Earth, Fire, Art: Pyrotechnology and the Crafting of the Social

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Introduction: Inside Out, Outside In

Celebrated for his depiction of atmospheric effects, the painter J. M. W. Turner is often regarded as a predecessor of impressionism or even abstract expressionism. Philosopher Michel Serres takes a different angle, proposing that the artist is a `proper realist' (1983: 57). With deadly accuracy, proclaims Serres, Turner reveals a social order being transformed by fiery energy. He is first amongst artists to truly capture the changes under way in the early nineteenth century, as a way of life pushed along by wind, water-flow and muscle submits to a world propelled by steam. While the form of trains, boats and bridges may still be visible amidst elemental upheaval, what Turner's paintings actually show, Serres insists, are the thermochemical reactions taking place *inside* the industrial heat engine: `Turner no longer looks from the outside… he enters into the boiler, the furnace, the firebox' (1983: 56). While the boiler envelops and harnesses the forces of the cosmos, so too does the whole universe begin to appear in the guise of the blazing energetic metamorphoses occurring within the steam engine: `the engine dissolves into the world that resembles it [….] Heaven, sea, earth, and thunder are the interior of a boiler which bakes the material of the world [….] Hotter and hotter, less and less confined by a boundary' (Serres 1983: 60).

As Serres would have it, Turner's canvasses show us not merely a societal energetic transition in process, but the emergence of a whole new way of relating to and understanding the earth and the universe: a cosmology mediated by machines whose primary purpose is to convert heat into work. But perhaps it is the late twentieth-century philosopher who is as much the visionary as his early Victorian subject. Serres' article on Turner was first published in 1974 – in the midst of an energy crisis but well in advance of the rise of global concern over climate change. As climate scientists would soon be telling us, the energetic reactions taking place *inside* the boiler, the turbine, the motor had indeed been transforming the world on the *outside*. The industrial heat engine's impact

was being felt far beyond the bounds of its metallic casing: its cumulative carbon emissions quite literally baking the material of the world, rendering the earth hotter and hotter.

Climate change has quickly emerged as an imperative – perhaps unprecedented in scale and urgency – to reinvent the social. Successive international forums, reports, manifestos have called for new and binding international legislation, novel political architectures, technological and infrastructural transition, new economic instruments, and even complete socioeconomic system change. If the semantic core of invention, as Jacques Derrida (2007: 6), reminds us, is the Latin *venire* – to come – so too is climate change, in the most literal sense, an incoming, an arrival, an event. Recent research points to an eventual sea level rise of around 2.3 meters for each degree of warming – an irreversible advance of salty and increasingly acidic water into the low-lying coastal zones where our species now clusters in vast numbers (Montaigne 2013). Along with these more-or-less calculable changes comes a host of possible but defiantly unpredictable outcomes; nonlinear shifts in climatic systems, ecosystem collapses, extreme weather events. Shorthanded in the Anthropocene concept is the proposition that thermo-industrially induced changes in atmospheric composition are one of the main drivers pushing the entire earth system into a new state, a possibility that would afford humankind – or part thereof – the status of a geological agent (Crutzen 2002; Zalasiewicz et al. 2008; Clark 2014).

At the 2015 UN Climate Change Conference in Paris representatives of 195 nation states agreed in principle that the prevention of dangerous climate change requires some 80% of known reserves of fossil hydrocarbons to remain in the ground. One way or another, Turner's world of irrupting fiery energy – which is still in many ways our own energetic cosmos – must undergo yet another transformation. A pressing question is now whether the productivity, mobilities, and levels of consumption attained through combusting the fossilised biomass of ancient geological epochs can be sustained using alternative energy sources. Or whether there needs to be a fundamental shift in the kinds of social existence that we are trying to power (see Urry 2013). A related and no less important question is whether we should be thinking in terms of social groups and formations with heavy carbon footprints renouncing their geological agency – or whether it might be more fruitful to consider what other forms or modalities of collective `geological being' might be explored and developed (see Yusoff 2013). To ask, in other words, what kinds of geological agents we might yet become.

