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Temporal Poetics of Planetary Transformations

Alexander von Humboldt and the Geo-anthropological History of the Americas

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> As a historian of America, I wanted to clarify facts and specify ideas by means of comparisons and statistical data.
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> —Alexander von Humboldt, *Political Essay on the Island of Cuba*

While Earth System Science has created a more holistic view of the interconnection of all the aspects of our ecological crisis, it seems that particularly humanistic knowledge is still largely missing from the equation.[1] The truly integrative connecting of the human and natural sciences largely remains to be done, and an important obstacle is arguably the prevailing will, within academia and beyond, to keep these large disciplinary cultures separate (interdisciplinarity has been implemented to a relatively large extent within the disciplines of the humanities, but less so between the humanities and the natural sciences).[2] This divide emerged in the second half of the nineteenth century, and was reinforced with C. P. Snow's notion of two irreconcilable cultures in the 1960s, and many attempts have been made to overcome the divide in the past decades.[3] This inability to integrate epistemic cultures has been gaining more attention over the past decade, notably with regards to history and geology.[4]

How does this great epistemic divide relate to the current status quo paralysis and lack of proper response to the eco crisis, in spite of the massive scientific knowledge amassed and presented over the past fifty years? One possible answer is that scientific reductionism and specialization bears responsibility on an epistemic level.[5] According to this hypothesis, the ever increased specialization of the natural sciences led to an obscuring of the planetary dimension of the imminent threat, which was made worse by the fact that

many of the consequences are effects of feedback loops between the earth's systems, so that that the instability of one inevitably destabilizes another. The same tendency applies to world history, where smaller and smaller units of specialization prohibited a view over longer timespans.[6]

Against this background, this chapter revisits the geological work of Alexander von Humboldt (1769–1859), who saw it as his mission to develop a holistic and global understanding of life on earth. Despite being world famous and hailed as a leading scientist at his death in 1859, Humboldt fell into oblivion soon thereafter and it would take until the turn of the twentieth century until his reappraisal could begin. This is likely due to the tradition of scientific reductionism and specialization that have viewed synthetic scientists like Humboldt with great suspicion. The same scientific qualities that made him incomprehensible then are now driving the reappraisal of him as a founder of Earth System Science.[7] Given the importance of Humboldt and later integrative scientists like James Lovelock for a unified perspective on the earth's atmosphere, hydrosphere, cryosphere, and biosphere, it is relevant to also combine this perspective with the more humanistically oriented aspects of Humboldt's thought and see these not as curiously different but rather integrated with and defining for his hypothesis about the global environment.

At the time of writing in 2019, Humboldt's 250th birthday is celebrated with a new interest in his work resulting in symposia, publications, and translations. Most scholars have focused on his understanding of space and the ecological connections between different places on earth, but hardly anything has been said about his work on history and geology, even though they were arguably core parts of his scientific project. It is particularly visible in his work on the natural and cultural history of the Americas, which was the subject of a major debate of the time. In this chapter I will discuss Humboldt's work on the entwined human and geological temporality of the Americas and his interdisciplinary methods moving from poetry to geology in a geo-anthropological poetics of the planetary. The term "geo-anthropology" goes back to the era of Humboldt but has not been current since the nineteenth century. Now the concept is being revived as a way to integrate geology, environment, and human sciences to understand the conditions of living in the Anthropocene. Jürgen Renn has proposed geo-anthropology as an emergent transdisciplinary research field of human-earth interaction, which is meant to be truly integrative of human and natural sciences and provide a common theoretical framework. The aim of this framework is to enable the address of multiple scales from micro- to macrospheres as well as various temporalities of deep time, history, present, and future.[8]

In the following, I focus on how Humboldt historicizes the American continent and responds to the debate about the geological age of the so-called New World that had started with propositions by Comte de Buffon towards

the end of the eighteenth century about American environmental degeneracy.[9] While Humboldt's embryotic understanding of climate change in the early nineteenth century is now widely acknowledged, my focus is on how the conflation of geological time, natural history, and human history, as well as environmental and social sciences enabled him to grasp global change in a unified vision of planet earth and its history. An essential point of departure is that change is always the effect of time, and that the way changes in climate, ocean, biosphere, and geology are currently understood still suffer from the lack of integration between human and nonhuman timescales.[10] In this way, change in world history and geology follow the same rules. We try to find a marker of transition between periods in order to make sense of large chunks of time. As the Anthropocene has become an important historiographical concept in addition to being a geological epoch, and since it is defined by the mark of man, it offers an interesting case of conflation of human and geological timescales. The work of establishing the Anthropocene as a geologic unit requires the identification of a Global Stratotype Section and Point (GSSP). All geological temporal subsections require a GSSP to mark the transition from one stratigraphic layer to another, but the case of the Anthropocene challenges our preconceptions because we need to find a geological signal of human impact that is global. That is, we need to combine a sensible interpretation of global history with a nuanced view of geological transitions. The two strongest candidates for a GSSP for the Anthropocene are probably the so-called Bomb Spike of 1952 that uses the signal from nuclear bomb testing and the Orbis Spike of 1611, which finds its signal in a marked dip in global CO_2 preserved in two Antarctic ice core cylinders. This decline in CO_2 has been demonstrated to be due to the rapid depopulation and mass death of about sixty-five million humans in the Americas, whose farmland was therefore abandoned and allow to rewild, resulting in a quick CO_2 uptake.[11] Depending on which GSSP is chosen, we get different conceptions of the Anthropocene—one associated with World War II and the onset of the Great Acceleration and one connected to Early Modern globalization and colonialism. This issue, which currently occupies many minds of academia, seem to me to resonate with Humboldt's work on defining geological and environmental changes as global, and his historicizing of the Americas as both world and geological history as a form of geo-anthropology. How did Humboldt historicize the Americas on various timescales to relate the New World to a sense of global time? What was the role of geology in Humboldt's integrative cosmographic vision as he presented it in *Views of Nature* (1809)? How did he integrate knowledge across human and natural sciences?

