The Deep 16th Century: Earthing Europe, Reforming the Planet

Nigel Clark

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Lightning Strikes, Twice

In the January 2016 issue of the journal *Climate Change* a research team headed at the University of Alberta published the results of an extensive study of wildfire trends in Canada. Future climate change, they predicted, `may have a profound and immediate impact on wildland fire activity'.[1] Just months later, following record warm temperatures and a snow-light winter, a massive blaze broke in Alberta. Spreading across 1,500,000 acres, the fires prompted the evacuation 88,000 people and caused enough damage to make it the most expensive disaster in Canadian history. Worst hit, with the loss of 2,400 homes and buildings, was Fort McMurray - the booming service centre for the mining of the Athabasca oil sands.

Critical commentators were quick to link oil sand extraction with climate change and the wildfire irruption. Such a connection is what is referred to in technical terms as a positive feedback loop: a situation in which an effect or outcome cycles back through a system in a way that reinforces the original driving force. But so too did the wildfires generate self-amplifying feedbacks of their own. Some of the most fearsome images of the disaster show towering, pyrocumulus clouds rising above the blaze. From these roiling, ash-laden clouds came forks of lightning arcing into as yet unburned forest - advancing the fire front still further and faster.[2]

From another continent, half a millennium ago comes an equally disturbing scene of lightning doing its incendiary work. One of the most dramatic images from Zurich's Wickiana collection is brightly coloured woodcut dated 15 June, 1571: a depiction of dark, billowing clouds from which shoot fiery shafts of lightning that are in the process of setting a church alight.[3] As a shocked onlooker rushes to the scene, a cutaway perspective show us tongues of flame descending on the altar and licking at the icons that grace the chapel's interior.

But here too, unbeknownst to the illustrator, a positive feedback loop may have been in play. For in 16^{th} century Switzerland, there were cases when congregations who had seen their places of worship consumed by flames set about replacing flammable timber roofs with metal ones, a fire safety measure that unintentionally rendered churches even more effective conductors of lightning. Though in a time of religious turmoil, worshippers who witnessed bolts from the heavens targeting god's own house would have more likely imagined that it was some manner of moral offence or violation that had incited divine retribution.

Our own era, which once more has wondering what we have done to upset the natural order, may not be as far from the 16^{th} century as we tend to assume. With his installation of a lighting conductor and earthing wire in the gallery space, Swiss artist Florian Germann suggests a current arcing between the domain of science and the world of myth and imagination, a subtle but surging flow that might also bridge our climate-jittery present with the equally uncertain worlds at the dawn of European modernity. With his fondness for tracing shadowy emanations and transformations of energy, we might see Germann as a kind of spirit guide to our currently fraught relationship with atmosphere, climate, and the Earth. But the materials he uses also remind us of Germann's ongoing fascination with a grittier minerality - the `riches that can be extracted in pure form from the depths of the mountains, such as iron, lead, copper, zinc . . . '[4] In this way the installation functions as a kind of `earthing', drawing us back not just to solid ground, but to the shifting, faulting, thrusting forces of the Earth's interior.

We might see Germann's lightning conductor as setting up a kind of feedback loop between Earth and heaven, or as geoscientists would have it, between the hard rock of geology and the more mobile flows of the Earth system. Today, the scientific understanding of our global environmental predicament discloses a new and unprecedented human impact at the scale of the whole Earth, the gleaning that our species is becoming a geological agent.[5] Though we might be bemused by the 16^{th} century naivety of cladding lightning-prone structures in highly conductive metals, we denizens of the 21^{st} century can hardly afford to be smug. For with our blazing wildfires, our melting permafrost, our gradual replacement of solar-reflecting icecaps with solar-absorbing ocean or rock, we are the progenitors of feedback loops that make small fry of fiery churches.

