los pasos de Alejandro de Humboldt por la minería novohispana," *Jahrbuch für Geschichte Lateinamerikas – Anuario de Historia de América Latina* 42, no. 1 (1964): 47-57, who argued that in Mexico Humboldt "had the

symbolic of the fact that Humboldt used the institutional resources available to him in Spanish America as a steppingstone for his own ambitions.[742]

In New Spain Humboldt found a land teeming with engineers, bureaucrats, and surveyors. It was a familiar scene: state actors busily reforming the metallurgic sector, channeling statistics from disparate *intendencias* into centralized depots, and producing that potent technology of territorial administration, the map. Humboldt's own *Atlas* was in many ways the product of an administrative "*Reconquista*" that began with the Bourbon reforms of the mid eighteenth century, concerned especially with the productivity of the land and the centralization of government in Spain and its dominions.[743] Humboldt entered New Spain just as the full force of its administrative reorganization under the Bourbon state took effect, making it the most prosperous colony in the world. To end royal trade monopolies, promote free trade,

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good fortune of participating in a high level academic ambience and took advantage of the scientific advances to incorporate them in his writings." David Y. Allen has emphasized Humboldt's particular debt to relief maps composed by Mexican cartographer José Antonio de Alzate y Ramírez as well as other Mexican scholars in David Y. Allen, "Alexander von Humboldt and the Mapping of Mexico," *E-Perimetron* 9, no. 2 (2014): 78-96. On the history of Latin American cartography to which Humboldt is indebted, and the history of his visual science on Spanish America more generally, see Amrei Buchholz, *Zwischen Karten: Alexander von Humboldts Atlas géographique et physique des régions équinoxiales du Nouveau Continent* (Berlin: De Gruyter, 2020), esp. 94-102.

[742] On Humboldt's unacknowledged debt to creole expertise and networks, see Jorge Cañizares-Esguerra, "How Derivative Was Humboldt? Microcosmic Nature Narratives in Early Modern Spanish America and the (Other) Origins of Humboldt's Ecological Sensibilities," in *Colonial Botany: Science, Commerce, and Politics in the Early Modern World*, eds. Londa Schiebinger and Claudia Swan (Philadelphia: University of Pennsylvania Press, 2005), 148–65. Elsewhere, Cañizares-Esguerra has shown how Humboldt relied heavily upon indigenous sources for his historical writings on the Americas, particularly in New Spain, and also that Humboldt was rather unique in the authority he accorded native records, for which he was criticized by European reviewers. See Jorge Cañizares-Esguerra, *How to Write the History of the New World: Histories, Epistemologies, and Identities in the Eighteenth-Century Atlantic World* (Stanford, CA: Stanford University Press, 2002), 124-29.

[743] From the perspective of Creole elites and their multi-ethnic collaborators, mining was seen, like botany and other natural sciences, as a cornerstone of Latin America's own Enlightenment. See Daniela Bleichmar, *Visible Empire: Botanical Expeditions and Visual Culture in the Hispanic Enlightenment* (Chicago: University of Chicago Press, 2012), esp. 17-42; Helen Cowie, *Conquering nature in Spain and its empire, 1750-1850* (New York: Manchester University Press, 2011); and Heidi V. Scott, "Taking the Enlightenment Underground: Mining Spaces and Cartographic Representation in the Late Colonial Andes," *Journal of Latin American Geography* 14, no. 3 (Oct. 2015): 7-34.

enhance revenue collection, and increase regulation in mining, the Bourbon reforms mobilized an expansive bureaucracy, not unlike that which Humboldt served in cameralist Prussia.[744] And although this reorganization was initially designed to limit the power of *criollos* (Americans of Spanish descent), it ultimately fostered a mixed Creole and Iberian administrative elite for whom a burgeoning Mexican patriotism was compatible with imperial governance.[745]

Humboldt saw in this caste of civil servants a reflection of his own zeal for economic oversight, and he came to see his science there as contributing to a "peaceful conquest" already afoot in Spanish America.[746] As we will see, the visibility of labor in Humboldt's Mexican science tracked with the politics of this Creole administrative elite. As Severo Martínez Peláez and Sophie Brockmann have shown, the landscapes constructed by Creole colonial administrators in this period tended to emphasize farmers, merchants, and other men of practical background while effacing indigenous and enslaved black labor.[747] A similar hierarchy persists through Humboldt's *Political Essay on the Kingdom of New Spain*, which elevated Creole technicians at the expense of the broader workforce involved in surveying.

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[744] On the Bourbon reforms, the administrative culture they produced in Spanish America, and their influence on science there, see Stuart George McCook, *States of Nature: Science, Agriculture, and Environment in the Spanish Caribbean, 1760-1940* (Austin, TX: University of Texas Press, 2002).
[745] Such patriotism, Sophie Brockmann argues, "was also a hallmark of the 'enlightened improvement' that shaped public life in Bourbon-era Spanish America." Sophie Brockmann, *The Science of Useful Nature in Central America: Landscapes, Networks and Practical Enlightenment, 1784-1838* (Cambridge: Cambridge University Press, 2020), 50. Compare to Jorge Cañizares-Esguerra, *Nature, Empire, and Nation: Explorations of the History of Science in the Iberian World* (Stanford, CA: Stanford University Press, 2006); Anna Toledano, "Forgotten Botany: Scientific Knowledge and the Royal Botanical Garden of New Spain," forthcoming in the Special Issue "Working at the Margins: Labor and the Politics of Participation in Natural History, 1700-1830," *Berichte zur Wissenschaftsgeschichte* (June 2021).
[746] Cañizares-Esguerra, "How Derivative Was Humboldt?"; Gerbi, *The Dispute of the New World*, 208. Humboldt used the same phrase (*friedlichen Eroberung*) to describe the agricultural conquest of vertical space by the pre-Hispanic populations. (Humboldt, *Neu-Spanien*, *3*, 8-9.)
[747] Severo Martínez Peláez, *La patria del criollo. Ensayo de interpretación de la realidad colonial guatemalteca* (Mexico City: Fondo de Cultura Econmómica, 2006), as discussed in Brockmann, *The Science of Useful Nature*, 4-5.

While in New Spain, Humboldt distributed his maps and manuscripts amongst "those called to carry out the administration of the colonies."[748] But this, again, is an inversion of the social relations that enabled the production of the *Atlas* in the first place. In drafting his "Carte General du Royaume de la Nouvelle Espagne," for instance, Humboldt began with 312 sites of mining activity recorded in the ledgers of the *Tribunal*. This provided a set of widely distributed and well-established coordinates from which to work.[749] In fact, the surveying route that led Humboldt to Veracruz by way of Cholula began at the *Real Seminario de Minería* in Mexico City. Established in 1783 alongside the colonial state's sweeping "New Mining Ordinances," the *Seminario* was designed, after the Freiberg model, as an agent of state oversight.[750] There, in October of 1803, Humboldt lectured on geognosy and received a medallion commemorating the institution's founding. The *Seminario* served, in effect, as a strategic base for his expeditions that autumn and winter, including a month-long inspection of silver mining operations in Guanajuato and two separative visits to the Huehuetoca Canal with Viceroy José de Iturrigaray before the voyage to Veracruz in early 1804.[751]

The *Seminario*'s founder, Don Fausto de Elhuyar, was Humboldt's greatest asset—and vice versa. Now director of the *Tribunal*, Elhuyar shared with Humboldt a Saxon engineering pedigree, linking the two in what might be called the Freiberg Network. Elhuyar was part of a generation of Spanish technicians sent by the Crown to study at Saxony's famous mining

[748] Alexander von Humboldt, "Vorwort," in *Alexander von Humboldt Werke*, vol. iv, Mexico-Werk*,* ed. Hanno Beck (Darmstadt: WBG, 2008), 90-91: "Im guten Glauben, dieses Werk könne denen nützlich sein, die zur Verwaltung der Kolonien berufen sind und die oft nach einem langen Aufenthalt noch keine genaue Vorstellung über den Zustand dieser schönen und weiten Regionen haben, hatte ich mein Manuskript all denen mitgeteilt, die es zu studieren wünschten."
[749] Humboldt, "Geographische Einleitung," 10, 58.
[750] Alfredo Uribe Salas, "Alexander von Humboldt en Nueva España y el Real Seminario de Minería de México," in *Alexander von Humboldt: Estancia en España y viaje americano*, eds., Mariano Cuesta Domingo and Sandra Rebok (Madrid: Real Sociedad Geográfica, 2008), 127-142.
[751] Echenberg, *Humboldt's Mexico*, 116-22.

academy. Fausto and his brother Juan José de Elhuyar, the admiral-savant Antonio de Ulloa, and Humboldt's own Freiberg classmate Andrés Manuel del Río all participated in a shared transatlantic culture of *Bergbaukunde* that bridged Freiberg, Clausthal-Zellerfeld, Potosí, and Mexico City.[752] Likewise, German technicians like Furchtegott Leberecht von Nordenflycht, whom Humboldt met in Peru, and Friedrich Traugott Sonneschmidt, who assisted him in Mexico, made their careers in the Americas, bringing with them amalgamation methods and mechanical devices.[753] Humboldt began his *Personal Narrative* by claiming no "foreigner" had ever received "so extensive a permission" to travel into Spanish dominions.[754] But his "free" passage through Spain's silver-rich colonies was granted by virtue of his expertise in mining. Part of a larger migration of technicians, Humboldt's itinerary circuited the Freiberg Network.

But by routing his travels through the Mexican mining industry, Humboldt also became the instrument of a larger administrative scheme. From Elhuyar's perspective, he was just the man to carry out plans already drafted by the *Tribunal* for a "detailed map of the most important mining and smelting operations" in the thirty-seven districts under his direction.[755] And so, in autumn 1803, Elhuyar provided his Prussian *Markscheider* the requisite labor force to "cast a trigonometric net over the earth." For Humboldt, it was an old task on new soil: he would coordinate a corps of well-trained *Seminario* students, much as he had managed Killinger,

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[752] Both Elhuyar brothers are listed as founding members of the Societät der Bergbaukunde, run by Freiberg Mining Academy graduates and German mining elites like Heinrich von Trebra and Ignatz von Born. (*Bergbaukunde*, 1-34.)
[753] Kendall W. Brown, *A History of Mining in Latin America from the Colonial Era to the Present* (Albuquerque: University of New Mexico Press, 2012), 27, 30, 34-35.
[754] Humboldt, *Personal Narrative*, 14.
[755] Humboldt, "Geographische Einleitung," 10: "Don Fausto de Elhyar, der Vorsteher dieser Schule, hatte seit langer Zeit Nachrichten über die Lage der Bergwerke von Neu-Spanien und über die Grenzen der 37 Bezirke gesammelt, welche jene Bergwerke unter dem Namen *Deputaciones de Minas* in sich begreifen. Er wünschte, für das oberste Bergkollegium eine ausführliche Karte verfertigen lassen, auf welcher die wichtigsten Hüttenwerke und Gruben angedeutet wären. Eine Arbeit dieser Art war in der Tat sehr notwendig, sowohl zur Verwaltung dieses Landes als zur Kenntnis des Gewerbfleißes seiner Bewohner."

Sievert, and the foremen of the *Bergschule* in Franconia. In Mexico City, he had scoured royal archives and monasteries for astronomical measurements of latitude and longitude (based on lunar distances, solar eclipses, and celestial navigation) in "drafts of unfinished maps and hand-written observations."[756] Now, he and his crew would now set about cross-referencing these coordinates with a new grid of geometric and hypsometric measurements.

In Humboldt's account of the undertaking, colonial administration has a strong presence as a supporting infrastructure, yet the labor of individual surveyors remains obscure. While describing the Mexico City–Veracruz route in his *Political Essay*, Humboldt presents the mystifying image of an ideal "traveler experienced in observation." In his solitude, this figure effaces the many assistants who sustained the project: he alone would bear "Hadley's sextant, or a Borda's repeating circle, a chronometer, an achromatic telescope, and a portable barometer for the measurement of elevation," traversing "New Spain in three directions."[757] Notes compiled at the time tell a different story. Just a few pages before the pyramid of Cholula, we encounter a corresponding set of bearings, now in a different hand (**Figures 9**). Signed "20 Nov. 1803 AHumboldt," it was in fact an unnamed assistant who, from the rooftop of the *Seminario*'s three-story building, took down the "*Azimut of popocatepetl con el sol*."[758] As notes in yet another

[756] Humboldt, "Geographische Einleitung," 9: "…wenn er zum Entwurf neuer Karten Pläne und handschriftlichen Bemerkungen benutzte, die in Archiven aufbewahrt oder in Klöstern versteckt lagen."
[757] Ibid., 12: "Um die Geographie dieser Länder gleichmäßig zu vervollkommnen, müßte ein im Beobachten geübter Reisender mit einem hadleyschen Sextanten oder einem bordaischen Wiederholungskreis, einer Längenuhr, einem achromatischen Fernrohr und einem tragbaren Barometer zur Höhemessung der Gebirge versehen, den Norden des Königreichs Neu-Spanien in drei verschiedenen Richtungen durchwandern…." John Hadley (1682-1744) was a British mathematician, tinkerer of telescopes, and inventor of a "double-reflecting octant" for measuring the altitude of celestial bodies above the horizon, which became the sextant. Jean-Charles de Borda (1733-1799) was a French mathematician and Navy officer who improved Etienne Lenoir's repeating circle, a device used in geodetic surveying (which accounts for the curvature of the earth) by fixing two telescopes upon a single axis with scales to measure the difference between the two.
[758] "Papiere über die Statistik und Geographie von Mexico und Cuba," BJK, Bl. 54.

hand show (**Figure 10**), this series of observations allowed Humboldt and his party to triangulate Mexico City based upon the three most prominent peaks to the east, then extend their trigonometry over the Plateau of Cholula to Veracruz.[759]

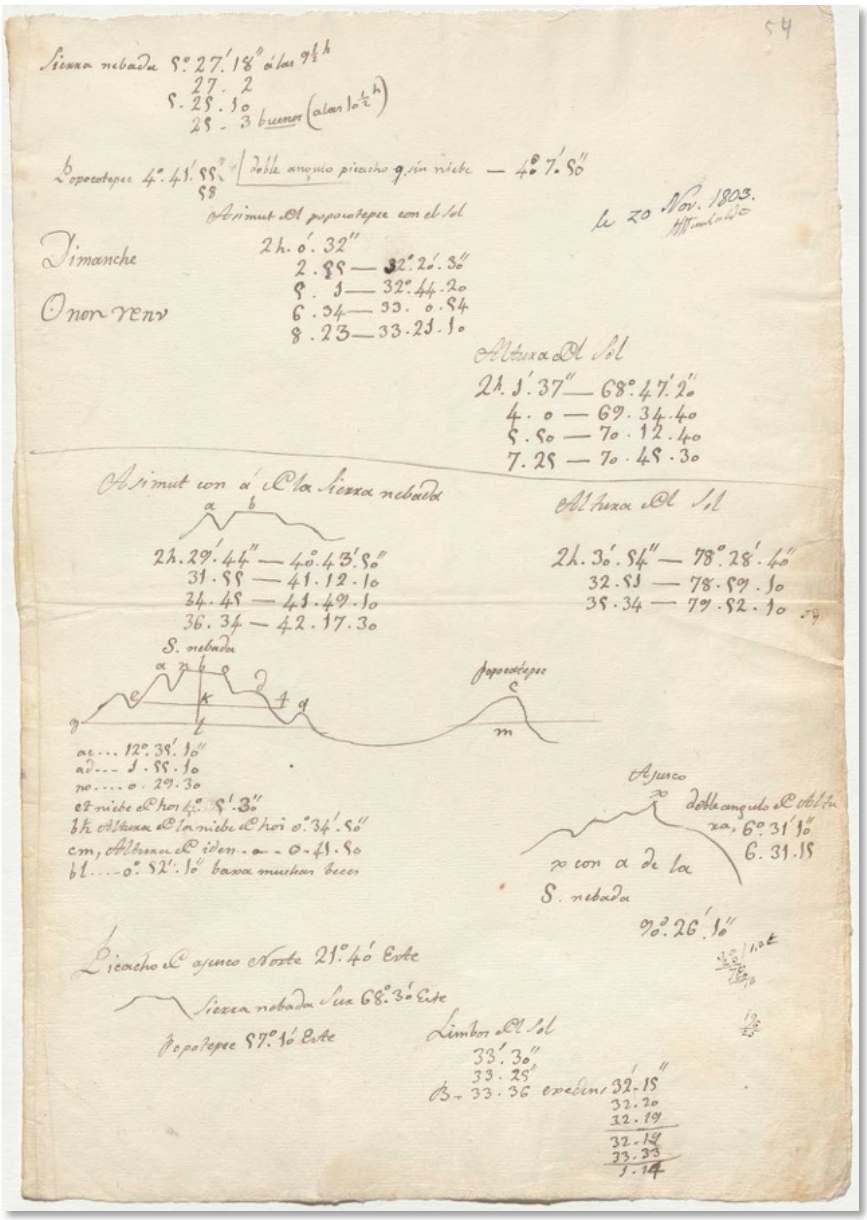

Figure 9. The triangulation of Popocatépetl and the Sierra Nevada from the roof of the Seminario in Mexico City. Azimuth is a measure of the peak's angular distance (usually from north or south) in the coordinate system. BJK, "Papiere über die Statistik und Geographie," Bl. 54. This is a measure of the peak's angular distance from south measured in the coordinate system.

[759] This page of notes is credited to, but not taken by, Miguel Costansó, a military engineer and cartographer whose coordinates Humboldt used in many of the *Atlas*'s maps. Figure 10 likely shows a *Seminario* student at work transposing Costansó's coordinates onto Humboldt's maps, now combined with and cross-referenced with the new set of astronomical and trigonometric measurements taken in 1803/04. See Ulrike Leitner, ed., *Alexander von Humboldt von Mexiko-Stadt nach Veracruz. Tagebuch*. Beiträge zur Alexander-von-Humboldt-Forschung 25 (Berlin: Akademie Verlag, 2005), 26-28.

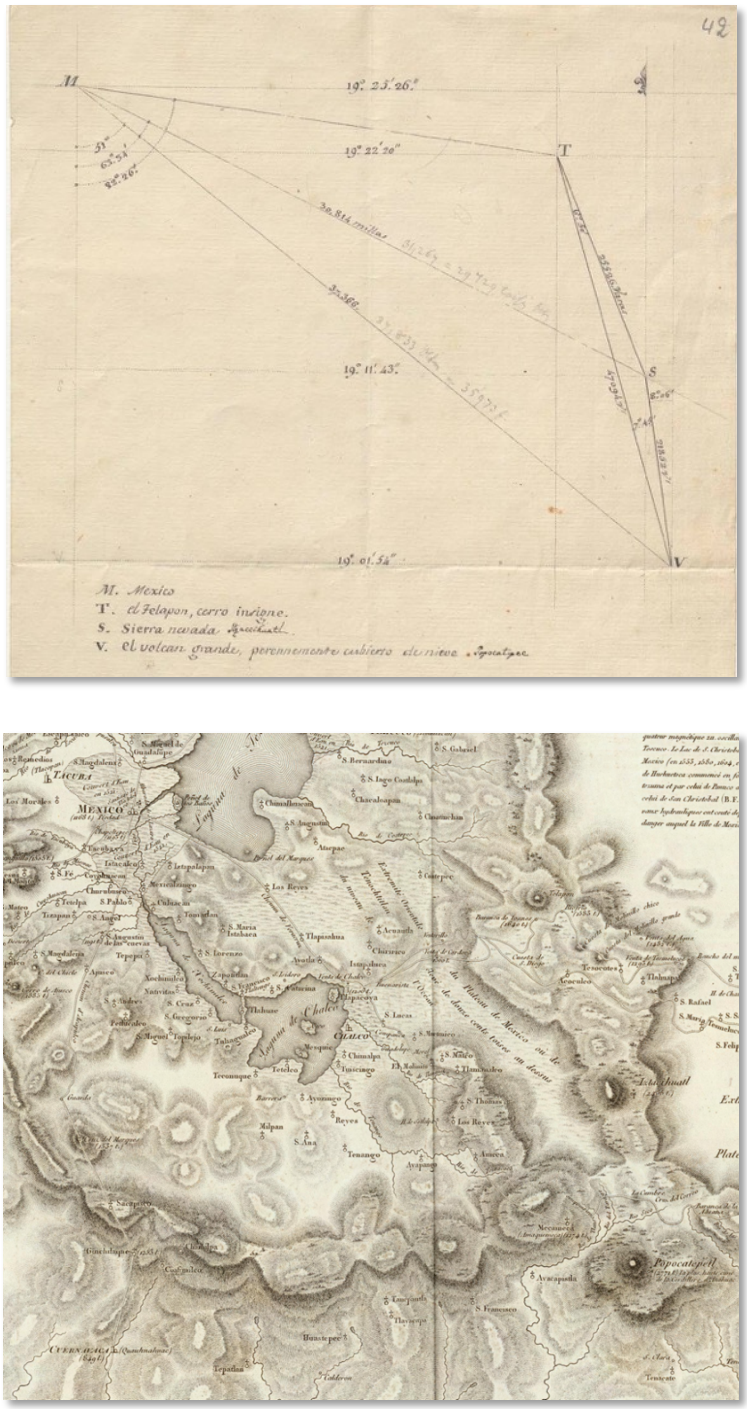

Figure 10. Above: Notes positioning Mexico City (M) with respect to Cerro Telapón (T), Iztaccíhuatl in the Sierra Nevada (S), and the Volcano Popocatépetl (V), which correspond to the placement of these coordinates on the map below. BJK, "Papiere über die Statistik und Geographie von Mexico und Cuba," Bl. 42. Below: Detail from the *Atlas*'s "Carte de la Vallée de Mexico," credited to "Don Luis Martin" in 1804 and later "corrected in 1807." Mexico City, the Sierra Nevada, and (just out of site) the Pyramid of Cholula all bear the celestial sign for "astronomical observations of latitude and longitude," while only Mexico City has the triangle indicating "a trigonometric operation." David Rumsey Historical Map Collection, Image No: 0328005.

