Mining as the Working World of Alexander von Humboldt's Plant Geography and Vertical Cartography

Patrick Anthony, *Vanderbilt University*

Abstract: By resituating Alexander von Humboldt in the "working world" of mining, this essay offers a case study of the way in which industry has shaped practice and theory in the history of science. While Humboldt's experience as a miner in Saxony and Prussia provided him a venue in which to study fossilized vegetation, revealing a fundamental link between the migrations of plants and of peoples, industrial concerns about miners' safety inspired a study of the interplay between plants and people that shaped his later articulation of the verticality of plant distribution. Moreover, the cartographic methods Humboldt employed during his American journey depended as much on drawing practices indebted to mining as they did on patterns of vertical mobility above and below the surface of the earth. These arguments ultimately encourage a departure from "Humboldtian Science," a term that has veiled an originally Prusso-Saxon science beneath a set of Anglo-American connotations.

It is nearly impossible to engage the Anglophone literature on Alexander von Humboldt (1769–1859) without confronting "Humboldtian Science," a term Susan Faye Cannon developed in the 1970s to represent a study of nature that combined instrumentation and quantification with a geographical sensibility.[1] Recall, though, that Cannon devised "Humboldtian" to replace "Baconian" as a term to characterize an avant-garde system of inquiry carried out by British and American scientists in the nineteenth century. In doing so, she inaugurated an Anglophone tradition of scholarship that has demonstrated Humboldt's immense importance in the history of

Originally from Maine, Patrick Anthony is a Ph.D. candidate in the Department of History at Vanderbilt University, where he studies the history of science and modern Germany. Department of History, 2301 Vanderbilt Place, PMB 351802, Nashville, Tennessee 37235, USA; patrick.anthony@vanderbilt.edu.

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[1] Susan Faye Cannon, *Science in Culture: The Early Victorian Period* (New York: Dawson/Science History Publications, 1978), pp. 73–110. As Cannon noted, it was William H. Goetzmann who first coined the term "Humboldtean science" (albeit with a different spelling) in his book *Army Exploration in the American West, 1803–1863*, published by Yale University Press in 1959. Where Goetzmann emphasized Humboldt's Romantic spirit, however, Cannon was more interested in the instrumentation and quantification integral to the causal science Humboldt modeled for his Victorian followers. See Cannon, *Science in Culture*, pp. 77–78.

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geographical and scientific thought, complementing a far older and more expansive German-language tradition, to say nothing of French- and Spanish-language scholarship.[2] But Humboldtian Science has also presented an obstacle to scholars interested in the actual scientific activities of its namesake, veiling what began as an eighteenth-century Prusso-Saxon science beneath a set of Victorian connotations—familiar images of admiring individuals like Charles Darwin and global scientific enterprises like the "Magnetic Crusade." Departing from the Cannonian tradition, this essay resituates Humboldt in the working world of mining, showing how industry shaped his plant geography and vertical cartography. Instead of viewing Humboldt through the retrospective lens of the "grand progeny of scientific travellers" that Darwin believed he had fathered, this essay views Humboldt vis-à-vis the imperatives and opportunities he encountered in the mining industries of central Europe and Spanish America.[3] Rather than asking how Humboldt shaped the world, this essay explains how the world shaped him.

Today the growing body of scholarship on Humboldt portrays him as a paragon of scientific cosmopolitanism: a savant of global vision who rediscovered South America and connected disparate natural systems with isothermal lines and *tableaux physiques* (see Figure 1), a Prussian who spent much of his life in Paris and fancied himself "half American," a proto-ecological visionary whose writings animated modern environmentalism.[4] Humboldt may have been all of these things to a greater or lesser degree. But I would also suggest that this scholarship corresponds to an image of Humboldt that he himself promoted *after* his American journey (1799–1804). In Humboldt's writings prior to 1799, by contrast, one finds a young mining official who zealously devoted himself to resource extraction and practiced science in the name of his Prussian "fatherland." Let us think with the historian Denise Phillips, who suggested that "rather than assuming we know what science is, and searching through history to find places where people are practicing it, we will need to pay attention to how people themselves described the cause that captured their allegiance."[5]

The overwhelming emphasis on Humboldt's American journey has marginalized the vital importance of his training at the Mining Academy in Freiberg, Saxony, and led to a general neglect of the fervor for practical knowledge and public utility that captured his allegiance to science in the 1790s. Conventional wisdom holds that Humboldt's decision to join the Prussian

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[2] Nicolaas A. Rupke, *Alexander von Humboldt: A Metabiography* (Chicago: Univ. Chicago Press, 2008). For recent French- and Spanish-language scholarship on Humboldt, consider the work of Bernard Debarbieux and Sandra Rebok: Bernard Debarbieux, "The Various Figures of Mountains in Humboldt's Science and Rhetoric [Figures et Unité de l'idée de montagne chez Alexandre von Humboldt]," *Cybergeo: European Journal of Geography*, 2012, http://cybergeo.revues.org/25488; and Sandra Rebok and Miguel Ángel Puig-Samper, *Alexander von Humboldt: Traducción y edición de sus obras en España* (Madrid: Fundación Ignacio Larramendi, 2013).

[3] Charles Darwin to Joseph Dalton Hooker, 6 Aug. 1881, in *The Life and Letters of Charles Darwin*, ed. Francis Darwin (New York: Appleton, 1905), Vol. 2, pp. 422–424.

[4] Ottmar Ette, "The Scientist as Weltbürger: Alexander von Humboldt and the Beginning of Cosmopolitics," in "Alexander von Humboldt's Natural History Legacy and Its Relevance for Today," special issue, *Northeastern Naturalist*, 2001, 8:157–182; Ette, *Weltbewußtsein: Alexander von Humboldt und das unvollendete Projekt einer anderen Moderne* (Weilerwist: Velbrück, 2002); Aaron Sachs, *The Humboldt Current: Nineteenth-Century Exploration and the Roots of American Environmentalism* (New York: Penguin, 2006); Laura Dassow Walls, *The Passage to Cosmos: Alexander von Humboldt and the Shaping of America* (Chicago: Univ. Chicago Press, 2009); and Gregory T. Cushman, "Humboldtian Science, Creole Meteorology, and the Discovery of Human-Caused Climate Change in South America," *Osiris*, 2011, N.S., 26:16–44.

[5] Denise Phillips, *Acolytes of Nature: Defining Natural Science in Germany, 1770–1850* (Chicago: Univ. Chicago Press, 2012), p. 9. For a few examples of Humboldt professing his *Vaterlandsliebe* see Alexander von Humboldt to Johann Friedrich Pfaff, 11 May 1789, in *Die Jugendbriefe Alexander von Humboldts, 1787–1799*, ed. Ilse Jahn and Fritz G. Lange (Berlin: Akademie, 1973) (hereafter cited as ***Jugendbriefe*, ed. Jahn and Lange**), p. 58; Humboldt to Georg Christoph Lichtenberg, 22 Feb. 1791, *ibid.*, p. 126; and Alexander von Humboldt, *Mineralogische Beobachtungen über einige Basalte am Rhein* (Braunschweig: Schulbuchhandlung, 1790), p. 106.

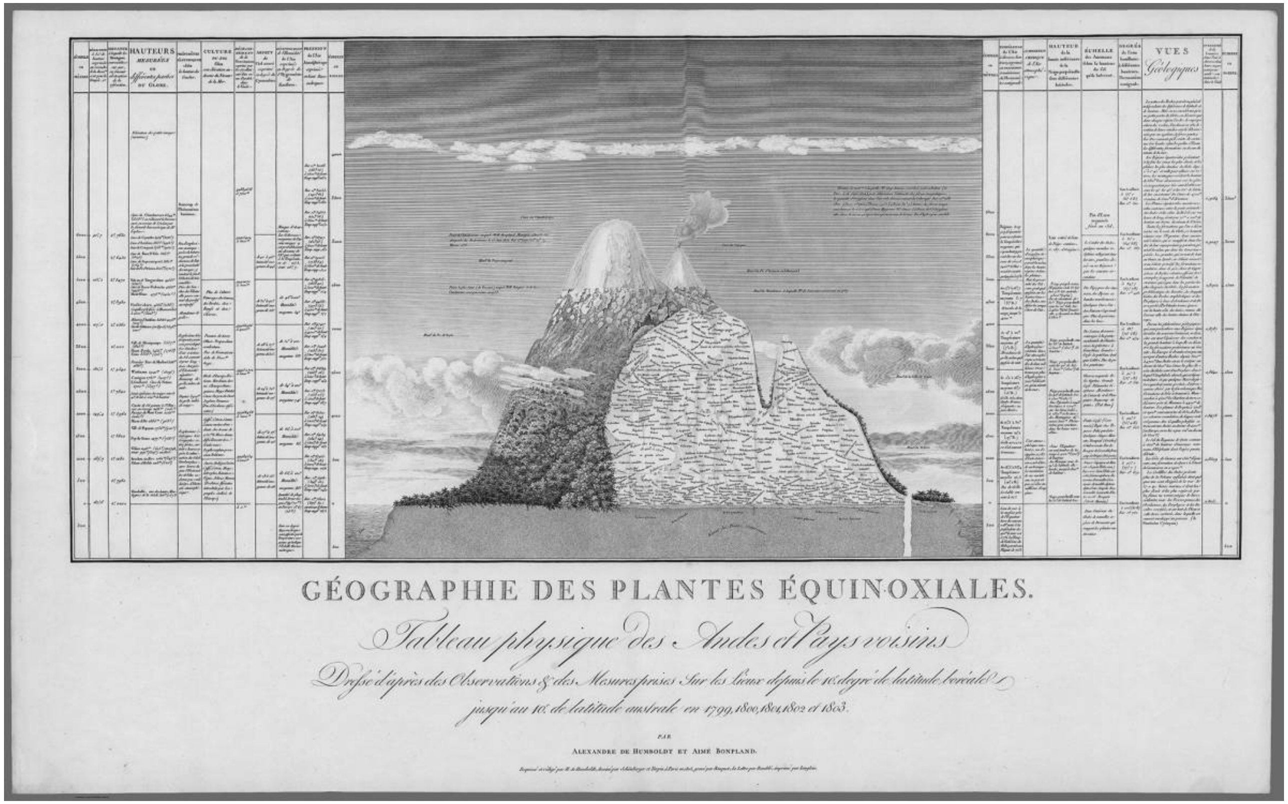

Figure 1. Humboldt's "Tableau physique des Andes et Pays voisins" (called the "Naturgemälde der Anden" in the 1807 German edition), published in Paris in 1805 with the *Essai sur la géographie des plantes*. Courtesy of the David Rumsey Map Collection, www.davidrumsey.com.

Mining Department was essentially a compromise. It would enable him to satisfy the demands of his family and noble birth (by earning an income and serving the state) while continuing to pursue the natural sciences on the side. When his mother died in 1796, the story goes, Humboldt received an inheritance large enough to untether him from Prussia and make possible a freer pursuit of science. But as Ursula Klein's pathbreaking studies of Humboldt's early career have demonstrated, mining was not an obligation for Humboldt; it was an opportunity.[6] To be sure, Humboldt sometimes mystified his own debt to mining, particularly after his American travels. Even before he set out for the Americas, Humboldt asserted that "the glory of the sciences is by no means dependent upon their so-called outer utility."[7] That Humboldt made this assertion in a text dedicated to the improvement of mining should not, however, be seen as a contradiction. Like many before and after him, Humboldt walked a fine line between what he described as the "outer" and "inner aims of the sciences," between his investment in utility and the authority he gained from disinterestedness. But Humboldt also knew that service in the Mining Department, far from inhibiting his science, had actually opened new frontiers for it. As he bragged to one university-based natural philosopher: "perhaps no one before me has had as many opportunities to observe [subterraneous plants] as I, who in ¾ of a year spent 4 to 5 hours of every day in the mines." Or, as his elder brother Wilhelm proudly observed, Alexander's "position as *Oberbergmeister* gave him the opportunity to collect a great quantity of interesting observations, better and more reliably than a mere theorist."[8]

This essay builds on Klein's Prussia-oriented scholarship by ranging outside of Prussia geographically and through the American journey temporally. Humboldt's scientific enterprise may have crystallized in Spanish America, but it took root in a fundamentally different context: the "underground Enlightenment" of central European mining.[9] Mining was, I argue, the original "working world" of Humboldt's science, the arena of economic activity that posed problems to which some of his earliest endeavors provided answers. "The power of science," Jon Agar has written, "lies in its ability to abstract and manipulate representations relevant to working world problems."[10] So it was for Humboldt, whose study of subterranean flora and approach to vertical cartography were encouraged by the practical imperatives he faced as a mining official. Hum-

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[6] Klein provided the first comprehensive study of Humboldt's career as a miner, while at the same time exploring the broader context of technical science that flourished in Prussia at the turn of the nineteenth century. See Ursula Klein, "The Prussian Mining Official Alexander von Humboldt," *Annals of Science*, 2012, 69:27–68; and Klein, *Humboldts Preußen: Wissenschaft und Technik im Aufbruch* (Darmstadt: Wissenschaftliche Buchgesellschaft, 2015).

[7] He continued: "Where this point of view has been adopted, where one determines the value of every scientific investigation by whether it has a greater or lesser influence upon the industry of men, nothing will prosper that is great and important for posterity. So little do I therefore strive to please those who subordinate the inner aims of the sciences to the outer ones." Friedrich Alexander von Humboldt, *Ueber die unterirdischen Gasarten und die Mittel, ihren Nachtheil zu vermindern: Ein Beytrag zur Physik der praktischen Bergbaukunde* (Braunschweig: Friedrich Vieweg, 1799), pp. 24–25 (here and throughout this essay, translations into English are mine unless otherwise indicated).

[8] Humboldt to Lichtenberg, 21 Apr. 1792, in *Jugendbriefe*, ed. Jahn and Lange, p. 184; and Wilhelm von Humboldt, "Vorrede," in F. A. von Humboldt, *Ueber die unterirdischen Gasarten und die Mittel, ihren Nachtheil zu vermindern*, pp. iii–iv. For other examples of men of science walking the fine line between practicality and disinterestedness see Jan Golinski, *Science as Public Culture: Chemistry and Enlightenment in Britain, 1760–1820* (New York: Cambridge Univ. Press, 1992), p. 8; and Jim Endersby, *Imperial Nature: Joseph Hooker and the Practices of Victorian Science* (Chicago: Univ. Chicago Press, 2008), pp. 1–12.