As we struggle to come to terms with this newfound sense of our geophysical agency, the search is on for some way to break out of the planet-scaled feedbacks we have set in motion. But we also find ourselves looking backward, trying to ascertain that moment when our geological powers first took hold. Just as we used to ask `when and where did we become modern?', now we also ask `when and how did humans begin to leave an imprint on the Earth system?'. While the most obvious candidate is the period of EuroAtlantic history that saw a great proliferation of fossil-fuelled machinery, researchers are increasingly turning to an earlier moment that provided the preconditions for European take-off. As social historian turned climate historian John Brookes assays the evidence: `the epoch between the Black Death and the onset of Industrial revolution was the fundamental hinge of human history'.[6] And this way, we pick up on Germann's pursuit of elemental resonances through history, joining him in a journey that leads from one set of explosive lightning strikes to another.

The Little Ice Age

At first glance, Brookes' chosen `hinge of history' seems like unpromising soil for propagating a new planet, especially if our gaze lingers at the grassroots level. Decimated by successive waves of plague, Europe in the 14th to 15th centuries was also exiting a period of relative warmth and bounteous harvests – sometimes referred to as Medieval Warm Period - and entering into a five century bout of cooler, more erratic weather. As glaciologist Jean Grove points out, the term that has been deployed since the 1930s to describe these less clement conditions is the Little Ice Age.[7] A series of climatic fluctuation more than a simple cold spell, the Little Ice Age was a mere wobble next to the vicious see-sawing between glacial and interglacial epochs across the two million years of the Pleistocene that our distant ancestors endured. But in an agrarian world, a climatic shimmy can suffice to push already precarious patterns of subsistence out of balance.

Even in times of plenty, recounts historian Fernand Braudel, the staple foodstuff of the European peasantry consisted largely of `insipid farinaceous gruels'.[8] From the 14th to the early 19th century, growing seasons in temperate Europe retracted and harvests faltered. With successive episodes of crop failure and livestock epidemics, and in the absence of infrastructure to move grain and other foodstuffs in sufficient quantities from one place to another, came the resurgence of the illnesses associated with hunger. Environmental scientists Siegfried Fred Singer and Dennis Avery paint a picture of a daily existence of relentless physical labor performed in muddy fields wearing rain-sodden clothing, followed by a return home to an overcrowded, insufficiently heated shelter. As they put it: `a typical North European dwelling had one small room, a bare earth floor, no insulation, no glass in any windows and leaky thatched roof'.[9] Here, `malnourished people huddled together …to share their meager fires and body warmth'.[10] So too, in such close and unsanitary quarters, did they share their parasites and pathogens.

It was Europe's highlands and Alps that felt the chill bite of the Little Ice Age most acutely. By the latter 18th century, the interplay of mountain formations and glaciation would provide an archive of Earth history that fascinated some of the earliest geoscientists, while the surging and plunging of great rivers of ice would send shivers of fearful delight through the sensorium of travelling aesthetes. But for many of those living and working in alpine Europe, mobile glaciers brought economic ruin and physical destruction. As Grove recounts:

> In the decades between the late sixteenth and late seventeenth centuries European glaciers swelled and their tongues advanced, destroying high farms and damaging mountain villages. Streams fed from glaciers flooded more frequently, sometimes catastrophically. In many areas this kind of hazard was compounded by landslides and avalanches triggered by increased precipitation and the greater glacial activity associated with it.[11]

Although agrarian communities lacked systematic records of changing weather conditions, collective memory of the more bountiful conditions of the Medieval Warm Period may offered at least a shadowy backcloth against which to mark off the trials of Europe's Little Ice Age. With shorter growing seasons and crop failure came localised food scarcity, price rises and bread riots, and with hunger and hardship came fear, social discontent and a flailing for explanations. If hoarders and speculators were often held culpable, so too did foreigners, vagrants and beggars make for convenient scapegoats.[12] Poor harvests and diminished fruitfulness tended to be read as signs of divine disfavor, lending weight to the idea that periods of climatic stress correlated with waves of persecution of so-called witches. As Johann Linden, a church canon from Treves put it in 1590: `Everyone thought the continuous crop failure was caused by witches from devilish hate, so the whole country stood up for their eradication'.[13] Famished and fevered imaginations may have been further unhinged by food poisoning. Continuously damp conditions rendered grain susceptible to mold infections, including the notorious ergot fungus – now known to cause burning sensations, convulsions and hallucinations.[14]