This chapter sets out to test the hypothesis that Humboldt, as a polymath and global thinker working just before the great epistemic divide and then largely in the shadows until recently, offers an interesting example of the

integrative thinking that is needed today to tackle the challenges of dealing with climate change, mass extinction, and living in the Anthropocene as exemplified in the concept of geo-anthropology. For the purpose of delineation, I will focus on Humboldt's *Views of Nature* (1809) and supplement it with material from his *Geognostical Essay on the Superposition of Rocks in Both Hemispheres* (1822).

Geological Time and the New World

Which place did time and temporality occupy in the work of Humboldt? Trained as a mining inspector in Freiburg, and later a student with the leading geologist Abraham Werner, Humboldt was always interested in relating the earth's deep time with that of human history. Like his fellow students, Humboldt initially subscribed to Werner's then dominant theory of Neptunism—the idea that all solid rock formation originated in a vast super ocean—but later switched to Volcanism (plutonism) and Uniformitarianism after having studied the volcanoes of the Americas and compared them to those found in Italy. Together with the geologist Leopold von Buch who had also been a student of Werner, Humboldt embarked on an expedition to Italy where they witnessed an eruption of Vesuvius, which changed their view of geology. Humboldt had already seen the power of the internal forces of the earth at work in the Quito earthquake in 1802. Volcanoes became key for his understanding of the formation of the earth and he noted that they were often formed along straight lines rather than randomly and often close to the oceans, an observation that prefigured the discovery of plate tectonics in the shaping of the earth.[12]

Humboldt and von Buch developed the principles of stratigraphic layering—which they called formations—in a way that is foundational to our current geological columns of globally valid systems like Jurassic or Cambrian corresponding to relative timescale periods with the same name.[13] The chronostratigraphic term Jurassic is derived from the fossil-bearing Jura mountains in Switzerland, which Humboldt was the first to recognize as a separate stratigraphic formation in 1795 and published a paper on in 1799. The stratigraphical position of Jura limestone named by Humboldt was then used as the basis in von Buch's definition of the still valid three part Jurassic system of *lias*, *dogger*, and *malm* in Lower, Middle, and Upper Jurassic stratigraphic formation corresponding to Early, Middle, and Later Jurassic epochs of geological time.

Geology—or geognosy as Humboldt and many Germans preferred to call it—was at the heart of Humboldt's scientific journey to the Americas and his global worldview. The rise of this field of study and the efforts to determine the

history of the earth would over the course of the nineteenth century lead to a split and strict separation between the two temporal regimes of world history on the one hand and geological history of the planet on the other. Although this tendency was already apparent in the mid-nineteenth century, Humboldt was a strong advocate of unity in knowledge both with regards to space in geographic positioning and with regard to time as he saw the entanglement of the earth's history and the history of man, particularly in the Americas. Moreover, he insisted on the feedback between systems, such as how geological formations of deep time shaped botanical green-layering, which in turn corresponded to and shaped climate zones, all of which affected and were affected by human endeavors like farming and deforestation.

Around the time of Humboldt's voyage to America there raged a debate in Europe on the epistemic status of the New World. Several well respected scholars insisted on the inferiority and degenerative nature of humans and animals in the Americas, for which they gave an environmental explanation in insisting that it was the undeveloped nature of the environment there that led humans and animals to be smaller and less productive. Interestingly, the debate was consistently cast as an entwinement of human history, natural history, and earth history. Comte de Buffon was the first to insist on this difference between the animals of the old world and the new and was followed by Cornelius de Pauw who became the main and most aggressive propagator of Buffon's notion that the New World was also new in a geological sense and had emerged from the world ocean at a much later time than the old.[14] Particularly, Buffon and de Pauw linked this geological newness to the relative humidity and dampness, which favored only cold-blooded animals like crocodiles and snakes in their view. Since they departed from the Neptunist view that all solid land had once been formed at the bottom of an ocean and then emerged, the humidity they associated with the American continent was explained by the continent's more recent formation as land. However, Buffon also expressed the view that the American continent would never reach the mature point of the European:

> In this state of abandonment, everything languishes, decays, stifles. The air and the earth, weighed down by the moist and poisonous vapors, cannot purify themselves nor profit from the influence of the star of life. The sun vainly pours down its liveliest rays on this cold mass, which is incapable of responding to its warmth; it will never produce anything but humid creatures, plants, reptiles, and insects; and cold men and feeble animals are all that it will ever nurture.[15]

Humboldt was one of the few European opponents to Buffon's widespread theory, which coincided with a peak in European interest in the Americas. Humboldt, who could speak from the vantage point of firsthand empirical

observations of the geological makeup of the new continent deemed these views unphilosophical and contrary to the laws of physics. That Buffon, G. W. F. Hegel, de Pauw, and others were wrong about both the geological and the world historical age of the Americas could be proved with reference to the monuments of the Indigenous people and the many volcanoes that that he had studied up close.[16]

Geo-anthropology and Integrative Views of Nature

In *Views of Nature* (1808) Humboldt wanted to convey the aesthetic pleasure of scientifically understanding the interconnected forces of nature in a combination of literary style and knowledge advancement. Apparently, such a project—which we would now recognize as transdisciplinary—resonated with the taste of the wider audience as it became his best known and most influential work as well as his own favorite; it was soon translated into English, Spanish, and French from the original German. This approach gave Humboldt the opportunity to counter notions of the geological youth of the Americas put forward by Buffon. By the time of the first publication of *Views of Nature* in 1808, these ideas had become rather widespread and championed by de Pauw. Humboldt used his accessible prose to act as a debunker of geological myths:

> If one side of our planet is thus said to be more humid than the other, then the observation of the present state of things is sufficient to solve this problem of inequality. The physical scientist need not wrap the explanation of such natural phenomena in the garb of geologic myths. It is not necessary to assume that the destructive battle of the elements upon the ancient Earth was settled at different times in the Eastern and Western Hemispheres, or that America emerged from the chaotic covering of water later than the other parts of the world, as a swampy island, home to alligators and snakes.[17]

This paragraph is a direct response to the geological foundation of Buffon's theory of American degeneracy, which stated that the humidity and swampiness of the continent favored only cold-blooded animals and was due to it being in a different geological epoch than the European continent. As the *Views of Nature* was meant to be read in an aesthetically pleasing manner without compromising the scientific basis of the knowledge conveyed, Humboldt used his footnotes in an exemplary manner. Often, the most interesting discussions are found in these notes that spawn several pages. They create a sense of horizontal and vertical motion in the essays, which are held together with a single thematic focus like "Concerning the Steppes and Deserts." As the narrative progresses horizontally through an overarching focus where the theme is connected on a global scale, the footnotes allow for vertical dives deeper into

the wells of the underlying science. While Humboldt did not name the propagators of the new world degeneracy theory in this essay, he used a footnote to develop the counterargument and explain the global nature of geological time.

> All too often, generally praiseworthy authors have repeated that America is, in every sense of the word, a new continent. The luxuriance of the vegetation, the enormous amounts of flowing water, the disquiet of mighty volcanoes announce (so they say) that the continually quaking, as not yet dried out Earth is closer to the chaotic, primordial state than it is in the Old continent. Such ideas, long before the beginning of my trip, seemed to me to be as unphilosophical as they were at variance with generally accepted physical laws. Fanciful images of youth and unrest, of increasing dryness and inertia of the ageing Earth can arise only among those who easily snatch up contrasts between the two hemispheres without making the effort to comprehend in a general way the construction of the planet. Should one presume that southern Italy is newer than its northern regions because it is almost continuously shaken by earthquakes and volcanic eruptions?

In this quote, Humboldt counters Buffon's and de Pauw's notions of more recent American geochronology as unphilosophical and at odds with the laws of physics. He observes the mistake made by these authors and their followers in assuming a connection between geology and climate without any scientific basis. It is interesting to see that the failure of Buffon and de Pauw comes down to their lack of effort to understand local geophysical phenomena in relation to *the construction of the planet*. It is striking how Humboldt's analysis of temporality constantly falls back on a planetary perspective, just like his geographical insights. As he made these points, he had just established the connection between geology and climate in *the Geography of Plants* (1807) with the iconic profile view of vegetation zones of Chimborazo. But the connection he established between the climate, vegetation zones, and geological makeup was instead based on the observation that as mountains are elevated geologically they push through the atmosphere and change the barometric pressure and temperature of the vegetation zone, which in turn picks up meteorological patterns circulating the planet. An isolated phenomenon like a volcano could not be explained geologically without connecting it to deep time and planetary logics of magma flows. His sarcastic comparison with the Italian volcanoes and the geological age of the region makes this point a rather poignant critique.

Humboldt continues his discussion about the geochronology of the American continent by conflating volcanic eruptions as events of world history with the transformations in geological time. "Moreover, what trivial phenomena are our current volcanoes and earthquakes in comparison to the revolutions of Nature that the geognost must postulate when pondering the chaotic conditions of the earth at the lifting, the solidification, and the

fracturing of the mountain masses?"[18] In this temporalization of the entangled timescales of world history and geochronology, Humboldt posits the geological live of volcanic eruptions and earthquakes in relation to the geological time of the slow formation of the earth's crust.[19] They are not posed as separate, but rather the scale of deep time (which in Humboldt's time was considerably shorter, or more shallow, amounting to about seventy-five thousand years, compared to the 4.5 billion years we count today) puts the human experience of an individual phenomenon into perspective, which serves the argument in pointing out the mistake in drawing a conclusion of the formation of continents based on singular volcanic eruptions.

In 1803 Humboldt had witnessed the eruption of the young volcano of Jorullo—formed only in 1759—and was the first to ascend the still active volcano with his companion Aimé Bonpland. This volcano became an exemplary model for earth science and earth history in Humboldt's work, as he was able to form a very personal experience-based relationship to it.[20] In this effort to reliably historicize the earth at this time, Humboldt was far from alone. Rather, as Martin Rudwick has demonstrated, the period coinciding with Humboldt's scientific career and the revolutions in Europe gave birth to the conceptual framework of geochronology, in which earth came to be understood as having its own deep history, in which humans were but a recent inhabitant.[21] Still, these synchronistic efforts of merging human and geogical time by Humboldt, his colleague Leopold von Buch, Georges Cuvier, and others have been largely overshadowed by the dominant narrative of linear and teleological historicism.[22] But these shadows are also due to the great epistemic divide that emerged just after this period.[23]

Continuing his argument, Humboldt offers a more solid explanation of the strong volcanic activity of the American continent. "In the new continent, the volcanoes continue to burn longer because the high mountain combs, upon which they burst forth in rows following long faults, are closer to the ocean, and because with few exceptions this proximity, in a way that has yet to be explained, seems to modify the energy of the subterranean fire. Also, the activity of earthquakes and fire-spewing mountains is periodical."[24] Humboldt thus notes that the volcanoes in the Americas are placed in straight rows close to the ocean, which increases the intensity of magma flows in a way that "has yet to be explained." Indeed, the discovery of plate tectonics a century later would explain that these meeting points of continental plates are weak zones where subduction and melting rocks feed explosive volcanism, like in the Andes where the South American plate meets the Nazca plate.[25]