[9] 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*, ed. Hartmut Schleiff and Peter Konečny (Stuttgart: Steiner, 2013), pp. 13–31. For the Latin American context see Heidi V. Scott, "Taking the Enlightenment Underground: Mining Spaces and Cartographic Representation in the Late Colonial Andes," *Journal of Latin American Geography*, 2015, *14*(3):7–34.

[10] Jon Agar, *Science in the Twentieth Century and Beyond* (Cambridge: Polity, 2012), p. 7. On the "working world" concept see pp. 3–6.

boldt's position provided him a venue in which to study fossilized vegetation, revealing of the fundamental link between the migrations of plants and of peoples. Furthermore, I demonstrate how industrial concerns about miners' safety also led Humboldt to a study of the interplay between plants and people from which he drew conclusions about verticality and plant distribution that would leave their stamp on his *Essai sur la géographie des plantes*, published in 1805. In these same years, I argue, Humboldt's exposure to technical methods of locating and extracting mineral ore provided him with a cartographic blueprint to follow in the Americas.

In demonstrating how some of the more conceptual and theoretical aspects of Humboldt's scientific enterprise were shaped by essentially economic concerns about labor and resource extraction, this essay engages three traditions of scholarship: the first concerning Humboldt specifically; the second, the history of science more generally; and the third, the history of mining and cameralism in the German states. For those interested in Humboldt and the development of his science, this study shows the value of what David Livingstone called "spaces of biography." Return Humboldt to the working world of mining and his global scientific enterprise, his "*physique du monde*," appears in a very different and eminently local light. Only in this biographical space is it possible to see how elements of Humboldt's science of plant migration were motivated by the imperatives he faced as *Oberbergmeister* and *Bergrat*, how his pictorial science drew on a visual culture that thrived at the Mining Academy in Freiberg, or how a pattern of vertical mobility begun "under [Abraham Gottlob] Werner's instructions [to] go daily into various mines" found expression in Humboldt's representation of nature's verticality.[11] Today these things are considered "Humboldtian." In the 1790s, they were "*bergmännisch*"—miner-like.

This essay thus returns Humboldt the cosmopolitan man of letters to his original national-industrial context in the cameralist states of central Europe: Saxony, where he was trained as a miner, and Prussian Franconia, where he served as one. It means acknowledging Humboldt as a central figure in what the historian Jakob Vogel has called the *Aufklärung untertage*, the "underground Enlightenment"—a body of knowledge and a set of practices that proliferated through mining academies, societies, and journals. In essence, the underground Enlightenment was a function of central European cameralism, a science aimed at rationally ordering the productive activity of the state. The historian Andre Wakefield has argued that "mining officials were the Ur-cameralists," an administrative elite trained "to dictate every aspect of behavior in and around the mines."[12] Wakefield reminds us that figures like Humboldt were administrators by training and, thus, that Humboldt's science in the mines was a kind of hybrid administrative-natural science in which increasing state revenue and advancing natural knowledge coalesced in a single enterprise. In this way, my study of Humboldt contributes to a more comprehensive understanding of the German "practical imagination."[13] Though scholars have traditionally pointed to terms like "*Geist*" and "*Bildung*" as evidence of the peculiar inwardness of German thought at the turn of the nineteenth century, this period also saw the flowering of eminently practical knowledge,

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[11] David Livingstone, *Putting Science in Its Place: Geographies of Scientific Knowledge* (Chicago: Univ. Chicago Press, 2003), p. 183; Humboldt to Marc-Auguste Pictet, 24 Jan. 1796, in *Jugendbriefe*, ed. Jahn and Lange, p. 487; and Humboldt to Dietrich Ludwig Gustav Karsten, 26 Nov. 1791, *ibid.*, pp. 160–161.

[12] Vogel, "Aufklärung untertage" (cit. n. 9); and Andre Wakefield, *The Disordered Police State: German Cameralism as Science and Practice* (Chicago: Univ. Chicago Press, 2009), p. 27.

[13] David. F. Lindenfeld, *The Practical Imagination: The German Sciences of State in the Nineteenth Century* (Chicago: Univ. Chicago Press, 1997). In this tradition of scholarship consider also Theodore Ziolkowski, *German Romanticism and Its Institutions* (Princeton, N.J.: Princeton Univ. Press, 1990); Frederick C. Beiser, *The Romantic Imperative: The Concept of Early German Romanticism* (Cambridge, Mass.: Harvard Univ. Press, 2003); David Blackbourn, *The Conquest of Nature: Water, Landscape, and the Making of Modern Germany* (New York: Norton, 2007); and Ursula Klein, *Nützliches Wissen: Die Erfindung der Technikwissenschaften* (Göttingen: Wallstein, 2016).

particularly in mining.[14] Humboldt may have lived in the era in which Germaine de Stael famously described Germany as the land of *Dichter und Denker*, poets and thinkers. But, as Humboldt's story reminds us, many of that land's most influential poets and thinkers—from Leibniz to Goethe—were also mining officials. This essay views Humboldt accordingly, as a man of "practical imagination," an *Aufklärer* of the underground.

Verticality is central to this essay's arguments, from Humboldt's insight as a miner that "nature knows no over- and underground" to his practice in the Americas of representing "entire countries as one would a mine."[15] Theorized in recent years by the geographer Bruce Braun and the architect Eyal Weizman, verticality has also become an object of study among historians of science like Gabrielle Hecht and Michael Reidy, who have stressed the link between knowledge-making practices and movement through vertical space.[16] If, as Reidy has argued, Humboldt's way of thinking ultimately became the cornerstone of a "vertical consciousness that engulfed science in the early nineteenth century," this study suggests that Humboldt imbibed a mode of vertical thinking—a style of seeing, conceptualizing, and representing nature's verticality—from his rhythmic practice of ascending mountains and descending into mines, a practice that bridges his European and American endeavors. Verticality is a pervasive theme in the writings of figures who were, like Humboldt, enmeshed in the working world of mining. Consider the following articulation of verticality by the poet Friedrich von Hardenberg (Novalis), who, after studying at the Mining Academy in Freiberg, described miners as "inverted astrologers" in his novel *Heinrich von Ofterdingen*. As astrologers "behold the heavens, and wander through their 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; you investigate the force of rocks and mountains, and the manifold workings of the layers of the earth and its rock bedding." A similar vertical consciousness is found in the journal of Georg Forster, who traveled to Saxony in 1784 to study *Bergbaukunde*, the science of mining. There Forster found in the "practical mining expert" a figure who "sees what the theorist never experiences, nor could ever believe." Indeed, Forster himself imbibed a new view of nature in the mines, which he expressed through cartographic imagery, envisioning "a map, with indications of all *converging* veins, [which] would make a peculiar display, particularly if one were to include a profile that indicated the form and heights of mountains, and *in this way* determine the richer bodies of ore."[17] Even the inscription on the St. Peter's Tower bell in Freiberg, which sounded the daily rhythms of the miners in Humboldt's time, evidences the culture of verticality that mining fostered: "Up, up, to the mines, I call you,

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[14] David Blackbourn, "Germany and the Birth of the Modern World, 1780–1820," *Bulletin of the German Historical Institute*, Fall 2012, no. 51, pp. 9–21.

[15] Humboldt, *Ueber die unterirdischen Gasarten und die Mittel, ihren Nachtheil zu vermindern* (cit. n. 7), p. 201, quoted in Hanno Beck, ed., "Alexander von Humboldt's 'Essay de Pasigraphie' (Mexiko 1803/04)," *Forschungen und Fortschritte*, 1958, 32(2):33–39, on p. 37 (Humboldt's essay appears in translation along with Beck's analysis).

[16] Bruce Braun, "Producing Vertical Territory: Geology and Governmentality in Late Victorian Canada," *Ecumene*, 2000, 7:7–46; Eyal Weizman, *Hollow Land: Israel's Architecture of Occupation* (New York: Verso, 2007); Gabrielle Hecht, *Being Nuclear: Africans and the Global Uranium Trade* (Cambridge, Mass.: MIT Press, 2012); Michael S. Reidy, *Tides of History: Ocean Science and Her Majesty's Navy* (Chicago: Univ. Chicago Press, 2008), pp. 274–281; 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 Univ. Press, 2010), pp. 17–38; and 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*, Oct. 2017, doi: 10.1177/0073275317732254. Recent interest in verticality is evident among historians of science: the 2016 and 2017 annual meetings of the History of Science Society included the sessions "Underground Knowledge: Miners' Bodies and the New History of Verticality" and "Vertical Sciences and the Vertical in Science."

[17] Reidy, *Tides of History*, p. 280; Novalis, *Heinrich von Ofterdingen*, in *Novalis Schriften*, 5th ed., Pt. 1, ed. Ludwig Tieck and Friedrich Schlegel (Berlin: G. Reimer, 1837), p. 115; and Georg Forster, 12 July 1784, in *Georg Forsters Werke: Sämtliche Schriften, Tagebücher, Briefe: Tagebücher*, ed. Brigitte Leuschner (Berlin: Akademie, 1973), p. 76.

I, who stands above; so often as you go into the depths, think up to the heights."[18] What here expressed a religious meaning for common miners rang true for their naturalist counterparts as well. It was an ascent/descent motif, and it resonated through Humboldt's science.

This essay takes Humboldt as a case study of the way in which industry shapes theory and practice in the history of science. In Section I, I examine two aspects of Humboldt's plant geography—namely, plant migration and plant distribution—as they were shaped by the opportunities and imperatives Humboldt encountered as a miner. Turning to the visual culture of Humboldt's science in Section II, I demonstrate how many of the cartographic methods he employed during and after his American journey depended as much on particular drawing practices indebted to the Mining Academy in Freiberg as they did on regular patterns of vertical mobility above and below the surface of the earth. Thus this section reveals the meaning behind Humboldt's claim to have "conceived of the idea of representing entire countries as one would a mine."[19] I conclude by analyzing the ways in which the underground perspective on Humboldt suggests a departure from "Humboldtian Science," a concept that has done more harm than good for those scholars interested in understanding the actual scientific activities of its namesake. The essay offers a fresh perspective on the development of Humboldt's science as a collective enterprise shaped by mines, miners, and the working world they composed.

I. "NATURE KNOWS NO OVER- AND UNDERGROUND": THE SHAPING OF HUMBOLDT'S PLANT GEOGRAPHY

When Humboldt published his *Essai sur la géographie des plantes* in Paris in 1805, he began by declaring that he had "conceived of the idea for this work" in his "earliest youth" and "communicated the first sketch . . . to the celebrated companion of Cook, M. Georges Forster, in 1790."[20] In this way, Humboldt implied that the period between 1790 and 1805—between his four-month journey to England with Georg Forster and his return from the Americas—had provided the opportunity to cultivate his long-intended geography of plants. What was it that occurred during those fifteen years to bring Humboldt's plant geography into its published form?

In answering this question, it may seem obvious to identify Humboldt's journey through the Americas from 1799 to 1805 as the crucial period in the development of his plant geography, especially considering the *Essai*'s focus on the "vegetational geography" of South America and its inclusion of the "Tableau physique des Andes et Pays voisins," inspired by the Ecuadorian volcano Mt. Chimborazo.[21] In this section, however, I will argue that Humboldt's activities over those other nine years—the ones he spent in Europe—profoundly shaped methodological and theoretical aspects of his plant geography. In Saxony and Prussia, mines and miners had made it possible for Humboldt to pursue a line of inquiry concerning the migration of plants—particularly those "plants that follow certain peoples"—a project he had partly inherited from Johann Reinhold Forster (Georg's father), for whom the study of plant geography was closely linked

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[18] Today this bell is kept in the Stadt- und Bergbaumuseum in Freiberg, where the inscription by Johann Gottfried Weinhold can still be read: "Auf, Auf, zur Grube ruf ich Euch, ich, die ich oben steh; so offt Ihr in die Tiefe fahrt, so denket in die Höh."

[19] Quoted in Beck, ed., "Alexander von Humboldt's 'Essay de Pasigraphie' (Mexiko 1803/04)" (cit. n. 15), p. 37.

[20] Al. de Humboldt and A. Bonpland, *Essai sur la géographie des plantes; accompagné d'un tableau physique des régions équinoxiales* (Paris, 1805), p. vi. Humboldt did not, however, begin the 1807 German edition, *Ideen zu einer Geographie der Pflanzen*, by recalling Forster and the 1790 journey.

[21] "Vegetational geography" is the term Malcolm Nicholson has used to distinguish Humboldt's plant geography from "floristics." Whereas floristics is concerned with groups of plants of the same species, Humboldt studied "vegetation," communities of plants of various species. See Malcolm Nicholson, "Alexander von Humboldt, Humboldtian Science, and the Origins of the Study of Vegetation," *Hist. Sci.*, 1987, *25*:167–193.

to that of human society.[22] Moreover, the imperative Humboldt faced as a Prussian mining official to mitigate the harmful effects of noxious plants on miners' respiration (and thus also on Prussian revenue) inspired a system of inquiry from which he drew the conclusion that "nature knows no over- and underground," an insight that I believe profoundly shaped his later articulation of the verticality of plant distribution in the *Essai*.[23]

The arguments in this section ought to be read alongside, and in concert with, the work of the historian Nils Güttler, who has convincingly shown how cartographic practices of plant geography in Humboldt's day grew out of cameralistic practices of mapping crop distribution. Taking note of Humboldt's training in the sciences of state at universities in Frankfurt (Oder) and Göttingen, Güttler points to his plant geography as an exemplary case of such cameralistic-turned-scientific practices. In Güttler's interpretation, Humboldt's practice of mapping crops alongside wild plants (see Figure 1) both illustrates his debt to the cameralist project of "taking the inventory of states" and also betrays contemporaries' tendency to interpret the altitudinal borders of crops as markers of natural vegetational zones, "the invisible borders of nature."[24] As this section will demonstrate, though, Humboldt's plant geography was shaped not only by cameralistic interest in crop distribution but also, in a more immediate way, by the extraction of mineral resources.