European Take-off

Sickly, underfed, overwrought, Europe in the 16th century might seem to be plunging downward rather than lifting off into the most explosive episode of transformation in human history. For many centuries, and with a range of motives, commentators have sought the causes and conditions of what Europeans came to call their `modernity'. Well before systems theorists codified the idea of feedback loops, prescient thinkers had intuited a certain self-augmenting circularity at the core of the modern condition. Hegel saw enlightened self-understanding spiraling into a world-changing ascent of reason, Marx explored the self-amplifying circuit of capital reinvestment, Weber showed how the quest for `other-worldly' elevation entered into a mutually amplifying relationship with the `worldly' pursuit of economic success.

In our own era, theorists have become less inclined to look to intrinsic features of European culture or society as the impetus for its `take-off', and more willing to consider Europe's achievements in the context of mutual relations of encounter, exchange and interconnectedness with the rest of the world. Philosopher Peter Sloterdijk draws our attention to a new kind of feedback loop with a global reach. By the 16th century, he proposes, European navigators, adventurers and traders had broken out of their terrestrial bounds and woven the world's waters into a single, unified space.[15] As seafaring became increasingly entrepreneurial, Sloterdijk argues, funding trans-oceanic voyages emerged as the model of a new kind of venture capital that wagered on successful circumnavigation as the way to make a literal `return' on an investment. In this way, as nautical techniques improved and with the development of new financial instruments for dealing with risk and futurity, globality itself became the ground of European modernity's self-augmenting ascendance.

While Sloterdijk may conceive of the entirety of the Earth's surface as an emergent sphere of operations for enterprising Europeans, his is still a planet predominantly constituted through the actions and imaginings of (certain) humans rather than being a force or agent in its own right. But just as humanities scholars have come to think of the globe in terms of its unification and interconnectedness, so too have Earth scientists come to conceive of the planet as single integrated system. Over the last few decades, Earth systems thinkers and other geoscientists have arrived at understanding of the operations of our astronomical body in terms of both its openness to the cosmos and its own internal dynamics. Construed as vastly complex system composed of jostling, mobile, mutually interacting subsystems, the Earth displays variability at every spatial and temporal scale.[16] And it is such a vision of the Earth as a dynamically interconnected system with a multiple possible operating states that helps us to understand how global climate can shift out of the warmer, more stable conditions of the Medieval Warm Period and into the cooler, more erratic Little Ice Age, how climates jump between glacial and interglacial phases, or how our planet makes the still more profound transition between geological epochs.

These insights from Earth science into our planet's turbulent `geohistory' can also open new windows onto different human collectivities and their varying fortunes. As research into climate change generates ever more detailed and extensive data sets, we get a clearer picture of the world-wide or `geosynchronous' footprint of the Medieval Warm Period and the Little Ice Age, as we do for other fluctuations in the Earth system. At the same time, increasingly comprehensive climate and Earth system change data throws considerable regional and local variations into relief, reminding us that terminology like `ice ages' are themselves relevant only in certain geographical regions or zones.[17]

Evidence suggests, for example, that what were experienced as the clement, bountiful conditions of Medieval Warm Period in temperate Europe were frequently manifest in the equatorial latitudes as megadrought – with catastrophic effects on some large-scale agrarian civilizations.[18] In European history, the collapse of the initially successful late Medieval Norse settlements in Greenland has long been linked to the coming of the cooler conditions of the Little Ice Age. But it is also important to consider how both Medieval drought and the more erratic temperatures of the Little Ice Age may have contributed significantly to the ecological, social and physiological susceptibility of local peoples around the world at the time of European exploration and colonial advance.[19]

Anthropologist Julie Cruikshank recounts how early European contact with indigenous peoples in the Pacific Northwest during the later stages of the Little Ice Age overlapped with rapid glaciation the region. 'A time of significant geophysical change', she notes '[. . .] coincided with dramatic social upheaval causing both readjustments and realignments among resident peoples and the permanent problem of powerful strangers who came to stay'.[20] As Brooke suggests, extended drought and famine during the 16th and 17th centuries fragmented once powerful West African states – resulting in heightened vulnerability which may have facilitated the brutal advance of the slave trade.[21] So too is it likely, he adds, that the Little Ice Age contributed to an exceptionally intense wave of war, famine and epidemics across much of the Eurasian landmass.