In this way, it is not only social futures but entire planetary futures that now seem to be at stake. From the point of view of social agency, however, the sheer scale of such issues – encompassing at once the spatial extent of the whole earth and the temporal span of past, present and possible geological epochs – can feel numbingly distant from lived experience and collective purchase (Jasanoff 2011: 237-8). It is in this sense that I want to come back to Serres' twist on Turner, and his elegant idea of turning outsides in and insides out. What Serres' depiction of the industrial heat engine as an enfolding of the forces of the earth might offer us is a means of moving between scales. His image of an envelopment, a concentration and intensification that in turn opens outwards to transform the world can take us from the tangible scale of a single enclosed space to the vastness of the planet. And back again. More than just a way of getting our *heads* around planet-sized problems, Serres' folding/unfolding logic points to how we might get our *hands* involved in the crafting of social and planetary futures. The idea of enfolding a section of the world's turbulence and forcefulness so that it is modestly scaled enough to actually do some work, I want to suggest, could help us imagine spaces conducive to collective experimentation with geological agency.

While Serres offers us an alluring entry point to the folding-in-and-out theme, it is Gilles Deleuze and Félix Guattari (1987) who have more systematically explored the fold as a worldly operation or practice that brings new things into being. Borrowing the idea of `creative involution' from Henri Bergson (1998), they propose that the most surprising and generative changes in the world tend to come not from following a single line of development (*evolution*) but from an enfolding or *involution* of an outside that is composed and structured very differently from the interior into which it is drawn. `Becoming is involutionary, involution is creative', Deleuze and Guattari intone (1987: 238, see also 46-7). Such creative involution might include previously distinct human technologies coming together or the conjoining of unrelated life-forms, but so too might it include human or other living things reengaging with the whole geological substratum in some new way (see De Landa 1997: 25-8). But Deleuze and Guattari also make it clear that capturing and incorporating elements from a completely different layer or stratum of existence is inherently risky, precisely because it involves a new intimacy with an entire domain of potent and unfamiliar forces (1987: 502-3).

What interests me in this chapter is how – in the context of changing climate and shifting earth systems – we might reinvent the social and ourselves as social beings by

transforming the way we tap into, enfold and incorporate the planet's geological strata. What I am not going to do is to try and map out the precise forms that such a geological renegotiation – a geologic *involution* – might or ought to take. Instead, I want to take an extended run up, and ask what the contemporary challenge of constructing novel geosocial futures might be able to learn from a long and rich history of prior social engagements with geological strata.

The early industrial moment that Serres (with the help of Turner) depicts so evocatively was far from the beginning of the enclosure and setting to work of the earth's fiery energies. In order to utilise the potent, condensed energy of fossilised hydrocarbons, the inventors of modern heat engines required a wealth of collective experience in working with fire and combustible matter. More specifically, they needed to be able to contain and control intense combustion in an enclosed space. This ability, I argue, emerged gradually over countless generations from diverse and widely distributed practices involving the use of concentrated heat in ovens, kilns and furnaces: a set of arts or techniques that is has been described as `pirotechnia' or more recently, `pyrotechnology' (Biringuccio 1990; Wertime 1964, 1973; Rehder 2000). Scholars of the deep history of technological innovation have spoken of `a single, complex pyrotechnic tradition' spanning some ten thousand years that includes the ceramic, metallurgical and glass-making arts (Wertime 1973: 676). But whereas modern heat engines are centred on the use of heat to produce force or do `prime-moving' work – these fiery arts are focused on the transformation of a whole range of materials into novel forms, structures and objects.

In a quite literal fashion, pyrotechnology generated many of the materials out of which sedentary – some would say `civilized' – social existence has been composed. But it is as much the process as the products that concern us here. Pyrotechnology can be seen as a multi-millennial spree of experimentation – one that involved a whole new enfolding of the geological domain into the social world. It is in this sense that we might ask what lessons, insights and inspirations the pyrotechnic arts offer for any current social renegotiation with the geologic. And in particular, what role fire might come to play in the invention of novel social worlds if it were to be set to tasks other than burning fossilised hydrocarbons to perform repetitive and predictable tasks.