Humboldt's botanical endeavors as a miner in the 1790s can be divided into two types of inquiry. The first focused on "submerged vegetation" (*untergegangene Vegetation*), which, having been fossilized or turned to coal, evidenced the historical migration of plant species. Humboldt called this his "Forsterian project." The second type concerned living "subterraneous vegetables" (*unterirdische Vegetabilien*)—particularly "cryptogams," a group of plants that included mosses, lichens, and fungi in Linnaean taxonomy—which Humboldt identified as the cause of the "corruption" of mine air. This was an important facet of a broader system of inquiry that Humboldt dubbed "subterraneous meteorology." Ultimately, by 1805, elements of both inquiries came to bear on his geography of plants—a "science," Humboldt wrote in the *Essai*, "that concerns itself with plants in their local association in the various climates . . . from the regions of perpetual snows to the bottom of the ocean, and into the very interior of the earth, where there subsist in obscure caves some cryptogams that are as little known as the insects feeding upon them."[25]

From its very inception, Humboldt's plant geography was linked to the Enlightenment Sciences of Man.[26] Indeed, throughout the 1790s Humboldt understood much of his science as contributing to a larger sociopolitical program—a sentiment perfectly in keeping with the reforming ethic of philosophy and natural history in the late Enlightenment and early Romantic

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[22] Humboldt to Paul Usteri, Autumn? 1791, in *Jugendbriefe*, ed. Jahn and Lange, pp. 163–164. Malcolm Nicholson noted that for Johann Reinhold Forster, as for Humboldt, "the vegetation of a region was an expression of the physical environment, and also a direct influence on Mankind, both materially and spiritually": Nicholson, "Alexander von Humboldt, Humboldtian Science, and the Origins of the Study of Vegetation," p. 177.

[23] Humboldt, *Ueber die unterirdischen Gasarten und die Mittel, ihren Nachtheil zu vermindern* (cit. n. 7), p. 201.

[24] 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*, ed. Denise Phillips and Sharon Kingsland (Basel: Springer, 2015), pp. 27–52, on pp. 30, 39.

[25] Humboldt to Usteri, Autumn? 1791, in *Jugendbriefe*, ed. Jahn and Lange, p. 164 ("Forsterian project"); Humboldt, *Ueber die unterirdischen Gasarten und die Mittel, ihren Nachtheil zu vermindern* (cit. n. 7), pp. v–vi, 27–28 ("subterraneous meteorology"); and Alexander von Humboldt and Aimé Bonpland, *Essay on the Geography of Plants*, ed. Stephen T. Jackson, trans. Sylvie Romanowski (Chicago: Univ. Chicago Press, 2009), p. 65.

[26] According to his own recollections, it was in Frankfurt, where the brothers Humboldt studied in 1787 and 1788, that Alexander realized that botanical knowledge was a necessary prerequisite for understanding important cameralist texts like Johann Beckmann's *Beiträge zur Oekonomie, Technologie, Polizei- und Kameralwissenschaft*. See Alexander von Humboldt, *Aus meinem Leben*, ed. Kurt R. Biermann (Munich: Beck, 1987), p. 33.

periods.[27] Thus, the spirit of public utility that would undergird Humboldt's endeavors as a miner was equally palpable in his earlier botanical studies. "To a great many enthusiasts," Humboldt observed in his introduction to a 1789 botanical treatise by the Göttingen medical student Steven van Geuns,

> the study of the utility of plants 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 [*Politiker*] who recognize the worth of these treasures, and who have dreamt of such a thing as precious dye materials [*Farbenmaterial*] hidden among the sordid lichens.[28]

Natural resources were, in Humboldt's time, "natural treasures," and a reverence for nature was entirely consistent with its exploitation. This was an era in which those who loved nature could write with joy, as Johann Wolfgang von Goethe did, of a "remarkable exploitation of the manifold surfaces and depths of the earth and mountains."[29] Having taken an interest in cryptogams and their utility while botanizing with Carl Ludwig Wildenow in the Berlin Tiergarten in 1789, Humboldt linked cryptogams and political economy—plants and states—in England in 1790. After he and Forster had "penetrated the vast subterranean" on what Humboldt described as a "mineralogical tour to the *Peak of Derbyshire*"—a journey into a limestone cavern called Poole's Hole—Humboldt noted in his journal the plants flourishing around the entrance of the cave.[30] Earlier, in Mattlock, Derbyshire, en route to Poole's Hole, Humboldt had remarked that "the cryptogamatic study [*das kryptogamatische Studium*] is not so insignificant as one is accustomed to believing." Rather, he asserted that "in a good political economy, stone mosses should contribute to national prosperity as well." Humboldt referred here to Europe's long history of extracting dyes (or "litmus") from lichens like the *parmelia saxatilis*, which he observed in Derbyshire. Fifteen years later, in the *Essai*, Humboldt would again list cryptogams among "the factors that link the geography of plants to the political and intellectual history of mankind."[31] Mining, as we shall

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[27] Güttler refers to this as Humboldt's "philanthropic background," though it might just as easily be described as a paternalistic or statist background. See Güttler, "Drawing the Line" (cit. n. 24), p. 39; Klein, *Nützliches Wissen* (cit. n. 13); Keith Thomas, *Man and the Natural World: Changing Attitudes in England, 1500–1800* (1983; New York: Oxford Univ. Press, 1996), pp. 69–70; and Beiser, *Romantic Imperative* (cit. n. 13).

[28] [Alexander von Humboldt], "Einleitung zur Steven van Geuns *Verhandeling over de inlandische Plantgvvassen*," *Magazin für Botanik*, *4*:150–151.

[29] Quoted in Rüdiger Safranski, *Goethe: Life as a Work of Art*, trans. David Dollenmayer (New York: Norton, 2017), p. 558. For studies that place natural history in economic and commercial contexts in the eighteenth and early nineteenth centuries see Lisbet Koerner, *Linnaeus: Nature and Nation* (Cambridge, Mass.: Harvard Univ. Press, 2001); Londa Schiebinger, *Plants and Empire: Colonial Bioprospecting in the Atlantic World* (Cambridge, Mass.: Harvard Univ. Press, 2007); Fredrik Albritton Jonsson, "Rival Ecologies of Global Commerce: Adam Smith and the Natural Historians," *American Historical Review*, 2010, *115*:1342–1363; and Jonsson, *Enlightenment's Frontier: The Scottish Highlands and the Origins of Environmentalism* (New Haven, Conn.: Yale Univ. Press, 2013).

[30] On Humboldt's botanizing with Wildenow see Klein, *Humboldts Preußen* (cit. n. 6), p. 13. On the Poole's Hole findings see Georg Forster to Johannes Müller, 12 July 1790, in *Georg Forsters Werke: Sämtliche Schriften, Tagebücher, Briefe: Briefe 1790 bis 1791*, Vol. 16, ed. Brigitte Leuschner and Siegfried Scheibe (Berlin: Akademie, 1980), p. 156; Humboldt to Friedrich Heinrich Jacobi, 3 Jan. 1791, in *Jugendbriefe*, ed. Jahn and Lange, p. 117; and Alexander von Humboldt, "Tagesbuch Beilagen," in Karl Bruhns, *Alexander von Humboldt: Eine wissenschaftliche Biographie*, Vol. 1 (Leipzig: F. A. Brockhaus, 1872), p. 292. Bruhns cites this as "Aus der von Radowitz'schen Autographensammlung, Nr. 6255, in der königlichen Bibliothek zu Berlin."

[31] Humboldt, "Tagesbuch Beilagen," p. 291; and Humboldt and Bonpland, *Essay on the Geography of Plants* (cit. n. 25), p. 73. On the history of lichen dyes see Alexander Tilloch, *The Philosophical Magazine: Comprehending the Various Branches of Science, the Liberal and Fine Arts, Agriculture, Manufactures, and Commerce*, Vol. 2 (London, 1798), pp. 319–326.

see, would further entrench Humboldt's botanical inquiries in social contexts, illuminating for him the multiple ways in which human activity affected plant migration.

The 1790 journey to England provides one starting point from which to trace out Humboldt's study of fossilized plants, through the mines of Saxony to the 1805 *Essai*. "In order to solve the great problem of the migration of plants," he wrote in 1805, "the geography of plants delves into the interior of the earth: it looks at the ancient monuments that nature has left behind in petrifactions, in wood fossils, and in coal strata that are the tomb of the initial plant life of our planet." Likewise, Humboldt's own path to the *Essai* began when *he* delved into the interior of the earth. Coerced by his mother to attend the Commercial Academy in Hamburg, Humboldt left the "happy island" of England "with a heavy heart." "Botany does not evade me," he wrote his friend, the botanist Paul Usteri, from London in June 1790, "but I endlessly evade this venerable study of nature!" Then, writing from Hamburg in September of that year, Humboldt told the elder Forster that he had "designated [mineralogy] a matter of necessity for my future," though he also confessed that he remained a "stranger" to the field. According to his own reckoning, it was in 1789, while studying in Göttingen, that Humboldt had decided to "study geognosy and the history of cultivation together with botany"—a statement he made in autumn 1791.[32] Humboldt penned this letter from Freiberg, where he studied at the Mining Academy under Germany's most celebrated mineralogist, Abraham Gottlob Werner.

It was at the Mining Academy in Freiberg that Humboldt's mineralogical-botanical project blossomed. What better place to explore the deep history of plant migration, Humboldt came to believe, than in mineshafts laden with fossils and coal deposits? As the historian Martin Rudwick has demonstrated, Humboldt's era saw the discovery of "deep history"—the application of methods used to investigate human history to the natural history of the earth and the establishment of a "geo-historical" timescale in European consciousness. Fossils became the artifacts of a "pre-Adamitic former world," as Göttingen's Johann Friedrich Blumenbach phrased it; stratified layers became pages in the book of time; and the underground came to be seen as the archive of earth, human, and—for Humboldt especially—botanical history. Indeed, for him they made up but *one* common history. In this way, mines provided Humboldt an ideal venue in which to pursue what his mentor, Wildenow, called the "*Geschichte der Pflanzen*," the historical development of plant distribution.[33]

From Freiberg in 1791, Humboldt explained to Usteri how his "mining study and Werner's lessons [in geognosy and mineralogy] are of great interest to me, particularly for my Forsterian project [referring to the elder Forster], which requires one to seek out submerged vegetation (wood coal, brown coal p.) in the mines." Humboldt then sketched out the core concept of a work that would have taken him "20 to 30 years" to complete had Forster not invited him to collaborate on "this neglected part of universal history." Together, Forster and Humboldt envisioned "a history of plant migration" that included "maps of socially living plants [*Karten für die gesellschaftlich lebenden Pflanzen*]" illustrating how "Europe became inundated with Caucasian plants" when "Arabs, Greeks, Persians, and especially the Vandals and Goths" spread across the continent.[34]

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[32] Humboldt and Bonpland, *Essay on the Geography of Plants*, p. 69; Humboldt to Usteri, 27 June 1791, in *Jugendbriefe*, ed. Jahn and Lange, pp. 96–98; Humboldt to Johann Reinhold Forster, 24 Sept. 1790, *ibid.*, p. 108; and Humboldt to Usteri, Autumn? 1791, *ibid.*, p. 163.

[33] Martin J. S. Rudwick, *Bursting the Limits of Time: The Reconstruction of Geohistory in the Age of Revolution* (Chicago: Univ. Chicago Press, 2005), pp. 2, 298; and Nicholson, "Alexander von Humboldt, Humboldtian Science, and the Origins of the Study of Vegetation" (cit. n. 21), pp. 172–173. On Humboldt's botanical studies with Wildenow in Berlin and his interest in cryptogams see Klein, *Humboldts Preußen* (cit. n. 6), pp. 13–17.

[34] Humboldt to Usteri, Autumn? 1791, in *Jugendbriefe*, ed. Jahn and Lange, pp. 163–164.

Humboldt's Forsterian project thus sought to illustrate a point that would, by 1805, become *the* argument of the *Essai*. "Plants that follow certain peoples," Humboldt wrote in 1791, "have made me especially mindful of this idea"—the idea of representing the historical migration of plants cartographically. Humboldt's argumentation in the *Essai* is strikingly similar. "The Greeks took with them vines, the Romans, wheat, and the Arabs, cotton," he wrote, echoing his 1791 letter to Usteri in his description of how the Persian walnut and peach trees, the Armenian apricot tree, and the Syrian fig, pear, pomegranate, olive, plum, and mulberry trees spread across Europe. Even after five years of botanizing in the Americas, Humboldt's conclusion remained consistent: "Winds, currents, and birds are not the only ones that help plants migrate," he wrote; "the primary factor is man."[35] Historians have written a great deal about the profound influence of South American biogeography on Humboldt's way of thinking—and rightly so.[36] But Humboldt's insight that plants follow peoples was also rooted in a drastically different context, for it was Germany's industrial underground that made possible Humboldt's study of the geohistorical record of plant migration.

Humboldt's "cryptogamatic study" with Wildenow in Berlin and Forster in England likewise serves as a helpful starting point from which to trace the development of his study of living subterranean plants, which ultimately bore fruit in his articulation of the verticality of plant distribution in the *Essai*. In Freiberg and, later, in Prussian Franconia Humboldt took his cryptogamatic study underground. In the same 1791 letter in which Humboldt explained his Forsterian project to Usteri, he also sent his friend a draft of his "cryptogam[atic] Flora" (a predecessor to his taxonomic monograph *Florae Fribergensis specimen*, published in 1793). The draft he sent Usteri included sketches he had made of subterranean biota like the "L[ichen] verticillat[us]," found in Freiberg's mines, and the "L[ichen] crispus," which he had observed "in Bohemia during a miner's journey [*bergmännischen Reise*]."[37] To Dietrich Ludwig Gustav Karsten, a professor at the Mining Academy in Berlin, Humboldt boasted of having discovered "14–18 new *species*" of subterranean plants. Among them was "the largest *Cryptogam*[*atic*] plant known to date, 4–6 feet in breadth. I call it *Usnea verticillata*," he proudly wrote. However much Humboldt mystified his debt to mining in subsequent years, his private letters at the time show that he was well aware of the unique opportunities afforded him by his position. Only a miner could have had such unequaled access to "the most exquisite fungi and lichen from depths of 900 to 1,000 feet . . . indeed an entire subterraneous Creation of animals [*Thierschöpfung*]."[38]

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[35] *Ibid.*, p. 163; and Humboldt and Bonpland, *Essay on the Geography of Plants* (cit. n. 25), pp. 70–71.

[36] See, e.g., 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*, ed. Londa Schiebinger and Claudia Swan (Philadelphia: Univ. Pennsylvania Press, 2005), pp. 148–165.