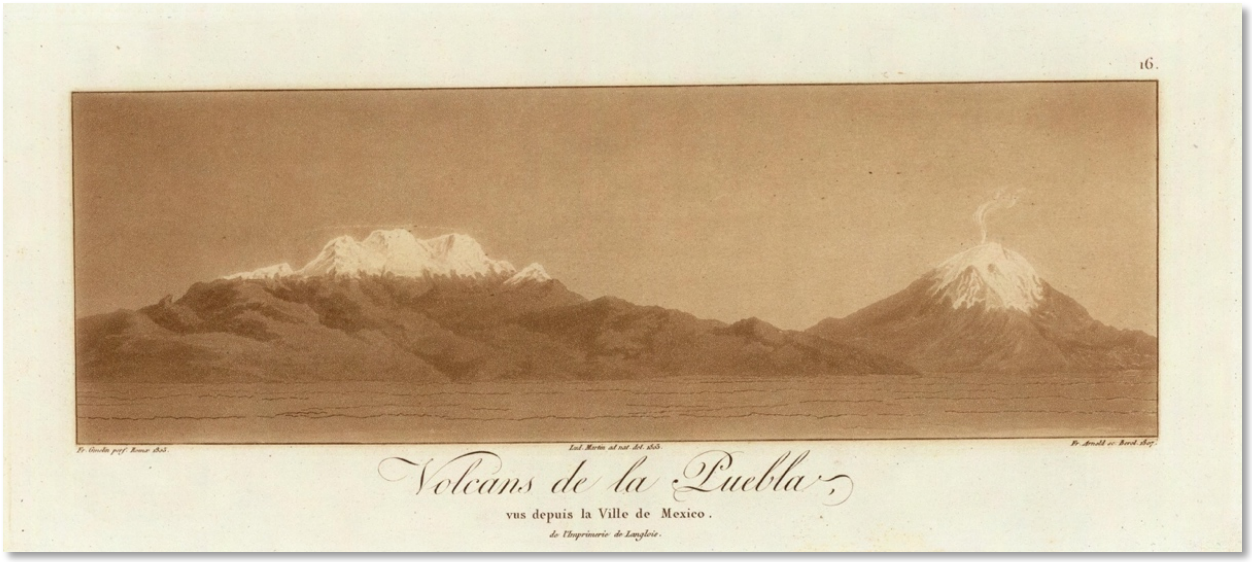

Figure 11. "Volcans de la Puebla" in Humboldt's *Atlas géographique et physique du Royaume de la Nouvelle-Espagne* after Martín's illustration. The serene landscape portrait quietly erases the busy network of surveyors, cartographers, and mathematicians amongst whom Martín toiled. Credit is given in fine print: "*Lud. Martin ad nat. del. 1803*." David Rumsey Historical Map Collection, Image No: 0328016.

Perhaps it was the hand of Luis Martín, a student of the *Academia de Bellas Artes*, who composed the first drafts of many of the *Atlas*'s maps and profiles, including a profile of Popocatépetl from the *Seminario*'s roof (**Figure 11**).[760] Or maybe it was one of the *Seminario*'s own students, like Juan José Rodríguez and Rafael Dávalos, who similarly assisted Humboldt as draftsmen, surveyors, and calculators.[761] Another candidate is the mathematician and fellow *Seminario* pupil Juan José Oteyza, with whom Humboldt collated great amounts of trigonometric

[760] Martín, the most visible of Humboldt's Creole assistants, is credited in the *Atlas* for having "sketched on site" (*esquissée sur les Lieux*) the "Carte de la vallée de Mexico et des Montagnes voisines," which combined the trigonometric "operations" of Joaquín Velásquez de León (1732-1786), a Creole mathematician and first director general of the Corps of Mining who, with Antionio de León y Gama and other Mexican savants, preceded Humboldt in fixing the first lines of latitude and longitude throughout New Spain. The idea for the *Seminario* is sometimes credited to him, and he is known as the author of the *Nuevas Ordenanzas de Minería* of 1783. See discussion on Humboldt's collaboration with *Seminario* students, particularly Martín, in Leitner, *Mexiko-Stadt nach Veracruz*, 23-28.
[761] Humboldt, "Geographische Einleitung," 81.

data. Oteyza was, like Humboldt, a multifaceted intellectual. His description of Cholula's antiquities would later inform Humboldt's own account in *Vues des Cordillères* (1810).[762]

These are the few Creole technicians whom Humboldt chose to highlight in his published works. Like his ideal traveler, however, they stood proxy for a far more expansive collective. Writing in the passive voice, Humboldt explained how "black powder signals" ignited atop tall, isolated summits "could be observed by persons at a great distance" to determine longitude by the difference in local times.[763] Behind Humboldt's idealizations and actor-less visions a massive instrumental and cartographic workforce begins to appear: academicians busily recording measurements atop the *Seminario*'s roof, or turning coordinates into great maps in the cartographer's workshop; assistants lugging sextants and repeating circles up volcanoes and pyramids, dragging a "trigonometric net" across all of New Spain; perhaps even a crew of *barrenadores* (as Mexican miners skilled in blasting were called) lining the summits of the Cordilleras with explosives and chronometers.[764] The distance between Humboldt's ideal traveler and this vast network of workers—between the *Atlas*'s frontispiece and the reality of its production—is a measure of the authority he assumed over skilled laborers.[765]

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[762] Comprehensive lists of *Seminario* pupils and professors with whom Humboldt collaborated can be found in https://edition-humboldt.de/register/einrichtungen/detail.xql?id=H0000577 and Clementina Díaz y de Ovando, *Los veneros de la ciencia mexicana: crónica del Real Seminario de Minería, 1792-1892* (UNAM, Facultad de Ingeniería, 1998), 101. On Oteyza, see Ulrike Leitner, "Aus dem Humboldt-Nachlaß: Juan José de Oteyzas Beschreibung der Pyramiden von Teotihuacán," *HiN* 7, no. 12 (2006): 6-30.

[763] Humboldt, "Geographische Einleitung," 17: "Pulversignal können in großen Entfernungen von Personen beobachtet werden…." Humboldt notes that this method was pioneered by the French surveyor César-François Cassini de Thury, who coordinated the first trigonometric survey of an entire country, the *Carte géométrique de la France* published in 1789. Humboldt believed that the Sierra Nevada he sighted from Mexico City and climbed in September 1803 were particularly well suited for this method.

[764] Humboldt, "Geographische Einleitung," 15: "ein trigonometrisches Netz über einen Erdraum zu werfen…."

[765] Here I play on Steven Shapin's argument that "The transparency of technicians' roles in making scientific knowledge reflects both historical and modern attitudes toward the value of skilled work." (Steven Shapin, "The Invisible Technician," *American Scientist* 77, no. 6 (1989): 554-63, on 554.)

(De-)Colonizing the Cordilleras

The *Political Essay* and its *Atlas* sparked a frenzy of European investment in Mexican mining, particularly after independence in 1821.[766] In twenty-one maps and five volumes, Humboldt offered European readers their first comprehensive look at annual silver output in Mexico. He also contradicted conventional wisdom about the decline of mining in Spain's American colonies and predicted a steady rise in profits for years to come.[767] In the United States, too, a young nation built on belligerent westward expansion, Humboldt's maps of New Spain were a print sensation.[768] Financial speculation and imperial interests meant celebrity, if not fortune, for Humboldt, who privately complained about being "unable to profit from fame."[769] As Nicolaas Rupke has demonstrated in his reception study of Humboldt's oeuvre, it was the *Political Essay* "that gave content to Humboldt's international fame—the treatise that made his name a household word in the educated circles of the Western world."[770]

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[766] Dettelbach, "Romanticism and Administration," 162. The *Political Essay* was published first as *Essai politique sur le royaume de la Nouvelle-Espagne* in France in 1808 then in German and English in 1809 and 1811, respectively.

[767] See discussion in Vera M. Kutzinski and Ottmar Ette, "All the Bumps in the Road: Alexander von Humboldt's Mexican Tableau. An Introduction," Alexander von Humboldt, *Political Essay on the Kingdom of New Spain*, vol. 1, eds. Vera M. Kutzinski and Ottmar Ette (Chicago: University of Chicago Press, 2019), xvi-xx. Humboldt's records are generally corroborated by modern studies showing a steady increase in silver production throughout Spanish American in the eighteenth century. See John J. TePaske, *A New World of Gold and Silver*, ed. Kendall W. Brown (Leiden: Brill, 2010), 113.

[768] The publication of Humboldt's Mexico works coincided with uprisings throughout Spanish America. North Americans devoured his works, some out of a desire to see "sister republics" emerge to the south, others with an imperious gaze toward Mexican mining prospects and westward expansion into a destabilized region. See discussion in Ingo Schwarz, "Alexander von Humboldt's Visit to Washington and Philadelphia, His Friendship with Jefferson, and His Fascination with the United States," *Northeastern Naturalist* 8, no. 1 (2001): 43-56; Sandra Rebok, *Humboldt and Jefferson: A Transatlantic Friendship of the Enlightenment* (Charlottesville, VA: University of Virginia Press, 2014); and Patrick Anthony, "Race and Republicanism in Philadelphia's *Aurora*: How Anglophobia and Anti-monarchism Shaped William Duane's Views of Revolutions in Saint-Domingue and Latin America, 1798-1822," *The Pennsylvania Magazine of History and Biography* 141, no. 1 (January 2017): 31-58, on 48.

[769] As quoted in Echenberg, *Humboldt's Mexico*, 133.

[770] Nicolaas Rupke, "A Geography of Enlightenment: The Critical Reception of Alexander von Humboldt's Mexico Work," in *Geography and Enlightenment*, eds. D. N. Livingstone and C. W. J. Withers (Chicago: University of Chicago Press, 1999), 319-39, on 326.

But there is also a more profound geopolitical agenda embedded in Humboldt's Mexico works. Here he forged an anti-imperial stance from the language he knew best: the rational administration of natural resources. Humboldt recognized a palpable anti-colonial spirit in New Spain, particularly amongst its Creole intelligentsia. The *Political Essay*, it has been argued, "was independent Mexico's presentation card for the rest of the world."[771] In New Spain, as in Prussian Franconia, Humboldt promoted a generation of administrators whom he judged capable of delivering the mining industry, and indeed all Mexico, from the economic institutions that had inhibited the colonial state. In a land torn between "royal monopolies" on the exportation of silver, gold, and powder and the self-interest of private mine owners, the *Tribunal* appeared a moderating force, straight out of the paternalist playbook of German cameralism.[772]

Humboldt believed many of the same (o)economic failures that beleaguered Prussian Franconia were amplified in Spanish America. Excessive felling of forests, investors' myopic lust for precious metals, horrific labor conditions in the mines—to the erstwhile *Oberbergmeister* all this smacked of administrative negligence, of *Raubbau*.[773] This was most vividly portrayed in

[771] Clair and Ávila, "Los pasos de Alejandro de Humboldt por la minería novohispana," 47. In the same vein, Laura Dassow Walls has interpreted the *Political Essay* as "an instruction manual for the economic development of an independent, postcolonial Mexico." (Laura Dassow Walls, *The Passage of the Cosmos: Alexander von Humboldt and the Shaping of America* (Chicago: University of Chicago Press, 2009), 123.)

[772] Humboldt's *Political Essay* is rife with his criticism of the royal monopolies on mineral exportation, and of the colonial state's still more "odious monopoly" of tobacco production. See Hanno Beck, "Erläuterungen zu Humboldts Mexico-Werk," in *Alexander von Humboldt Werke*, vol. iv, Mexico-Werk, ed. Hanno Beck (Darmstadt: WBG, 2008), 547-48. The fiscal structure of mining that developed in eighteenth-century New Spain would have also been familiar to Humboldt, where local investors (rather than the traditional "silver banks" in Mexico City) began to supply the capital for privately owned mines. See Brown, *A History of Mining in Latin America*, 32-33. Moreover, mine owners in New Spain exerted precisely the kind of control over labor that Humboldt and his administrative ilk so feared in Germany, imposing a sort of financial serfdom on "free" laborers through debt peonage. See ibid., 89.

[773] On Humboldt's critique of denudation and desertification in the Americas, see Walls, *The Passage of the Cosmos*, 9-10; Engelhard Weigl, "Wald und Klima: Ein Mythos aus dem 19. Jahrhundert," *HiN* 5, no. 9 (2004): 81-99. Joachim Radkau described Humboldt's anxieties about deforestation as "second nature" to Germans of his generation, but also argued that "concern over the preservation of nature in the wake of human colonization is only an occasional theme" in Humboldt's American writings, adding that "nature

the "daily searches" of laborers suspected of stealing silver ore, lodged in their throats or anuses, upon exiting the shafts. That "Mexican miners are not as honorable as German or Swedish miners," Humboldt believed, was a failure not of their race, but of their government.[774] As in Franconia, both the "honor" and the "health of the miners" served as a measure of the administration's oversight. Here it was not subterranean vegetation and carboniferous strata that suffocated the miners but "mofettes," or gaseous volcanic vents. Yet Humboldt prescribed a familiar remedy of administrative discipline and technological ingenuity, believing the social conditions of labor would improve "in proportion as the mines of New Spain come to resemble those of Freiberg, Clausthal-Zellerfeld and Schemnitz."[775] These were, crucially, the location of central Europe's eminent mining academies.

But even the influence of German miners, Humboldt believed, would have little effect if not bolstered by a strong state apparatus.[776] Though the output of silver mines had tripled in fifty-two years and sextupled in the previous century, the *Political Essay* argued that investors' exclusive interest in precious metals nonetheless stunted the country's economic potential. Here

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in Latin America struck him as inexhaustible." (Joachim Radkau, *Nature and Power: A Global Environmental History*, trans. Thomas Dunlap (Cambridge: Cambridge University Press, 2008), 204, 168.)

[774] Humboldt, *Neu-Spanien*, *4*, 104: "Auch sind die mexikanischen Bergleute nicht so ehrlich, wie die deutschen und schwedischen…. […] Es ist ein niederschlagender Anblik, in den grossen Bergwerken von Mexiko ganze Hunderte von Arbeitern unter denen sehr viele ehrliche Männer sind, zwingen zu sehn, sich beim Herauskommen aus dem Schacht oder der Gallerie durchsuchen zu lassen."

[775] Humboldt, *Neu-Spanien*, *4*, 100-04: "[U]nd wirklich wird auch die Gesundheit der Bergleute durch den Einfluss der Mofetten [gaseous volcanic vents] und der zu anhaltenden Anstrengung der Muskeln immer weniger gefährdet werden, je ähnlicher die Minen von Neu-Spanien denen von Freiberg, Klaus-Thal und Schemnitz werden." Cf. ibid., 98-101, where Humboldt urges the adoption of hydraulic pumps and other hoisting technologies to relieve the Indian laborers called *Tenateros* who, he noted, are "regarded as the beasts of burden of Mexican mines." They "carry a load of 225 to 350 pounds for six hours," he continued, noting the extremely high temperatures to which they are exposed and the ascent of some 1800 steps eight that laborers might make eight or ten times in succession.

[776] Humboldt, *Neu-Spanien*, *4*, 93-94: "Auf Kosten des Hofes wurden deutsche Bergmänner nach Mexiko, Peru und Neu-Grenada gesandt; allein ihre Einsichten fruchteten nichts, da die mexikanischen Bergwerke als Eigenthum von Privatleuten angesehen werden, die die Arbeiten selbst leiten, und der Regierung nicht den geringsten Einfluss auf dieselben gestatten."

he took a page directly out of the cameralist literature, arguing that while precious metals yielded only "nominal value," iron, lead, copper, zinc and other "useful" metals possessed an "inner value" as raw material for manufacturing and agriculture.[777] And yet, on his surveying expeditions, he found even "the richest veins of iron and lead in the Cordillera entirely neglected." As a corrective, Humboldt entwined paternalist oversight with anti-imperial politics:

> In proportion as the population of Mexico increases, sets itself in greater independence from Europe, and turns its attention to the great variety of useful products in their own soil, the mining industry must adapt. A more insightful administration will stimulate this labor, which has as its aim the exploitation of minerals possessing an *inner value*. The private man will no longer exist as such, and the interest of the state will cease to be sacrificed to deep-rooted prejudices, once it is realized that the working of a coal, iron, or lead mine is ever so advantageous as the exploitation of a silver vein.[778]

This formula ensured the *Tribunal* a central role in the political destiny of Mexico. Drawing directly on Elhuyar's own reports, he argued that the *Tribunal,* by distributing officials as far as they could cast their "trigonometric net," were uniquely capable of "nurtur[ing] public spirit in a country whose citizens, scattered across an enormous stretch of land, are not able to understand the unity of their interests." It was the *Tribunal*'s prerogative not only to "enlighten" mine owners in their far-flung *Deputaciones* but also to promote "liberty" throughout the country.[779]

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[777] Michael Fessner and Christoph Bartels, "Von der Krise am Ende des 16. Jahrhunderts zum deutschen Bergbau im Zeitalter des Merkantilismus," in *Geschichte des deutschen Bergbaus*, vol. 1, eds. Christoph Bartels and Rainer Slotta (Münster: Aschendorff Verlag, 2012), 471-74.

[778] Humboldt, *Neu-Spanien*, *3*, 1-3: "In dem Maass übrigens, in welchem die Bevölkerung in Mexiko zunehmen wird, und die Bewohner, in grössere Unabhängigkeit von Europa gesezt, ihre Aufmerksamkeit mehr auf die grosse Mannigfaltigkeit nüzlicher Produkte in ihrem eigenen Boden richten werden, muss das Bergwerkssystem sich ändern. Eine einsichtsvollere Administration wird die Arbeiten anfeuern, welche die Ausbeutung derjenigen Mineralien zum Zwek haben, die einen *innern Werth* haben. Der Privatmann wird nicht mehr sein und das Staats-Interesse eingewurzelten Vorurtheilen aufopfern, und einsehen, dass die Bearbeitung eines Steinkohlen- Eisen- oder Blei-Bergwerks eben so vortheilhaft werden kann, als die Ausbeutung eines Silbererz-Gangs."

[779] Humboldt, *Neu-Spanien*, *4*, 162: "Es nährt den Gemeingeist in einem Lande, wo die Bürger bei ihrer Zerstreuung über einen ungeheruen Raum Bodens nicht genug fühlen, dass ihre Interessen gemeinschaftlich sind; es verschaft dem höchsten Bergrath die Leichtigkeit, jedesmal, wenn von einer grossen und nüzlichen Unternehmung die Rede ist, beträchtliche Summen zusammenzubringen. Indess wäre es zu wünschen, dass der Direktor des Tribunals mehr auf die Ausbeutung in den Provinzen wirken

Humboldt's vision for an independent Mexico contained an almost Jeffersonian frontier ethic, which focused on mining as well as agriculture. Humboldt's frontier, moreover, was a not only a horizontal but also a vertical expanse. For an "insightful administration" would ascend to "the most uninhabited regions of the Cordilleras" to exploit veins of inner value, stimulating agriculture and industry alike. A student of the vertical orientation of pre-Hispanic civilization, Humboldt saw the pursuit of mineral exploitation high in the Cordilleras as civilizing agent.[780] "Travelling upon the crest of the Andes or in the most mountainous regions of Mexico one encounters the most striking examples of the happy influence that the metallurgic industry exerts over agriculture," Humboldt wrote, convinced that "after the discovery of a lucrative mine, the founding of a new city invariably follows."[781]

Before Humboldt promised Boussingault an institute in the Cordilleras, his *Political Essay* amounted to a handbook for the establishment of high-altitude colonies. According to this plan, the cultivation of alpine soil and the peopling of these "Cantons" in the Cordilleras, would survive the exhaustion of the mineral veins that first attracted pioneers.[782] Such was Humboldt's vision of an independent Mexican mining state. Here a system of administration that spanned

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könnte, und dass die Eigenthümer der Bergwerke, weniger eifersüchtig auf das was sie ihre Freiheit nennen, und aufgeklärter über ihre wahren Vortheil wären."

[780] Humboldt took a particular interest in the way mountains shaped peoples' economic and spiritual life. See Alexander de Humboldt, *Researches, Concerning the Institutions & Monuments of the Ancient Inhabitants of America*, vol. 1, trans. Helen Maria Williams (London, 1814), 23-25, 40-42, 102-03.

[781] Humboldt, *Neu-Spanien*, *3*, 7-8: "Ueberhaupt hat überall, wo Metall-Gänge in den unbewohntesten Gegenden der Cordilleren, auf isolierten, öden Plateaus entdekt wurden, die Ausbeutung der Bergwerke, statt den Anbau des Bodens zu hindern, ihn vielmehr besonders begünstigt, und bei Reisen auf dem Rücken der Anden oder in der gebirgigsten Gegend von Mexico begegnet man den auffallendsten Beispielen solch glücklichen Einflusses metallurgischer Industrie auf den Ackerbau. […] Auf die Entdeckung eines beträchtlichen Bergwerks folgt immer die Gründung einer neuen Stadt."