An epidemic is itself one of biological life's most momentous expressions of positive feedback. The growing contact between European and Asian populations is known to have played a large part in the successive outbreaks of plague in the 13th to 14th centuries. This formation of a single `disease pool' would itself have dire consequences when European and Asian voyagers later made contact with the `epidemiologically naïve' populations of other regions. But it may also have been significant that the generally cooler temperatures of the Little Ice Age, though they frequently visited famine-related illness on susceptible European peoples, had the advantage of helping suppress recurrent outbreaks of plague.[22]

In multiple ways that have yet to be fully teased out, Europe's lurch into self-amplifying circuits of accumulation and change is implicated with an Earth system whose rhythms emerge out of its own dense arrangement of positive and negative feedback loops. Some of these entanglements framed and conditioned European contact with the peoples of the rest of the world, many of whom were – for a variety of social and physical reasons – already in motion. Other factors contributing to the take-off of Europe were more domestic, including the turn to higher productivity agro-ecosystems – often premised upon the appropriation and enclosure of farmland formerly in the hands of peasant cultivators. As archaeologist Brian Fagan sums up: `The changes came, above all, from self-improvement, from individual landowners adapting to cooler weather, more difficult farming conditions, and opportunities in the marketplace'.[23]

In important respects the cooler, more erratic weather between the 14th and 19th centuries can be seen as just another one of numerous fluctuations throughout the 10,000 or so years of the Holcene epoch.[24] To understand how the Little Ice Age is implicated in the momentous shift towards human planetary or geophysical agency, we need consider not only how the vicissitudes of climate have made a difference, but also to ask about geological elements and processes with which different social groups joined forces. And this means digging deeper than the flows and circulations of the Earth system. Or to borrow from the title of one of Florian Germann's works, we must turn to `Riches from the Depths of the Mountains.'[25]

The 16th Century in 3D

As a hinge between the 16th century and our own climatically precarious era, let us return to those ill-fated churches with their less flammable but more conductive metal roofs. If the electronic discharge of the lighting bolt establishes a connection between the Earth's atmosphere and objects on its surface, so too have we seen - with help from Germann - that it forges a less direct link with subsurface. For the origin of the metals used to sheath roofs - or more sensibly, to function as conductors to divert lightning harmlessly into the ground - lies in the faulted, folded and stratified formations of the subterranean Earth.

As we have seen, Sloterdijk - along with most other social theorists of globalization- focuses his inquiries on the rise of western modernity on a set of intensifying *horizontal* mobilizations and interconnectivities. But the Age of Discovery also had profound *vertical* dimension. At the same time as Europeans were increasingly travelling outwards, they were also voyaging downwards. 'While Vasco da Gama, Columbus, and other explorers were finding new sea routes', notes historian John Nef, '[. . .] the Western peoples were again on the lookout for minerals'.[26]

Europe has an ancient history of extracting metals and other minerals, though many mining operations were significantly reduced or shut down after the fall of the Roman Empire. Increasing demand for metals in the late Medieval economy –for coinage, construction, tools, armour and weapons – saw a significant return to mining in Europe, accompanied by growing use of coal for smelting ores.[27] Already at this time, observes Nef, in ore-rich regions `mining and metallurgy affected every political authority and every kind of country landholder from the emperor to the meanest serf'[28]. By the latter 15th century, stagnation related to the decimations of the plague years was over and Central Europe entered into boom years for mining silver, copper, iron and other metals - with old mines being reopened and a rush of major new mineral discoveries.[29]

There is evidence of the erratic weather conditions of the Little Ice Age impinging on mining operations. In 1595 floodwaters from a tributary of the Rhône that were triggered by fluctuating glaciation inundated newly opened silver mines in the Val de Bagnes.[30] But in general, successive advances in technology afforded miners more control over subsurface operations than their farming counterparts enjoyed on the Earth's surface, while mineral extraction provided vital resource and income streams that largely persisted through climatic instability. In the mid 15th century new processes enabled silver to be separated from copper, at the same time that advances in pumping and drainage reduced the problem of flooding – permitting mining operations to plumb unprecedented depths.[31] One of the first `open source' textbooks, Georgius Agricola's *De Re Metallica* - published in 1556 - was at once a compendium of mining and metallurgical knowledge and a spirited defense of the social and economic benefits of intensifying interchange with the metallogenic subsurface.[32]