[37] Humboldt to Usteri, Autumn? 1791, in *Jugendbriefe*, ed. Jahn and Lange, p. 163. Humboldt's second book, the *Florae Fribergensis*, classified 258 cryptogams according to the Linnaean system, including the *Lichen saxatilis* he had collected with Georg Forster in Derbyshire. See Fredericus Alexander ab. Humboldt, *Florae Fribergensis Specimen: Plantas Cryptogamicas Praesertim Subterraneas Exhibens* (Berlin: Heinrich August Rottmann, 1793); and Wolfgang-Hagen Hein, "Notizen zur Humboldt-Chronologie aus seiner 'Flora Fribergensis,'" *Sudhoffs Archiv*, 1997, *81*(1):120–123, on p. 121.

[38] Humboldt to Karsten, 26 Nov. 1791, in *Jugendbriefe*, ed. Jahn and Lange, p. 161; and Humboldt to Lichtenberg, 21 Apr. 1792, *ibid.*, p. 184. In 1792 Humboldt reported in the *Journal der Physik* that he had "discovered with rapt attention a *species of lichen* (which appears to make the interior of the earth its *exclusive* habitat)." He described in detail how "due to a delicate inner structure [it] sometimes acquires a breadth of 7–8 feet" and "coats the stone" walls of the mineshafts in Freiberg, where it can still be seen today in the Fürstenstollen Fundgruben. Its name—"*verticillatus*"—likely comes from the upward, vertical manner in which its "young swirling tips" grow. See F. A. von Humboldt, "Versuche und Beobachtungen über die grüne Farbe unterirdischer Vegetabilien," *Journal der Physik*, 1792, 5(1):195–204, on pp. 196–197.

As a mining official in the principalities of Bayreuth and Ansbach from June 1792 through the end of 1796, Humboldt continued to study cryptogams in connection with political economy, now homing in on their harmful effects on human respiration. Humboldt's cryptogamatic study thus evolved into an ideal example of Jon Agar's "working world" concept. Responding to the problem of the vitiation of mine air, Humboldt developed a system of inquiry that included the cultivation of underground gardens, the development of breathing apparatuses, the measurement of gases with self-made instruments, and the use of human bodies as experimental organisms. After cultivating gardens at various depths in the mines in 1792, Humboldt became convinced that "nitrogen and hydrogen . . . corrupt [*empestée*] the atmosphere of our mines [and] generally act on subterraneous vegetation, as light acts on those found on the surface of the earth."[39] In addition to the miner's lamp and respiration device Humboldt invented in the winter of 1795–1796, he also developed his own eudiometer, a glass tube fashioned to detect changes in gas volume. Here Humboldt drew on the tradition of "pneumatick chemistry," whose eudiometer-wielding practitioners sought to locate "dangerous miasmata that emanated from marshes" and, with such knowledge, gain control over "the goodness of air."[40] What Joseph Priestley and the pneumatick chemists referred to as "vitiation"—the "*kind* of injury" that air suffered from flame, respiration, and certain plants—Humboldt described with the German "*Verderbniss*" or the French "*empestement*." Chemists of Priestley's brand charged their eudiometric chemistry with the populist impulses and reforming ethic of the Enlightenment. And as a child of the Enlightenment, Humboldt shared his predecessors' conviction that one could effect social change by measuring the "virtue" of airs. Viewed from a different angle, Humboldt's underground science is also telling as to how he came to view the body itself as an instrument. After attempting to summit Mt. Chimborazo in 1802, Humboldt wrote that his body had served as "a kind of gauge" for measuring atmospheric rarefaction at high altitude. It was not on mountains, however, but in mines that Humboldt learned to employ his own and others' respiratory systems to register the effects of various types of air. In 1796—just one year after attaching electrodes to his body in galvanistic self-experimentation—Humboldt wrote that he "nearly became the victim of [his] own experiment" and had to be "dragged out" of a mine by his miner-assistants after falling unconscious.[41] What is more, miners themselves served as living eudiometers in Humboldt's cryptogamatic study, experimental organisms whose respiration he incorporated into his scientific program and who, on at least one occasion, kept him breathing too.

By 1799 Humboldt's study of underground flora, eudiometric chemistry, and respiration devices had culminated in a book titled *Ueber die unterirdischen Gasarten und die Mittel, ihren Nachtheil zu vermindern* [*On Subterraneous Species of Gas, and the Means of Mitigating Their Harmful Effects*]. Here Humboldt made practicality and verticality the pillars of a science he

[39] Agar, *Science in the Twentieth Century and Beyond* (cit. n. 10), pp. 3–6; and Humboldt to Jean-Claude de Lamétherie, 10 Jan. 1792, in *Jugendbriefe*, ed. Jahn and Lange, pp. 167–168. Humboldt's experiments on the color of subterranean flora culminated in his book *Aphorismen aus der chemischen Physiologie der Pflanzen*, trans. Gotthelf Fischer von Waldheim (Leipzig: Voss und Compagnie, 1794).

[40] Golinski, *Science as Public Culture* (cit. n. 8), p. 120; and Frederic L. Holmes, "The 'Revolution in Chemistry and Physics': Overthrow of a Reigning Paradigm or Competition between Contemporary Research Programs?" *Isis*, 2000, *91*:735–753, esp. pp. 743–746. For more on Humboldt's inventions see Klein, "Prussian Mining Official Alexander von Humboldt" (cit. n. 6), pp. 52–54.

[41] Holmes, "'Revolution in Chemistry and Physics,'" p. 746 (quoting Priestley); Livingstone, *Putting Science in Its Place* (cit. n. 11), p. 75 ("kind of gauge"); and Humboldt to Carl Freiesleben, 18 Oct. 1796, in *Jugendbriefe*, ed. Jahn and Lange, p. 533. On Humboldt's galvanistic self-experiments see Stuart Walker Strickland, "The Ideology of Self-Knowledge and the Practice of Self-Experimentation," in "The Mind/Body Problem," special issue, *Eighteenth-Century Studies*, 1998, *31*:453–471, esp. p. 457; and 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*, 1999, *30*:473–504, esp. p. 478.

called "subterraneous meteorology," which he had been developing since 1795. After dismissing the trivial pursuits of natural philosophers "busy replicating instruments" and miners incessantly "modifying the shape of a barrel, sledge, or shovel," Humboldt laid out his own ambitions:

> My wish . . . is to bring to the attention of practicing *Physiker* the culture of a field infinitely important to the life and prosperity of one of the most valuable and industrious classes of men; I wish to draw downwards what *Deluc*, *Saussure* and *Lichtenberg* have drawn up toward the region of the clouds. Nature knows no over- and underground. All that is contained in fluid elements is counteractive, *mixed*. No sooner does the miner begin his underground work . . . than he confronts the daunting afflictions caused by a shortage of respirable air.

Humboldt's point was both theoretical and methodological. When he said that "nature knows no over- and underground," Humboldt meant that the same weather phenomena occur above as below the surface of the earth. Far from dismissing the boundary between the terrestrial and the subterrestrial, though, Humboldt was acknowledging the equal significance and interrelation of scientific inquiry in both spaces. Here Humboldt had important predecessors in Jean-André Deluc, Horace-Bénédict de Saussure, and Georg Christoph Lichtenberg, who utilized cutting-edge instrumentation to record variation along nature's vertical axis. In 1777, for instance, Deluc had published an account of "barometrical observations on the depth of the mines in the Hartz," employing in mines a method he had proven useful on mountains.[42] Humboldt effectively made this approach his own.

In the seventh and final section of the text, Humboldt turned to "the means of making mine air respirable and light-retaining." Besides endorsing the apparatuses he had invented, Humboldt also called on miners to "strenuously endeavor to eradicate" all cryptogams. His keen eye for the causes and consequences of plant migration revealed to him the irony that the plants for which miners had inadvertently established subterranean habitats needed to be eradicated in order to preserve the human presence in those very habitats. Subterranean cryptogams, Humboldt explained, contribute to the vitiation of the air in two ways: first, by decomposing water; and second, by absorbing oxygen from the air without replenishing it. "Whereas the green plants in sunlight exhale life-air [*Lebensluft*], thereby contributing to the enhancement of the atmosphere above ground, we find the opposite is true for subterraneous plants, which grow in mines." The primary cause of vitiation, Humboldt believed, was a particularly resilient "white fungus" that absorbed and decomposed water by "assimilating" oxygen and exhaling "carbonized hydrogen." "Because they know no alteration in year- and day-time," Humboldt wrote, "they enjoy an everlasting spring night, and so it is not difficult to understand how these curious plant genera so quickly make their atmosphere irrespirable through an uninterrupted operation." One of the chief implications of Humboldt's "subterraneous meteorology" was, therefore, to facilitate the extraction of one natural resource by eradicating another.[43]

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[42] Humboldt, *Ueber die unterirdischen Gasarten und die Mittel, ihren Nachtheil zu vermindern* (cit. n. 7), p. 201; and Jean-André de Luc, *Barometrical Observations on the Depth of the Mines in the Hartz: By John Andrew de Luc . . . Read at the Royal Society, March 20, 1777* (London: W. Bowyer and J. Nichols, 1777).

[43] Humboldt, *Ueber die unterirdischen Gasarten und die Mittel, ihren Nachtheil zu vermindern*, pp. 158–160, 233–235. Notably, Humboldt's call for the extermination of plants and his Romantic nature-loving sensibility were not mutually exclusive. Consider how both he and Carl Freiesleben were awed by the bioluminescent quality of the very "white fungus" whose extermination they called for. As Freiesleben had written (quoting a fellow mining official), these fungi had the effect of transforming the shaft into a "magic castle [*Zauberschloss*]" bathed in "faint moonlight": J. C. Freiesleben, "Lichterscheinungen, I: Leuchten der Rhizomorphen," *Journal der Chemie und Physik*, 1825, *44*:65–73, on p. 66.

Six years later, cryptogams and their geographical distribution would figure centrally in the *Essai*, where Humboldt argued for two types of correspondence in botanical geography: the first between high elevation and low latitude (between mountaintops and poles) and the second between high elevation and subterranean depth (between mountaintops and mines). "The opposite limits of plant life," Humboldt believed, "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." Rhetorically, too, Humboldt juxtaposed the extremes of nature's vertical expanse, encouraging those with souls "sensitive to works of art" and "educated enough in spirit to embrace the broad concepts of general physics" to contemplate all that there is to be "discovered in the heavens and the oceans, in the subterranean grottoes, or on the highest icy peaks." Humboldt even devoted a page of the *Essai* and a section of the "Tableau physique des Andes" to "*the region of subterranean plants*," describing how he "saw the same species . . . in the mines of Germany, England, and Italy, as in those of New Grenada and Mexico, and, in the southern hemisphere, in the mines of Hualgayoc in Peru."[44]

Humboldt's inclusion of subterranean flora in the *Essai* was not merely descriptive; he did not merely wish to make these plants known to naturalists. Rather, subterranean flora had a theoretical importance for Humboldt, which bears the stamp of his earlier description of the subterranean not as a space apart but as a *corresponding* space. Humboldt's meteorological insight that "nature knows no over- and underground"—that the same weather phenomena occur above as below the surface of the earth—echoes through his climatological point in the *Essai* that the environs at opposite extremes of the earth are hospitable to corresponding vegetation. The underground was for Humboldt one of two "opposite limits of plant life." In the accompanying "Tableau physique des Andes," Humboldt illustrates this point by placing the "Région des Plantes Souterraines" rather arbitrarily at sea level (see Figure 2). As such, the viewer encounters this region not as one belonging to crags, caverns, and mines at various elevations but, rather, as a region held in vertical juxtaposition to the mountainous "Région des Lichens," from 4,600 to 4,900 meters. As Malcolm Nicholson has argued, Humboldt's endeavor to study "vegetational geography" (plant communities composed not of one but of various species) drew heavily on the scholarly botanical tradition marked out by Wildenow and the elder Forster, particularly their respective studies of "regionality" in plant distribution. But Humboldt's meteorological-turned-climatological insight about plant distribution in the earth's "opposite limits" was also gained, to borrow his own words, by "climbing up from the interior of the earth or from the interior of mines to the icy peaks of the Andes."[45] Mountains and mines put the verticality in regionality.

II. "REPRESENTING ENTIRE COUNTRIES AS ONE WOULD A MINE": THE SHAPING OF HUMBOLDT'S VERTICAL CARTOGRAPHY

"I conceived of the idea of representing entire countries as one would a mine," Humboldt proclaimed in his *Essay on Pasigraphy* of 1803, having "occupied [myself] with such drawings since 1795."[46] In 1809, he reflected: "The Mexican Atlas contains a series of vertical cross-sections or

[44] Humboldt and Bonpland, *Essay on the Geography of Plants* (cit. n. 25), pp. 64–65, 64, 75, 87–88.

[45] Nicholson, "Alexander von Humboldt, Humboldtian Science, and the Origins of the Study of Vegetation" (cit. n. 21), pp. 171–177; and Humboldt and Bonpland, *Essay on the Geography of Plants*, pp. 64, 87.

[46] Quoted in Beck, ed., "Alexander von Humboldt's 'Essay de Pasigraphie' (Mexiko 1803/04)" (cit. n. 15), p. 37. As the *Essay* is transcribed in Beck's article, this statement reads: "Jai concu l'idee de figurer des pays entiers comme on represente une mine. Je me suis occupé de ces dessins depuis 1795 mais Mr. Escher m'a [denoncé?] à publier dans le Bergmännische Journal de Freyberg un dessin fait sur des idées analogues quoique sans signes geognostiques et sans mesures. Je parle d'une petite carte qui est à la suite de son voyage ein Suisse, Memoire plein de sagacité et de vues vrayment geognostiques."