[782] Humboldt, *Neu-Spanien*, *3*, 8: "Noch mehr; der Einfluss der Bergwerke auf die allmählige Urbarmachung des Bodens ist viel daurender, als sie selbst sind. Sind die Metallgänge endlich erschöpft, und verlässt man die unterirdischen Arbeiten, so leidet Bevölkerung des Cantons freilich, indem die Bergleute anderswo unterzukommen suchen; allein der Colonist wird durch die Liebe zum Boden, auf dem er geboren wurde, und den seine Väter mit ihren eigenen Händen urbar gemacht haben, zurükgehalten."

mountains and mines would, at once, serve as a system of observation. For the same technicians whom he entrusted with the socio-environmental reformation of New Spain would create supply chains of coordinates, minerals, and geognostic and meteorological observations from across the ocean. If ever Humboldt's "republic of instruments" was to manifest itself in an actual polity, it was here in the vertical colonies of the Mexican Cordilleras.

By integrating *Seminario* pupils into his republic of instruments, Humboldt simultaneously established himself at the head of a transatlantic system of observation. He praised the "diligent" Dávalos, and lauded Rodríguez's "thorough knowledge of the natural sciences." Yet Humboldt also reminded readers that their maps were made "under my eyes."[783] Dávalos and Rodríguez were not merely agents of a colonial state but also, like the miner-measurers of Franconia, emissaries of Humboldt's governance of the natural world. In this way *physique du monde* became a truly global enterprise, first through the mining elite of Mexico City, and later through their counterparts in French and British imperial ventures. When, in his *Political Essay*, Humboldt implored the Spanish empire to promote knowledge of its own possessions, and to do so publicly, he implied his own role as a mediator of global geographical knowledge. "The Royal Navy lack neither instruments nor practiced astronomers," he wrote, having established close ties with military surveyors as well as miners:

> The Mining Academy of Mexico, where the study of higher mathematics is rigorously pursued, distributes over the terrestrial surface of the immeasurable empire a great number of young men who, animated by the noblest zeal, are capable of operating the astronomical instruments entrusted to them. By similar means the British East India Company has been able to produce precise maps of a territory greater than England and France combined.[784]

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[783] Humboldt, "Geographische Einleitung," 81: "Das Profil des Wegs, welcher aus der Stadt Mexico nach den Bergwerken von Guanajuato führt, welche die reichsten der bekannten Welt sind, ist unter meinen Augen von einem sehr fleißigen jungen Mann, Herrn Raphael Davalos, einem Zögling der Bergschule in Mexico-Stadt gezeichnet worden."

[784] Humboldt, "Geographische Einleitung," 17-18: "In der königlichen Marine fehlt es weder an Instrumenten noch an geübten Astronomen. Die Bergakademie von Mexico, in welcher das Studium

Few passages so vividly capture the full scope of Humboldt's ambitions. In three sentences, he scales up from the participation of individual observers, whose instrumental capacity doubles as proof of their own legitimacy, to a balance of imperial powers, similarly assured through the publicity of geographical knowledge: "The time has passed when kings once sought to secure their sovereignty through secrecy, unwilling to unveil the wealth of their possessions in both Indies to foreign nations," Humboldt concluded. As he saw it, global physics was also geopolitics: transparency amongst world powers implied a free communication of knowledge amongst their scientific agents.

The publication of the *Political Essay* coincided with the outbreak of revolution in New Spain. By the time the *Atlas* hit the press in 1811 some of Humboldt's mining contacts had already lost their lives in the independence movement. Dávalos, who graduated from the *Seminario* in 1805 to apply his mathematical expertise in the silver city of Guanajuato, was publicly executed for his participation in the Hidalgo Revolt of 1810.[785] As revolutionaries retreated from Mexico City to Guanajuato in November of that year, another of Humboldt's mineralogical network, José Casimiro Chovell, prepared the city for a Royalist offensive. Seven years earlier, when Chovell was appointed director of Guanajuato's Valenciana mine, he supplied Humboldt with a *Descripción geognóstica y el plano geográfico* of Mexico's most

höheren Mathematik gründlich betrieben wird, verbreitet über die Oberfläche dieses unermeßlichen Reiches eine große Anzahl junger Männer, die von dem edelsten Eifer beseelt und fähig sind, sich der astronomischen Instrumente zu bedienen, die man ihnen anvertrauen würde. Durch ähnliche Mittel hat es die Britisch Ostindische Companie dahin gebracht, sich genaue Karten eines Länderbezirkes zu verschaffen, der England und Frankreich zusammengenommen an Größe übertrifft. Jene Zeiten sind vorüber, in welchen die Könige wähnten, sich durch Verheimlichung ihre Staatskräfte zu sichern, in welchen sie sich nicht getrauten, fremden Nationen die Reichtümer ihrer Besitzungen in Indien zu enthüllen." Here Humboldt referenced the so-called Great Trigonometric Survey of British India.

[785] Leitner, *Mexiko-Stadt nach Veracruz*, 25, 141.

lucrative silver mine during his month-long tour of the region.[786] Now, in the midst of revolution, Chovell directed his miners to drill tunnels, excavate trenches, and erect earthen ramparts around the city as they set in for a siege. Ultimately, he met the same fate as Dávalos.

Back in Europe, Humboldt continued to see his science as engaged in a common endeavor with Mexican independence. By October 1822, now fifty-three years old, Humboldt had developed an elaborate plan for his return to a free Mexican Republic. "I have great plans for a grand central institute of science in Mexico," he wrote to his brother Wilhelm, "which will serve the entirety of liberated America." Humboldt scribbled the letter on his knees in the antechamber of Prussia's King Friedrich Wilhelm III, whose royal retinue he had been obliged to join at the Congress of Verona. "It is difficult for me to comprehend the utility of this trip," he complained of the Congress, designed in part to quash Jacobinism in France and restore Ferdinand VII to the Spanish throne—the same Bourbon monarch who had recently refused to recognize the independent Empire of Mexico. After fourteen years of insurgency, the new Mexican polity was fragile, but Humboldt believed its imperial constitution would soon give way to "a republican government." "I have fixed upon the idea of ending my days there in a manner most enjoyable and most useful to the sciences," he continued, describing the "glory" of "gathering together many learned people" to "explore the 19/20^{ths} of the country I did not see."[787]

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[786] Chovell's communication with Humboldt is described in Carlos Prieto, *Mining in the New World* (New York: McGraw-Hill, 1973), 145 and Ferdinand Dmaschun and Ralf Thomas Schmitt, eds., *Alexander von Humboldt: Minerale und Gesteine im Museum für Naturkunde Berlin* (Göttingen: Wallstein, 2019), 116-17.

[787] Alexander von Humboldt to Wilhelm von Humboldt, 17 Oct. 1822, in *Briefe Alexander's von Humboldts an seinen Bruder Wilhelm herausgegeben von der Familie von Humboldt in Ottmachau* (Stuttgart: Cotta, 1880), 99-100: "Il m'est difficile de concevoir l'utilité de ce voyage. […] J'ai un grand projet d'un grand établissement central des sciences à Mexico pour toute l'Amérique libre. L'Empereur du Mexique que je connais personnellement, va tomber, il y aura un gouvernement républicain et j'ai l'idée fixe de terminer mes jours d'une manière la plus agréable et la plus utile pour les sciences dans une partie du monde où je suis extrêmement chéri et où tout me fait espérer une heureuse existence. C'est une manière de ne pas mourir sans gloire, de réunir auprès de soi beaucoup de personnes instruites et de jouir

Still in 1822, nearly two decades after serving as *Markscheider* of Mexico, Humboldt's plans for a "grand central establishment" in the Americas remained anchored in its mining industry. "Already in France, 4-5 million francs have been raised for the reorganization of mining operations in Mexico," he wrote, alluding to his efforts to enlist European investors in the industry he saw as the catalyst of Mexico's economic and intellectual prosperity. Here, again, Humboldt assumed the role of administrator, managing a vast economy of knowledge production. And yet, in the same breath, he delicately distanced himself from the financial interest required for such an undertaking:

> I would assume no responsibility in this great business of money, but it will be useful to me because the most distinguished men of science who, like me, wish to quit Europe will be employed by those who advance funds and who follow my advice whenever I wish to give it to them.[788]

Humboldt's grand "American project" never came to fruition—at least not in this form. Yet the institute he described to Wilhelm, like the *établissement* he promised Boussingault only two months earlier, is revealing of the groundwork laid for an expansive administration of observers who channeled knowledge from around the globe to his homes in Paris and Berlin.

From the 1820s on, mining technicians like Boussingault were joined by an ever-increasing number of civil servants engaged in surveying projects from the Andes to the Himalaya, as well as hydrographic enterprises from the cold-water current off the coast of Peru to the depths of the mid-Atlantic trench. *This* was Humboldt's "grand central institute"—not high

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de cette indépendance d'opinions et de sentiments qui est nécessaire à mon bonheur. Ce projet d'un établissement au Mexique en explorant delà 19/20 du pays que je n'ai pas vu (les volcans de Guetemala, l'Isthme…), n'exclut pas une tournée aux Philippines, et au Bengale."

[788] Alexander von Humboldt to Wilhelm von Humboldt, *Briefe Alexander's von Humboldts*, 100: "On réunit en France 4-5 millions de francs pour réorganiser le travail des mines au Mexique. Je n'aurais aucune responsabilité dans cette grande affaire d'argent, mais elle me sera utile, parce que les hommes les plus distingués dans les sciences et qui désirent comme moi de quitter l'Europe seront employés par ceux qui avancent ces fonds et qui suivent mes conseils chaque fois que je veux les leur donner."

in the Cordilleras but in his own home in Berlin. No longer a "run[ning] around the world like a vagabond physicist," as he once called himself, Humboldt gradually settled, with age, into the sedentary role of scientific administrator, exploring the world "by proxy."[789] But it was a familiar act for the erstwhile mining official, now a privy counselor since 1827. Having once collated reports from Killinger and Sievert, and overseen the labors of Dávalos and Martín, Humboldt now sent instructions to, and sourced data from, a sprawling network of agents, as though managing *Berg-Reviere* or *Deputaciones* that spanned continents and oceans.

Conclusion: The *Berg-Amt* on Oranienburger Street

In Henry William Pickersgill's 1831 portrait of Humboldt (**Figure 12**), there are no towering Andean peaks with their distinctive snowlines, no native porters or far-off landscapes. Instead, we meet Humboldt the Prussian aristocrat, as indicated by the star and sash of the Red Order of Nobility worn by those who served the Brandenburg line. This is also Humboldt the scientific administrator. The unmistakable likeness to a portrait of Sir Joseph Banks (**Figure 13**), autocrat of English natural sciences, is no coincidence. Banks's portrait was first exhibited in the Royal Academy in 1809, where Pickersgill had studied and exhibited his own work.[790] A member of the Academy himself, Pickersgill was well acquainted with Banksian iconography. Like Banks, Humboldt is shown as a statesman-scientist, his mild gaze befitting a benevolent, paternal ruler of natural and social realms. As a manuscript "On an Improved Reflecting Circle" sits before Banks, Humboldt's hand rests on another instrument of oversight: the map.

[789] Humboldt to Friedrich Wilhelm Graf von Reden, 6 Jan. 1796, *Jugendbriefe*, 489: "Je cours le monde en Physicien vagabond et Vous, mon cher Comte, Vous travaillez pour le bien de l'état." Gabriel Finkelstein, "'Conquerors of the Künlun'? The Schlagintweit Mission to High Asia," *History of Science* xxxviii (2000): 179-218, on 186.
[790] See Patricia Fara, "The Royal Society's portrait of Joseph Banks," *Notes and Records of the Royal Society* 51 no. 2 (July 1997): 199-210.

Banks, shown here seated in the Royal Society's presidential chair, stood at the head of a "learned empire" of knowledge, naturalia, people, and publication whose true metropolitan center, historians have argued, was his own home at 32 Soho Square.[791] As a young man under Bank's "care" in England, Humboldt marveled at the convergence of "persons and materials from both Indies in his home."[792] Now an aging savant vested with the authority of his own star and sash, Humboldt's home at Oranienburger Street 67 functioned similarly to Soho Square, as the high *Amt* of a learned administration.

Figure 12 (Left). Humboldt with his noble star and sash by Henry William Pickersgill, 1831. Wikimedia Commons. Figure 13 (Right). Joseph Banks portrayed by Thomas Philips, commissioned in 1809 by José de Mendoza y Ríos, author of the manuscript "On an Improved Reflecting Circle" that lays before him on the table. © The Royal Society, Image number: RS.9544.

[791] David Phillip Miller, "Joseph Banks, empire, and 'centers of calculation' in late Hanoverian London," in *Visions of Empire: Voyages, Botany, and Representations of Nature*, eds. David Phillip Miller and Peter Hans Reill (Cambridge: Cambridge University Press, 1996), 21-37, esp. 22.
[792] Alexander von Humboldt, 4 Aug. 1801, in Kurt R. Biermann, ed., *Aus meinem Leben: Autobiographische Bekenntnisse* (Leipzig: Urania Verlag, 1987), 39. See Chapter 3 of this dissertation.

Aside from his fame as a man of science, Humboldt's Prussian nobility and high rank in the King's court put him in a particularly strong position to exploit the knowledge of civil servants, engineers, military officers, and diplomats around the world. Mexico's foreign minister communicated atmospheric temperatures at various coordinates between Havana and Veracruz, while a young Charles Darwin reported measurements of the Antarctic current that culminated around the Galapagos Islands from H.M.S. Beagle's survey of the South American littoral.[793] From Britain's consul-general in Bolivia Humboldt learnt of new trigonometric measurements of Aconcagua and other Andean peaks that now surpassed Chimborazo, just as British East India Company surveyors supplied him with the latest calculations of the Himalaya's Dhaulagiri and Kangchenjunga, now judged to be the highest on earth.[794]

Around mid-century, the observable world was growing to new heights and plunging to new depths. "The horizon of life has expanded before our eyes," Humboldt wrote in the first volume of *Kosmos*—and he had eyes on every development.[795] Confined to a lowland, landlocked central European country, Humboldt nevertheless used his position atop Prussia's government to acquire nautical charts and bathymetric maps from US navy officers, relayed to Berlin by way of Prussia's American consul. In return, the Prussian Minister Plenipotentiary to the United States communicated Humboldt's approval of the nation's oceanographic

[793] Lucas Alamán y Escalada to Humboldt, 5 Mar. 1820, in SBB, Nachl. Alexander von Humboldt, gr. K. 4, Nr. 23; Charles Darwin to Humboldt, 1 Nov. 1839, ibid., Nr. 22. Alamán was himself trained in mining and drew directly upon Humboldt's Mexico works in his investments into mining there at the head of the United Mexican Association. Notably, Darwin echoed Humboldt's *Personal Narrative*, which he took with him on the Beagle voyage, in emphasizing that the measurements were "made by a very careful person employed by Capt. FitzRoy (*at his own expense*)." My emphasis.

[794] As in the letters above, which Humboldt kept in a file on ocean temperatures, these hypsometric records were stored in an envelope titled "Briefe von Joseph Hooker und [Joseph Barclay] Pentland," SBB, Nachl. Alexander von Humboldt, gr. K. 8, Nr. 41-48a.

[795] Alexander von Humboldt, *Kosmos: Entwurf einer physischen Weltbeschreibung*, vol. 1 (Stuttgart: Cotta, 1845), 369: "Die Lebenssphäre, man möchte sagen der Horizont des Lebens, hat sich vor unseren Augen erweitert."

undertakings to the American public in an effort to ensure continued funding.[796] Turning back to the mountains, Humboldt lobbied the King himself to finance the Schlagintweit brothers' geographic mission to the Himalaya, "transforming the expedition into an act of diplomacy" by securing them a place in Britain's "Magnetic Survey" of India.[797]

Mining officials played a significant part in this great terrestrial survey. In his Berlin manuscripts, alongside notes on deep-sea soundings and high-altitude trigonometry, are tabulated reports on subterranean temperatures from *Bergakademie* graduates stationed throughout Europe. Humboldt believed such data would yield the general laws by which temperature increases with depth, giving some indication of the nature of the earth's interior. Familiar names from the Freiberg Network are found here, too, as in detailed reports from an "eternally grateful and true Freiesleben."[798] Earlier, while returning to Berlin from Paris in December 1826, Humboldt

[796] American naval officer Matthew Fontaine Maury sent numerous charts and manuscripts to Humboldt by way of Johann Flügel (Prussia's American consul and correspondent at the Smithsonian Institution), while Humboldt responded with awards and public letters of support Humboldt sent in return via Friedrich von Gerolt (Prussian Minister Plenipotentiary to the United States). See Humboldt to Johann G. Flügel, 19 June 1850, in *Alexander von Humboldt und die Vereinigten Staaten von Amerika. Beiträge zur Alexander-von-Humboldt-Forschung, 19. Briefwechsel*, ed. Ingo Schwarz (Berlin: Akademie Verlag, 2004), 269-70; Friedrich von Gerolt to Humboldt, 28 Nov. 1853, in ibid., 327.

[797] Finkelstein, "'Conquerors of the Künlun'?" 188; Moritz von Brescius, *German Science in the Age of Empire: Enterprise, Opportunity and the Schlagintweit Brothers* (Cambridge: Cambridge University Press, 2019). On Humboldt as a diplomat in both the scientific and traditional sense of the word, see Ulrich Päßler, *Ein "Diplomat aus den Wäldern des Orinoko": Alexander von Humboldt als Mittler zwischen Preußen und Frankreich* (Stuttgart: Franz Steiner Verlag, 2009).

[798] Letters from Ernst Heinrich von Dechen (Professor of Mining at the Bergakademie Berlin) and Karl von Oeynhausen (a fellow Prussia mining officer) are found in SBB, Nachl. Alexander von Humboldt, gr. K. 11, Nr. 60, as well as ibid., kl. K. 14, nr. 10; letters from Freiberg graduate Carl Friedrich Naumann are ibid., gr. K. 2, Mappe 4, Nr. 8, 64; and letters catalogued as "Freiberger Gruben von Freiesleben" are Freiesleben to Humboldt, 1844, in ibid., gr. K. 11, Nr. 58. Cf. Freiesleben to Humboldt, 15 Mar. 1844, in Nürnberg, Germanisches National-Museum. Autographen-Sammlung. Abteilung V. Mineralogen. Deutschland. Bestand II. 2. Another Freiesleben letter, dated 1826, is found alongside oceanic temperatures recorded by Darwin and Alamán, in SBB, Nachl. Alexander von Humboldt, gr. K. 4, Nr. 21, Bl. 14. Further notes on mine temperatures were sent to Humboldt by the Belgian astronomer Adolphe Quételet, in ibid., gr. K. 12, Nr. 61, alongside measurements of atmospheric temperatures in ibid., gr. K. 12, Nr. 72, 86a.

"spent two days underground in Freiberg."[799] The Freiberg tour was an act of intellectual diplomacy that ensured Humboldt a steady flow of data from local officials and technicians.

Deference and duty defined the "epistolary behavior" of Humboldt's scientific administration, echoing the bureaucratic genre of exchange to which most of its participants were already accustomed.[800] Often his correspondents trivialized their own contributions, reinforcing Humboldt's role as *Oberst*. By describing their research as partial and piecemeal—"a few extracts from my journals," said one, "such trivial observations," wrote another—correspondents implicitly acknowledged the superior expanse of Humboldt's terrestrial oversight. Francis Beaufort, for instance, then a captain in the Royal Navy, addressed Humboldt with the same humility and devotion he might affect towards one of his own superiors. The "horary variations of the Barometer traced through 86 consecutive degrees of latitude" that Beaufort enclosed amounted to a prodigious quantity of data. But by comparison with Humboldt's "profound view" over "so many years in so many climates," Beaufort judged his own measurements to be mere "ambulatory observations." There is an informal social contract in these letters, bound by a set of conventions drawn from the realm of service to crown and country. "It should be considered a public duty," Beaufort concluded, "to contribute to the stock of facts, which you already possess."[801] Humboldt signaled his approval in the same language, chiding Darwin, for instance, for understating "what you so modestly call 'The Journal of a Naturalist'!"[802]

The paternalistic form of governance Humboldt had served in Franconia and advocated in Mexico was integral to his epistolary practice in Berlin in the final third of his life. Humboldt's

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[799] Humboldt to Wilhelm von Humboldt, 12 Dec. 1826, in *Aus meinem Leben*, 198-99.
[800] Anne Secord, "Corresponding Interests: Artisans and Gentlemen in Nineteenth-Century Natural History," *The British Journal for the History of Science* 27, no. 4 (December 1994): 383-408, on 407.
[801] Francis Beaufort to Humboldt, 29 Nov. 1826, SBB, Nachl. Alexander von Humboldt, gr. K. 5, Nr. 40.
[802] Alexander von Humboldt to Charles Darwin, 18 Sept. 1839, Darwin Correspondence Project, "Letter no. 534," accessed on 28 Nov. 2020, https://www.darwinproject.ac.uk/letter/DCP-LETT-534.xml.

most ardent followers regularly cast themselves as the children of the Prussian *pater familias*. Most famously, Darwin described Humboldt as "the parent of a grand progeny of scientific travellers."[803] Frequently cited, the phrase is rarely read for its tacit politics. As Humboldt's generation of officials addressed their sovereign as the *Landesvater*, so the paternal idiom proxied for administrative order in his own scientific polity. Already in 1822, while describing his "American project" to brother Wilhelm, Alexander veiled the geopolitics of global physics as a matter of family legacy: for "when one has no large family, no children, one must think how to embellish his old age."[804] By the 1850s, Humboldt boasted to one diplomat that he was the "*Urvater* of all German writers," by which he meant: "I help others so eagerly when I foresee the prospect of success."[805]

Correspondents sometimes evoked the same familial language while describing their role in the making of actual empires, as though legitimated by the beneficence of Humboldt's paternalism. One who counted himself amongst Humboldt's progeny was Joseph Dalton Hooker.