Fiery Arts and the Invention of the Social

Revisiting Turner two decades after his first engagement, Serres speaks of the painter's `pyrotechnical canvases' (1997: 2): a phrase that gestures at once to the fiery themes of his artwork and to the more general way in which new modes of combustion were then transforming the very fabric of nineteenth-century society. But Turner, as his artworks indicate, is no cheerleader of the industrial revolution. His is a profoundly ambivalent vision of the turbulent new world. And he is not alone. For all their innovations in putting fossil hydrocarbons to work, northwest Europeans have been deeply equivocal about the whole business of combustion-driven industrialism – and *en masse* they have rarely mourned its out-sourcing to other regions. Then again, neither are Europeans particularly enamored with open-air fire (Pyne 2001: 168-170; Clark and Yusoff 2014: 209-10).

By planetary standards, Europe is `an anomalously fire-free patch', as environmental historian Stephen Pyne puts it (2001: 168). This is partly an effect of Europe's perennial coolness, dampness and corresponding lack of a defined fire season, though it also reflects the intensity of agriculture that can be supported by its recently glaciated soils (Pyne 1997: 18-20). In such a densely gardened region, there is simply not much of a niche left for burning. And not a lot of enthusiasm for letting flames claim a share of biotic productivity. Whereas most cultures worldwide have tended to appreciate the value of open fire or `broadcast burning' for enhancing the productivity of grassland, scrub and forest, Pyne observes, modern Europeans and their cultural progeny generally associate blazing fire with disorder and wastefulness. They have come to see open flame as a signal of bad farm management or societal breakdown rather than as a medium of regeneration and new life, a tool of insurgents and `firebrands' rather than a means of crafting communal bonds or caring for the landscape (Pyne 1997: 162–8; 2001: 145–6; see also Marder 2015). And this tendency to dwell on fire's destructive side seems to be being exacerbated by the highly publicised impact of combusting fossil fuels on global climate.

European discomfort for anything other than fully domesticated flame is paralleled by a marked marginalisation of fire in western scientific and philosophical thought, as Gaston Bachelard has noted (1987: 2-3). `In the twentieth century,' adds sociologist Johan Goudsblom, `social scientists have tended to follow their colleagues in the natural sciences and have dropped the subject of fire from their agenda' (1992: 3). That fire does not have its own science is remarkable when we consider that Earth is the only

planet in the solar system on which fire occurs; that *Homo sapiens* are the earth's only fire-manipulating species; and that over the last million or so years the genus *Homo* has deployed fire with such prodigiousness so as to have transformed most of planet's terrestrial surface (Pyne 1994; 1997: 3). Fire, as Pyne (2015) would have it, is not so much an element or a substance, but a reaction that brings together the earth's other elements – synthesizing air, water, life, and soil into a single event. This too is how we might see the role of fire in crafting social worlds. Not only do flames transform the very stuff of the world, but fire has a special role in simmering, fusing, melding, alloying and annealing the heterogeneous elements of social life into workable unity. To which must be added fire's omnipresent capacity to unravel and obliterate the very order it has helped bring into being (Derrida 1991: 43-4, 57; Clark, 2012).

How humans first came to an understanding of fire's transformative effects on vegetation, flesh, wood, bone, stone and clay is largely a matter of speculation. It is with the development of agriculture and more sedentary settlement patterns shortly after the end of the last Pleistocene glaciation – some 10 to 11,000 years ago – that evidence mounts of systematic use of heat to transmute the structure of inorganic matter (Wertime 1973). There is broad agreement amongst pyrotechnic scholars that ceramics was the first real pyrotechnology: emerging most likely as an offshoot of the ovens whose intense heat rendered grains and other agricultural products palatable (Wertime 1973: 676; Rehder 2000: 42). While the oven itself might appear to be no more than a stepwise development of the open cooking hearth, there is another sense in which we might view these novel enclosures of fire as a new kind of human geological agency – and as such one of the most `geosocially' significant innovations since the capture and propagation of fire by early hominins.

With advances in kiln technology in the ancient world came the gradual ascent of a ladder of heat intensity. Higher temperatures enabled an ever great range of materials to be subjected to transformation - from the baking of clay starting at around 500 °C through to the 1400-1600 °C required to smelt iron and fuse it with carbon (Wertime 1973; Rehder 2000, 6-7). More than a quantitative shift along the thermal spectrum, chambering allows skilled agents to set up and modulate the environment in which combustion occurs – a level of control that could never be achieved with the multiple variables at play in any `open air' combustive event. And it is in this sense that we might see fire's `creative involution' into contained spaces not simply as a human achievement,

but as a transitional moment in the very trajectory of terrestrial fire. Which would make it a significant event in the earth's own history (see Pyne 1994: 889).