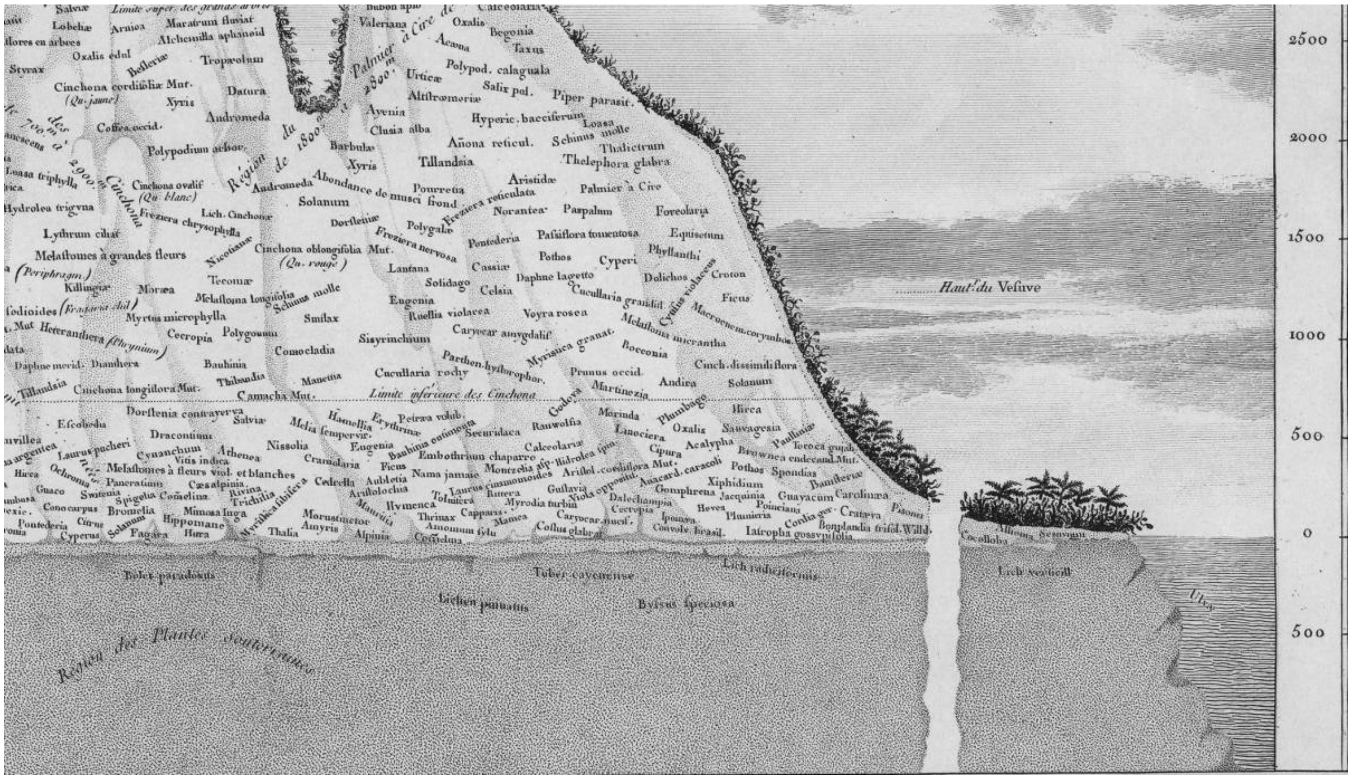

Figure 2. Detail from Humboldt's "Tableau physique des Andes et Pays voisins." Humboldt's placement of the "Région des Plantes Souterraines" at sea level was a theoretical maneuver, not intended to illustrate the actual location of mines and caves. Rather, it allowed him to idealize the harmonious juxtaposition of similar plant communities at opposite extremes of the earth. Courtesy of the David Rumsey Map Collection, www.davidrumsey.com.

geognostic profiles. I have sought to represent whole countries after a method, which, until now, has only been applied in mining or canal projects." This section of the essay tells the story behind these quotations, building on the work of scholars who have recognized the way in which Humboldt's "geological view" was laden with practices he learned as a miner.[47] In an effort to explicate this recognition, I will argue that the vertical projections Humboldt had in mind in 1803 and 1809, published in the *Atlas géographique* of 1811, are best understood as variations on a theme by miners and surveyors. As Martin Rudwick has demonstrated, practitioners of the earth sciences had been adapting mining sections into geognostic profiles—vertical projections depicting mineralogical information—throughout the latter half of the eighteenth century, though mining sections certainly have a much deeper history, reaching back at least as far as the sixteenth century. An exceptionally large-scale example here is Georg Christian Füchsel's section of part of Thuringia, published in 1761, which inferred subterranean strata from *Gebirge* (or "rock masses") exposed on the earth's surface. Cross-sectional representations were one of the primary mechanisms by which mining encouraged "a distinctive way of . . . seeing" nature in all its verticality and three-dimensionality.[48] And these are precisely the kind of maps Humboldt was trained to make and make use of as a mining official. Working parallel to Rudwick's argument about geognosy's "home, in the world of mining," I also suggest that Humboldt's cartographic methods were equally dependent on patterns of vertical mobility above and below the surface of the earth.[49] Indeed, this ascent/descent rhythm marks one of the most continuous elements in Humboldt's practice between 1791 and 1804. Humboldt's vertical cartography thus combined two types of practice: drawing and mobility. And both were rooted in his training and experience as a miner.

Humboldt's maps and *tableaux* have traditionally been viewed in the pedigree of the French Enlightenment, if not as direct descendants of maps made by Charles Marie de La Condamine, whom one scholar called a "Humboldtian scientist *avant la lettre*." Referring to the "Tableau physique des Andes," the same scholar wrote, "It is as if Humboldt looked at the correctly scaled representation of Chimborazo, zoomed in on two of La Condamine's tiny mountains, and blew them up to large proportions." To be sure, as Güttler has argued, Humboldt's "Tableau physique des Andes" also drew on the model of Abbé Jean-Louis Giraud-Soulavie's "Coup verticale des montagnes vivaroises," a pioneering application of geological cartographic practices to botanical geography, published in his *Histoire naturelle de la France méridionale* (1780–1783). Meanwhile, revisionist scholars have argued for the "other" Latin American origins of Humboldt's car-

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[47] Alexander von Humboldt, *Versuch über den politischen Zustand des Königreichs Neu-Spanien*, Vol. 1 (Tübingen: J. G. Cotta'schen Buchhandlung, 1809), p. 43; Nils Güttler, *Das Kosmoskop: Karten und ihre Benutzer in der Pflanzengeographie des 19. Jahrhunderts* (Göttingen: Wallstein, 2014), p. 164; Sandra Rebok, *Alexander von Humboldt und Spanien im 19. Jahrhundert: Analyse eines wechselseitigen Wahrnehmungsprozesses* (Frankfurt am Main: Vervuert, 2006), p. 167; and Beck, ed., "Alexander von Humboldt's 'Essay de Pasigraphie' (Mexiko 1803/04)," pp. 33–35. For Güttler's analysis of Humboldt's "Tableau physique des Andes" see Güttler, *Das Kosmoskop*, pp. 126–131. Additionally, Sylvie Romanowski has noted Humboldt's exposure to mining profiles: Sylvie Romanowski, "Humboldt's Pictorial Science: An Analysis of the *Tableau physique des Andes et pays voisins*," in Humboldt and Bonpland, *Essay on the Geography of Plants* (cit. n. 25), pp. 157–197, on p. 177.

[48] Rudwick, *Bursting the Limits of Time* (cit. n. 33), pp. 84–88, 25–26; for analysis of Füchsel's section see p. 89, fig. 2.16. On the link between mining and mapmaking in the earth sciences see also Martin Rudwick, "The Emergence of a Visual Language for Geological Science, 1760–1840," *Hist. Sci.*, 1976, *14*:149–195, esp. pp. 167–168; and Roy Porter, *The Making of Geology: Earth Science in Britain, 1660–1815* (New York: Cambridge Univ. Press, 1977), pp. 35–36. Nor was mining the only source of inspiration for vertical projections. Here we can also look at coastal profiles and sections of ocean depths, which date at least to the seventeenth century. Consider the coastal profiles in Jansz Blaeu's *Le flambeau de la navigation*, published in Amsterdam in 1625, and the section illustrating depth soundings in Thomas Burnet's *Telluris Theoria Sacra, or Sacred Theory of the Earth*, first published in Latin in 1681.

[49] Rudwick, *Bursting the Limits of Time*, p. 84.

tography. While David Y. Allen has highlighted affinities between Humboldt's relief maps and those of the Mexican cartographer José Antonio de Alzate y Ramírez, Jorge Cañizares-Esguerra traced Humboldt's "Tableau physique des Andes" to the work of the Colombian naturalist José de Caldas.[50]

I do not deny the significance of Humboldt's admiration for La Condamine, who had himself traveled to South America between 1735 and 1745, or of Giraud-Soulavie's "Coup verticale." Nor would I dismiss the admirable decentering impulse behind scholarship that shows how Humboldt's science was also shaped by non-Europeans. But my approach seeks to move beyond the recognition of visual affinities to the identification of shared practices. The historian Rachel Laudan has argued that "before Humboldt's campaign for accurate measurement in the early nineteenth century, no heights had been measured with any precision." The depths of mines, like the depths of waters, had, however, been subjected to such a campaign for accurate measurement. And if Humboldt's approach to mountains was novel in this regard, it was because he learned to see them as mines, appropriating underground conventions to suit overground landscapes. It is widely recognized that Humboldt infused natural history with a new visual culture with his innovative *tableaux physiques*. But Humboldt did this by drawing on the visual culture in which he was trained and practiced.[51] On a still broader scale, moreover, it is important to recognize that Humboldt worked within a larger culture of visuality that emerged in representational studies of earthquakes, in a "visual language" in the earth sciences, and in new forms of publication like the *Voyages pittoresques*. When the Frenchman Jean-Pierre Houël declared, "I prove my drawings through my words and bear testimony to my words through my drawings," he spoke for a generation of travelers that bound word and image in new ways.[52] Humboldt's pictorial science must be seen against this backdrop.

What were the cartographic methods that, according to Humboldt, had "only been applied in mining or canal projects"? Humboldt attended the Mining Academy in Freiberg at a time when miners, surveyors, and hydrographers were taught to represent a variety of landscapes from both aerial and vertical perspectives. Cartography was in fact central to Abraham Gottlob Werner's pedagogical program. As Laudan observed, Werner himself "had urged his pupils to construct maps, had personally directed some surveys, and had drawn up instructions for their coloring." In this way students were taught to visualize nature's volume and verticality.[53] In mining projects, aerial ground plans (*Grund Risse*) were typically accompanied by vertical cross-sections (*Durchschnitts Risse*) depicting the shafts, as in profiles by the Freiberg surveyor Carl Friedrich Freiesleben (see Figure 3), in whose house "Humboldt felt as though he was family." Canal and

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[50] Romanowski, "Humboldt's Pictorial Science" (cit. n. 47), pp. 176–177; Güttler, *Das Kosmoskop* (cit. n. 47), p. 83; David Y. Allen, "Alexander von Humboldt and the Mapping of Mexico," *E-Perimetron*, 2014, 9(2):78–96; and Cañizares-Esguerra, "How Derivative Was Humboldt?" (cit. n. 36), p. 152.

[51] Rachel Laudan, *From Mineralogy to Geology: The Foundations of a Science, 1650–1830* (Chicago: Univ. Chicago Press, 1987), p. 163. On the visual culture of mining in the late nineteenth and twentieth centuries see Eric C. Nystrom, *Seeing Underground: Maps, Models, and Mining Engineering in America* (Reno: Univ. Nevada Press, 2014).

[52] Jean-Pierre Houël, *Prospectus du Voyage de la Sicile, de Malte et de Lipari* (Paris, 1781), p. 12. On the larger culture of visuality see Susanne B. Keller, "Sections and Views: Visual Representation in Eighteenth-Century Earthquake Studies," *British Journal for the History of Science*, 1998, *31*:129–159; Rudwick, "Emergence of a Visual Language for Geological Science" (cit. n. 48), pp. 149–195; and Fritz Emslander, ed., *Reise ins unterirdischen Italien: Grotten und Höhlen in der Goethezeit* (Karlsruhe: Info, 2002), pp. 22–23.

[53] Laudan, *From Mineralogy to Geology* (cit. n. 51), p. 163. See also Nystrom, *Seeing Underground* (cit. n. 51), p. 194; Rudwick, *Bursting the Limits of Time* (cit. n. 33), p. 87; and Mott T. Greene, *Geology in the Nineteenth Century: Changing Views of a Changing World* (Ithaca, N.Y.: Cornell Univ. Press, 1982), p. 27. For a suggestive study of volume and its geopolitical ramifications see Stuart Elden, "Secure the Volume: Vertical Geopolitics and the Depth of Power," *Political Geography*, 2013, *34*: 35–51.

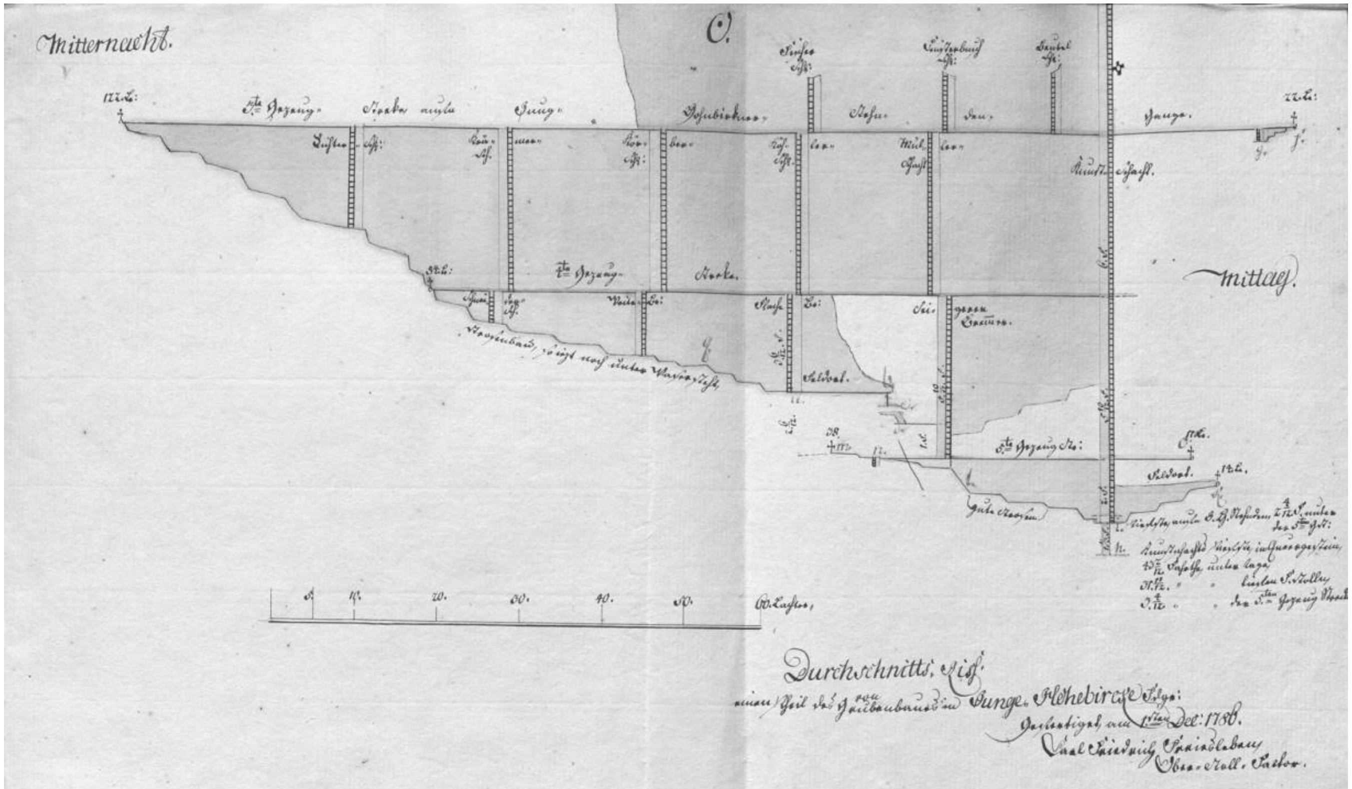

Figure 3. Carl Friedrich Freiesleben, "Durchschnitts Riss einen Theil des Grubenbaus in Bunge-Hohebirge," 1786. "*Mitternacht*" ("midnight") indicated north and "*Mittag*" ("midday") indicated south. Sächsisches Staatsarchiv, Bergarchiv Freiberg, 40174 Grubenakten des Bergreviers Freiberg, Nr. 194.