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[803] Charles Darwin to Joseph Dalton Hooker, 6 Aug. 1881, in F. Darwin, ed., *The Life and Letters of Charles Darwin* (New York, Appleton & Co., 1905), *2*, 422-24. Darwin might have had in mind Humboldt's praise for his "family's finest patrimony." While writing to Darwin, Humboldt described his own debt to the young naturalist's grandfather, Erasmus Darwin, "poetic author of *Zoonomia*, who proved that profound affinity with nature and an imagination that was not dreamy but powerful and productive, [which] enlarge[ns] in superior men the realm of understanding." Humboldt thus united himself and Darwin in a common patrilineal heritage of what he humbly called "superior men." (Humboldt to Darwin, 18 Sept. 1839, DCP, "Letter no. 534," DCP, "Letter no. 832," accessed on 16 June 2020, https://www.darwinproject.ac.uk/letter/DCP-LETT-534.xml.)

[804] Humboldt to Wilhelm von Humboldt, *Briefe Alexander's von Humboldts*, 100: "Tu riras peut-être de voir que je m'occupe si ardemment de ce projet américain, mais grand on n'a pas de famille, pas d'enfants on doit penser à embellir sa vieillesse."

[805] Humboldt to Johann Flügel, 20 June 1854, in *Humboldt und die Vereinigten Staaten*, 333: "Wie konnten Sie glaube, dass ich, der Urvater aller deutschen Schriftsteller, über das Anliegen eines Schriftsetzers unzufrieden sein könnte. Ich helfe so gern, wenn ich eine Aussicht des Gelingens voraussehe." Humboldt's "progeny" also wished to emulate the paternalism he has shown. Charles Darwin wrote his friend Hooker, who had just met Humboldt (the "most extraordinary man") in Paris, "of being a Humboldt to others" once he had established himself. See Darwin to Hooker, 10 Feb. 1845, DCP, "Letter no. 826," accessed on 28 Nov. 2020, https://www.darwinproject.ac.uk/letter/DCP-LETT-826.xml and Hooker to Darwin, late Feb. 1845, "Letter no. 832," accessed on 28 Nov. 2020, https://www.darwinproject.ac.uk/letter/DCP-LETT-832.xml.

Humboldt pledged public support for Hooker's proposal to travel through the Himalaya in 1847-50, and even joined forces with the eminent publisher Berghaus to help finance the voyage. Taking a particular interest in the Tibetan plateau, just beyond the Kingdom of Sikkim's contentious Chinese border, Humboldt provided Hooker many a "long kind & instructive letter, full of valuable counsel." From a series of updates posted out of "Darjeeling Sikkin Himalaja," we know Humboldt kept tabs on Hooker's trigonometric surveying, the heights of mountains calculated thereby, the "perpetual snowline" on different aspects, and all manner of questions about the geographic distribution of plants that such precise topographical knowledge might illuminate (see **Figure 14**). "The work shall go forth as the offspring of Baron Humboldt's matured experience," Hooker reported to Berlin in April of 1849, praising his "admirable & unexceptionable plan."[806]

Like many colonial surveying operations, however, the plans Humboldt drafted for his Himalaya delegates did not proceed as smoothly as he imagined.[807] For Hooker, carrying out "the plan of Baron Humboldt's" also meant disregarding local law and crossing into the Tibetan plateau so coveted by his benefactor. In a publicly printed letter of 1847, Humboldt had urged Hooker to "penetrate" "the plateaus of Tibet, whose mean elevation … is a dignified object of inquiry!"[808] In fact, Humboldt kept his entire correspondence with Hooker in a file of notes titled

[806] The Hooker-Humboldt correspondence from April 1849 to August 1851 is SBB, Nachl. Alexander von Humboldt, gr. K. 8, Nr. 41-44, beside an envelope titled "Tibet" (gr. K. 2, Mappe 4, Nr. 8-10) with additional newspaper clippings on "Hooker und Tübet" in ibid., gr. K, 11, Nr. 2a and assorted notes on Hooker's travels in a file called "Hebung" (elevation) gr. K. 11, Nr. 8-10.
[807] The Schlagintweit brothers' expedition was interrupted by the political unrest in India and then criticized in the British press as "one of the most gigantic jobs that ever disgraced the annals of science." (*The Athenaeum*, 17 Aug. 1861, as quoted in Finkelstein, "'Conquerors of the Künlun'?" 199.)
[808] Humboldt's letter of 30 Sept. 1847 was printed in the article "BOTANICAL INFORMATION. *Dr. Hooker's Botanical Mission to India*," *The London Journal of Botany*, vol. vi (1847): 604-07, which was edited by Hooker's father, William Jackson Hooker. (See the elder Hooker's correspondence with Humboldt in SBB, Nachl. Alexander von Humboldt, gr. K. 8, Nr. 43.) In his 1847 letter to J. D. Hooker, Humboldt wrote: "Que je suis heureux d'apprendre, mon excellent ami, que vous allez pénétrer dans ces

"Tibet." The Sikkim Rajah, fearing hostilities with China, saw less dignity in Hooker's Tibetan transgression and had his party imprisoned for their reckless act. Ultimately it was Britain whom the Sikkim King had to fear. After Hooker's release, the British colonial government exploited the incident to seize yet more territory from Sikkim.[809]

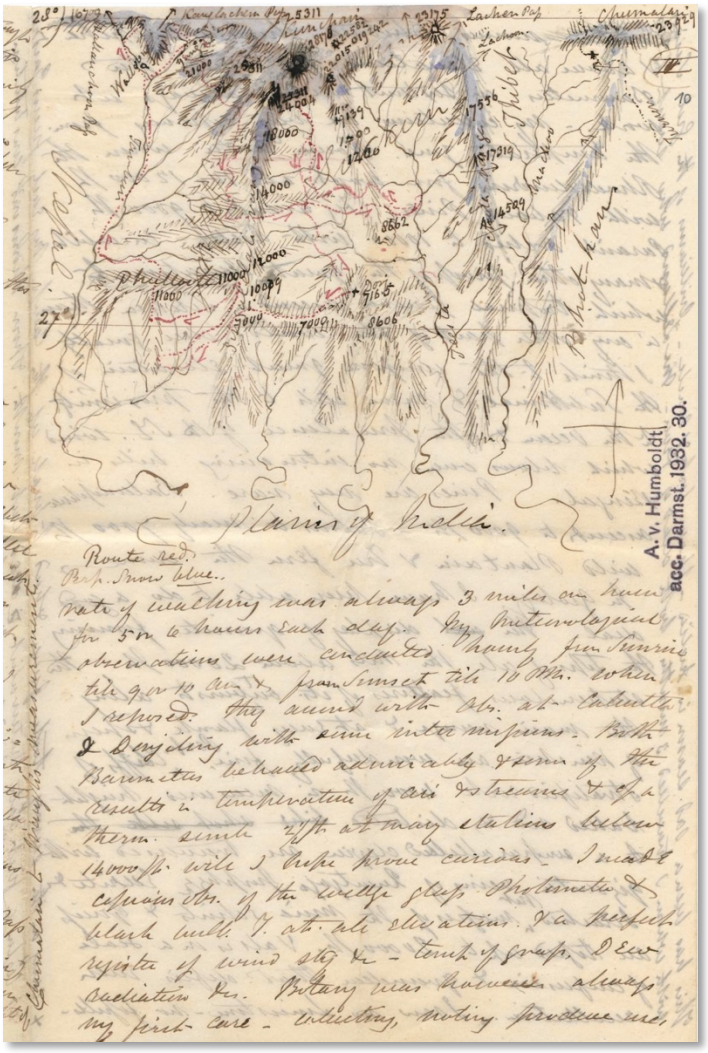

Figure 14. Hooker's sketch of the Himalaya in a letter to Humboldt from April 1849, marking his route in red and the snowline in blue. In April, the dotted red line of his route had yet to cross into the valley to the east labelled "Thibet," in the top right of the sketch. Digitalisierte Sammlungen SBB, Alexander von Humboldt, gr. K. 8, Nr. 41b.

belles vallées de l'Himalayah, et même au-delà vers Ladak et les plateau de Thibet, dont la hauteur Moyenne, non confondue avec celles des cîmes que s'élèvent dans le plateau même, est un objet digne de recherche!" In the same article the tenuous geopolitical situation between Britain and the Kingdom of Sikkim, allied against a common foe in China, was masked by a pending treaty, "now in progress of negotiation . . . with reference to the boundaries of Thibet." The author hinted that it was "possible even the latter interesting region may be visited by Dr. Hooker in the course of his journey." It is clear, then, that both Humboldt and Hooker had their sights set on Tibet from the start.

[809] Michael S. Reidy, "From Oceans to Mountains: Spatial Science in an Age of Empire," in *Knowing Global Environments: New Historical Perspectives on the Field Sciences,* ed. Jeremy Vetter (New Jersey: Rutgers University Press, 2010), 30-32.

While Humboldt never advocated annexation, the mutualism between territorial expansion and the "progress of hypsometric knowledge" was always implicit in his correspondence with Hooker. As Humboldt produced his Mexico *Atlas* for application in "the administration of the colonies" there, so Hooker, half a century later, dedicated his maps to "the country, for whose benefit the charts are planned."[810] Now, though, the vertical frontier Humboldt had merely envisioned in the Cordilleras had become a very real site of conflict in the Himalaya. Nevertheless, Hooker's reports came just in time to feature in the new preface to an expanded edition of his *Ansichten der Natur* (written in March 1849), which offered a novel "hypsometric comparison" of the Andes and Himalaya, specifically highlighting its "greatly enriched" knowledge of Tibet. Here Hooker's border transgression could be recast as a "border-plotting expedition," as though a part of Humboldt's "unexceptionable plan" all along.[811]

Others took Humboldt's plans into the oceans.[812] The US naval officer Matthew Fontaine Maury explicitly adopted Humboldt's phrase "physical geography of the sea" to describe his oceanographic project.[813] Maury saw oceans as Humboldt saw mountains, only with ships in the

[810] Hooker to Humboldt, 26 Apr. 1849, in SBB, Nachl. Alexander von Humboldt, gr. K. 8, Nr. 41.
[811] Alexander von Humboldt, *Views of Nature*, eds. Stephen T. Jackson and Laura Dassow Walls, trans. Mark W. Person (Chicago: The University of Chicago Press, 2014), 28, 64-73.
[812] Examples abound in the records of Humboldt's Berlin correspondence. The US-American polymath Charles Thomas Jackson, for instance, credited Humboldt with the U.S. Coast Survey's plan to "measure the mean sea level on both sides of this continent, and to fix permanent marks & measurements" along each coast. "This work will now be done, as you suggested it ought to have been, long ago," Jackson wrote Humboldt in a letter that also communicated detailed reports on mining prospects in Virginia and the Carolinas. (SBB, Nachl. Alexander von Humboldt, gr. K. 11, Nr. 8-10, Bl. 34.) The letter may have been written in the 1830s, when Jackson carried out a survey of the mineralogy and geology along the coastlines of Nova Scotia. Or, given the letter's mining references, it might have been written in 1844-45, when Jackson was employed on-site consultant to the Lake Superior Copper Company.
[813] Within a year of meeting Humboldt in 1853, Maury began making use of his phrase "Physical Geography of the Sea" in the sixth edition of his *Explanations and Sailing Direction*; and in 1855 he published an ambitious oceanographic book under this title. In its Introduction, Maury declared that "Baron Humboldt is of the opinion that the results already obtained from this system of research are sufficient to give rise to a new department of science, which he has called the PHYSICAL GEOGRAPHY OF THE SEA." (Matthew Fontaine Maury, *Physical Geography of the Sea* (New York: Harper & Brothers Publishers, 1855), xiii.) Oceanography is itself a term that came into use in Maury's lifetime.

place of mines, and seamen instead of miners. As head of the United States Naval Observatory and Hydrographic Office, Maury commanded his subordinates to synthesize the immense archive of unexploited data stored in the hundreds of maritime logbooks housed there. Their aim was to inscribe the ocean's tides, currents, winds, and depths into a set of innovative visuals.[814]

As at Humboldt's *Bergschule*, moreover, Maury saw the broader workforce who made their living on the main as an opportunity for his new science of the sea. And so he set about schooling merchant mariners through a set of widely distributed "Abstract Logs." Mariners would submit completed Logs to the National Observatory in exchange for the most up-to-date *Wind and Currents Charts* to which their observations contributed. When a copy reached Humboldt, he penned his approval through diplomatic channels: "I beg you to express to Lieut. Maury, the author of the beautiful chart of the winds and currents, prepared with so much care and profound learning, my hearty gratitude and esteem," he wrote to Prussia's American consul, believing the undertaking "equally important to the practical navigator and for the advance of meteorology."[815]

Like foremen equipped with the means of geognostic inquiry, Maury's seamen-scientists comprised a "large corps of observers … spread upon the waters." Their observations, tabulated in "Pilot Sheets" (**Figure 15**), enabled the creation of new visual technologies—Maury's favorite medium—that codified winds and currents with unprecedented precision.[816] Maury's "Pilot

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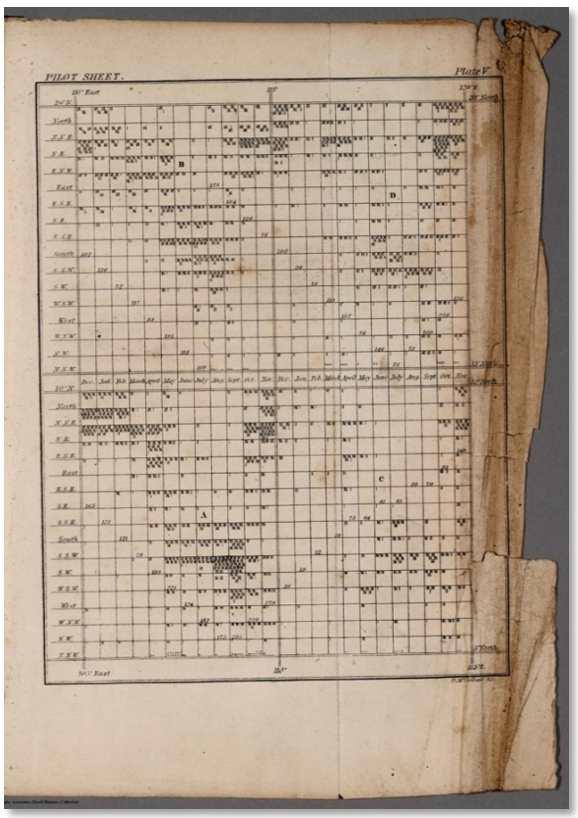
[814] On Maury's transformation of the Depot of Charts and Instruments into the National Observatory in the 1840s and 50s, see Stephen J. Dick, "Centralizing Navigational Technology in America: The U. S. Navy's Depot of Charts and Instruments, 1830-1842," *Technology and Culture* 33, no. 3 (July 1992): 467-509; Helen M. Rozwadowski, *Fathoming the Ocean: The Discovery and Exploration of the Deep Sea* (Cambridge, Massachusetts: Belknap Press, 2005), 75-76.
[815] Humboldt to Johann G. Flügel, 19 June 1850, in *Humboldt und die Vereinigten Staaten*, 269-70.
[816] Penelope K. Hardy, "Every Ship a Floating Observatory," in *Soundings and Crossings: Doing Science at Sea, 1800-1970*, eds. Katharine Anderson and Helen M. Rozwadowski (Sagamore Beach: Watson Publishing International, 2016), 17-48. As Hardy notes, Maury believed visual media—various types of

Charts," for instance (**Figure 16**)—a distant cousin of the Mining School's paper compasses—helped mariners navigate seasonal variations in the winds for each one-by-one-degree sector of the ocean with a twelve-part diagram.[817] By 1855, Maury could boast that "[e]very ship that navigates the high seas with these charts and blank abstract logs on board may henceforth be regarded as a floating observatory, a temple of science."[818]



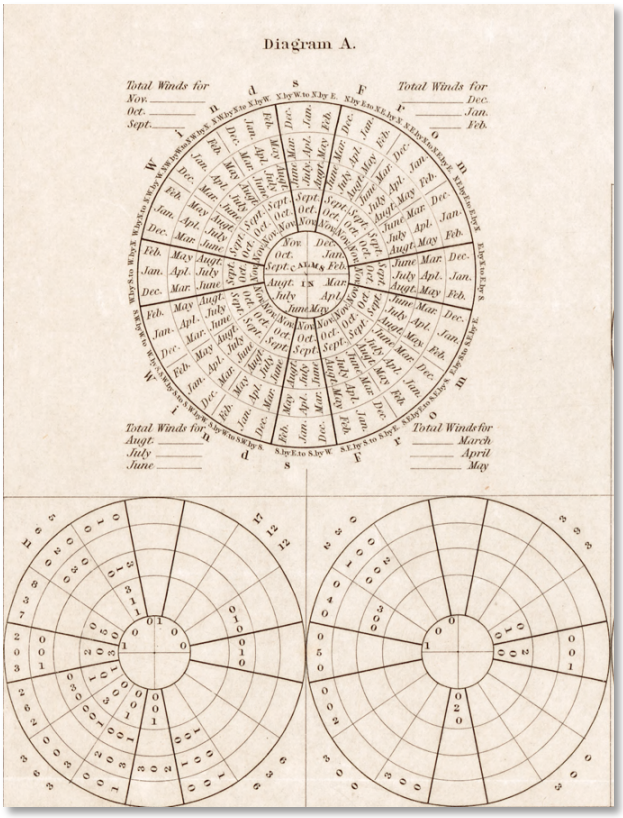


Figure 15 (Left). An example "Pilot Sheet" that Maury published as a guide for mariners in the 1857 edition of his *Physical Geography of the Sea*. David Rumsey Historical Map Collection, Image No: 0475012. Figure 16 (Right). Matthew Fontaine Maury, Charles Morris, *Pilot Chart for Cape Horn* (Washington, D.C.: United States Hydrographical Office, 1852). Library of Congress, Geography and Map Division, G5332.H6C75 1852 .M3.

charts and profiles—superior to textual description in conveying theoretical information "at a glance, & with a perspicuity, certainty & generalization that written accounts cannot give." (As quoted in ibid., 39.)

[817] Another example is Maury's "Track Charts," which codified prevailing wind patterns with hairs that were either constrained or feathered according to the regularity and irregularity of color-coded seasonal winds. See Chester G. Hearn, *Tracks in the sea: Matthew Fontaine Maury and the mapping of the oceans* (Camden, ME: International Marine/McGraw Hill, 2002).

[818] Maury, *Physical Geography of the Sea*, xiii.

The likeness between Maury's floating observatories and Humboldt's subterranean surveying is no coincidence: the Prussian privy counselor had a heavy hand in promoting Maury's endeavors, writing letters of support to US government officials and publicly sponsoring the first international Marine Meteorology Conference, which Maury organized in 1853.[819] Two years later, the King of Prussia awarded Maury the nation's highest scientific honor, the "Kosmos-Medaille." As Humboldt wrote, the medallion recognized the "affection with which you have honored me for so long."[820] Like Hooker before him, Maury responded in the appropriate patrilineal language. "[L]ike the child that brings its caps full of pebbles gathered on the sea shore to its protector," he wrote to Humboldt in 1859, just one day before his death, "so I would often fain have laid the results of my investigations at your feet."[821]

Here, as in Hooker's letters, familial expressions signaled the institutional support that Humboldt ensured his "progeny." When Maury told Humboldt of how his "approval" "strengthens mightily my hands," he spoke, in fact, about the many *other hands* required to sustain his "poor labors": "it removed difficulties," Maury continued, "and enlists many laborers for the field," noting how the US government had ordered "every public cruiser to take a deep sea sounding" in order to "determine the depths of the ocean, the shape of the Marine basins &c."[822] Humboldt was among the first to receive the results of the Atlantic Ocean soundings in the 1850s, which, like Hooker's hypsometric reports, he promptly integrated into his own works.