A recurrent theme in pyrotechnical scholarship is that the impulse toward heat-induced metamorphosis of earth materials cannot simply be read off the uses eventually found for its outputs. As metallurgist and materials scientist Cyril Stanley Smith observes: `the making of ornaments from copper and iron certainly precedes their use in weaponry, just as baked clay figurines come before the useful pot' (1981: 242). It is not only that beauty and adornment so often anticipate – and exceed – utility, but that the very process of discovery seems to resist cause-effect relations (Clark 2015). It has often been noted that many of the thermo-chemical reactions discovered by ancient artisans involve changes too dramatic to have been intentional. How it came to be known that crumbly ores could transmute into lustrous metals or powdery oxides into translucent glazes, it is surmised, could only have come about by accident or some kind of open-ended experimentation (Childe 1942: 85; Forbes 1950: 201). What metallurgical historian R. J. Forbes - one of Deleuze and Guattari's key sources – has to say about his own field would seem to apply to pyrotechnology more generally: `the early metal worker was not pushed along the path of progress because he had no idea it was a path at all' (1950: 12).

But discoveries indeed settled into pathways, both figuratively and literally. `Although they might have been launched as innocent and isolated skills', observes archaeometallurgist Theodore Wertime, `the pyrotechnic crafts in the years between 10,000 B.C. and 2000 B.C. became formidable industrial "disciplines," entailing the most severe chemical controls on daily operations' (1973: 670). So too were pyrotechnic products channeled into particular uses – both practical and symbolic (Forbes 1950: 11). As the objects fired and fashioned by artisans were set to work, many of them came to play their own formidable disciplining role in the operations of daily life. As metallurgist and historian J. E. Rehder sums up: `The material fabrics of nearly all settled civilizations have by and large consisted of things that exist only because of pyrotechnology' (2000: 3). Or as we might say in another register, the oven, the kiln and the furnace helped forge and weld together an entire `order of things' (see Foucault 1989).

In the context of burgeoning sedentary life – as human beings convened in unheard of numbers and unprecedented proximities – the outputs of the artisanal oven came to play a vital role in the ordering of time and space. Just as they could collect and channel flows of water, impound seeds or grains, or store and portion out foodstuffs, pyrotechnic

products could also help distribute and direct living bodies. Kiln-fired materials lent substance and durability to the built environment: a hard-baked rigidity that served to regulate 'the movement of human flesh' (De Landa 1997: 27–8). So too, from out of the artisan's furnace arrived eye-catching adornments and sumptuary objects – used in `visual displays of identity' that signaled where and when bodies belonged in ever-more complex urban spaces (Roberts et al. 2009: 1019). And not least, from the ancient foundries came standardized and portable mediums of exchange: gleaming metallic tokens that both aided in the circulation of other objects and provided hitherto unthinkable possibilities for hoarding wealth (Wertime 1973: 680; Goudsblom 1992: 63).

As Bruno Latour (1996; 2002) has noted, one of the key characteristics that distinguishes human societies from those of other complex organisms is their propensity to extrude, sediment and concretize social interactions into durable objects. But as Latour continues, the objects, materials and techniques that we enroll as the mediators of our social transactions rarely function in a neutral and predictable manner. `They do not transmit our force faithfully', he muses, `any more then we are faithful messengers of theirs' (1996: 240). While the proliferation of the pyrotechnic arts across much of ancient world effected an irruption of artifactual quantity, diversity and durability, it is only in retrospect that anything like a coherent story can be pieced together of the contribution these productions made to emergent social orders and formations. Latour's attending to the transmission of force is well taken, with the addition that it is not only the power or potentiality of the *objects themselves* that is at stake, but the way these objects actualize and express the forces of *an entire stratum*. For what both the products and the processes of the pyrotechnic arts encapsulate, I suggest in the following section, is something of the very forcefulness of the earth itself. And it is the experiential breadth and depth of this enfolding of the geologic into the social that makes the ten thousand year pyrotechnic adventure so relevant for any renewed negotiation with the stuff of the earth.