dam building projects, moreover, were still closely linked to the mining industry, as evidenced by the education of hydrographers like Johann Gottfried Tulla, who trained alongside miners in Freiberg.[54] Dams in particular tended to be visualized from both perspectives in single displays, as in the "Ground Plan and Cross-Section" of a dam built near Freiberg to collect the water drawn from its mines (see Figure 4). On top is the aerial view, complemented by a vertical projection with corresponding letters and coloration below. From the "practice tasks of the mining students [*Probearbeiten von Bergschülern*]" in the 1790s, it is evident that Freiberg's training regimen fused technical and artistic cultures. Students were sent into the mines to construct written reports that included sketches of building structures, mineshafts, and mechanical apparatuses. Freiberg was, to borrow from Nick Hopwood, a "school for sight," a place where students were disciplined not in rote memorization but in practical visualization.[55]

Humboldt readily integrated these methods into his scientific enterprise. After taking up a position as *Oberbergmeister* in the principalities of Bayreuth and Ansbach in August 1792, he drew an extensive map of Germany's salt springs, which in Ursula Klein's words "attempted to establish relations between salt springs and mountain formations." In 1794, now a high-ranking *Bergrat*, Humboldt told his former classmate Carl Freiesleben (son of the aforementioned surveyor and fellow cartographer) about his plans to "have engraved geognostic views from drawings" for his "major geognostic project." Humboldt's oft-envisioned but never published "major" geognostic work reveals the endurance of a vertical way of thinking about and representing nature that visual affinities alone could not have explained. Steeped in Saxon geognosy and cartography, this approach remained integral to Humboldt's enterprise long after his years as a mining official. Klein observed that it was "only some three decades later" that "Humboldt could actually publish a work on the stratification of rocks." Here she referred to Humboldt's *Geognostical Essay on the Superposition of Rocks; in both Hemispheres*, published in French and English in 1823. But even in the *Geognostical Essay* (hardly a "major" work by comparison with those he had already published), Humboldt envisioned a still greater "*geognostic atlas*" comprising "profiles or vertical *sections*."[56]

Humboldt's idea for a "major project" goes back at least to September 1792, when he wrote to Carl Freiesleben about "the project of jointly printing geognostica in the future." By 1794, he referred to a similar project as "my book on *Strata* and *Bedding*." "My idea is this," he told Freiesleben in January of that year: "To employ the most admirable flora and geogn[ostic] descriptions of whole regions as *vehicula* with which to bring to the world a *single* observational overview." Earlier, in September 1794, Humboldt had told Freiesleben he now knew "how exactly everything in west[ern] Germany is *composed*." Having "travelled into the mines [and] described

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[54] Carl Friedrich Freiesleben, "Durchschnitts Riss einen Theil des Grubenbaus in Bunge-Hohebirge," 1786, Sächsisches Staatsarchiv, Bergarchiv Freiberg, 40174 Grubenakten des Bergreviers Freiberg, Nr. 194; Karl Bruhns, *Alexander von Humboldt: Eine wissenschaftliche Biographie*, Vol. 1 (Leipzig: F. A. Brockhaus, 1872), p. 123; and Blackbourn, *Conquest of Nature* (cit. n. 13), pp. 85–92 (on Tulla).

[55] August Friedrich Bollner, "Grund und Durchschnitts Riss von einen Theil des Ober Groshartmannsdorfer Bergwerks Teichdammes," 1796, Sächsisches Staatsarchiv, Bergarchiv Freiberg, 40010 Bergamt Freiberg, Nr. 2927, Blatt 351; Sächsisches Staatsarchiv, Bergarchiv Freiberg, 40001 Oberbergamt Freiberg, Nr. 3296 (*Probearbeiten von Bergschülern*); and Nick Hopwood, *Haeckel's Embryos: Images, Evolution, and Fraud* (Chicago: Univ. Chicago Press, 2015), p. 35.

[56] Klein, "Prussian Mining Official Alexander von Humboldt" (cit. n. 6), pp. 44, 48 (quoting Humboldt), 44; and Alexandre de Humboldt, *A Geognostical Essay on the Superposition of Rocks; in both Hemispheres* (London: A. & R. Spottiswoode, 1823), pp. 78–79. This essay reveals Humboldt's continued engagement with Freiberg-educated mining officials. Here he noted that Johann von Charpentier, director of salt works in Switzerland, had shown him "his excellent description of the Pyrenees, the most complete work which we possess on a great chain of mountains." He also acknowledged that "much of the information of the porphyries of Europe" was "taken from a sketch that [he] wrote in some degree under the inspection of M. Werner, when that celebrated man came, for several days, from Carlsbad to Vienna, (in 1811)": *ibid.*, p. 77.

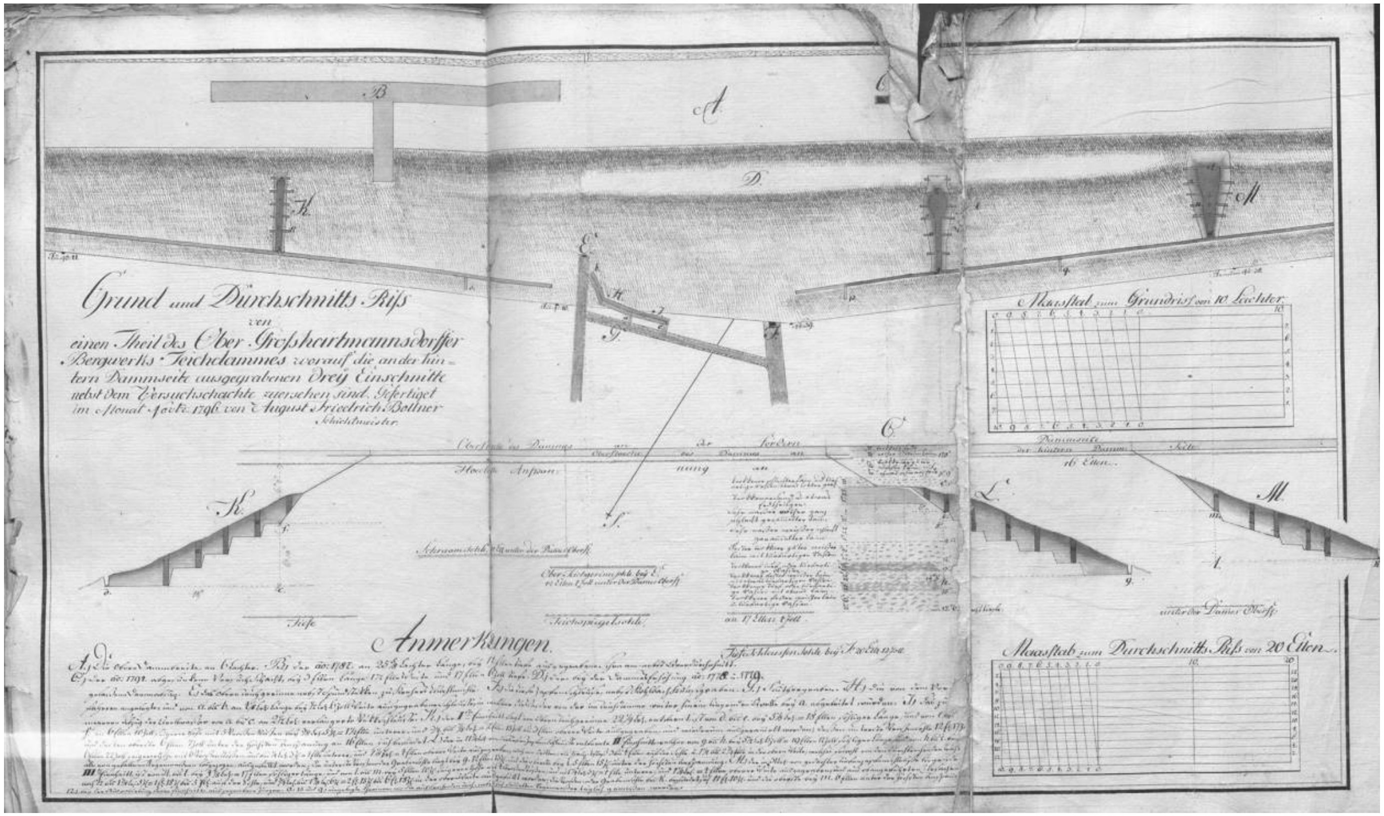

Figure 4. August Friedrich Bollner, "Grund und Durchschnitts Riss von einen Theil des Ober Groshartmannsdorfer Bergwerks Teichdammes," 1796. Sächsisches Staatsarchiv, Bergarchiv Freiberg, 40010 Bergamt Freiberg, Nr. 2927, Blatt 351.

their veins," he fixed on the idea for a "major Mineral[ogical] work, *a type of geognostical view of Germany* [*einer Art geognostischer Ansicht von Deutschland*]." Two years later Humboldt assured Werner of his tireless efforts on an even more expansive work to be titled *On the Construction of the Terrestrial Body in Central Europe, Particularly on the Strata and Bedding of Rock Masses*. In his last letter from the European continent in 1799, Humboldt regretfully told a friend that his "work on the construction of the terrestrial body" would have to wait until his return to be published.[57] That Humboldt never wrote this book does not, however, mean that he left its conceptual basis behind. On the contrary, I would suggest that Humboldt took with him the very set of practices that had sustained this project since 1792: ascending mountains, descending mines, and depicting nature, from strata to summit, in geognostic profiles. Ultimately, Humboldt's geognostic aspirations had become something much more than a "major work." They had crystallized into a vertical system of natural inquiry.

Part of this approach was a pattern of vertical mobility above and below the surface of the earth, a program begun in the Old World and continued in the New. Just as Humboldt's eudiometric experiments in Europe had included "measurements on high mountains" and "tests on my own mines," so his ascent of nine peaks and volcanoes in the Americas was matched by his descent into the shafts of eight mining districts.[58] Between Humboldt's near ascent of Mt. Chimborazo and his first draft of the "Tableau physique des Andes" was a descent into the mines at Chimborazo's base, an ascent of the neighboring Cerro el Tablón, a return to the subterranean in Cajamarca, and a visit to the State Mining Archives in Lima, Peru, where he made the acquaintance of fellow Freiberg graduate Fürchtegott Leberecht von Nordenflycht. After drafting the "Tableau physique des Andes," Humboldt and his travel companion Aimé Bonpland boarded a ship for New Spain, where—having climbed Cerro las Navajas, descended into four mining areas, and scaled Jorullo Volcano—Humboldt drafted the geognostic profiles (see Figures 5 and 6) that later composed the *Atlas géographique et physique du royaume de la Nouvelle-Espagne*, published in 1811.[59] In Mexico City Humboldt wrote his only Spanish work, *Tablas geográfico-políticas des reino de Nueva España*, published in a text coauthored by his former Freiberg classmate Andrés Manuel del Río and "prepared for the use of the Royal School of Mines of Mexico." It was here that Humboldt first boasted of having "conceived the idea of representing entire countries as one would a mine."[60]

To be sure, Humboldt's profiles in the *Atlas géographique*, with their emphasis on mountains and comparatively massive scale, differ markedly from their Saxon predecessors. But given Humboldt's training in Freiberg and continued engagement with mining in Latin America, I want to suggest that these differences are best seen as innovations within a single visual tradition grounded in resource extraction and water management. To see "entire countries as one would a mine" meant first and foremost to visualize nature in all its verticality. But in a more subtle way it also meant appropriating a set of conventions. Compare Figures 3 and 6, Carl Friedrich Freiesleben's "Durchschnitts Riss einen Theil des Grubenbaus in Bunge-Hohebirge" ["Cross-sectional plan of part of a mine in Bunge-Hohebirge"] and Humboldt's "Tableau physique de la pente

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[57] Klein, "Prussian Mining Official Alexander von Humboldt," pp. 43, 48 (quoting Humboldt); Humboldt to Freiesleben, 20 Jan. 1794, in *Jugendbriefe*, ed. Jahn and Lange, p. 312; Humboldt to Freiesleben, 10 Sept. 1794, *ibid.*, p. 352; Humboldt to Abraham Gottlob Werner, 21 Dec. 1796, *ibid.*, p. 561; and Humboldt to Karl Maria Erenbert von Moll, 5 June 1799, *ibid.*, p. 682.

[58] Humboldt to Freiesleben, 2 Oct. 1796, in *Jugendbriefe*, ed. Jahn and Lange, pp. 529–530.

[59] The chronology assembled here is taken from a far more extensive chronology created by contributors to the Alexander-von-Humboldt-Forschung at the Berlin-Brandenburgische Akademie der Wissenschaften: http://avh.bbaw.de/chronologie/. In the *Essai* Humboldt claimed to have "sketched out the tableau for the first time in the port of Guayaquil, in February 1803": Humboldt and Bonpland, *Essay on the Geography of Plants* (cit. n. 25), p. 80.