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[819] Bolstered by Humboldt's support and backed by the US Navy's new secretary, Maury organized the first international Marine Meteorology Conference in Brussels in 1853, inviting delegates of all major maritime nations in the Western Hemisphere. There, the delegates of nine European nations (joined subsequently by five more European and two South American states) agreed upon a standardized Abstract Log, which, like its American predecessor, would be sent to Depot in exchange for Maury's latest charts.
[820] Humboldt to Maury, 3 Feb. 1855, *Humboldt und die Vereinigten Staaten*, 341. The medallion was, Humboldt wrote, "struck for me upon the publication of my 'Cosmos'."
[821] Maury to Humboldt, 5 May 1859, ibid., 479. Cf. Maury to Humboldt, 12 Apr. 1855, ibid., 344.
[822] Maury to Humboldt, 1 Apr. 1851, ibid., 284-86; Maury to Humboldt, 5 May 1859, ibid., 479. Maury repeated this while eulogizing the late Humboldt, emphasizing his ability to enroll "laborers" in Maury's

With ambassador-kin like Maury and Hooker sprawling over the earth, each at the head of their own workforce, Humboldt drew mountain heights and ocean depths into the synthetic vision for which he is famous.[823] To speak again with Dettelbach, Humboldt's holistic "oversight" of the natural world reflected that which he exercised in social worlds—first as a Prussian mining official, then as an agent of the colonial state in New Spain, and finally from his home-cum-*Amt* in Berlin.[824] Nowhere is that oversight more vividly illustrated than in an address Humboldt communicated to the Royal Academy of Sciences in Berlin in 1853. A *Promemoria* of sorts, the address collated individual reports from Hooker, Maury, and other correspondents into a single synopsis. The latest seafloor soundings plunged "nearly 17,000 Paris feet deeper than the heights of Kintschinjunga," Humboldt reported, proposing that "only once we imagine the earth like the moon, without a liquid shroud, will the mountain-masses and summits, indeed the entire surface of the earth, appear in its true form."[825]

To empty the oceans as one pumps a flooded mine made for a stunning act of "imagineering."[826] But *Entwässerung*, as miners called their drainage process, was a familiar

undertakings by securing him institutional resources. See Maury, 26 May 1859, "Dokument 45 Briefe an Marshall Lefferts, Domestic Corresponding Secretary der American Geographical and Statistical Society, New York," in *Humboldt und die Vereinigten Staaten*.

[823] On the labor of Indian explorers involved in British geography, see Tapsi Mathur, "How Professionals Became Natives: Geography and Trans-Frontier Exploration in Colonia India" (PhD Diss., The University of Michigan, 2018).

[824] E.g. Dettelbach, "Romanticism and Administration," 8: "Like *Kosmos* itself, Humboldt's isomaps were not so much tools of administration as representations of the new brotherhood of imperial administrators, travelling the world in Humboldt's name."

[825] The address survives partly in its printed form, and partly in the form in which Humboldt's personal assistant, Buschmann, transcribed his dictation: SBB, Nachl. Alexander von Humboldt, gr. Kasten 11, nr. 71, 61a: "Wenn wir uns die Erde, wie den Mond, ohne eine flüssige Umhüllung denken, so erscheinen uns Bergmassen und Gipfel, ja die ganze Oberfläche der Erde dann erst in ihrer wahren Gestalt. […] Die Meerestiefe von mehr als 43000 Par. Fuss, welche Cap. Denham vorigen Herbst erreicht hat, ist fast 17000 Par. Fuss grosser als die Höhe des Kintschingjinge, des höchsten wohlgemessenen Gipfels des Himalaya-Gebirges, den wir seit meines Freundes, Joseph Hookers, tibetanischer Reise kennen."

[826] Lissa Roberts, "Practicing oeconomy during the second half of the long eighteenth century: an introduction," *History and Technology* 30, no. 3 (2014): 133-48, on 134.

practice to Humboldt, who had studied the history of Spain's efforts to drain the entire Valley of Mexico and consulted Saxon engineers in drainage projects that pumped water from the Ore Mountains to the Elbe.[827] Hydraulics played a significant theoretical role, too. In *Ansichten*, Humboldt reverse engineered the high steppe south of Caracas to imagine the "great inland sea" that once covered its "rocky crust." At least this was the effect of "the undulating haze" that, in the faint light of the night sky, gave the appearance of "a boundless ocean."[828]

Such scenes impressed Humboldt with a sense of "higher order"—and this is precisely what he wished to impress upon Mining School pupils in his first great act of hydraulic imagineering. A half-century before Humboldt invited academicians to behold the dehydrated globe "in its true form," he instructed Mining School pupils to imagine the "ocean floor without water," turning islands into "mountains rising from the sea."[829] Later, in *Kosmos*, mountains themselves appear as "green forested shoals" rising through the "aerial ocean."[830]

This image of nature, charming in its simplicity, bespeaks nothing of administration, governance, and work. Gone are the states and empires, soundings and surveys, civil servants, draftsmen, and indeed the miners from this characteristically Humboldtian conception of the earth as a mountainous moonscape—a "view from nowhere," it might be called. But cosmic science, I have argued, was always managerial science. And this particular view can be located in the sprawling empire of observation that Humboldt governed from Oranienburger Street 67. Humboldt's hypsometric globe is the very image of his cosmic oversight.

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[827] Humboldt devoted considerable space in his *Political Essay* on New Spain to discussing the history of the Huehuetoca Canal. See Humboldt, *Neu-Spanien*, *2*, 93-119. On the Meissner Erbstolln in Saxony, see Ulrich Stottmeister, "Umweltgedanken zu Alexander von Humboldt," *HiN* 18, no. 35 (2017): 75-94.
[828] Humboldt, *Views of Nature*, 29.
[829] StABa, KDK, Nr. 7114, vol. 1, Bl. 93.
[830] Humboldt, *Kosmos*, *1*, 321.

Conclusion

A Deeper Commerce: Humboldt's Labor Theory of Climate

> *The more manifold the relations into which Man enters with the world around him, and the more powerful and various his influence upon organic and inorganic nature, the more he gains in intellectual cultivation from these entangled relations.*[831]
>
> *Ueber die unterirdischen Gasarten*, 1799

> *We enter into a deeper commerce with the external world and we are not indifferent to that which betokens both the industrial progress and the intellectual cultivation of Mankind.*[832]
>
> *Kosmos* vol. 1, 1845

Humboldt's life can be read as a record of the evolving relationship between working and knowing through the *Sattelzeit*, a period that began in the rural, agrarian, and water-powered economy of early modernity and ended with recognizably modern forms of market capitalism, urban industrialization, and steam-power. Yet one of this dissertation's main findings is that Humboldt's explicit references to the industrial underpinnings and practical utility of his science actually tended to diminish as the concept of "work," working-class movements, and the labor theory of value gained prominence in nineteenth-century society.[833]

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[831] Alexander von Humboldt, *Ueber die unterirdischen Gasarten und die Mittel, ihren Nachtheil zu vermindern: Ein Beytrag zur Physik der praktischen Bergbaukunde* (Braunschweig: Vieweg, 1799), 3-4: "Je mannigfaltiger die Beziehungen sind, in welche der Mensch mit den Gegenständen um sich her tritt, je mächtiger und vielseitiger er auf die belebte und unbelebte Natur einwirkt, desto mehr gewinnt unter verwickelten Verhältnissen seine intellectuelle Bildung."

[832] Alexander von Humboldt, *Kosmos: Entwurf einer physischen Weltbeschreibung*, vol. 1 (Stuttgart: Cotta, 1845), 34: "Wir treten in einen innigeren Verkehr mit der Außenwelt, bleiben nicht untheilnehmend an dem, was gleichzeitig das industrielle Forstschreiten und die intellectuelle Veredlung der Menschheit bezeichnet."

[833] The "working-class" is itself a historical concept that originated during this period. On the significance of work in nineteenth-century German society, see Jürgen Kocka, ed., *Work in a Modern Society: The German Historical Experience in Comparative Perspective* (New York: Berghahn, 2013), as well as the

The young Humboldt was a remarkably faithful autobiographer. Born into a Germany where paternalist governance nurtured the unity of administrative, technical, and intellectual cultures, Humboldt reflected the holism of his cameralist training. What might be described as ecological in his science was, I have argued, born of an expansive sense of political (o)economy, after which he modelled "global physics" as a program of natural and social administration. In the 1790s, Humboldt readily acknowledged his debt to the mining industry and its practices of governance and resource use. "It has had such a fundamental influence on my way of thinking," he wrote of his tenure in Franconia, "what great plans I forged there."[834] And on the eve of his departure for the Americas, Humboldt presented himself as a figure who resolved the "political and moral circumstances that threaten to divide the *Techniker* and the *Theoretiker*."[835]

But the new century brought drastic changes that threatened to distance the two further still. Amidst increased mechanization, urbanization, and proletarianization, profound institutional and cultural shifts also led to a sharper delineation between *Naturwissenschaften* and *Technikwissenschaften*, which once cohered in the concept of "useful knowledge."[836] And so Humboldt was increasingly concerned to distinguish his scientific personae—the savant and the technician—marketing certain projects to investors while maintaining a gentlemanly air of

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literature on Imperial Germany, e.g. Sebastian Conrad, *Globalization and the Nation in Imperial Germany*, trans. Sorcha O'Hagen (Cambridge: Cambridge University Press, 2010).

[834] Humboldt to Carl Freiesleben, 14 Dec. 1795, in Ilse Jahn and Fritz Lange, eds., *Die Jugendbriefe Alexander von Humboldts, 1787–1799* (Berlin: Akademie Verlag, 1973), 474: "Es hat so einen wesentlichen Einfluß auf meine Denkart gehabt, ich habe so große Pläne dort geschmiedet…."

[835] Humboldt, *Ueber die unterirdischen Gasarten*, 24: "In einer Epoche, wo politische und moralische Verhältnisse in manchen Orten den Techniker von dem Theoretiker zu entfernen drohen, dürfte ein solches Beispiel nicht unwirksam seyn."

[836] Ursula Klein, *Nützliches Wissen: Die Erfindung der Technikwissenschaften* (Göttingen: Wallstein, 2016), 181-87 and Karl-Heinz Manegold, *Universität, Technische Hochschule und Industrie* (Berlin: Duncker & Humblot, 1970). Divisions also emerge amongst engineers themselves, as the "shop culture" of "nonacademic" *Techniker* now vied with "diploma engineers." See Kees Gispen, *New Profession, Old Order: Engineers and German Society, 1815-1914* (New York: Cambridge University Press, 1989).

disinterestedness in others. It was a delicate balancing act: when offered a position as chairman of the Franco-Mexican Association, whose mining investments he had encouraged, Humboldt declined, insisting he did not wish to profit from his science.[837] The "*Wechselwirkung*" between epistemic and economic activity that Humboldt had prized in the age of cameralism was no less present in the age of capital—only re-cast in a manner that tended to distance his science from the working worlds of its making.[838]

Humboldt's celebrity grew in pace with industrial society, but sometimes seemed at odds with it. One contemporary account from Bettine von Arnim, a close friend, recapitulates the arc of Humboldt's career in a parable that fancifully delineated the savant from the technician. In her 1843 "King's Book," an indictment of Prussian society in general and the government's neglect of the working class in particular, Arnim began with a tale before the Fall, as it were. Here Humboldt appears as the child of "colliers who live deep in the forest where blossoming trees do not grow," a "lonesome wilderness" unpenetrated by the "secrets of nature." Only after discovering an apple—and with it, "the spiritual ideal of nature"—did the collier's son learn he was gravely mistaken in all he thought he knew of nature. Communing with God himself, boy-Humboldt asks: "Is that not smoke from the charcoal stack carried by the stiff morning breeze through the pines?" "No!" Arnim admonishes, it was the Deity's own beard that whisked

[837] Myron Echenberg, *Humboldt's Mexico: In the Footsteps of the Illustrious German Scientific Traveller* (Montreal, Ontario: McGill-Queen's University Press, 2017), 133. Cf. Michael Dettelbach, "Romanticism and Administration: Mining, Galvanism and Oversight in Alexander von Humboldt's global physics" (PhD diss., University of Cambridge, 1992), 162-63.

[838] Humboldt, *Kosmos*, *1*, 37: "Was von diesem Wissen in das industrielle Leben der Völker überströmt und den Gewerbfleiß erhöht, entspringt aus der glücklichen Verkettung menschlicher Dinge, nach der das Wahre, Erhabene und Schöne mit dem Nützlichen, wie absichtslos, in ewige Wechselwirkung treten." Eric Hobsbawm, *The Age of Capital, 1848-1875* (London: Weidenfeld & Nicolson, 1975).

through the woods. And so "the good Humboldt"—the collier who learned to see divine beauty where he had once seen the fumes of industry—set out to "make the apple appetizing."[839]

Arnim represents a green thread in German Romanticism, which viewed modern industry and sometimes the bourgeois class as antithetical to a true love of nature and social harmony. Even some of the *Dichter und Denker* who once devoted themselves to the mining industry now saw the factory system and steam engine as threats to the social and moral order. This critique went far beyond earlier disputes about the relative efficiency of hydraulic and steam power discussed in Chapter 1, both hailed as "sustainable" solutions to perceived wood shortages.[840] Goethe, who once directed mines in Ilmenau, appears to have straddled two distinct mentalities at the end of his life. Returning to Ilmenau in 1831, he described the extraction of "colossal prehistoric coal seams" there as a "wondrous" phenomenon: "And so it goes on from ancient granite up through contiguous epochs," he wrote of both carboniferous strata and the labor involved in their exploitation: "as evermore problems arise, the newest World-Creators [*Weltschöpfer*] easily draw forth solutions from the depths of the earth."[841] But while Goethe could still see Ilmenau's mines as a fixture of the old economic order, he viewed the new *Weltschöpfer*, the capitalist bourgeoisie, as its destroyer. "Just as the steam engines are not to be stifled," he wrote later that year, "neither is the new morality: the briskness of trade, the rustle of

[839] Bettina von Arnim, *Dies Buch gehört dem König*, vol. 1, 2nd ed. (Berlin, 1852), iii-viii.
[840] See discussion of debates about the efficiency of water-, wood-, and steam-power see also Joachim Radkau, *Wood: A History*, trans. Patrick Camiller (Cambridge: Polity Press, 2012), 227.
[841] Goethe to Carl Friedrich Zelter, 4 Sept. 1831, in *Johann Wolfgang Goethe*, vol. 38, Die letzten Jahre. Teil II: Vom Dornburger Aufenthalt 1828 bis zum Tode, ed. Horst Fleig (Munich: Deutscher Klassiker Verlag, 1993), 455-56: "Steinkohlen mit unglaublicher Mühseligkeit zu Tage gebracht, kolossale Urstämme, in der Grube unter dem Arbeiten entdeckt … ; und so ging's denn weiter, vom alten Granit, durch die angrenzenden Epochen, wobei immer neue Probleme sich entwickeln, welche die neusten Weltschöpfer mit der größten Bequemlichkeit aus der Erde aufsteigen lassen. Im Ganzen herrscht ein wundernswürdiges Benutzen der mannichfaltigsten Erd- und Bergoberflächen und -Tiefen."

paper money, the accumulating debt to pay off other debts—those are monstrous elements."[842] Nearly two decades later, Marx and Engels offered a famous, if frequently misunderstood, rendition of Goethe's critique: "All that firmly exists in the order of estates evaporates into steam [*verdampft*]," they wrote in the *Manifesto* (1848), evoking the steam engine (*Dampfmaschine*) to symbolize the bourgeoisie's accumulation of both thermodynamic and social power.[843]

Humboldt was directly implicated in this mid-century reorganization of energy and labor. For cosmic science now promoted capitalism much as its antecedents had served cameralism and colonialism. He idealized industrial society as a "peaceful competition" amongst "free" commercial forces, which contributed to "deeper insight" into a corresponding "struggle amongst competing elements" in nature.[844] This formulation was a reflection of the world in which Humboldt conceived of *Kosmos*. The exploitation of coal fields in Saxony and the Ruhr, the displacement, division, and discipline of labor made possible by the transition from water to steam, the expansion of the German railway and locomotive production, as well as Luddite uprisings against mechanization in Silesia and the first systematic pollution studies at the iron foundries in Saxony—all this came to a head as the first volumes of *Kosmos* hit the press in 1845, '47, and '50.[845]

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[842] As quoted in Rüdiger Safranski, *Goethe: Life as a Work of Art*, trans. David Dollemayer (New York: W. W. Norton, 2017), 558.

[843] See analysis of "*Alles Ständische und Stehende verdampft*," conventionally translated as "All that is solid melts into air," in Johnathan Sperber, *Karl Marx: A Nineteenth Century Life* (New York: Liveright Publishing, 2014), 206-07. On the link between thermodynamic and social power, see Andreas Malm, *Fossil Capital: The Rise of Steam Power and the Roots of Global Warming* (London: Verso, 2016), 18.

[844] Humboldt, *Kosmos*, *1*, 15-16, 36-37: "in dem Kampf der streitenden Elemente das Ordnungsmäßige…;" "im friedlichen Wettkampfe…."

[845] Freiberg had also seen the first Newcomen steam engine in German lands, imported by Director of Machines Christoph Friedrich Brendel in 1808. Brendel oversaw the construction of the first steam engine and railway in Germany in 1817 and 1829. On pollution studies there, see Franz-Josef Brüggemeier, "Waldsterben: The Construction and Deconstruction of an Environmental Problem," in *Nature in German History*, ed. Christof Mauch (New York: Berghahn Books, 2004), 119-31, on 123-24.

Humboldt's science of climate in particular, linked to a field known as *climatologie* since the 1830s, developed in this precise moment not of a concern for humankind as a destructive planetary force, but of a commitment to the analogy between natural and artificial means of manipulating the earth and its elements—"a deeper commerce" between Man and nature. "Man cannot exert his influence upon nature, nor appropriate any of its forces," Humboldt reasoned, "if he does not know the laws of nature according to their proportions and ratios."[846] Humboldt chronicled "the progress of climatology" accordingly, as keeping pace with the expansion of "European civilization," identifying the close relationship between empire and environmental science.[847] Moreover, Humboldt believed the social value of climatology's thermometric grid—his iconic isothermal lines—could be measured by its influence "on the agriculture, industry, and the relative prosperity or poverty of peoples."[848]

The concept of "climate" was still used in a plural, regional sense; and while nineteenth-century climatographers began to see "across scales," connecting local, regional, and planetary phenomena, the modern idea of one global climate truly developed in the mid-twentieth century with historical models based on ice core samples.[849] What did occur in the nineteenth century

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[846] Humboldt, *Kosmos*, *1*, 36: "Der Mensch kann auf die Natur nicht einwirken, sich keine ihrer Kräfte aneignen, wenn er nicht die Naturgesetze, nach Maaß- und Zahl-Verhältnissen, kennt." Cf. Frank Holl, "Alexander von Humboldt und der Klimawandel: Mythen und Fakten," *HiN* 19, no. 37 (2018): 37-56.
[847] See Richard Grove, *Green Imperialism: Colonial Expansion, Tropical Island Edens, and the Origins of Environmentalism* (Cambridge, UK: University of Cambridge Press, 1995); Deborah R. Coen, *Climate in Motion: Science, Empire, and the Problem of Scale* (Chicago: Chicago University Press, 2018).
[848] Humboldt, *Kosmos*, *1*, 341-43: "Die Fortschritte der *Klimatologie* sind auf eine merkwürdige Weise dadurch begünstigt worden, daß die europäische Civilisation sich an zwei einander gegenüberstehenden Küsten verbreitet hat…. […] [O]hne specielle Vergleichung der Winter- und Sommertemperatur an den gegenüberstehenden Küsten kann man sich von den eigentlichen klimatischen Verhältnissen, in so fern sie auf den Ackerbau, auf die Gewerbe und das Gefühl der Behaglichkeit oder Unbehaglichkeit Einfluß haben, keinen deutlichen Begriff machen."
[849] Deborah R. Coen, "Imperial Climatographies from Tyrol to Turkestan," *Osiris* 26, no. 1 (2011): 45-65; Dania Achermann, "Vertical glaciology: The second discovery of the third dimension in climate research," *Centaurus* 62, no. 4 (2020): 720-43. Cf. Sarah Dry, *Waters of the World: The Story of the Scientists Who Unraveled the Mysteries of Our Oceans, Atmosphere, and Ice Sheets and Made the Planet Whole* (London: Scribe Publications, 2019), esp. 58-59, 250-69.

was a historicization of climate, which prefigured the concept's gradual globalization.[850] Humboldt's case shows how mining played a particularly vital role in the making of climate as a subject of geo-historical inquiry. It has been argued that from about 1850 forward climatology "externalized nature" from economic concerns, widening the fissure between the human and natural sciences. In its pursuit of global thermometric patterns, early climate science flattened local topographies that once served as "the basis for reflection on the human making of climate and the climatic making of societies."[851] But the making of climate history was nonetheless steeped in industrial culture. In fact, one of the first uses of the term "climatology" came from Freiberg, in an 1806 study by the chemist and *Bergakademie* professor Lampadius.[852]

In Humboldt's science of climate, labor and industry became a part of his epistemology, instrumentalized as a way of knowing. John Tresch has identified Humboldt within a coterie of Parisian scientists who, amidst industrialization in France in the 1810s and 20s, produced a "labor theory of knowledge." As economists of the period made work the basis of material value, so experimentalists believed scientific knowledge hinged on the capacity of instruments, machines, and observers to modify natural forces, making the invisible visible, the intangible actionable. What was seen and known depended on what was made and done. And so the steam engine (a symbol of combustion and conversion) now replaced the Enlightenment's clocks and scales (icons of balance and equilibrium) as the cosmological model for a new industrial age.[853]

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[850] Theodore S. Feldman, "Climate and History in the Late 18th and Early 19th Centuries," *Eos* 73, no. 1 (7 Jan. 1992): 1-8.
[851] Jean-Baptiste Fressoz and Fabien Locher, "Modernity's Frail Climate: A Climate History of Environmental Reflexivity," *Critical Inquiry* 38 (Spring 2012): 579-98; Christophe Bonneuil and Jean-Baptiste Fressoz, *The Shock of the Anthropocene: The Earth, History and Us*, trans. David Fernbach (London: Verso, 2017), 30, esp. Chapter 9. "Agnotocene: Externalizing Nature, Economizing the World."
[852] Feldman, "Climate and History," 7; Wilhelm August Lampadius, *Systematischer Grundriss der Atmosphärologie* (Freiberg: Craz und Gerlach, 1806), 217, 45.
[853] John Tresch, *The Romantic Machine: Utopian Science and Technology after Napoleon* (Chicago: The University of Chicago Press, 2012), 100-05. See also Norton M. Wise and Crosbie Smith, "Work and

When Humboldt turned to the construction of *Kosmos* after leaving Paris in 1827, he understood climate as his contemporaries understood other physical forces: through, and in terms of, industry.[854] One could even say the abstraction of labor within Humboldt's cosmic epistemology tracked with the separation of workers from means of production under the heavy industrialization that beset Prussia in the 1840s and 50s.[855] As the division and de-skilling of labor intensified in the steel mills and locomotive manufactories that sprang up around Humboldt's home in Berlin (**Figure 1**), so work was increasingly mystified—*verdampft*—in his science of climate. In that science Humboldt dug great earthworks of the imagination, implied analogies between thermodynamic and planetary forces, and instrumentalized the mining industry in a quantitative, historical study of climate that gave primacy to subterranean forces.