> Now physical unrest and political calm prevail in the New continent, while in the old, the devastating conflicts of the people disturb the enjoyment of

> a Nature at peace. Perhaps times will come when, in this curious conflict between the physical and moral powers, one part of the world will take over the role of the other. Volcanoes rest for centuries before they erupt anew; the idea that in the older country a certain peace in Nature must prevail is based on a mere flight of our imagination. No reason exists to presume that an entire side of our planet is older or newer than the other. . . . Also, the order and identity of the sedimentary layers, like the organic remains of prehistoric plants and animals contained within them, show that many great geological depositions occurred almost simultaneously over the entire surface of the Earth.[26]

In this passage, the tradition of a nontemporal nature is dismissed as fantasy and the earth is cast as having a history of its own, in which continents and mountains formed in deep time are related and humans are understood to be recent inhabitants. The conflation of timescales connects human revolutions with geological unrest and Humboldt eloquently contrasts the recent American independence against the eruptions of volcanoes and earthquakes while noting a converse situation in Europe where Napoleonic wars and revolutions rage while geological action is relatively sparse and limited to Etna and Vesuvius. This, he reminds his readers, may change soon enough as volcanic cycles of eruption happen over centuries, and the nature of the European continent is as much a part of earth's longer history as the American. The scientific basis for his claims is presented with reference to the fossils found in sedimentary layers on both continents, which again temporalizes a global geological history.

The geological myths Humboldt set out to debunk supposed a connection between humans, animals, climate, and geology that imagined that the humidity of the climate and the activity of volcanoes resulted from the fact that the Western hemisphere was still in the process of formation while the old world had dried up and calmed down. These Eurocentric notions of natural history and geology were of course mirrored by notions of Western superiority in terms of taming nature in agricultural practice.[27] Humboldt could not have known that the Neolithic revolution, which until the end of the twentieth century was still generally held to have occurred first in the European continent and then much later in the Americas, would also be proven to have been global and occurred simultaneously in the Americas and northern Africa about ten thousand years ago. There is no consensus on a single explanation for why the transition from hunter-gatherer to farming happened, but taken together the more accepted theories suggests global environmental conditions on the planet played the major role, much in line with Humboldt's planetary vision of human environmental history. The end of the Pleistocene and beginning of the Holocene saw environmental change globally in the form of climate change, creating warmer, wetter, and more humid air with a higher

concentration of carbon dioxide as the ice sheets began melting away, which favored growing processes. These new climatic conditions twelve thousand years ago also led to a rapid relative population growth, causing a food crisis, which led humans to look for new sources of nourishment. An ecological theory holds that the extinction of so called megaherbivores, like mammoths, opened a large niche, which was filled by humans.[28]

In the essay "Concerning the structure and action of volcanoes" in *Views of Nature*, Humboldt comes back to his globalizing argument about geology. While Buffon had characterized the earth's history as Epochs and defined humans within deep time in a manner that prefigures the concept of the Anthropocene, he was clearly not able to grasp this history as planetary in the manner required for a GSSP, since he insisted that the Western hemisphere had formed its continents at a much later stage.[29] This other aspect of the intellectual history of the Anthropocene finds its formulation in Humboldt's global geology:

> The same sorts of stone, seeming to attract and repel one another in groups, occur in both hemispheres from the equator to the poles . . . This reveals rather a consistency in the constituent minerals, the stratification of various masses, and their periodic reappearance, which excites the wonderment of the geognost. In the Andes chain, as in the central range of Europe, one formation seems to some degree to call forth another . . . Thus, every mountainous region of considerable extent reflects, with greater or lesser clarity, the entire inorganic world; yet to recognize completely the important phenomena of the composition, the relative age, and the emergence of various types of rock, observations from the most disparate regions of the planet must be compared to one another. If the distant zones, as has often been noted, present to us no new types of rock, i.e., no unknown combinations of basic materials, then they teach us rather how to unmask the great laws that are the same everywhere, the laws by which the layers of the Earth's crust alternately support one another, break apart into channels, or are lifted by elastic forces.[30]

The consistency of the order of stratigraphic layering is taken as a point of departure for a global understanding of geology. Humboldt rightly insists that to gain better insight into geochronology, stratigraphic layering must be compared across the globe to find not just the common geochemical principles of rock formation but also the deposits of organic remains in each layer. This is precisely what the GSSP does today as biostratigraphic definitions based on the emergence or disappearance of specific life-forms across the globe are used as beginnings and ends of time units like epochs and eras.[31] Since 1977, the International Union of Geological Sciences (IUGS) has tasked the scientific body of the International Commission on Stratigraphy (ICS) with preparing and suggesting GSSPs for all geological stages. The GSSP fixes the lower boundary of the stage and the upper boundary is defined by the lower

boundary of the overlying stage. Most of the GSSPs have at least one marker and use the top or bottom range of a fossil species, but multiple markers are understood to improve a GSSP.[32] An essential criterion for a GSSP is "global correlation" of the stage boundary, meaning that the identified marker is compared in sections in different areas and preferably on different continents. This complex process is also the basis for the current debate around the formal adoption of the Anthropocene, as discussed above, for which the end of the Holocene will be defined by a global human marker, where the ICS currently favors the radiographic signal of the atom bomb. From this perspective, Humboldt's geochronological endeavors appear highly relevant today. By arguing from a standpoint where human and natural sciences were not separated, he was not an eccentric exception but rather someone who pushed a general tendency of geochronology further in the first half of the nineteenth century. As Rudwick explains, "ideas, concepts, and methods for analyzing evidence and for reconstructing the past were deliberately and explicitly transposed from the human world into the world of nature, often with telling use of the metaphors of nature's documents and archives, coins and monuments, annals and chronologies."[33] He further explains that those who were most prone to pursue the idea of the earth having its own history were those who already had a profound historical perspective, not only on world history but also of the place of the human in cosmos as a part of an unrepeated sequence of contingent events. It was thus on the basis of a planetary perspective of searching for interconnections and comparing phenomena across the globe that Humboldt comes to see a global geochronology with regards to the formation and composition of strata. It was not a coincidence that he named his final integrative and synthetizing five-volume magnum opus *Kosmos* (1845).