[60] Beck, ed., "Alexander von Humboldt's 'Essay de Pasigraphie' (Mexiko 1803/04)" (cit. n. 15), pp. 35, 37. See also Rebok, *Alexander von Humboldt und Spanien im 19. Jahrhundert* (cit. n. 47), p. 167 nn 262–264.

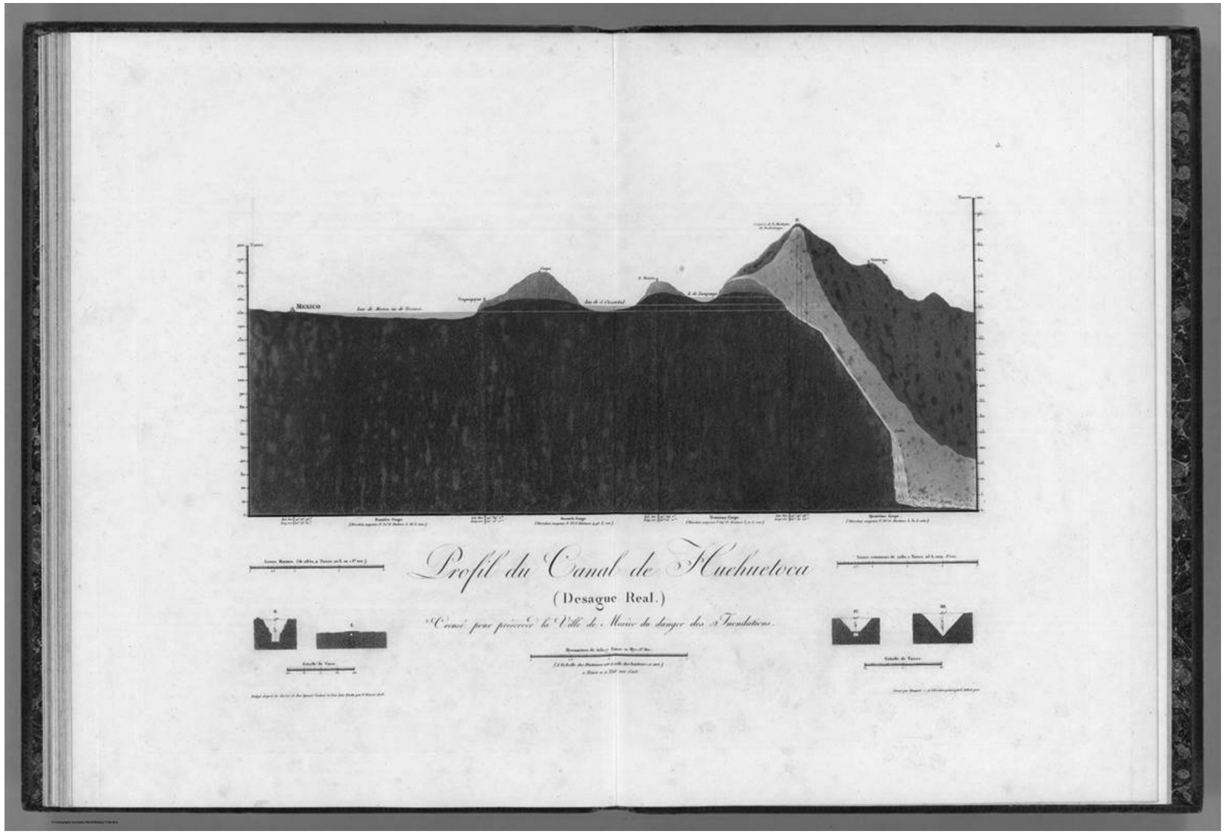

Figure 5. Humboldt's "Profile du Canal de Huehuetoca," engraved in 1808 and published in Paris in 1811 as part of the *Atlas géographique*. It contains large-scale human and natural phenomena as well as the heights of mountains. Courtesy of the David Rumsey Map Collection, www.davidrumsey.com.

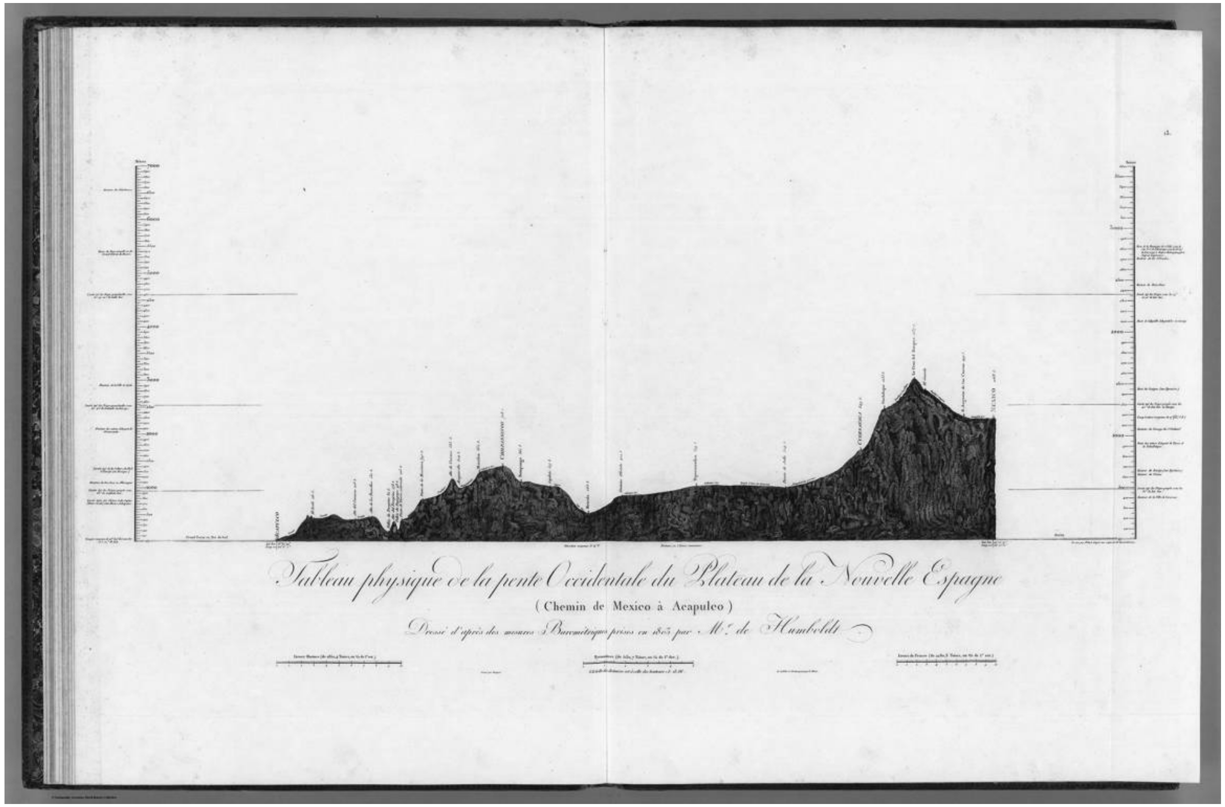

Figure 6. Humboldt's "Tableau physique de la pente Occidentale du Plateau de la Nouvelle Espagne," engraved in 1807 and published in the *Atlas géographique* in 1811. This profile is the left-most (and western-most) third of a three-part series spanning New Spain from coast to coast. Courtesy of the David Rumsey Map Collection, www.davidrumsey.com.

Occidentale du Plateau de la Nouvelle Espagne," a portion of his continent-spanning series of vertical profiles published in the *Atlas géographique*. In a simple and legible manner, the "Cross-sectional plan" shows mineshafts from a vertical perspective. And just as the "Cross-sectional plan" shows no geological layers (which Freiesleben would have called "*Gebirge*"), but simply displays the deepest extent of mines not submerged in water with a single, clear line that slants across the bottom of the page, so Humboldt's "Tableau physique . . . de la Nouvelle Espagne" reveals none of the stratigraphic content of the landforms it depicts, only their heights. Indeed, a closer look at the middle section of the three-part "Tableau physique . . . de la Nouvelle Espagne" (namely, the "Tableau du Plateau central des Montagnes du Mexique"; see Figure 7) reveals Humboldt's inclusion of the Valenciana mine in New Spain, the deepest point of which he recorded on the map's scale. Depicted in a symbolic rather than technical or *wissenschaftlich* fashion (by turn-of-the-century mining academy standards), the single mineshaft serves to indicate the relationship between mines and mountains so central to Humboldt's biography and science. Furthermore, although Humboldt claimed to have "sketched" the "Tableau physique . . . de la Nouvelle Espagne" in 1803, he also wrote that it had been "drawn" again "under my supervision" in 1804 by Rafael Davalos, "a very diligent . . . pupil of the Mining Academy in Mexico City."[61] Cartographically, Humboldt and his miner-draftsman gave a visual reality to his dictum that "nature knows no over- and underground," turning the "Cross-sectional plan" of the mine right side up, as it were.

The "Geographical-Astronomical Introduction" to Humboldt's *Political Essay on the Kingdom of New Spain* gives a detailed, if retrospective, overview of the administrative-industrial impulses behind the maps he produced "shortly before [his] departure from the Royal Mining Academy" in 1803. It also shows how mining institutions were truly central to Humboldt's cartography in this period. As in Prussia, the *sine qua non* for Humboldt's cartographic undertaking was, as Alistair Sponsel wrote of Darwin and Humboldt, his "autocratic position with respect to data created and collected by a variety of people." The Real Seminario offered him the most rigorous and far-reaching data-collecting enterprise in the land. Indeed, there is a sense in which Humboldt's *Atlas géographique* had been in the making before he ever set foot there. As Humboldt noted, the director of the Mining Academy, Don Fausto d'Elhuyar (and many other people as well), "had long been collecting information on the state of the mines of New Spain." Echoing the sociopolitical agenda of an *Oberbergmeister*, Humboldt believed this cartographic campaign "as necessary for the administration of [New Spain] as it was for an understanding of the industriousness [*Gewerbfleißes*] of its people."[62] Importantly, Humboldt understood his own project as drawing on and contributing to that of the Mining Academy there. Upon his return to Europe, moreover, Humboldt actively marketed the *Atlas géographique* and related data on Mexican silver mines to English business circles.[63] Humboldt's mapmaking in New Spain was no less tied to imperialism than his eudiometric chemistry in Prussia had been to cameralism.

When we place it alongside the *Atlas géographique*, we see that the iconic "Tableau physique des Andes" was one of many *tableaux*. Indeed, it was first drafted, in February 1803, amidst the

[61] Humboldt, *Versuch über den politischen Zustand des Königreichs Neu-Spanien* (cit. n. 47), pp. cxliii–cxliv.

[62] Alistair Sponsel, "An Amphibious Being: How Maritime Surveying Reshaped Darwin's Approach to Natural History," *Isis*, 2016, *107*:254–281, on p. 281; and Humboldt, *Versuch über den politischen Zustand des Königreichs Neu-Spanien*, p. v. The original text, published in Tübingen by the J. G. Cotta'schen Buchhandlung, actually printed "*Bewerbfleisses*" ("*Bewerb*" meaning "competition" and "*Fleiß*" meaning "diligence"), not "*Gewerbfleisses*." As other editions of this text, including the Darmstädter Ausgabe edited by Hanno Beck, print "*Gewerbfleißes*," I have chosen to translate this word.

[63] Douglas Botting, *Humboldt and the Cosmos* (London: Sphere, 1973), p. 185. After visiting Washington and Philadelphia in 1804, Humboldt promoted his Mexico works among U.S. statesmen. See Sandra Rebok, *Humboldt and Jefferson: A Transatlantic Friendship of the Enlightenment* (Charlottesville: Univ. Virginia Press, 2014); and Ingo Schwarz, "Alexander von Humboldt's Visit to Washington and Philadelphia, His Friendship with Jefferson, and His Fascination with the United States," in "Alexander von Humboldt's Natural History Legacy and Its Relevance for Today," special issue, *Northeast. Natur.*, 2001, 8:43–56.

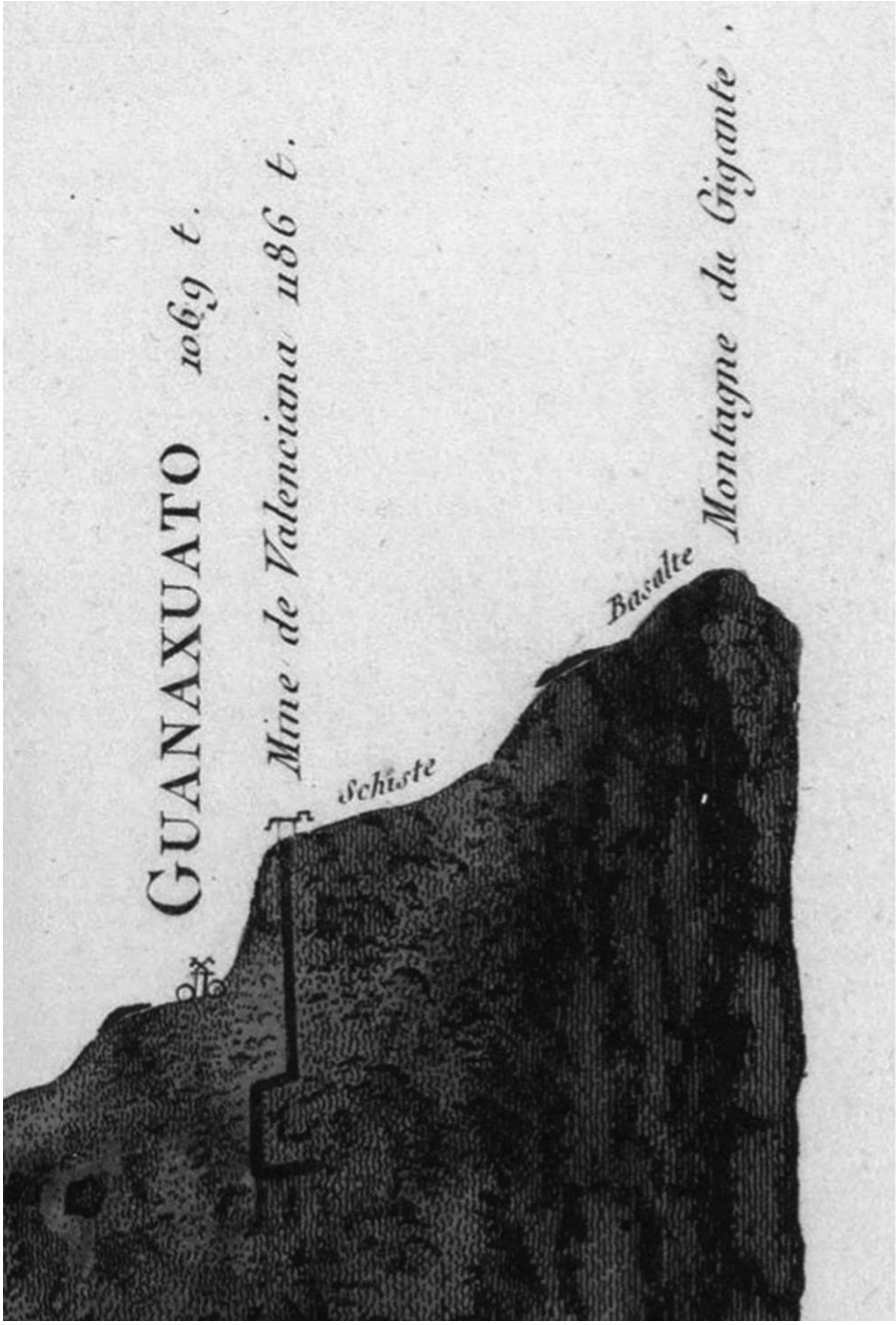

Figure 7. Detail from Humboldt's "Tableau du Plateau central des Montagnes du Mexique, entre les 19 et 21° de Latitude boréale," sketched in 1803 by Humboldt, drafted again in 1804 by Rafael Davalos, and published in the *Atlas géographique* in 1811. The "Tableau du Plateau" is the central section of the three-part series. Courtesy of the David Rumsey Map Collection, www.davidrumsey.com.