Figure 1. August Borsig's Machine Factory, built in 1837, was located at Chausseestraße 1, on the corner of Torstraße, a five- or six-minute walk from Humboldt's home at Oranienburgerstraße 67. Carl Eduard Biermann (1847), oil on canvas, 110,0 x 116,5 cm. Wikimedia Commons.

Waste: Political Economy and Natural Philosophy in Nineteenth Century Britain (II)," *History of Science* 27, no. 4 (December 1989): 391-449, on 392-93, 422.

[854] Berlin's "technical-industrial environment," and especially the concept of "work," profoundly shaped mechanical theory such as Helmholtz's "*Erhaltung der Kraft*" (conservation of force) in 1847. See M. Norton Wise, *Aesthetics, Industry, and Science: Hermann von Helmholtz and the Berlin Physical Society* (Chicago: University of Chicago Press, 2018).

[855] Such parallels between industrial-capitalist society and the social organization of science were not lost on contemporaries. Consider the example noted in Anne Secord, "Science in the Pub: Artisan Botanists in Early Nineteenth-Century Lancashire," *History of Science* 32, no. 3 (1994): 269-315, on 289.

For a glimpse of Humboldt's labor theory of climate, we can return to the letter he penned to Charles Darwin in 1839.[856] Gushing with praise for the young naturalist, Humboldt seized upon Darwin's description of "Pachyderms," an order of extinct mammals that included the giant sloths, armadillos, and monstrous rodents that he found fossilized in South America during the Beagle voyage.[857] To explain their presence alongside tropical vegetation at chilly Patagonian latitudes of 45°-55°, Humboldt drew upon his experience as a miner and his knowledge of the internal heat of the earth. He knew from making "observations in the interior of mines dug at an altitude of more than 2,000 *toises*"—nearly 4,000 meters high in the Andes—that even the most elevated "terrestrial layers are isothermal near the exterior of the crust of the earth." As he would explain in *Kosmos*, seasonal fluctuations in air temperature appeared to have little effect on these terrestrial layers, whose average annual temperature was determined not by the sun but by the "fluid part of the Interior."[858] So strong were the earth's emissions of heat, Humboldt believed, that the "stratum of invariable temperature" lay just 60 feet beneath the surface of the earth in the latitudes discussed with Darwin.[859]

Judging from the regular increment of temperature in mines and wells, as from the action of the thermal vents (*hornitos*, or "little ovens") he observed in the trans-Mexican volcanic belt, Humboldt suggested to Darwin that the earth's climate had long been determined not so much

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[856] Alexander von Humboldt to Charles Darwin, 18 Sept. 1839, Darwin Correspondence Project Letter no. 534, accessed on 16 Oct. 2020, https://www.darwinproject.ac.uk/letter/DCP-LETT-534.xml.
[857] On Darwin's discovery of "pachyderms" in South America, see Peter J. Bowler, *Charles Darwin: The Man and his Influence* (Cambridge: Cambridge University Press, 1990), 56-57 and Chapters 5, 7, and 8 of Charles Darwin, *Journal of Researches into the Geology and Natural History of the Various Countries Visited by H. M. S. Beagle*…. (London: Colburn, 1839).
[858] The differences in external and internal temperatures in the Gualgayoc and Micuipampa mines, cited in the letter to Darwin, is described in Alexander von Humboldt, *Ansichten der Natur mit wissenschaftlichen Erläuterungen*, vol. 1 (Tübingen, 1808), 324. En route to the Micuipampa mines at the base of Hualgayoc, Humboldt met the German mine engineer Fürchtegott Leberecht Freiherr von Nordenflycht, one of many Spanish American ties back to Freiberg.
[859] On "isothermal" strata, see *Kosmos*, *1*, 181-82.

"from its position relative to a central star" but "from within." Citing Joseph Fourier's mathematical theory of thermal flow, for which he gathered massive quantities of data from mines around the world, Humboldt believed the earth's "central heat" was a residual effect of its condensation from "nebular matter."[860] "With time," he explained to Darwin, great "open fissures" in the earth were "filled with mineral matter (veins)." Only then did the "climates at different latitudes" stabilize in relation to the sun.[861]

Underground industry was not only a deep fount of empirical knowledge for Humboldt; the environmental engineering involved in mining—the excavation of adits, pits, and vast hydraulic works—was also a source of imagination. Geologists of the period viewed natural caves as "passage[s] through the epistemic barrier that separated the observable present from the prehuman past."[862] For miners, it followed that one could dig one's way into primordiality. Recall Humboldt's explanation to Darwin of how "an 1800-3000-foot-deep trench dug from Hamburg to the Alps would once again today give most of Germany a climate suitable for olive and pomegranate trees." For the erstwhile mining official, such acts of "imagineering" were

[860] Humboldt argued that "Fourier has proven theoretically and my observations in the interior of mines … confirm" that "this state of affairs would continue as long as the fault and its edges … remained in equilibrium with the superficial neighboring layers…." He kept notes on Fourier's application of the theory of heat conduction to the earth in articles like "SUR *la Température de l'intérieur du globe*" in *Annales de Chimie et de Physique*, Tome 13 (1820): 183-212 (see SBB, Nachl. Alexander von Humboldt, gr. K. 5, Nr. 39). Cf. Alexander von Humboldt, "Von den isothermen Linien und der Verteilung der Wärme auf dem Erdkörper," in *Alexander von Humboldt Werke*, vol. vii, Schriften zur Physikalischen Geographie, ed. Hanno Beck (Darmstadt: Wissenschaftliche Buchgesellschaft, 2008), 94-96.

[861] Humboldt articulated the same theory at the end of a lecture before the Academy of Sciences in Berlin in January of 1823, later printed as "Über den Bau und die Wirkungsart der Vulkane" in *Ansichten der Natur*, ed. Adolf Meyer-Abich (Ditzingen: Reclam, 1969), 110-11, and again in his Cosmos Lectures (1827-28), now available as Alexander von Humboldt and Henriette Kohlrausch, *Die Kosmos-Vorlesung an der Berliner Sing-Akademie*, eds. Christian Kassung and Christian Thomas (Berlin: Insel Verlag, 2019), 91-92.

[862] Martin J. S. Rudwick, "Encounters with Adam, or at least the hyenas: Nineteenth-century visual representations of the deep past," in *History, humanity and evolution*, ed. J. R. Moore (Cambridge: Cambridge University Press, 1989), 244-45. See also Michael Shortland, "Darkness Visible: Underground Culture in the Golden Age of Geology," *History of Science* 32, no. 1 (1994): 1-61.

second nature—indeed they produced a "second nature" in the mind.[863] Decades earlier, Humboldt wrote that the dream of boring a mineshaft to the earth's core "has ever occupied the imagination of humankind."[864] In 1818, he was even invited on a journey to the center of the earth led by U.S. Army officer John Cleves Symmes, who planned to penetrate the supposedly hollow planet at the North Pole. Humboldt blasted Symmes's plan as a "jovial fiction"—mere "entertainment," like the mineshaft he had pupils of the Mining School imagine digging through the diameter of the earth.[865] Yet Humboldt persisted in his own theoretical excavations.

Humboldt's theorizing about nature was inextricably linked to his efforts to manipulate it. His works of imagineering were only imaginative in scale. The world's most profound mine, which Humboldt recorded at just over 2000 feet, made it possible to fathom the climatic effect of the 1800- to 3000-foot trench he described to Darwin. Trained to draft profiles of mines and canals, Humboldt illustrated trenches of enormous scale in his *Atlas géographique* (1811), like the ambitious Huehuetoca Canal, a two-hundred-year project to drain the Valley of Mexico. In fact, Humboldt was widely recognized for popularizing some of the first plans for a Central American canal to unite the Pacific and Atlantic oceans—plans taken up by Captain Fitzroy of H.M.S. Beagle.[866] And in the 1830s, prior to his letter to Darwin, Humboldt consulted Saxon

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[863] Lissa Roberts, "Practicing oeconomy during the second half of the long eighteenth century: an introduction," *History and Technology* 30, no. 3 (2014): 133-48, on 134.
[864] Humboldt, *Kosmos*, *1*, 418; Humboldt, *Ueber die unterirdischen Gasarten*, 59-60: "Sollte daher je das Projekt, welches so lange die Phantasie der Menschen beschäftigt hat, das Projekt, zur Aufklärung der Gebirgskunde einem Schacht von ungeheurer Teufe abzusinken…."
[865] Humboldt and Kohlrausch, *Die Kosmos-Vorlesung*, 109-10; Humboldt, *Kosmos*, *1*, 178.
[866] See Alexander von Humboldt, *Ansichten der Natur, mit wissenschaftlichen Erläuterungen*, vol. 1, 3rd ed. (Stuttgart: Cotta, 1849), 387-92 and 21 Feb. 1827 in Johann Wolfgang von Goethe, *Conversations with Eckermann and Soret*, trans. John Oxenford (London: Smith, 1850), 363-64. The revolutionary leader Simón Bolívar, a close friend of Humboldt, ordered measurements taken after Humboldt's plan to dig a canal not through Panama (a plan he explicitly opposed, having never traveled there) but the northwest of Columbia. Fitzroy endorsed Humboldt's "illustrious" plan in his "Considerations on the great Isthmus of Central America," *Journal of the Royal Geographic Society of London* 20, Pt. 2 (1850): 161 and "Further Considerations of the Great Isthmus of Central America," *Journal of the Royal Geographic Society of London* 23 (1853): 171-90. Humboldt's own contributions to the project were

mining experts on daring new engineering projects like the Meissner Erbstollen, an adit of some 50 kilometers designed to drain groundwater from the Ore Mountains to the River Elbe.

Humboldt's science of climate *did work*, too, establishing the "proportions and ratios" that he viewed as a prerequisite for Man to "exert his influence upon nature." To this end, he collected mean annual temperatures from correspondents around the world. Generally understood as a project of horizontal spatial imagination, spanning continents and oceans, Humboldt's quest to establish isothermal lines was in truth a three-dimensional endeavor that sought regular thermal patterns on the vertical plane—in the earth, ocean, and aerial ocean.

In his letter to Darwin, for instance, Humboldt asked "about the cold-water current that hugs the coast of Peru," referring to what would soon be called the Humboldt Current, "and which has so much occupied me, because I believe it greatly modifies the coastal climate."[867] Darwin responded with temperature readings at depths of 20 to 250 fathoms near the Galapagos, where the cold current appeared to terminate (**Figure 2**).[868] "I was informed by some whalers," he wrote of Humboldt's climate query,

> that the clouds, which hang so low, along the coast of Peru & northern Chile extend during winter many hundreds of miles over the Pacific. (I believe nearly halfway from the coast of S. America towards the Low Archipelago). Is it possible that this region of clouds can mark the breadth of the cold southern ocean-stream?[869]

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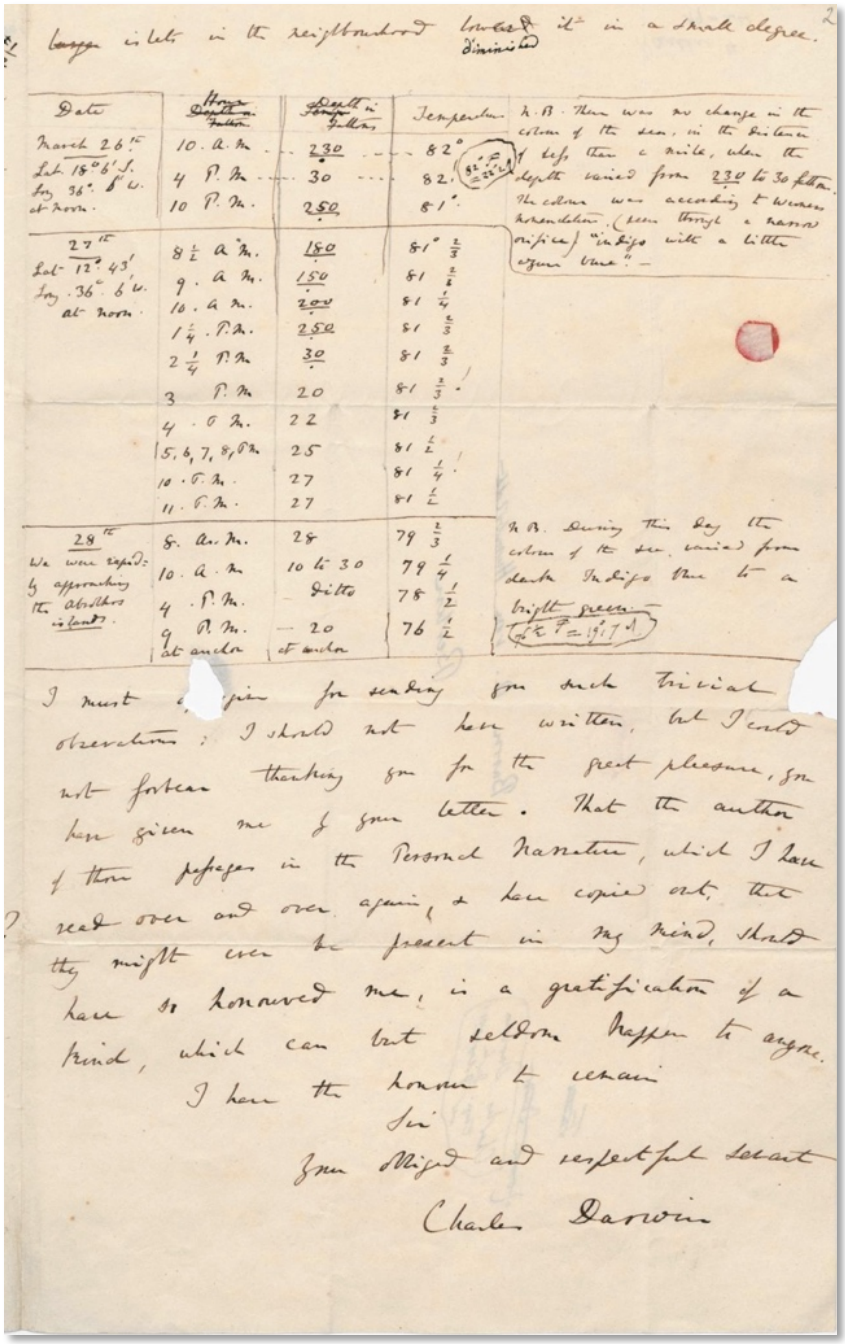
printed by the *Royal Geographic Society* in 1851 and 1856, as in numerous other publications catalogued in Wilhelm Constantin Wittwer, *Alexander von Humboldt: Sein wissenschaftliches Leben und Wirken* (Leipzig: Weigel, 1860), 290.

[867] Alexander von Humboldt, "Der Perustrom," in *Allgemeine Länder- und Völkerkunde*, vol. 1, ed. Heinrich Berghaus (Stuttgart: Berghaus, 1837), 575-83.

[868] Charles Darwin to Alexander von Humboldt, 1 Nov. 1839, in SBB, Nachl. Alexander von Humboldt, gr. K. 4, Nr. 22. He also noted the color of the sea "according to Werners nomenclature," the same Werner who schooled Humboldt in mining at the Saxon *Bergakademie*. Darwin referred to *Werner's nomenclature of colours*… ed. Patrick Syme (Edinburgh: William Blackwood, 1821).

[869] Humboldt similarly credited Amerindians with priority in discovering what he called the Peru Current. He downplayed the honor of its title by saying it "was already well known 300 years before me amongst fishing boys from Chile to Payta [Peru]: I have merely done the service of being the first to measure the current." Humboldt recorded his measurements in Berghaus's *Allgemeine Länder- und Völkerkunde* in 1837. (Gerhard Kortum, "'Die Strömung war schon 300 Jahre vor mir allen Fischerjungen von Chili bis

Such data, whether sourced from whalers or miners, made it possible to construct climate as a three-dimensional field of mean annual temperatures in which local and seasonal variations could be traced in fluid currents coursing through earth, water, and air.



Date	Hours	Depth in Fathoms	Temperature
March 26th Lat. 18°6' S. Long. 36° 8' W. at noon.	10. A. M.	230	82°
	4 P. M.	30	82.
	10 P. M.	250	81°.
27th Lat. 12° 43' Long. 36° 6' W. at noon.	8½ A. M.	180	81° ⅔
	9. A. M.	150	81 ⅔
	10. A. M.	200	81 ¼
	1¼. P. M.	250	81 ⅔
	2¼ P. M.	30	81 ⅔
	3 P. M.	20	81 ⅓.
	4. 0 M.	22	81 ⅓
	5, 6, 7, 8, 9 P. M.	25	81 ½
	10. 0. M.	27	81 ¼.
	11. 0. M.	27	81 ½
28th We were rapidly approaching the Abrolhos islands.	8. A. M.	28	79 ⅓
	10. A. M.	10 h. 30	79 ¼
	4. P. M.	Ditto	78 ½
	9 P. M. at anchor	20 at anchor	76 ½

N.B. There was no change in the colour of the sea, in the distance of less than a mile, when the depth varied from 230 to 30 fathoms. The colour was according to Werner's nomenclature, (seen through a narrow orifice) "indigo with a little azure blue". —

N.B. During this day the colour of the sea varied from dark indigo blue to a bright green —

I must apologize for sending you such trivial observations: I should not have written, but I could not forbear thanking you for the great pleasure, you have given me by your letter. That the author of those passages in the Personal Narrative, which I have read over and over again, & have copied out, that they might ever be present in my mind, should have so honoured me, is a gratification of a kind, which can but seldom happen to anyone. I have the honour to remain Sir Your Most and respectful Servant Charles Darwin

Figure 2. Darwin's temperature readings came from the Galapagos Islands. Scientists now believe the Islands' biodiversity is sustained by the massive upwelling of nutrient rich waters borne by the Humboldt Current, which cycles water up Antarctica along the coast of Chile and Peru. Darwin to Humboldt, 1 Nov. 1839, in Digitalisierte Sammlungen SBB, Nachl. Alexander von Humboldt, gr. K. 4, Nr. 22

Payta bekannt': Der Humboldtstrom," in *Alexander von Humboldt. Netzwerke des Wissens*, ed. Frank Holl (Ostfildern: Hatje-Cantz, 1999), 98-99.)