Globalizing Deep Time

After his return from the five-year expedition to the Americas, Humboldt settled in Paris, the capital of science at the time, and worked on transforming all the scientific insights of his travels into publications. He was prolific, and published numerous works across disciplines during the first decades of the nineteenth century. In 1823, his major contribution to geology was published as *Geognostical Essay on the Superpostion of Rocks In Both Hemispheres*. This book had first been printed as a very long article in the *Diccionaire d'histoire naturelle* published 1822 in Paris by professors of the Museum of Natural History and then reprinted as a stand-alone book, which was immediately translated into English and German. Humboldt had been working on the manuscript for some time and already in 1814, when he shared the manuscript with his English colleague Georges Bellas Greenough, he expressed

that understanding the stratification of rocks and the identity of formations had been the goal of all his fieldwork since the end of the eighteenth century. While this book today is largely forgotten and overlooked in Humboldt's vast scientific œuvre, it was one of the most important geological works of its time.[34]

Among the many highlights of this book, is his early notation of how the Atlantic coasts of West Africa and South America fit together like a jigsaw puzzle and must have at some point in deep time been joined together. He presented the idea that the Atlantic Ocean has the features of a great valley formed as the two continents must have been ripped apart. The coasts of Brazil find their counterpart in the Gulf of Guinea while the shores of Mexico seem to fit with coastal formations on the corresponding latitude, which leads him to the idea that these corresponding land masses must once have been one. In pointing out these geohistorical circumstances Humboldt again prefigures the modern theory of continental drift, which explains how the world's last supercontinent Gondwana fell apart 130 million years ago and formed the American and African continents.[35] As in the cases discussed above, it is by constantly connecting and comparing geochronological phenomena on a global scale and refusing the emerging specialization that he is able to make these assessments. Instead of trying to dig deeper into one narrow field of science, Humboldt constantly tries to put his insights into relation with other knowledge. In his method, he shows that even if we can enrich science by increasing detailed analysis of a delineated area, if we fail to connect it to a larger picture much of the insight will be lost. Analyzing relationships is thus not mere "contextualizing," but rather an integral part of the knowledge itself. The idea that one can isolate a scientific fact from other related but potentially distracting facts is refuted by Humboldt and resonates with the challenge we face today as historians of nature and culture.

In his analysis of the geological makeup of the Americas and the volcanoes of the Andes and Mexico, Humboldt came to view volcanoes not as isolated phenomenon, which was the prevailing position among many scholars, but as eruptions of subterranean lava connected as a bed under the crust of the planet and springing forth in the weaker areas. In doing so, he connected the world history of the Americas with the geological timescale.

> These lines of volcanoes, these upheavings across continued rents, these subterraneous noises which are heard in the midst of a district of schist and transition porphyry, connect, in our imaginations, the still active forces of the New World, with those which in the most remote times heaved up chains of mountains, fractured the surface, and made fountains of liquefied matter (lavas) gush out amidst strata more anciently consolidated. Even in our days this liquefied matter does not constantly issue from the same openings in

> the orifice of a mountain (crater at the summit of a volcano) or its shattered flank; the earth sometimes (Iceland, table-land of Quito) opens in the plains, from whence currents of lava issue, overflow, cross, and cover each other; or small cones of a muddy substance (moya de Pelileo de Riobamba viejo, February 4, 1797) which seems to have been a trachyte-pumice, and which, being combustible and staining the fingers black, is mixed with the carburet of hydrogen. The rocks which we are accustomed to arrange together under the name of substances of volcanic formation exclusively, have been hitherto more considered as to the oryctognostic and chemical relations of their composition, or those of their origin, than according to the geognostic connection of their position and their relative age. At every epocha, since the first oxidation of the crust of the globe, the fire of volcanoes has acted across the rocks of the intermediary, secondary, and tertiary formations. With the exception of some freshwater rocks, volcanic rocks alone continue to be formed in modern times. If the lavas of the same volcanoes (the intermitting springs of liquefied matter) vary at different epochas in their eruptions, it may well be conceived that volcanic matter, which during thousands of years has been progressively raised towards the surface of our planet in such different circumstances of mixture, pressure, and cooling, must display both contrasts and analogies.[36]

Here Humboldt paints a vivid portrait of what has recently been termed geosocial formations, the staging ground for encounters between earth science and social science playing on the dual meaning of formations in both fields as the outcome of dynamic spatio-temporal processes.[37] The lines of volcanoes seen in the Americas are felt to connect humans with the forces of formation from deep time. The making of rocks and mountains come vividly to life in Humboldt's account and he observes that the crust can spring open in less dramatic places than volcanoes too. He engages with the combustible substances of carbon and hydrogen, noting their black coloring effect. His main point however, is that these igneous rock formations continue and connect his present moment with the deep time of stratigraphic layers and suggest the need for deeper engagement with these processes. As an interesting point of comparison, Humboldt's contemporary and compatriot Hegel, who followed Buffon and de Pauw in propagating the theory of New World degeneracy, declared in 1817 that geological processes belonged to the distant past and was now superseded by human development and having no philosophical significance whatsoever. Reading "philosophical" as "social" or "political" as Hegel intended, Nigel Clark and Kathryn Yusoff suggest this position sums up the role ascribed to geophysical processes in mainstream social thought over the last two centuries, a position now looking rather shaky.[38] It is telling that while Humboldt has spent most of this time in the shadows, dismissed as an eccentric and uncontrolled thinker, Hegel has been hailed as the greatest philosopher of the modern era.