There has been a great deal of attention to the technological advances – from map-making and sailing ship construction, through to compasses and chronometers – that facilitated trans-oceanic navigation. What Agricola's richly illustrated volume foregrounds is the contemporaneous importance of advances in navigating *through* the Earth. Here, as a case in point, he describes in detail one set of techniques deployed by mining experts to negotiate, gauge and map the three dimensional spaces intrinsic to the successful extraction of mineral resources:

> The Swiss surveyors, when they wish to measure tunnels driven into the highest mountains [. . .]employ an instrument peculiar to them which has a needle [. . .]they carry in their hands a chart on which they inscribe the readings of the instrument. The instrument is placed is placed on the back part of the rod so that the tongue, and the extended cord which runs through the three holes of the tongue, demonstrates the direction, and they note the number of fathoms [. . .] They measure the tunnels for the purpose of knowing how many fathoms they have been increased in elevation; how many fathoms the lower is distant from the upper one; how many fathoms of interval is not yet pierced by the miners who on opposite sides are digging on the same vein [. . .] or two veins which are approaching one another.[33]

Just as the mercantile voyages of early modernity – as they pressed further outwards - embodied a new kind of literal `return' on investment, so too was mining – as it pressed downwards - the stimulus for new ways of financing and organizing production. During the

Central European mining boom, Braudel recounts, escalating financial requirements of equipment needed to access ever-deeper ores enabled absentee investors to gain control over mining. 'Capitalism', he proclaims, 'entered a new and decisive stage'.[34] Or as cultural historian Lewis Mumford puts it: 'more closely than any other industry, mining was bound up with the first development of modern capitalism', before adding that by the 16th century it was also the occasion for 'the use of the strike as a weapon of defense, the bitter class war, and finally the extinction of the guilds' power'.[35]

If this regard, mining in Europe in the 15th - 16th centuries helped generate a new set of relations – both between different social groups and between humankind and the Earth. Like the discovery of new worlds across the ocean, the traversal of the underworld – with its seemingly inexhaustible richness – served to open the European imagination to unbounded horizons and the idea of limitless accumulation.[36] In a more practical way, mining for metallic ores helped establish technological pathways that would be crucial for the intensified extraction of fossil fuels, it provided raw materials and many of the templates for the construction of later industrial machinery, it helped give rise to venture capital oriented to large scale, future-oriented projects, and it supplied the precious metallic coinage that mediated and promoted market relations

As metallurgical historian Theodore Wertime observes, metals have long served as stimuli and accelerants in the social world: 'they became catalysts of social life for men, even as they had been catalysts of energy exchanges for cells in the biological organism'.[37] Viewed in its totality, the accelerating traffic between surface and subsurface that literally reached new levels in the 16th century can be seen as a key at to Europe's self-sustaining take-off. More than this, however, it is the very ability to experience and imagine the Earth in three dimensions that crystallized during the Central European mining boom which provided the formative insights of geological thinking, and in this sense helped open the way to today's understanding of a changeable Earth system

From the Deep 16th Century to the Anthropocene

In laying out the contours of the modern world system, Fernand Braudel spoke of `the long 16th century' (c. 1450–1640) in order to explain how capitalism arose from the drawn out crises of European feudalism.[38] Today, when we find ourselves increasingly thinking about the global socio-economic system and the Earth system together, we might think of the 16th century as being *deep* as well as *long*. Deep, that is, in the literal sense of its subterranean excursions. But deep also in the way that 16th century's intensifying exchanges with the subsurface are implicated in a lasting physical transformation of the Earth - and in the modern understanding of our planet as a rich, layered and dynamic entity

While the rise of Earth systems thinking has helped us comprehend how the different components of our planet work together to generate variability and change, it is important to keep in mind than an older geological science – focused on the rocky strata that comprise the Earth's crust – still plays a vital role in thinking about what our planet did in the past what it may do in the future.[39] Today, the `stratigraphic' expertise of geologists reveals how past changes in the Earth system left enduring traces in the stony or `lithic' layering of the outer Earth, and provides vital evidence of the way that the more recent human `unearthing' of ancient energy and mineral-rich strata impacts upon the planet as a whole.