For Humboldt, knowing climate meant making climate, too. After all, his 3000-foot trench would have made Germany suitable for the cultivation of Mediterranean plants. Like so much of Humboldt's science, this relationship is rooted in popular eighteenth-century views of climate as potentially amenable to human productivity. In the Europe of Humboldt's youth, reports from colonists in North America told of how they had "improved" the climate there by felling forests and cultivating the land, gradually warming the winters thereby. Although modern reconstructions show cooling rather than warming trends in colonial North America, contemporaries boasted of the anthropogenic "Change of Climate in North America and Europe" as a mark of civilizational progress.[870] Humboldt's isothermal climatology, and indeed the first notions of a "climatic system," developed from the same culture of environmental "improvement," which spurred intense interest in meteorology amongst agricultural and economic societies in Germany in the late eighteenth century.[871]

Coupled with natural indicators, like the "line of perpetual snow" in the Andes, Alps, or Himalaya, isothermal lines described a global geography of habitation on Earth, which in turn prescribed the possibilities for human enterprise. "The temperature decreases six times as quick in the sea as in the aerial ocean," Humboldt wrote in *Personal Narrative*.[872] What appeared here as an abstract claim about general laws was re-written as a physiocratic manual in the *Political Essay on the Kingdom of New Spain*. Here the decrement of heat above (and below) the surface

[870] Samuel Williams as quoted in Anya Zilberstein, *A Temperate Empire: Making Climate Change in Early America* (New York: Oxford University Press, 2016), on 2.
[871] Theodore S. Feldman, "Late Enlightenment Meteorology," in *The Quantifying Spirit in the Eighteenth Century*, eds. Tore Frängsmyr, J. L. Heilbron, and Robin E. Rider (Berkeley, CA: University of California Press), 143-79.
[872] Alexander de Humboldt, *Personal Narrative of Travels to the Equinoctial Regions of the New Continent, During the Years 1799-1804…*, trans. Helen Maria Williams (London, 1818), 57. Compare to Alexander von Humboldt, *Versuch über den politischen Zustand des Königreichs Neu-Spanien*, vol. 3 (Tübingen: Cotta, 1812), 2. On superimposed strata, see Chapter Four of this dissertation.

of the sea is understood as demarcating the zones suitable for "the development of organic life." Humboldt then marshalled his thermal formula to promote the cultivation of the Cordilleras and the establishment of vertical colonies pioneered by the Mexican mining administration, as discussed in Chapter 5. By working within that administration to map Mexico's vertical prominence from coast to coast, Humboldt projected this "arrangement of nature" onto New Spain. "In a country as vast and mountainous as Mexico," he concluded, "there is scarcely a plant in the world that could not be cultivated in some part of New Spain."[873]

By the 1830s, Humboldt belonged to a Europe-wide collective who, like Fourier, translated between the science of heat conduction, closely linked to industrial questions about mechanical work, and the science of the earth, which many now viewed as a heat engine in its own right. According to Fourier and those who took up his equations, the earth could be studied as a temporal problem of heat exchange, its thermal gradients beholden to the same physical properties as the heated iron globes he experimented on.[874] "Heat had acquired the cosmic significance possessed previously only by gravity," two historians have written of the application of thermal physics to geo-theory, noting how "heat engines [supplied] a new epitome for scientific explanation in natural philosophy as in political economy."[875] As with an engine, which depends on expendable sources of fuel, the earth's thermal emissions appeared to be

[873] Humboldt, *Neu-Spanien*, *3*, 7-8: "Nach dieser Einrichtung der Natur ist es begreiflich, dass die Manichfaltigkeit der einheimischen Produkte in einem so gebirgigten und ausgedehnten Lande, wie Mexico, ausserordentlich seyn muss, und dass es schwerlich eine Pflanze auf dem übrigen Erdboden gibt, welche nicht in einem Theil von Neu-Spanien gebaut werden könnte."
[874] Mott T. Greene, *Geology in the Nineteenth Century: Changing Views of a Changing World* (Ithaca, NY: Cornell University Press, 1982), esp. 90-91; Bonneuil and Fressoz, *The Shock of the Anthropocene*, 203; Simon Schaffer, "Empire as far as the skies: hydraulics, heat and climate in Restoration France," Forthcoming.
[875] Wise and Smith, "Work and Waste" (II), 428-29. In the early 1840s, William Thomson similarly drew on Fourier's equations of heat conduction to estimate the age of the earth based on the rate at which it was supposed to be cooling. See idem., "Work and Waste: Political Economy and Natural Philosophy in Nineteenth Century Britain (III)," *History of Science* 28, no. 3 (September 1990): 221-261, esp. 240-41.

losing energy over time, a phenomenon later described as "entropy." Humboldt himself had long advocated for Germany's adoption of steam-power, and he had devoted considerable time to improving the efficiency of coal-fired engines at the Prussian porcelain manufactory in the early 1790s.[876] The workings of Fourier's model were therefore familiar to the erstwhile *Techniker*. To the *Theoretiker*, moreover, an entropic earth had enormous explanatory potential for understanding climates past and present.

Since the earliest conception of his geography of plants, around 1790, Humboldt had been skeptical of those who said catastrophic floods or changes to the tilt of the earth's axis could account for the tropical flora and fauna found fossilized in temperate and frigid climes. Now, around 1840, Humboldt could conceive of climate as a product of the earth's own industriousness, and reverse engineer its original, nebular state. As he wrote to Darwin, the nebular hypothesis accounted for the apparent volatility of the "primitive world," where "tropical climate could exist for some time in every zone." At the same time, the earth's gradually dissipating emissions of heat explained how volcanicity continued to shape the earth's crust, albeit with less violence than in the primitive world.[877] Many now believed, like Humboldt, that the dwindling "igneous powers" of the earth continued to affect climate in this way, by inflecting isothermal lines according to the elevation of islands and mountain chains and the shifting shape of continents.[878] Indeed, Humboldt defined "comparative climatology" as the study of these

[876] For Humboldt's engagement with steam-power, see Ursula Klein, *Humboldts Preußen: Wissenschaft und Technik im Aufbruch* (Darmstadt: Wissenschaftliche Buchgesellschaft, 2015), 23, 247-49; Ursula Klein, "Alexander von Humboldt – Vater der Umweltbewegung?" in *Achtsamer Umgang mit Ressourcen und miteinander – gestern und heute. Abhandlungen der Humboldt-Gesellschaft für Wissenschaft, Kunst und Bildung e. V.,* vol. 37, Manuskript des Vortrags, gehalten am 6. Mai 2016 anlässlich der 103. Tagung der Humboldt-Gesellschaft in Freiberg/Sachsen (September 2016): 115–27.
[877] Humboldt to Darwin, 18 Sept. 1839, DCP, "Letter No. 534."
[878] William Whewell as quoted in Wise and Smith, "Work and Waste" (II), 430. Yet Humboldt's climatology was also taken up by those who argued for a steady-state theory of the earth, as opposed to the directionalist, entropic account to which he ascribed. Charles Lyell read Humboldt's climatological

inflections as they vary from the hypothetically parallel isothermal lines of an Earth perfectly spherical in shape and uniform in composition.[879]

The primacy Humboldt accorded to subterranean forces also bespeaks the centrality of mining to his climate science.[880] When, in 1803, Humboldt described the "*construction* of the globe" as the "noblest end of science," he spoke of the earth's own industry.[881] That he said this before a corps of mining students in Mexico City, moreover, prompts an epistemological reading. Humboldt's geophysical science of climate relied upon precise ratios of temperature gradients in the earth, making mines the primary site of its "thermal fieldwork."[882] Today, in Freiberg, a granite monument bearing Humboldt's name marks the old Kuhschacht where he took the temperature of the rock at various depths during his time at the Saxon *Bergakademie*. In its earliest iterations, this aspect of Humboldt's climate science developed out of a cameralist's regulatory concerns for miners' health and productivity, which he brought first to Prussian

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data not as evidence of the dissipating interior heat of the earth, but rather that physical geography alone explained climatic variation. See Rachel Laudan, *From Mineralogy to Geology: The Foundations of a Science, 1650-1830* (Chicago: University of Chicago Press, 1987), 210-12. It was also widely assumed that volcanic activity has a more direct influence on climate through its gaseous emissions. See Humboldt and Kohlrausch, *Die Kosmos-Vorlesung*, 109.

[879] Humboldt, *Kosmos*, *1*, 340-41: "Wenn die Oberfläche der Erde au seiner derselben homogenen flüssige Masse oder aus Gesteinschichten zusammengesetzt wäre, welche gleiche Farbe, gleiche Dichtigkeit, gleiche Glätte, gleiches Absoptionsvermögen für die Sonnenstrahlen besäßen und auf gleiche Weise durch die Atmosphäre gegen den Weltraum ausstrahlten, so würden Isothermen, Isotheren und Isochimenen sämmtlich dem Aequator parallel laufen. […] Von diesem mittleren, gleichsam primitive Zustande, welcher weder Strömungen der Wärme im Inneren und in der Hülle des Erdsphäroids, noch die Fortpflanzung der Wärme durch Luftströmungen ausschließt, geht die mathematische Betrachtung der Klimate aus. Alles, was das Absorbtions- und Ausstrahlungsvermögen an einzelnen Theilen der Oberfläche, die auf Gleichen Parallelkreisen liegen, verändert, bringt Inflexionen, in den Isothermen hervor." Compare to "Recherches sur les causes des Inflexions des Lignes Isothermes," in Alexandre de Humboldt, *Asie centrale*, vol. 3 (Paris: Gide, 1843), esp. 103-20.

[880] Consider the case of John Tyndall, who around the time of Humboldt's death theorized that the earth's thermal emissions were just one factor in producing the slight changes in atmospheric composition that could explain both warming and cooling in the earth's history. See Dry, *Waters of the World*, 51-52.

[881] As quoted in Amrei Buchholz, *Zwischen Karten: Alexander von Humboldts Atlas géographique et physique des régions équinoxiales du Nouveau Continent* (Berlin: De Gruyter, 2020), 141. My emphasis.

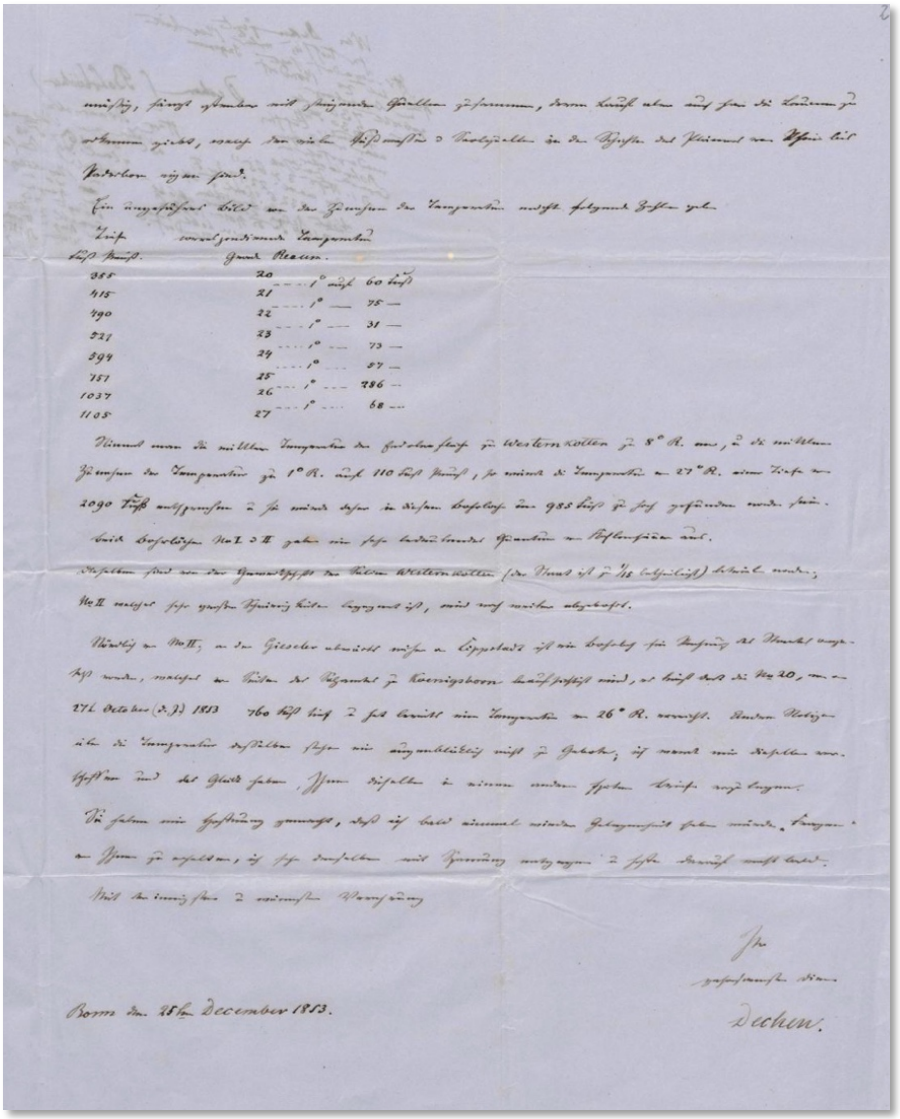
[882] Simon Schaffer, "Empire as far as the skies: hydraulics, heat and climate in Restoration France," Forthcoming.

Franconia and then to New Spain. Having recorded a temperature of 34 degrees centigrade at a depth of 513 meters in the great silver mine of Valenciana, he concluded that the "Mexican miner is, consequently, exposed to a change of temperature of more than 30 degrees," as compared to the 15.6-degree change experienced in Freiberg's deepest pits.[883]

Now in Berlin around mid-century, at the head of a scientific administration, Humboldt solicited reports from old friends in Freiberg as well as new contacts in the deep copper and tin mines of Cornwall and the coal fields of France and Belgium. Their thermometric charts of "new boring experiments" at various depths resembled Darwin's account of ocean temperatures (**Figure 3**).[884] In his notes and marginalia, Humboldt condensed this data into one-degree ratios, his hand busily converting between Celsius, Réaumur, and Fahrenheit, as between meters and feet (Prussian and English). In one mine he noted an increment of 1° centigrade for every 32 meters; in another, 1° for every 29.6 meters (**Figure 4**), both consistent with Fourier's calculations. An English geologist recorded "a rate of increase equal to 1° F[arenhei]t in 51 ½ feet" in the tin mines outside Falmouth, describing the manner in which he had lodged a thermometer into granite bore holes.[885] From the United States, another correspondent employed at the copper and silver mines near Lake Superior reported an increment of "1° F in 29-60 feet," locating "the plane of invariable temperature 30 feet from the surface."[886] Humboldt added these

[883] Alexander von Humboldt, *Versuch über den politischen Zustand des Königreichs Neu-Spanien*, vol. 1 (Tübingen: Cotta, 1809), 102-03.
[884] In the SBB Nachl. Alexander von Humboldt, which houses the notes Humboldt compiled for the Cosmos lectures and subsequent books, consider thermometric data in letters from Carl Freiesleben, 1844, gr. K. 11, Nr. 58; Adolphe Quételet, 1845, gr. K. 12, Nr. 61; and Ernst Heinrich von Dechen and Carl von Oeynhausen, 1844, gr. K. 11, Nr. 60; and Oeynhausen, 1854, kl. K. 14, Nr. 10.
[885] Robert Were Fox to Humboldt, 1853, ibid., gr. K. 11, Nr. 118, Bl. 1-2. Fox published numerous studies on the thermal increase in mines between 1820 and 1860, for instance Robert W. Fox, "On the Temperature of Mines," *Transactions of the Royal Geological Society of Cornwall* 2 (1822): 14-29 and Robert Were Fox, "Some Remarks on the High Temperatures in the United Mines," *The Edinburgh New Philosophical Journal* XLIII (1847): 99-106.
[886] Charles Thomas Jackson to Humboldt, SBB, Nachl. Humboldt, gr. K. 11, Nr. 8-10, Bl. 34.

ratios to his stockpile—a great thermal geography of the underground—alongside similar figures drawn from mines and wells from Peru and Columbia to Switzerland and Russia.[887]



Born den 25ten December 1853.

Dechen.

Figure 3. "An approximate image of the increase of temperature" from Heinrich von Dechen, based on coal mines in the Rhineland. The chart lists temperatures in Réaumur at depths ranging from 355 to 1105 Prussian feet, alongside one-degree increments per foot. Dechen to Humboldt, 25 Dec. 1853, Digitalisierte Sammlungen SBB, Nachl. Alexander von Humboldt, gr. K. 11, Nr. 116, Bl. 2.

[887] Humboldt, *Kosmos*, *1*, 179-81, 425-27. Cf. "The Existence and Distribution of Heat in the Interior of our Globe," in Alexander von Humboldt, *Cosmos: A Sketch of a Physical Description of the Universe*, vol. 5, trans. E. C. Otté (New York: Harper & Brothers, 1890), 37-50. Humboldt's footnotes reveal a large literature on this topic that emerged in the 1830s, as in Jean-Baptiste Boussingault, "Sur la Profondeur à laquellese trouve la Couche de Température invariable entre les Tropiques," *Annales de Chimie et de Physique* LIII (1833): 225-47 and Ferdinand Reich, *Beobachtungen über die Temperatur des Gesteins in verschiedenen Tiefen in den Gruben des Sächsischen Erzgebirges* (Freyberg, 1834).

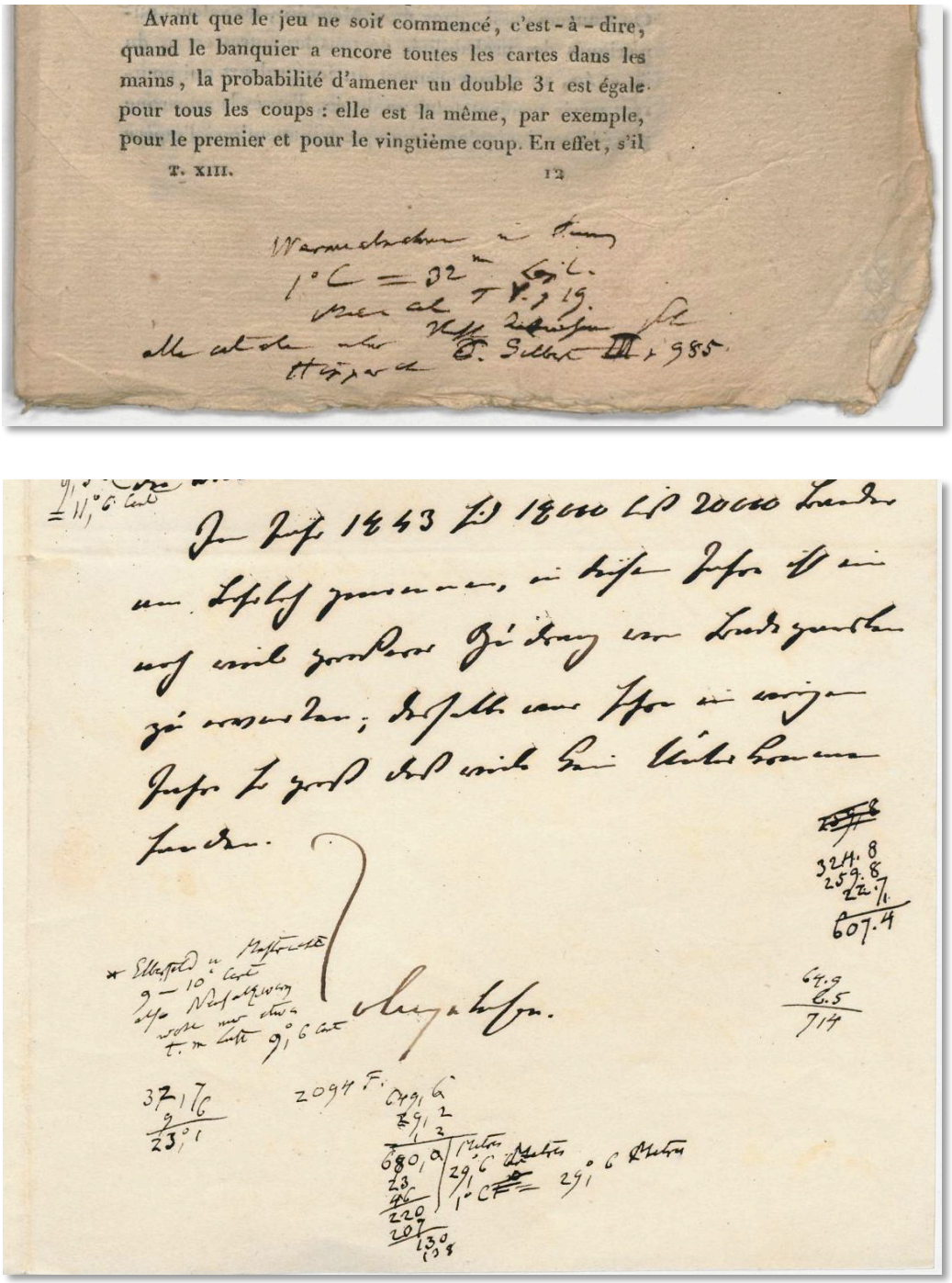


Figure 4. Notes on thermometric data from d'Aubuisson de Voisins and Oeynhausen, both of whom trained as mine engineers in Germany. D'Aubuisson's publication (above) details mines in Freiberg while Oeynhausen's letter (below) describes a "new boring experiment" in Saxony-Anhalt. Humboldt's conversion of one-degree increments follows ("1° = 32 M" in the first, "1° C = 29,6 Meter" in the second), along with a reference to passages of Fourier's work alongside D'Aubuisson's article. See "Observations faites par M. Daubuisson dans les mines de Freyberg," *Annales de Chimie et Physique*, Tome 13, SBB Digitalisierte Sammlungen SBB, Nachl. Alexander von Humboldt, gr. K. 5 Nr. 39 and Oeynhausen to Humboldt, 1844, ibid., gr. K. 11, Nr. 60a, Bl. 2.

Humboldt applied Fourier's equations, concerning "the movement of heat through homogenous metallic spheres," with some caution. Much remained unknown about the earth's interior composition, particularly "the variation in the capacity of different superimposed masses to conduct and radiate heat." But where the most profound reaches of human toil terminated, in the 2000-foot shafts of Joachimsthal in the Ore Mountains, Fourier's "ingenious analytic calculation" allowed Humboldt to plunge deeper still, well beyond the trans-German trench of 1800 to 3000 feet. Judging from thermometric data he had amassed, Humboldt reckoned "that a stratum of granite would be in a liquid state at a depth of nearly [twenty-one] geographical miles." As such depths had no equal in artifice, he employed his favorite measuring rod of all, locating the liquid interior of the earth at a depth some "four or five times the height of the highest summit of the Himalaya."[888]

To his mid-century readers, many of whom lived, like Humboldt, in an industrializing Prussia, even the cautious application of thermal physics prompted analogies between earth and engine. Summarizing Humboldt's geology in *Kosmos*, his publisher, Bernhard Cotta, drew upon technologies he knew from his own study of mining at the Saxon *Bergakademie* in the late 1820s, by which time Freiberg had become a pioneer in the adoption of coal-fired steam-power in Germany.[889] Cotta declared that geysers in particular have no equal in the natural world,

[888] Humboldt, *Kosmos*, *1*, 179-80: "Was ein kunstreicher, für diese Classe von Untersuchungen eigens vervollkommneter analytischer Calcül über die Bewegung der Wärme in homogenen metallischen Sphäroiden gelehrt hat, ist bei unserer Unkenntniß der Stoffe, aus denen die Erde zusammengesetzt sein kann, bei der Verschiedenheit der Wärme-Capacität und Leitungsfähigkeit auf einander geschichteter Massen…." "Befolgte diese Zunahme ein arithmetisches Verhältniß, so würde demnach … eine Granitschicht in der Tiefe von 5 $^{2/10}$ geographischen Meilen (vier- bis fünfmal gleich dem höchsten Gipfel des Himalaya-Gebirges) geschmolzen sein." Cf. ibid., 27.