"geognostic profiles" Humboldt sketched "on the spot [in Latin America] in 1802 and 1803." Certainly, the vertical projections of La Condamine and Giraud-Soulavie are fairly regarded as important predecessors to Humboldt's "Tableau physique des Andes." But the "Tableau physique" was also, in a more immediate and embodied sense, the product of an ascent/descent rhythm of natural inquiry through which Humboldt used meteorological instruments to measure mine airs and mining methods to measure mountains. It is worth pausing here to appreciate the vertical expanse of natural phenomena captured in the "Tableau physique"—from the "Région des Plantes Souterraines" up through the continent's ten additional regions of plant life, from the wind patterns whipping off the western slope of the Andes around three thousand meters up to a dark plume of smoke signaling volcanic activity atop the "Cone du Cotopaxi." The poet Goethe, who had himself been a mining official in the Duchy of Saxe-Weimar, was so enamored of the "Tableau physique des Andes" (the German edition of which Humboldt dedicated to him in 1807) that he drafted his own "Humboldtian landscape." In Goethe's words, it brought the "Old and New Worlds into a single comparative illustration," with the Alps to one side of a great valley and the Andes to the other. Later, in 1828, when Goethe received geological maps and cross-sections from the Mining Directorate of Elberfeld, he remarked that the cartographer had "prudently continued along the von Humboldtian path."[64] Goethe was right to link maps and mobility. For Humboldt's *tableaux* were indeed representations of vertical movement, as only mountains and mines could offer.

CONCLUSION: RECOVERING HUMBOLDT'S SCIENCE FROM HUMBOLDTIAN SCIENCE

The most immediate implication of this essay is that Humboldt's science cannot be fully understood apart from the industrial context in which it first developed.[65] In 1792, while explaining the curiously green color of subterranean plants to Paul Usteri, Humboldt queried: "Where is a discovery whose seed was not already sown?" By resituating Humboldt in the national-industrial context that predated his voyage to the Americas, it becomes evident that the seeds of his own discoveries were sown in the people, practices, and places that made central Europe's dynamic mining industry possible. Upon meeting the nineteen-year-old Humboldt in 1788, the philosopher Friedrich Heinrich Jacobi described his rare "speculative genius" in a letter to Georg Forster. But if there is something like genius behind Humboldt's science, it was not so much "speculative" as it was "smelted genius [*verschmelzendes Genie*]." This is the phrase Humboldt used to describe the way in which Forster's supposedly uniquely German cultivation fused together "poesy, profound philosophy, [and] thorough erudition."[66] Humboldt's science, I have argued,

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[64] Humboldt, *Geognostical Essay on the Superposition of Rocks* (cit. n. 56), p. 177; Johann Wolfgang von Goethe, Annalen, 1807, in *Goethes Briefwechsel mit den Gebrüdern von Humboldt, 1795–1832*, ed. Franz Thomas Bratranek (Leipzig: Brockhaus, 1876), pp. 349–350; Goethe, Annalen, 1808, *ibid.*, p. 351; and Goethe to Kaspar Maria von Sternberg, 18 Jan. 1828, *ibid.*, p. 355.

[65] The history of science abounds in analogous cases. Consider Peter Galison's study of Albert Einstein and Henri Poincaré, two figures who independently developed theories of relativity, not as solitary thinkers contemplating an abstract cosmos, but as a Swiss "tinkerer" and a French "polytechnician" responding to industrial and technological concerns about clock coordination, railway schedules, telegraphy, and cartography. The Bern patent office and the Paris Bureau of Longitude were to Einstein's and Poincaré's respective theories of relativity what the mineshafts of Freiberg, Bayreuth, and Ansbach were to Humboldt, his plant geography, and his cartography. See Peter Galison, *Einstein's Clocks, Poincaré's Maps: Empires of Time* (New York: Norton, 2003), pp. 46, 38.

[66] Humboldt to Usteri, 10 Jan. 1792, in *Jugendbriefe*, ed. Jahn and Lange, p. 165; Jacobi to G. Forster, 16 Nov. 1788, in *Georg Forsters Werke: Sämtliche Schriften, Tagebücher, Briefe, Achtzehnter Band: Briefe an Forster*, ed. Siegfried Scheibe, Klaus-Georg Popp, Annrose Scheider, and Brigette Leuschner (Berlin: Akademie, 1982), p. 286; and Humboldt, *Aus meinem Leben* (cit. n. 26), p. 37.

smelted together the visual thinking of a Freiberg graduate, the economic imperatives of a Prussian *Oberbergmeister*, and the vertical mobility of both.

This argument ultimately erodes the integrity of Humboldtian Science, suggesting that the term has done more harm than good for scholars interested in understanding the actual scientific activities of its namesake. Indeed, this essay has sought to excavate Humboldt's original Prusso-Saxon science, long veiled beneath a set of familiar Anglo-American connotations. For Susan Faye Cannon, "Humboldtian" replaced "Baconian" as a term to characterize an avant-garde system of inquiry that Humboldt modeled for his Victorian followers. In 1987, Malcolm Nicholson lent breadth to the term by arguing that Humboldtian Science comprised not only quantitative, instrument-based sciences but also plant geography, which incorporated Romantic aesthetic sensibilities that Cannon had intentionally excluded from her original formulation. Another iteration came in 1992, when Michael Dettelbach suggested that Humboldtian Science had been "black-boxed" into an essentialized type that lost sight of its namesake. And so Dettelbach reexamined Humboldt's original "terrestrial physics"—its content as well as its style—"examining the notion of natural order operative" therein. Dettelbach's work revealed in Humboldt's writings and visual technologies an underlying insistence on balance, equilibrium, types, and lawfulness in nature.[67]

This essay goes a step further, suggesting a move from Humboldtian Science back to Humboldt's science. Ursula Klein—a leading figure in the historiographical tradition that seeks to situate Humboldt in cameralist states and imperialist enterprises—has argued that Humboldt's experience at the Mining Academy in Freiberg "paved the way for [Humboldtian Science]."[68] My study of Humboldt and mining arrives at a different conclusion, pointing out the inadequacy of Humboldtian Science for explaining the development of Humboldt's own practices and theories. Like Dettelbach before him, Alistair Sponsel has recently cautioned historians against the essentializing tendency of Humboldtian Science, arguing that what made Darwin appear "Humboldtian" on the *Beagle* voyage was not a style he imbibed through Humboldt's *Personal Narrative* but the way in which his approach to natural history was shaped by hydrographers' practices. Indeed, Sponsel "speculate[d] that Humboldt's training and practical work as a mining engineer played a role in generating his 'geographical sensibility' similar to the role that [he argued] hydrography played for Darwin." In this essay I have shown how Humboldt's experience as a miner generated something more specific than a general "geographical sensibility." It shaped his conceptualization of the verticality of plant distribution and endowed him with a cartographic imagination that viewed "entire countries as one would a mine."[69] Humboldt's science in the Americas did not merely resemble the work of a surveyor or mining engineer. As I have illustrated, Humboldt took himself to be extending a set of practices and a way of thinking learned in the working world of German mining to the study of vegetation and physical geography in Spanish America.

The very question of how mining shaped Humboldt's science reveals the extent to which it ought to be regarded as a collective enterprise that continued to evolve throughout his lifetime.

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[67] Cannon, *Science in Culture* (cit. n. 1), pp. 73–110; Nicholson, "Alexander von Humboldt, Humboldtian Science, and the Origins of the Study of Vegetation" (cit. n. 21); and Michael Dettelbach, "Humboldtian Science," in *Cultures of Natural History*, ed. N. Jardine, J. A. Secord, and E. C. Spary (Cambridge: Cambridge Univ. Press, 1996), pp. 287–304, on pp. 304, 288. Later, in 1999, Dettelbach demonstrated how Humboldt combined cartography and instrumentation with a "properly cultivated" observational sensibility in order to let "Nature speak its own, universal language": Dettelbach, "Face of Nature" (cit. n. 41), pp. 491, 481.

[68] Klein, "Prussian Mining Official Alexander von Humboldt" (cit. n. 6), p. 34. In this new tradition consider also Güttler, *Das Kosmoskop* (cit. n. 47); and Güttler, "Drawing the Line" (cit. n. 24).

[69] Sponsel, "Amphibious Being" (cit. n. 62), pp. 262 (for the quotation see n. 17), 281; and Beck, ed., "Alexander von Humboldt's 'Essay de Pasigraphie' (Mexiko 1803/04)" (cit. n. 15), p. 37 (quoting Humboldt).

Humboldt himself recognized the enormous influence of Johann Reinhold Forster in his "Forsterian project"; he acknowledged the way in which Werner's courses at Freiberg and "instructions [to] go daily into various mines" shaped his thought and practice; and he attributed his earliest vertical science to Deluc, Saussure, and Lichtenberg. Scaling out, it is also clear that the economic ambitions of cameralist states and the raw circumstances of late eighteenth-century resource extraction were equally powerful factors in shaping what historians have come to call "Humboldtian." In striking out for the New World, furthermore, Humboldt followed a path blazed by earlier mining officials who radiated out from Freiberg to Latin America. When he returned, Goethe would call Humboldt "our conqueror of the world," and the reading public would hail him as "the *second* Columbus."[70] But in 1799 Humboldt was one of many Freiberg graduates to pursue sciences in Latin America—an individual participant in that remarkable migration of young men to and from Freiberg captured in Rachel Laudan's apt phrase "the Wernerian radiation." In Lima, as noted above, Humboldt met Nordenflycht, who had helped found the Peruvian Mining School after the Freiberg model under which he was trained. And at the Mining Academy in Mexico City Humboldt conducted experiments alongside his Freiberg classmate Andrés Manuel del Río, one of four Latin America–based members of the Saxon Societät der Bergbaukundige. Thus, while I am critical of the argument that Humboldt "could not have failed" to be impressed by local traditions that viewed "the Andes as a microcosmic space for testing theories of biodistribution," I at the same time see my argument about the influence of industrial interests on Humboldt's science as being in concert with the decentering impulse of postcolonial scholars like Jorge Cañizares-Esguerra and Mary Louise Pratt.[71] My contribution to a history of Humboldt *from below* has been more literal, and it has focused on cameralism where others have emphasized imperialism.

Humboldt himself was well aware—even proud—of his debt to mining, and he knew that his debt would outlive his career. In 1794 he told Carl Freiesleben that "in order to pursue higher scientific plans" he must "leave the Mining Department [*Dienst*]." This would seem to suggest that his quitting the Mining Department and lighting out for South America marked the beginning of an unencumbered pursuit of science. Yet in the following lines Humboldt explained 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 [*wesentliche Dienste*], services which will endure for posterity."[72] For Humboldt, being a miner *was* pursuing higher scientific plans. Writing in the spirit of the underground Enlightenment, with its fervor for practical knowledge and public utility, Humboldt determined to leave one service for another, using the German word "*Dienst*" while referring to both the Prussian Mining Department and the enterprise of science. Through both *Dienste*, moreover, he would remain a *Bergmann*, a miner. And insofar as regular vertical mobility and the application of mining methods to mountainous landscapes lay at the very core of Humboldt's science in the Americas, there is indeed an important sense in which his career as a miner never ended at all.

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[70] Humboldt to Karsten, 26 Nov. 1791, in *Jugendbriefe*, ed. Jahn and Lange, pp. 160–161; Blackbourn, "Germany and the Birth of the Modern World" (cit. n. 14) (quoting Goethe), p. 13; and Walls, *Passage to Cosmos* (cit. n. 4), p. 13.

[71] Laudan, *From Mineralogy to Geology* (cit. n. 51), pp. 102–105, 178–179; F. W. H. v. Trebra, *Bergbaukunde*, Vol. 1 (Leipzig: Georg Joachim Goeschen, 1789), pp. 405–408; Cañizares-Esguerra, "How Derivative Was Humboldt?" (cit. n. 36), p. 152; and Mary Louise Pratt, "Alexander von Humboldt and the Reinvention of América," in *Imperial Eyes: Travel Writing and Transculturation* (New York: Routledge, 1992), pp. 109–140.

[72] Humboldt to Freiesleben, 21 Nov. 1794, in *Jugendbriefe*, ed. Jahn and Lange, p. 378. Klein concluded that this letter "is not easy to interpret for those historians who argue that Humboldt saw a fundamental contradiction between his activity as a mining official and his scientific inquiries": Klein, "Prussian Mining Official Alexander von Humboldt" (cit. n. 6), p. 49. Klein is right to be critical of such arguments. In this essay I have tried to show why.