Before it became the province of specialized scientific researchers, however, the basic idea that the rocky parts of the Earth were built up of a succession of different layers belonged to miners, quarrymen and others whose daily work took them beneath the Earth's surface. Surveying several centuries of European extractive labor, geological historian Martin Rudwick explains:

> Mining provided [. . .] not only [. . .] empirical data on the dimension of depth in the earth's crust, but also – far more importantly – a distinctive way of thinking and even of seeing. Anyone involved in the mining industry, from ordinary miners right up the social scale to those who managed and administered mines, worked in a three-dimensional world of rock *structures*.[40]

From plying the subterranean realms came the early evidence of life forms no longer living, and the first gleaning that the going deeper into the Earth equated with going backwards in time. Eventually, contemplation of the layering of the Earth and the recognition that each stratum had its own specific fossil complement gave rise to the idea that the Earth itself must have had a long and active history.[41] At the same time, observation of glaciers on the move in the alpine regions of Europe in the latter stages of the Little Ice Age and a growing interest in the processes through which mountains were formed added to the understanding of the Earth's surface as a dynamic expression of deep temporal forces and processes.

It has taken several centuries for geoscientists to arrive at a more systematic understanding of the interplay between the enduring geological formations of the Earth and the more variable and flowing components of the Earth system. It is out of this convergence, Earth scientists themselves relate, that we are beginning to grasp how collective human activity is nudging the Earth system into a novel operating state – otherwise known as the Anthropocene thesis.[42]

But just as the long and deep European 16th century engendered some of the earliest stirrings of `geological' knowledge, so too are contemporary insights into the dynamics of the Earth system providing novel perspectives on the phenomenon of the Little Ice Age.

Alongside the changes in the Earth's axis and orbit that are known to produce variation in the amount of solar radiation received by our planet's surface, researchers have proposed that exceptional bursts of volcanism are behind the abrupt onset of the Little Ice Age. After close examination of Arctic ice cores, geologist Gifford Miller and his colleagues conclude that `intervals of sudden ice growth coincide with two of the most volcanically perturbed half centuries of the past millennium'.[43] Volcanic explosions, they argue, loaded enough sunlight-refracting sulphur particles into the stratosphere to reduce temperatures in the global climate system, with further cooling resulting from positive feedbacks involving enhanced reflection of sunlight from an increased sea-ice cover.

Volcanoes are not the only `geological' events capable of transforming atmospheric composition in ways that alter the amount of sunlight reaching the Earth. It has long been known that decimation of indigenous peoples in the Americas and elsewhere through the violence of European conquest and outbreaks of disease massively disrupted traditional farming based around the use of fire to clear forests. Although the idea is strongly contested, scientists recently proposed that the resultant regrowth of forests was on such a scale that it absorbed enough carbon dioxide from the Earth's atmosphere to impact global climate. According to ecologist Simon Lewis and climatologist Mark Maslin, the population crash resulting from the collision of Europe and the `new world' coincided with the coolest phase of the Little Ice Age - from around 1550 to 1650 - and in this sense can be considered to have triggered a lasting, worldwide change in global climate.[44]

So too are we seeing the emergence of novel hypotheses about the waning of the Little Ice Age. Climatologists have recently argued that even before the onset of a warmer climatic regime, particles of black carbon from coal combustion during the early Industrial Revolution had already begun to the blanket Europe's alpine regions. Both the rise of industrial activity around the Alps and the growth of coal-fired rail systems, it is suggested, resulted in significant sooty deposits causing snow and ice to absorb more sunlight - to such an extent of triggered the retreat of glaciers in Central Europe.[45]

The current position of leading Anthropocene theorists is that, while potentially significant, none of these events is momentous enough to have left a permanent, worldwide signature in the rocks – the planetary reformation that would qualify for the arrival of a new post-Holocene geological epoch. But the very proliferation of new theories – especially those with a pronounced `geosocial' dimension are indicative of profound shifts in the way we understand the interplay of social and geological processes. And in this way they bring into relief the depth and degree of entanglement of the 16th century with our own era.