[889] By 1824, the mining industry in Cotta and Humboldt's native Prussia had installed some 79 steam engines, 56 of them in coal mines in Westfalia, the Rhineland, Silesia, and Lower Saxony. See Wolfhard Weber, "Erschließen, Gewinnen, Fördern: Bergbautechnik und Montanwissenschaften von den Anfängen bis zur Gründung Technischer Universitäten in Deutschland," in *Geschichte des deutschen Bergbaus:*

comparing only to works of human artifice. Humboldt himself had explained how geysers were animated by "volcanic ovens," which steamed the water that percolated through the earth.[890] Cotta re-worked the passage into a scene of technological sublimity, comparing the "violent force" of these ovens "more correctly to the emissions of a steam engine's boiler" from which "an eight-foot-thick column of water bursts into the purest foam of the most splendid colors."[891]

Humboldt espied similar analogies between nature and artifice, echoing generations of writers who had likened the earth to the technologies of their time. Recall, too, that the *hornitos* which encircled Mexico's Jorullo Volcano (**Figure 5**) had performed significant theoretical work in the imagineering of Humboldt's great trench. In the journal he kept during his trek to Jorullo, Humboldt described how the fear he felt venturing into this otherworldly landscape, with its gaseous emissions and sulfuric stench, vanished at the "majestic" site of the *hornitos* and "the satisfying idea of finding one's self at the center of the great forge-fire of the Cyclopes."[892]

Salze, Erze und Kohlen, vol. 2, eds. Klaus Tenfelde, Stefan Berger, and Hans-Christoph Seidel (Münster: Aschendorff Verlag, 2012), 275-76.

[890] Humboldt, *Kosmos*, *1*, 230: "…Entstehung heißer Quellen durch das herabsinken kalter Meteorwasser in das Innere der Erde und durch Berührung mit einem vulkanischen Heerde…."

[891] "20. Brief. Geyser," in Bernhard Cotta, ed., *Briefe über Alexander von Humboldt's Kosmos: Ein Commentar zu diesem Werke für gebildete Laien* (Leipzig: Weigel, 1848), 87: "Nirgends bietet die Natur Etwas, das jenen Erscheinungen gleichkäme, und noch weniger gelang es der Kunst, Anlagen zu schaffen, welches ich damit messen könnten; denn was auf der Wilhelmshöhe bei Kassel zu sehen und in den gepriesenen Gärten von Versailles, steht dem Geyser sehr nach. Mit gewaltiger Kraft, von unterirdischem Getöse, dumpfem Brüllen oder Donnern, richtiger den Ausströmungen aus dem Kessel einer Dampfmaschine vergleichbar, begleitet, und indem der Boden erzittert, so daß der Beckenrand zu bersten droht, bricht die volle, acht Fuß starke Wassersäule mit den glänzendsten Farben, mit dem reinsten Schaume hervor."

[892] Alexander von Humboldt, *Reise auf dem Río Magdalena, durch die Anden und Mexico*, 2 Ed., Pt. 2, ed. and trans. Margot Faak (Berlin: Beiträge zur Alexander-von-Humboldt-Forschung, 2003), 284: "Aber die majestätische Größe der Gegenstände, die uns umgaben, die befriedigende Idee, sich im Zentrum eines Schmiedefeuers der Zyklopen zu befinden, ließ uns jeden Gedanken an Gefahr vergessen. [...] Wir fingen Luft auf, und das war das interessanteste Experiment; weshalb ich vor allem in den Krater hinabsteigen wollte. Mangel an Sauerstoff, ein Übermaß an Kohlensäure. Wir kehrten auf unseren Spuren zurück und stiegen am Krater [außen] hinab, wobei wir auf dem Hinterteil hinabrutschten und uns die Hosen zerrissen. [...] Auf dem Lavatrümmerfeld am Fuß des Vulkans frühstückten wir im Schatten einer Mimose, sehr froh, dass die Expedition so glücklich verlaufen war." See also Ulrike Leitner, "Über die

Figure 5. Jorullo Volcano and its "*hornitos*," as depicted in Humboldt's *Vues des Cordillères* (1810). The emphasis on running water in the foreground, resembling a cross-sectional profile through the earth, is consistent with Humboldt's description of geysers as "ovens" that steam the groundwater, as seen in the vapors that rise near the *hornitos*. Science History Images / Alamy Stock Photo.

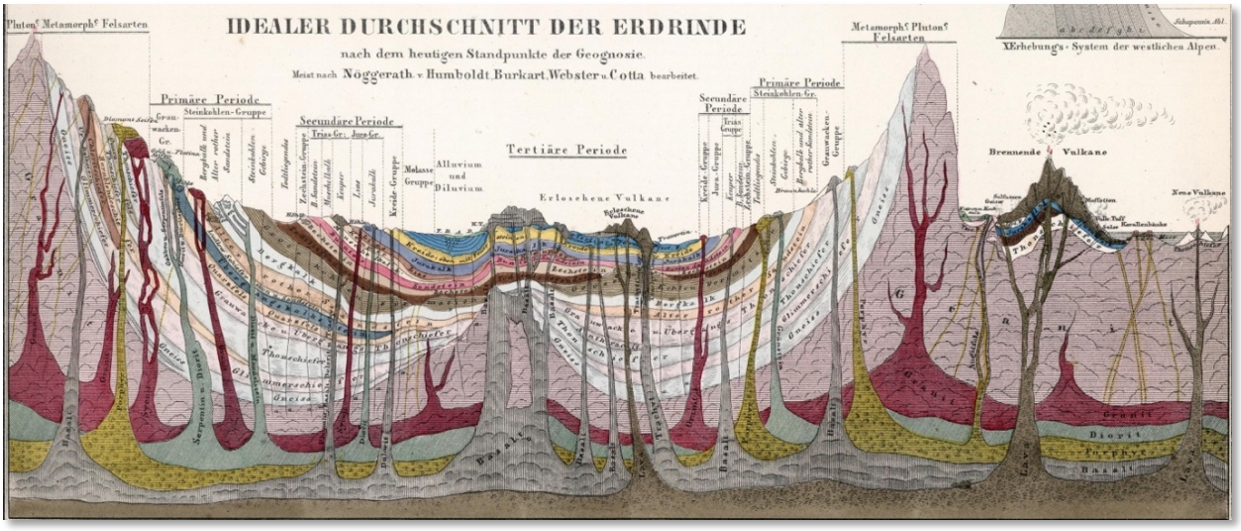


Figure 6. Detail from "Idealer Durchschnitt der Erdrinde" by Humboldt, Cotta, and others, 29 cm x 35 cm (Stuttgart, 1851). This plate was bound in a leather atlas titled "Atlas zu Alex. v. Humboldt's Kosmos." David Rumsey Historical Map Collection, Image No. 1615013.

Quellen der mexikanischen Tafeln der 'Ansichten der Kordilleren' im Nachlass Alexander von Humboldts," *HiN* 11, no. 20 (2010).

Educated European readers familiar with Hesiod and Ovid would have known that monstrous smithies of Classical mythology were said to have labored in subterranean workshops, and that Pliny even credited them as the first to forge iron and bronze. So Humboldt mythologized the great "oven" that boiled beneath the "entire chain of volcanos" to which Jorullo belonged.[893]

To Humboldt, Earth appeared in a perpetual state of construction, an "uninterrupted reaction of the interior and exterior."[894] Volcanicity was the product of this "reaction," a process of ignition by which "the combustible, unoxidized materials of the interior of our planet" expand upon contact with the oxygen-rich atmosphere. Pressurized within a volcano's *Kesselthal*—the German for caldera, literally meaning "boiler-basin," added to geological lexica around mid-century—"elastic vapors push the molten, oxidizing materials upward through deep fissures," as a working fluid fires a piston.[895] Humboldt and Cotta illustrated the earth's diminishing igneous powers in a cross-section (**Figure 6**). It emphasizes the cylinder-like channels through which molten fluids wrought mountains and volcanos as the planet cooled and contracted.[896]

Viewing the earth as a forge, oven, or an engine, with thermal flows powered by an expendable source of nebular energy, meant considering climate in a historical, directionalist manner. This ran counter to Humboldt's commitment to cosmic equilibrium, a legacy of

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[893] Humboldt, *Kosmos*, *1*, 250.
[894] Ibid., *1*, 218-19: "Wenn man Nachricht von dem täglichen Zustande der gesammten Erdoberfläche haben könnte, so würde man sich sehr wahrscheinlich davon überzeugen, daß fast immerdar an irgend einem Punkte, diese Oberfläche erhebt, daß sie ununterbrochen der Reaction des Inneren gegen das Äußere unterworfen ist."
[895] Alexander von Humboldt, "Concerning the Structure and Action of Volcanoes in Various Regions of the Earth," in *Views of Nature*, eds. Stephen T. Jackson and Laura Dassow Walls, trans. Mark W. Person (Chicago: University of Chicago Press, 2014), 254-56; Humboldt, *Kosmos*, *1*, 240-41.
[896] On Humboldt's theory of orogenesis (mountain formation), which is based on the nebular theory of the earth's gradually cooling and contraction, see Greene, *Geology in the Nineteenth Century*, 80-90; See Bernard Debarbieux, "The Various Figures of Mountains in Humboldt's Science and Rhetoric," *Cybergeo: European Journal of Geography* (2012), https://journals.openedition.org/cybergeo/25488, esp. "Traces: Mountains and the internal forces of the globe."

Enlightenment cosmology. In the age of combustion engines, the stability of present-day climates began to seem uncertain. "Whether the mean temperature has experienced any considerable differences in the course of centuries, whether the climate of a country had deteriorated, and whether the winters have not become milder and the summers cooler, can only be answered by means of the thermometer," Humboldt wrote, lamenting the fact that the instrument had only been applied as such for some "120 years."[897]

On several occasions Humboldt even speculated that the clearing of forests and the proliferation of heat engines might have altered local climates.[898] In Philadelphia, for instance, he suggested that an apparent increase in mean annual temperature of 2.7° Fahrenheit over the course of a half-century "may fairly be ascribed to the extension of the town, its greater population, and to the numerous steam-engines."[899] But evidence of the general stability of North American climates was far more plentiful, and Humboldt gave little further thought to the thermal effects of human industry. By contrast, he devoted considerable space to the residual effects of the earth's thermal emissions, to which he attributed significant variation in the permafrost, mean annual temperatures, and the distribution of plants under different meridians.[900]

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[897] Humboldt, *Kosmos*, *1*, 182-83: "…ob das Klima eines Landes sich verschlechtert hat, ob nicht etwa gleichzeitig die Winter milder und die Sommer kälter geworden sind, kann nur durch das Thermometer entschieden werden; und die Erfindung Instruments ist kaum drittehalbhundert Jahre, seine verständige Anwendung kaum 120 Jahre alt." On estimates about the relative stability of the earth's climates, consider how Humboldt cites Fourier's calculation that the planet's internal temperature "can only decrease by 1 degree in 30,000 years," in Humboldt and Kohlrausch, *Die Kosmos-Vorlesung*, 92.

[898] See Humboldt's account of "Dampf- und Gasmassen an den Mittelpunkten der Industrie" in Alexander von Humboldt, *Central-Asien: Untersuchungen über die Gebirgsketten und die vergleichende Klimatologie* (Berlin: Kleeman, 1844), 214.

[899] Alexander von Humboldt, *Views of Nature*, trans. E. C. Otté (London, 1850), 102-03. See also Gloria Meynen, "Schwarze Paradiese: Eine Reise zu den Enden der Welt," in *Mensch macht Natur: Landschaft im Anthropozän*, eds. Gabriele Mackert and Paul Petritsch (Berlin: De Gruyter, 2016), 66-77, on 72-73.

[900] See Humboldt, Cosmos *5*, 50.

The combustive processes that generated steam-power formed a mode of inquiry for Humboldt and his contemporaries—a condition of possibility for theorizing about the earth as a climate-engine—not the subject of investigation. It is in the implicit analogy between natural and social worlds, which first found expression in his efforts to govern resources and labor in Prussian mines, that Humboldt's global science of climate coheres. "As in the life of nations so in nature," Humboldt wrote in *Kosmos*, quoting the poet and sometime mining official Goethe, who described nature as a realm of "ceaseless action and becoming, which curses all that stands still."[901] Understanding the industry of the earth was the precondition for advancing that of humankind. This was precisely the point of Humboldt's comparative climatology—as of his subterranean meteorology a half-century beforehand. Humboldt's was truly a working world.

* * *

"Science begins with the mind's appropriation of matter," Humboldt wrote in 1845, "*Wissenschaft fängt erst an, wo der Geist sich des Stoffes bemächtigt*." As Anglophone readers encountered the phrase: "Science is the labor of the mind applied to nature." Drawing as much from working worlds of industry and extraction as from Kantian metaphysics, Humboldt argued that nature, as perceived by human minds, and artifice, as crafted by human hands, are commonly wrought through a process of "intellectual production power."[902] Here he used the

[901] Humboldt, *Kosmos*, *1*, 35-36: "…denn in dem Lebensgeschick der Staaten ist es, wie in der Natur, für die, nach dem sinnvollen Ausspruche Göthe's 'es im Bewegen und Werden kein Bleiben giebt und die ihren Fluch gehängt hat an das Stillestehen." Goethe's original poem is somewhat different, reflecting an organic sense of natural development that Humboldt re-works into a claim for the industrious parallel between modern nations and the natural world: "Es ist ein ewiges Lebens, Werden und Bewegen in ihr, und doch rückt sie nicht weiter. Sie verwandelt sich ewig, und ist kein Moment Stillestehen in ihr. Fürs Bleiben hat sie keinen Begriff, und ihren Fluch hat sie ans Stillestehen gehängt. Sie ist fest. Ihr Tritt ist gemessen, ihre Ausnahmen selten, ihre Gesetze unwandelbar." (Heinrich Schmidt, ed., *Goethe-Lexicon* (Paderborn: Salzwasser Verlag, 2015), 161.)

[902] Humboldt, *Kosmos*, *1*, 69: "Man mag nun die *Natur* dem Bereich des *Geistigen* entgegensetzen, als wäre das Geistige nicht auch in dem Naturganzen enthalten, oder man mag die *Natur* der *Kunst* entgegenstellen, letztere in einem höheren Sinne als den Inbegriff aller geistigen Productionskraft der

term *Productionskraft*, which had earlier implied natural powers of organic growth but increasingly represented the industrial output of machines, manufactories, and laboring bodies.

"Nature's Working Worlds" is a history of epistemic labor. In the period known as the *Sattelzeit*, working worlds of textile production, mineral extraction, and mountain surveying were sites of political, environmental, and scientific imagination. The first part of this dissertation has shown how, in the decades around 1800, some reformers understood spinning collectives, smelting operations, and other sites of making as generative of their own political ideologies. Many viewed industry itself as an agent of *Bildung* in civil society. A similar relationship between material practice and social imagination is found in both the administrative and vernacular cultures of hard rock mining. There, actors of learned and laboring classes commonly invested resource management with moral and political attitudes.

The second part of this dissertation traced the "intellectual labor power" involved in Humboldt's science over the long arc of his life, giving the relationship between working and knowing a history that bridges the eighteenth and nineteenth centuries. The place of work and workers in the history of science is contingent. One's proximity to working worlds could be an asset in one time and place and a liability in another, depending on the social value accorded to labor in different cultures and economies. As Lissa Roberts and Simon Schaffer wrote:

> If ambitious savants often took the high ground of intellectual sanctity, it was just as common for them to announce their indispensability to the state and church, to the market and the navigator. Their knowledge and skills were hence powerful because secluded, yet powerful also because networked and productively effective.[903]

Menschheit betrachtet; so müssen diese Gegensätze doch nicht auf eine solche Trennung des Physischen vom Intellectuellen führen, daß die *Physik der Welt* zu einer bloßen Anhäufung empirisch gesammelter Einzelheiten herabsinke. Wissenschaft fängt erst an, wo der Geist sich des Stoffs bemächtigt, wo versucht wird, die Masse der Erfahrungen zugewandt zu der Natur." See the English discussed in Tresch, *The Romantic Machine*, 77, where Humboldt's debt to Kantian metaphysics is thoroughly explored. On "productive power," compare to Arnim, *Werke und Briefe*, *4*, 579, on pp. 96-97 of this dissertation.

[903] Lissa Roberts and Simon Schaffer, "Preface," in *The mindful hand: Inquiry and invention from*

The latter chapters of this dissertation have shown how Humboldt himself oscillated between the power of his seclusion and that of his networks. Moreover, by viewing his engagement with various industries over the course of some seventy years, I have also suggested that this dynamic generally had a temporal character, as complex and protracted as industrialization itself.

Working within cultures of "useful knowledge" that spanned the Atlantic around 1800, Humboldt often emphasized his proximity to, not distance from, men of practical experience. In his years of service, as a cameralist official and a de facto colonial surveyor, Humboldt understood plant geography as political economy and wrote multi-volume works in the name of economic enlightenment. This was an age in which territorial administration and resource exploitation were constitutive of natural inquiry and early environmental thought. Even so, he was just as likely to stress his oversight of scientific labor, like the mapmakers in Mexico City who worked "under [his] eyes," as he was to the credit individually differentiated laborers, like the Franconian foreman who participated—and suffocated—in his "subterranean meteorology."

Toward the middle of the nineteenth century working people and practices became increasingly mystified in Humboldt's science—in the instrumentalization of mines and mountains as measuring rods, for instance, or in his tendency to theorize about the natural world through the miner's methods of excavation and drainage. The earth itself appeared as a worksite of sorts, and nature a product of cognitive labor—both legacies of the way in which Humboldt's earlier sciences described a natural world that he was actively engaged in shaping. Humboldt's own celebrity in these years owes a tremendous debt to the labors of his translators and transcriptionists—Helen Maria Williams, Henriette Kohlrausch, Elise Otté, and Thomasina

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the late Renaissance to early industrialization, eds. Lissa Roberts, Simon Schaffer, and Peter Dear (Amsterdam: Royal Netherlands Academy of Arts and Sciences, 2007), xxiii.

Ross—who brought his French- and German-language works to the Anglophone world throughout the nineteenth century.[904]

The popular image of Humboldt in these later years, found in iconic paintings of the lone savant in his worldly library (**Figure 7**), is one of both solitude and omniscience. But Humboldt's science was no less a collective enterprise in the 1850s than it was in the 1790s. It is rather the case that the social organization of that science, which originally mapped onto the division of labor Humboldt managed in the mines, assumed a loftier guise in the global scientific administration he governed from his home in Berlin, even while its delegates remained embedded in worlds of industrial production and colonial expansion.

Figure 7. The solitary savant in his worldly library. After Eduard Hildebrandt's *Humboldt in His Library* 1856, chromolithograph on paper, 18 5/8 x 26 5/8 in. Collection of Mr. and Mrs. Robert F. Norfleet Jr., Photo: Travis Fullerton, Virginia Museum of Fine Arts.

[904] The British novelist Williams translated Humboldt's *Personal Narrative* and *Researches concerning the institutions and monuments of the ancient inhabitants of America* from the French for Longman, Hurst, and Rees in London (1814-1829). Kohlrausch transcribed Humboldt's Cosmos Lectures of 1827-28, which has since been archived in the SBB (Ms. Germ. Qu. 2124) as *Physikalische Geographie. Vorgetragen von Alexander von Humboldt*. Otté translated *Cosmos* and *Views of nature* from the German for the London publisher Bohn (1850-51) in addition to her own works on Scandinavian grammar and history. And Ross, who reported and translated for the *Times* and *Literary Gazette* among other papers in London, translated Humboldt's *Personal Narrative* from the French also for Bohn (1852-53). See Alison E. Martin, *Nature Translated: Alexander von Humboldt's Works in Nineteenth-Century Britain* (Edinburgh: Edinburgh University Press, 2018) and Judith Johnston, *Victorian Women and the Economies of Travel, Translation and Culture, 1830-1870* (Farnham: Ashgate, 2013).

It has been said that Humboldt's ubiquitous influence over generations of scientists gave the impression of his being "nowhere in particular"—a fitting legacy, perhaps, for a man who sought to describe the whole of the cosmos.[905] Yet this dissertation has shown how the science called Humboldtian was made collectively by people living—and working—in particular environments and institutions. Humboldt knew this. That is why he conceived of knowing as working, as "the mind's appropriation of material." Science in *this* Humboldtian sense cannot be confined to the savants and voyagers conventionally associated with him. It must also include the "shared labor" on which he knowingly relied: the technicians and foremen he equipped with the means of inquiry, the men and women of various classes who trod the vertical routes on which he travelled, and the Creole surveyors and draftsmen he toiled alongside.[906] Phrases like "intellectual production power" evidence the mystification of this diverse set of actors—and the enduring influence of the working worlds they populated.

[905] Laura Dassow Walls, "'Hero of knowledge, be our tribute thine': Alexander von Humboldt in Victorian America," *Northeastern Naturalist* (2001): 121-34, on 129.
[906] Tresch, *The Romantic Machine*, 65.

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