Cultural Techniques of Conveying Deep Time

In the *Geognostical Essay* from 1823 Humboldt also first presented the visual sign system called pasigraphy that he had invented in Mexico for the purpose of geological education in the national school of mining and metallurgy. The name pasigraphy stems from the Greek words *pasi* (everything) and *graphe* (writing), and the word was used by philosophers like G. W. Leibniz and René Descartes to express dreams of a universal language. In Humboldt's version however, it was the universality of mathematics that inspired him and the idea was that these signs would be universally recognizable and transcend linguistic borders. It was first published in Spanish in 1805 as an appendix to the first American book on fossils and mineralogy by the Mexican geologist Andrés del Rio, an old friend of Humboldt's from Werner's Freiburg school and who was also principal of the school of mining. Apart from the narrative technique of conveying deep time discussed so far in this text, a cultural technique of visual depiction of geological matters was developing around this time.

In the 1805 Spanish text *Introducción a la Pasigrafía Geólogica*, Humboldt explains that he has invented a sign system for geological charts so that the public can easily take part in the new insights about the earth. His rationale for inventing this time-binding technique is clearly oriented towards media and perception, as he discusses the difficulty of remembering the verbal description of a stratigraphic layering even from the best geological text. The visual system is meant to immediately convey to the reader the immense scale of geological layering in a chart, and being sign-based meant it could also be used algebraically as a quote in a verbal text. The complex structure of geological formations and the understanding of their relation to deep time in terms of the age of each stratum would be improved, Humboldt explains, if one could quickly assess the layers and then compare them with others in the next chart of an atlas.

This insight was crucial for the development of geology, and while Humboldt developed these ideas in Mexico in working with Andrés del Rio in 1804, the English canal builder William Smith had similar ideas while mapping British coal mines. Like Humboldt, he had noticed how rocks and fossils repeated themselves in a predictable manner. Smith developed a coloring pattern for his geological map, giving each type of strata a particular color.[39] Smith's map (Figure 7.1) was the first of its kind and would have a huge impact on the development of geology in general, and cultural techniques of representing deep time in particular.[40] The coloring code of rock layers was represented in a stratigraphic table published alongside the map.[41] The technique would be deployed in most geological maps and became standard first in England and later throughout Europe.

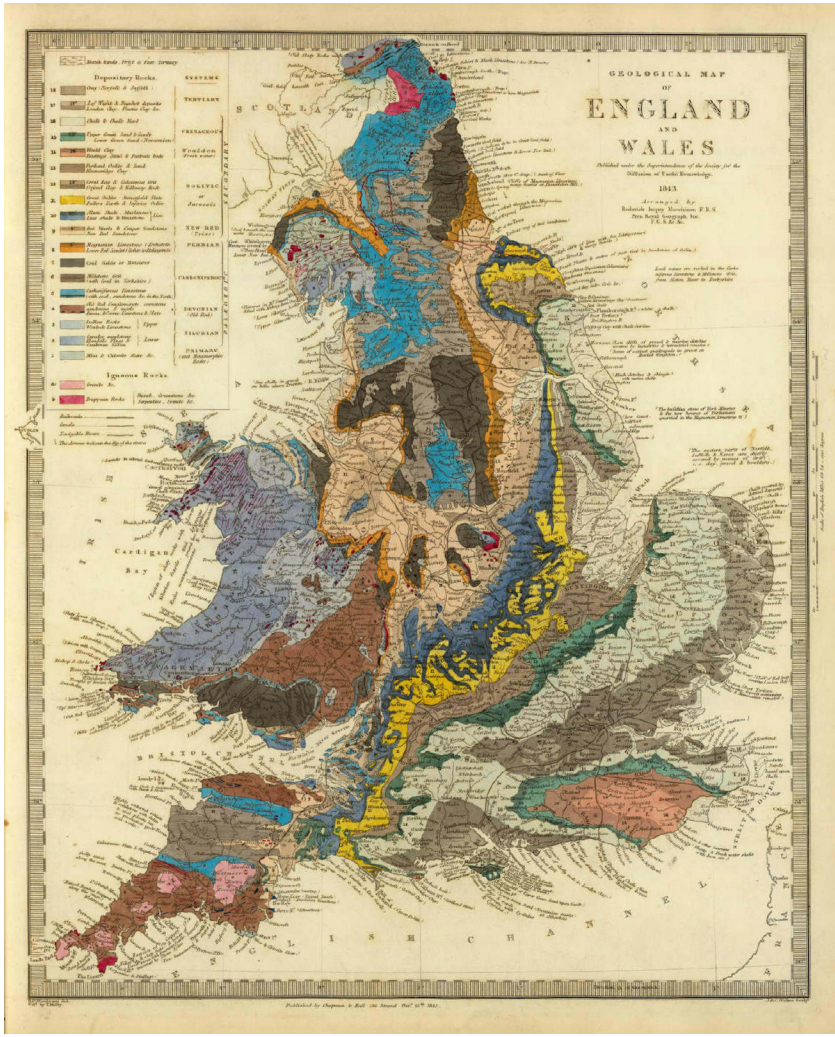

Figure 7.1 William Smith's *Geological Map of England and Wales* (1815). Wikimedia Commons, public domain.