Illuminated both by the flash of lightning and by the shimmer of mineral strikes, Europe in the midst of the Little Ice Age was every bit as adventurous vertically as it was horizontally. Or we might say, in the course of long 16th century Europeans achieved a kind of positive feedback between their outward and downward traversals of the Earth. Today, it is the runaway, cascading consequences of this intensified traffic between the inner and outer Earth that once again has us doubting the surety of our world. Only this time, it is not the advance of glaciation that perturbs us but the disappearance of ice, less the failure of harvests from too little warmth we fear than the wilting of crops from excessive heat. And as Jean Grove reminded us, across the world it is the impoverished and the marginalised who experience the severest exposure to climatic extremity: `as in Little Ice Age Europe, the poorest suffer most and those least able to adapt to changing circumstances are most affected'.[46]

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[1] M. D. Flannigan, B. M. Wotton, G. A. Marshall, W. J. de Groot, J. Johnston, N. Jurko and A. S. Cantin, "Fuel Moisture Sensitivity to Temperature and Precipitation: Climate Change Implications," in *Climatic Change,* 134 (2016) 59–71, p. 61.

[2] Eric Holthaus, "We Need to Talk About Climate Change" *Slate,* May 6 (2016)http://www.slate.com/articles/health_and_science/science/2016/05/the_mcmurray_fire_is_worse_because_of_climate_change_and_we_need_to_talk.html (accessed April 7, 2018).

[3]https://commons.wikimedia.org/wiki/Category:Wickiana#/media/File:Wickiana_Blitzschlag_Bischofszell.jpg (accessed April 7, 2018).

[4] Alexandra Blättler, "Saint Helena—Arenenberg—Saint-Léonard" http://floriangermann.ch/cms/files/media/FG_Blaettler.pdf (accessed April 7, 2018).

[5] Paul Crutzen, "Geology of Mankind", *Nature*, 415: 6867 (2002), p.23; see also Nigel Clark and Kathryn Yusoff, "Geosocial Formations and the Anthropocene", *Theory, Culture & Society* 34:2-3 (2017), pp. 3-23.

[6] John Brooke, *Climate Change and the Course of Global History: A Rough Journey*, New York: Cambridge University Press, 2014, p. 413.

[7] Jean M. Grove, *The Little Ice Age,* Abingdon: Taylor & Francis, 1989, p. 4.

[8] Fernand Braudel, *Capitalism and Material Life 1400-1800*, trans. by Miriam Kochan, Glasgow: Fontana/Collins, 1974, p.141.

[9] Siegfried Fred Singer and Dennis Avery, *Unstoppable Global Warming: Every 1,500 Years* Lanham, MD.: Roman and Littlefield, 2006, p.109.

[10] Singer and Avery, *Unstoppable Global Warming,* p.109.

[11] Grove, *The Little Ice Age,* p. 2.

[12] C. Pfister and R. Brázdil, "Social Vulnerability to Climate in the "Little Ice Age": An Example from Central Europe in the Early 1770s", *Climate of the Past,* 2: 115–129 (2006), p. 124.

[13] Cited in Singer and Avery, *Unstoppable Global Warming,* p.109.

[14] Pfister and Brázdil, "Social Vulnerability to Climate in the "Little Ice Age" p. 120; Singer and Avery, *Unstoppable Global Warming,* p.109.

[15] Peter Sloterdijk, *In the World Interior of Capitalism*, trans. by Wieland Hoban, Cambridge: Polity, 2013, pp.10, 112–15.

[16] W. Steffen, A. Sanderson A, P. Tyson et al, *Global Change and the Earth System: A Planet Under Pressure*. Berlin: Springer-Verlag, 2004, p. 295

[17] Pfister and Brázdil, "Social Vulnerability to Climate in the "Little Ice Age", p. 120.