Enfolding Geology

Excavations of the Neolithic town of Çatalhöyük in southern Anatolia have revealed a remarkable mural featuring a dappled orange mound foregrounded by a black and white grid-like formation (Schmitt et al. 2014). Some researchers refer to the image as the earliest documented landscape painting, others, the world's oldest warning sign. Though

interpretations abound, the favoured reading is of a volcano spewing effluvia over a townscape. It has been proposed that the twin peaks of the frescoed mountain represent the double volcanic cones of Hasan Dağı, located seventy miles north east of Çatalhöyük. Adding heft to this hypothesis, volcanologists recently confirmed that Hasan Dağı erupted around 9000 BP (before present), a date just prior to the estimated execution of the wall painting (Schmitt et al. 2014).

Widely regarded as the largest and best-preserved Neolithic settlement, Çatalhöyük is also the site of some of the oldest known pottery works. Excavated kilns, featuring thick walls, built-in covers, and flues to regulate air supply, are again dated at around 9000 BP (Rehder 2000: 9; Joseph 1999: 1-2). Çatalhöyük is also one of the earliest sites with plentiful copper artifacts and clear evidence of working with metal. The ceramic-copper concurrence may be more than coincidental. Copper was most likely the first terrestrial metal that artisans learnt to smelt, a process entailing the use of heat and a reducing agent to trigger a chemical reaction that separates metal from its ore. The smelting of copper calls for temperatures of around 1100 °C – well within the thermal range of the pottery kilns found in the Anatolian settlement. The reduced or oxygen-poor atmosphere required to fire the red or black clay used by the potters of Çatalhöyük would also have produced the conditions required to melt copper ores (Joseph 1999: 2). Moreover, azurite and malachite, two of the ores of copper, are known to have been introduced into the firing processes in the form of pigments used in the decorative glazing of ceramics – leading to speculation about the accidental discovery of smelting in the course of ceramic production (Aitchison 1960: 40).

Whether this adds up to evidence of very early copper smelting in Çatalhöyük or whether the metalwork that shows up in the excavations relied upon naturally occurring (hence unsmelted) copper is still debated (Birch et al. 2013). Even more speculative is any clear connection between pyrotechnic breakthroughs and proximity to volcanic activity, though it is well established that the active plate tectonics of this region – a belt of folding and thrust where the Eurasian and Arabian plates meet – results in crustal stresses that squeeze out exceptionally rich and visible fluxes of metallic ores (Yener 2000: 1-2). But direct causal linkages need not concern us here. What I want to explore is a more general line of inquiry that contextualises pyrotechnic innovation within an expanded field of geological eventfulness and potentiality.

Both the well-documented climatic volatility of the Pleistocene and the possibility of an unstable Anthropocene have served to accentuate the stability of the Holocene. This exceptional spell of climatic quiescence is often credited with providing the preconditions for agriculture and sedentary life. It is important to note, however, that the exit from the last Pleistocene glacial maximum was anything but smooth. Between 15,000 and 6000 BP, a span that includes the early Holocene and takes us into the heart of the pyrotechnic developments in question, sea levels rose by 120-130 meters (Nunn, 2012). Not only were coastlines drowning and new alluvial flats forming, there is strong evidence that the crustal stresses caused by changing ice volumes triggered an intensification of volcanic activity. As geophysicist Bill McGuire and his colleagues (1997) demonstrate in a study of the eastern Mediterranean, despite the distance of the volcanic edifices from the melting ice sheets there is a significant correlation between rapid sea level rise from 17,000-6000 BP and enhanced frequency of explosive activity of volcanoes.

For their human witnesses, such geological upheavals can be experienced as both threat and incitement, as Emmanuel Kant (2005: 75-6) ventured several centuries ago. Philosopher Elizabeth Grosz puts a more Deleuzean spin on this intuition. Grosz sets out not from any Kantian sense of the innate powers of the human subject to rise above the chaos of the cosmos, but from the idea that human practical and creative capacities are ultimately an extension of the dynamism and self-differentiating structure of the universe itself (2008: 19). For her, *art* – understood in the broadest sense – is the propensity of human and nonhuman life to express itself in ways that exceed immediate need or utility: `Art is an agent of change in life, a force that harnesses all the other forces of the earth, not to make sense of them, not to be useful, but to generate affects and to be affected, to affect subjects, but also objects and matter itself' (2011: 189).