While Smith is generally credited as the inventor of the first geological map, the technique was developed simultaneously by Humboldt, although he used the pasigraphic sign system instead of color coding. By the mid-nineteenth century, pasigraphy was forgotten and when Humboldt published his physical atlas with Berghaus that was meant to accompany and illustrate his final work *Kosmos*, he used Smith's coloring table rather than his own pasigraphic sign

system (Figure 7.2). Perhaps he recognized that his sign system would have difficulty reaching a vast audience and opted for Smith's system because of the communicative value, which would fit well with his position on science as a field that needed to be communicated broadly.

Humboldt insisted that a crucial condition for improving knowledge of the earth and its history is the development of better visual media, and the improvement should spring from a combination of more accurate data and more effective visualization techniques. "The most instructive projection for geology is the vertical profile, and in the beginning of 1795, I tried to figure whole countries like mines" he explains.[42] He also discusses other attempts of geological charts from the end of the eighteenth century, but dismisses them all for confusing rather than clarifying stratigraphic layering. The choice of a sign-based system instead of colors is motivated by the difficulty of distinguishing color nuances and remembering them, and he therefore limited himself to three main colors. As he returned to his pasigraphy in 1822, Humboldt explained his geological methodology as double, in that it can express itself "figurative representing the superposed beds by parallelograms placed above one another; or algorithmic, indicating the superposition of rocks, and the age of their formation, as the terms of a series."[43] The first method was exemplified in the plates for his Spanish 1804 text and "it offers the advantage of addressing itself to the eye more directly, and of expressing *simultaneously in space* two series or systems of rocks, which cover the same formations."[44] This cultural technique was meant to convey the complexity of deep time formations understood as layers in what he calls parallelograms, allowing one to see several strata simultaneously. "It offers the advantage of addressing itself to the eye more directly, and of expressing simultaneously in space two series or systems of rocks, which cover the same formation."[45] Humboldt thus directs knowledge through the visual faculty by rendering complex information perceptible at a glance, which also facilitates its repetition. In his view, eighteen signs representing eighteen types of rock are enough to form a geological table, just like we express everything through the twenty-four letters of the alphabet. He is explicitly seeking simplicity in complexity for reasons of communication of knowledge. Worrying that too much detail can obscure the more important insights of science—an idea that clearly resonates with twenty-first-century critique of the great epistemic divide—he draws on ideas of mathematics and visuality as he develops the pasigraphic system.[46]

As geological insight was rapidly progressing during these first decades of the nineteenth century, cultural techniques of conveying the structural and temporal dimension of the earth's crust became important. The solving of how to convey the complexities was thus not just a matter of adding an illustration, but of rendering and making legible the layering of geological

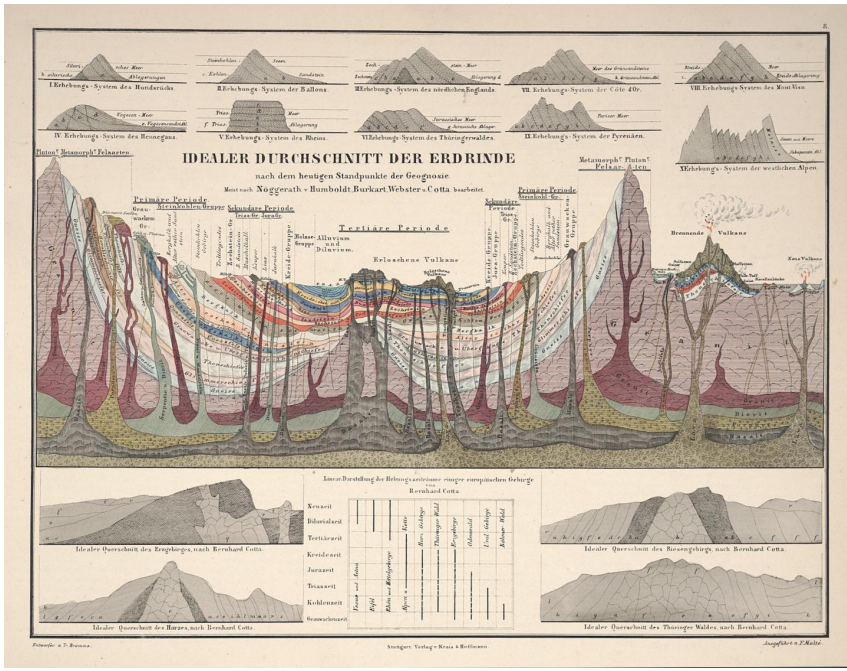

Figure 7.2 Alexander von Humboldt's *Idealer Durchschnitt der Erdrinde* (1851), Berghaus, *Atlas zu Humboldt's Kosmos*. Photo by Missouri Botanical Garden, Peter H. Raven Library, public domain.

makeup. According to Martin Rudwick, it was only after the 1820s that geohistory truly entered the scene of international geology, in the work of Charles Lyell, Georges Cuvier and Alexandre Brongniart, among others, while geognosy remained primarily focused on structural aspects.[47] However, it is clear from a close reading of Humboldt's *Geognostical Essay* that relative age of formations is just as important as structure. Above all, while it was never adopted, the attempt to develop a new technique for visually conveying the structure and temporality of formations seemed to have served the purpose of advancing knowledge by changing scale from the local to the global by means of comparison, which presupposes a quick and effective overview. Lyell visited Humboldt and became his friend in 1823 just as the *Geognostical Essay* had been published, and the two corresponded over the coming decades. The fact that this text is written with geochronological advancement in mind can be seen in the frequent references to fossils and the discussion of how different species' appearance and disappearance determine the age of epochs. "Since in consequence of the important researches of MM. Cuvier and Brongniart, a profound examination of fossil organic bodies has diffused new spirit into the

study of tertiary deposits, the discovery of the same fossils in the analogous beds of very distant countries has rendered still more probable the isochronism of widely extended formations."[48]