[18] Brooke, *Climate Change and the Course of Global History*, pp. 359, 370–1.

[19] Nigel Clark and Yasmin Gunaratnam, "Earthing the *Anthropos*? From `Socializing the Anthropocene' to Geologizing the Social". *European Journal of Social Theory,* 20: 1 (2017) pp.146–163.

[20] Julie Cruikshank, *Do Glaciers Listen? Local Knowledge, Colonial Encounters and Social Imagination*. Vancouver: University of British Columbia Press, 2005, p.10.

[21] Brooke, *Climate Change and the Course of Global History*, pp. 443–7.

[22] Brooke, *Climate Change and the Course of Global History*, p. 458.

[23] Brian Fagan, *The Little Ice Age: How Climate Made History 1300-1850*. ACLS Humanities E-Book, 2002, p. 245.

[24] Grove, *The Little Ice Age,* p. 5.

[25] http://www.floriangermann.ch/chapters/st-helena (accessed April 7, 2018).

[26] John Nef, *The Conquest of the Material World.* Cleveland: Meridian Books, 1964, p. 70.

[27] Nef, *The Conquest of the Material World*, pp 13-15.

[28] Nef, *The Conquest of the Material World*, p.15.

[29] Brooke, *Climate Change and the Course of Global History*, pp. 454-5.

[30] Grove, *The Little Ice Age,* p. 165.

[31] Martin Lynch, *Mining in World History*, London: Reaktion Books, 2002, pp. 19-24.

[32] Georgius Agricola, *De Re Metallica*, trans. by Herbert Hoover and Lou Hoover, New York: Dover Publications, 1556/1950.

[33] Agricola, *De Re Metallica*, pp.145-7.

[34] Fernand Braudel, *The Wheels of Commerce*, trans. by Siân Reynolds, London: Collins. 1982, p. 321.

[35] Lewis Mumford, *Technics & Civilization*, Chicago: University of Chicago Press. 1934/2010, pp. 74–5.

[36] Jason W. Moore, “Silver, Ecology, and the Origins of the Modern World, 1450-1640”, in Alf Hornberg, J. R. McNeill and Joan Martinez-Alier, *Rethinking Environmental History: World-System History and Global Environmental Change*, 2007, pp. 123-142: p.124.

[37] Theodore Wertime, “Pyrotechnology: Man’s First Industrial Uses of Fire”, *American Scientist,* 61: 6 (1973) pp. 670–682., p.680..

[38] Fernand Braudel, *The Mediterranean and the Mediterranean World in the Age of Philip II*, trans. by Siân Reynolds, Vol. 1 and 2 London and New York: Harper and Row, 1972-73.

[39] Will Steffen, Reinhold Leinfelder, Jan Zalasiewicz et al, “Stratigraphic and Earth System Approaches to Defining the Anthropocene”, *Earth’s Future*, 4 (2016), pp. 324–345.

[40] Martin Rudwick, *Bursting the Limits of Time: The Reconstruction of Geohistory in the Age of Revolution*, Chicago: University of Chicago Press, 2005, p 84.

[41] Nigel Clark, “Politics of Strata”, *Theory, Culture & Society* 34: 2-3 (2017) pp. 211-231.

[42] Steffen et al, “Stratigraphic and Earth System Approaches to Defining the Anthropocene”.

[43] Gifford H. Miller, Áslaug Geirsdóttir, Yafang Zhong et al, “Abrupt Onset of the Little Ice Age Triggered by Volcanism and Sustained by Sea-Ice/Ocean Feedbacks”, *Geophysical Research Letters*, 39, (2012) L02708.

[44] Simon Lewis and Mark Maslin, “Defining the Anthropocene”, *Nature*, 519 (2015) pp 171-180; p. 175.

[45] Thomas H. Painter, Mark G. Flanner, Georg Kaserc, Ben Marzeion, Richard A. VanCuren, and Waleed Abdalat, “End of the Little Ice Age in the Alps Forced by Industrial Black Carbon”, *Proceedings of the National Academy of Sciences*, 110: 38 (2013), pp. 15216–15221.

[46] Grove, *The Little Ice Age,* p. 420.