It is the same inhuman forces of the earth and cosmos that threaten to overwhelm us, Grosz would have it, that also provide `the excess of colors, forms, materials' that are taken up, extended and elaborated upon in creative processes (2008: 9). But this is not a matter of plunging unprotected into the fire, the volcano, or the tumult of biological life – which would be more than most of us could endure. Drawing on Deleuze and Guattari's creative involution theme – and their injunction to experiment cautiously – Grosz speaks of the need to extract, isolate and envelop something of the forcefulness of the earth in order to bring it down to human scale. Just as `the living produce a barrier, a cell, an outline, a minimal space or interval that divides it from its world', any other

creative agent must find a way to calve off a more hospitable interior from a vast and potentially hostile exteriority (Grosz 2011: 38).

Though Grosz does not explicitly engage with the pyrotechnic arts, her logic of an extrapolation on the forces of the earth played out on a manageable scale would seem to be exemplified by the walling of fire in a robust chamber, the control of atmospheres of combustion, and the application of heat to metamorphose matter. Which is to say that we might conceive of the oven, the kiln, the furnace as a means to `temporarily and provisionally slow down chaos enough to extract from it something not so much useful as intensifying, a performance, a refrain, an organization of color…' (Grosz 2008: 3). Or as Michel Serres puts it, in a related sense: `The furnace is the engine for going back toward chaos' (1983: 61). Mythopoeic accounts of pyrotechnology are, of course, replete with volcanic imagery. But Grosz's diagramming of the creative impulse, with its reference to specific physical forces – `the relation between fields, strata, and chaos', `the geology of the earth' – invites a more literal interpretation (2008: 45; 2011: 45). A reading, that is, which takes seriously the rise and fall of sea levels, climatic turbulence, volcanic and seismic activity.

Not merely a backcloth or context, nor even an object of representation like the Çatalhöyük mural, *the geologic* manifests itself in the pyrotechnic arts as process or force. Rehder points out that as ancient artisans improved their pyrotechnic skills, their kilns and furnaces regularly achieved levels in excess of 1200-1300°C. This, he reminds us, is around the temperature that volcanologists believe to be the maximum heat of molten lava (Rehder 2000: 54). And indeed, outside of lightning, this is the highest temperature naturally occurring anywhere on the surface of the planet. Across much of the ancient world, then, wherever pyrotechnology emerged or spread, human settlements forged themselves around and through heat intensities rivaling those of the most powerful `inhuman' forces on earth.

We might say that what the pyrotechnic arts do is to introduce the igneous and metamorphic processes of the earth itself into very core of social existence. In short, pyrotechnology inserts the transformative power of volcanism and other geologic forces into the space of the village and into the rhythms of everyday life. And this is much more than just a diffusion or multiplication of force. Over the generations, artisans attempted to transmute nearly every conceivable mineral element. They explored spaces of possibility that included compounds, variations, embellishments as yet unrealised by

the earth itself. Many of the resulting products have a beauty and exuberance that still enchant contemporary audiences, while the skills that were acquired are often credited with being vital precursors of the scientific knowledge and industrial techniques of the modern world (Smith 1981: 242, 203-6; see also Childe 1942: 86).

In retrospect, we can track continuities between the chambered fire of the ancient world and the heat engines that powered the late eighteenth-early nineteenth century industrial revolution. Without the experience of controlling heat in robust chambers, and without the metals and the metalworking skills to construct these casings, there would have been no blazing boilers, no steam-powered machines, no internal combustion engines. But the emergence of industrial machinery fuelled by buried hydrocarbons is by no means a necessary endpoint of pyrotechnical innovation. This is no simple progression, no `path of progress' – to recall Forbes' point about metallurgy. What is vital to remember is that the chambered fire of the pyrotechnic artisan is intended to transmute the structure and properties of heterogeneous materials into new forms. For the firebox of the modern era, on the other hand, metamorphosis is simply the means to an end. The contained fire of the industrial heat engine is primarily devoted to the conversion of fuel into routinized motive or kinetic functions. From the point of view of the power these new machines unleash, they represent a massive *expansion* on the exertions of their predecessors. But from the perspective of their metamorphic or transformational capacities, the application of chambered fire to prime moving or mechanical work can be seen as an equally momentous *contraction* (Clark and Yusoff 2014: 212; Clark 2015). From being `the great transmuter' (Pyne 2001: 120), fire has been reduced to pushing and shoving in predetermined directions.