The second part of Humboldt's pasigraphic method used the same signs taken from the letters of the Greek alphabet with superscripts to express a series of layers as a notation. This part focused on efficient expression of the relation of "relative position, alternation and superposition."[49] The method represents the ambition of using the "conciseness of algebraic language" to capture the complexity of stratigraphic relations. Abstraction here served to express the succession and relative age of formations. The cultural technique of pasigraphy thus emerged as a sign-based and mathematical way of explaining how geological age and structure related to each other. The method was more concise and precise than lengthy narratives, in which the reader could easily be lost and find it hard to memorize and then visualize and compare local formations on a global scale. As Humboldt approached the issue of deep time from a polymath perspective before the great epistemic divide, he was concerned not just with scientific precision but also with the communicative quality of knowledge production. Time could not be understood in isolation, but had to be related to both human observation and planetary transformation.

Humboldt's transdisciplinary methods led him to develop cultural techniques for efficient expression of scientific insights. Figuring the geological makeup of a larger landscape or even a whole country makes possible the comparison and scaling, which is a precondition for knowledge of the earth as a planet. Combining narrative text, which verbally temporalizes the earth, with the visual cultural technique of pasigraphy and charts was further aimed at producing a cognitive simultaneity in the perception of knowledge. This pasigraphic technique was the basis for Humboldt's iconic *naturgemälde* of Chimborazo, where he switched from conveying deep time to climate zones and plant geography, which he of course understood as part of the same general project.

Conclusion

My purpose in discussing the instances related to scientific temporalization of the earth where Humboldt turned out be correct or to have prefigured modern scientific insights is not to say that he was an early visionary, which has already been said by others, but rather to pose the question of why and how he could see certain phenomena more clearly as a polymath before the great epistemic divide, and how this approach to transdisciplinary human and natural sciences may resonate with scientific needs in the present era of climate change and Anthropocene time, which collapse century-old distinctions.[50]

The well-known cosmological and global vision of space and climate zones here finds its counterpart in a planetary geological vision of time and the history of the earth.

In examining closely the geochronological arguments of Humboldt in figuring the geological makeup of Americas in a global perspective, it becomes increasingly clear that he was not only prefiguring modern insights about global spatial relations like climate zones, but also temporal ones. This decisive contribution to the emerging deep temporality of the earth in the early nineteenth century has been rather overlooked. Humboldt's work with temporalizing the history of the earth paved the way for the emerging geochronology of the first half of the nineteenth century. His unifying perspective came to an equally strong expression in his scientific narrative skills as in his infographic cultural techniques of charts and tables and served to place human history within the horizon of planetary history.

But the conclusion to draw from these insights is not so much the oft repeated and quite tiresome trope that Humboldt was a man of genius, but rather that it was his overt and explicitly polymath scientific practice moving effortlessly between geology and poetry, climate science and world history, that enabled his insights. In the same way, we might consider the lack of what we now call transdisciplinary openness as a major obstacle to such planetary and crucial insight in the age of specialization and reductionism. In this chapter I have tried to shift the perspective from the focus on the certainly fascinating individual and his life story of breakthroughs to interrogate his transdisciplinary method in investigating natural and cultural time.

We may also recall how a decade ago, following the failure of the UN Climate Change Conference in Copenhagen (COP15), Gaia theorist and Earth System Science founder James Lovelock lamented the separation of earth's climate problem into very separate specialties, preventing any one scientist from seeing it as a whole topic involving earth as an entirety, including humans, living organisms, the ocean, atmosphere, and surface rocks.[51] Already in the 1970s, he concluded that the bottom-up perspective of mainstream science obscured the proper understanding of the scale of earth's systems, which could only be seen in a top-down approach.[52] His ideas are foundational to the transdisciplinary field of Earth System Science, which aims at understanding the physical, chemical, biological, and human interactions that determine the past, present, and future of the earth, but his ideas have long been met with resistance from conservative scientists. Still today, the epistemic heritage of the twentieth-century specialization prevents many individual scientists, policymakers, and politicians from seeing the earth and life on it as a dynamic interactive system.[53] Humboldt's perspective and insights resonate strongly with Lovelock's, and together they represent two scientists that challenged the great epistemic divide in their respective century and who are therefore enjoying a strong renaissance today.

For the multiple timescales of deep time and human time to become integrated and comprehensible, an epistemic unity is necessary. Everything happening since the postwar in terms of human impact on the global environment has been termed the Great Acceleration because of the rapid increase in virtually all areas of impact. This process was visualized in the so-called hockey stick curves presented by Will Steffen in 2009. Arguably, this acceleration of impact is related to the epistemic divide in terms of the lack of insight, which formed a condition of possibility for its continuation. This is not the place to speculate on why emerging insights in the 1970s of human impact on the earth system did not lead to a rapid transformation, but other authors suggest neoliberalism may have played a part.[54] This synchronicity of the Great Acceleration and the great epistemic divide has still not been fully explored.[55] It now seems possible to postulate that were it not for super specialization and prohibition of large scale perspectives, knowledge and insight on anthropogenic effects on climate, oceans, and biodiversity would have been attainable much earlier. My sense in investigating Humboldt's transdisciplinary methods of understanding earth's history against the background of a twenty-first-century escalating ecological crisis is that there is a relation between the lack of integrated perspectives over the past two centuries and the increase in anthropogenic change in the earth system. To curb the Great Acceleration, we may first have to bridge the great epistemic divide.

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