It is in this sense – rather than in any notion of pure aestheticism or art for arts sake – that we might reconsider the open-endedness and experimentality of the pyrotechnic arts for our own era. As we have seen, the current environmental predicament is beginning to prompt industrialised social formations to turn away from their dependence on fossilised hydrocarbons. Both conventional economic logic and ecological critique, in this context, exhort us to do more with less, to tighten and close the circuits of matter-energy. But the carbon descent question can also be posed in terms of what other geological strata, what other forces of the earth we might turn to. Or what else energy or matter is for; what else we might *do* with fire. Such questions do not necessarily eschew efficiency or renounce restraint. What they can do, however, is to draw us away from the preoccupation with how much work we can get out of available energy and turn us

toward all the other possibilities that still inhere in the geological strata. These are questions, practical challenges, that bring us to the potentiality of the earth itself – to the field of forces, processes and properties that, as Deleuze or Grosz would insist, is far in excess of whatever humans or other forms of life have yet been able to make of it.

And it is this sense of the virtuality of the earth exceeding its actuality that invites renewed mineral-energetic probing, new variations on igneous and metamorphic themes, further elaboration on the rhythms and singularities of the earth: experimental modes that are likely to be as least as much aesthetic as techno-scientific or managerial (Clark, 2015). So too, as we enter an era of possible destabilisation of earth systems, is it important to keep in mind that the pyrotechnical innovations of the early-mid Holocene may have responded, in some indeterminate and irrecoverable way, to the provocations of geologic and climatic unrest. It would be unfortunate if this were to be taken as a call to aestheticise or dramatise geophysical catastrophe. But what it might do is to help attune us to the ways in which the earth explores its own possibilities, crosses its own thresholds, enacts its own experiments And to remind us that this very unruliness is what we will need to reach into, enfold and take hold of in order to perform our versions of experimentation.

Future Earth and Planetary Conventions

By tracking the chambering of heat back to its primordial moments, and by characterising pyrotechnic origins as an experimental involution of the geological substrata, I have sought to salvage a genre of inventive engagements with the earth from the dense accretion of functions and purposes it later accrued. This is not to ascribe any originary purity to artful genesis or to assume that all functionality is a fall from grace. If artistic expression is indeed an extrapolation of the excessive forces of an inhuman earth, there is no guarantee of beneficent creation. For as Grosz reminds us: `art is also capable of that destruction and deformation that destroys territories and enables them to revert to the chaos from which they were temporarily wrenched' (2008: 13). Or in the words of Smith, reviewing the long history of craft production: `aesthetic creation suggests things that may, if widely adopted, cause disruptive change' (1981: 346). And if fire is the medium of our creative ventures, that capacity for destruction or disruption will never be far away. Mayhem will be as near as a stray spark, a flicker of inattention.

To play on the theme of primordial pyrotechnology is not to imply that we can or should dis-assemble subsequent developments and start anew from some baseline of raw, uncommitted artisanal potentiality. But it is to suggest that any pathway out of the `new and burning society' we have composed for ourselves will need to engage on the same excessive and unstable plane. Just as our species has gradually learnt how to isolate, encapsulate and intensify the unruly forces of the cosmos, so too will we have to learn to enfold, enclose and elaborate on the chaos that our own activities have added to the earth's inherent turbulence.

We should be mindful too that any call for a new societal involution of earth processes quickly comes up against complications or tensions that inhere in the very idea of invention. Deleuze and Guattari are insistent that destratification – the reworking of the earth's constitutive strata – needs to be done with caution. It calls for trial runs, a slow accumulation of skill and experience, a safety net of fallow spaces and uncommitted resources to fall back on if things go wrong (1987: 161). Such provisos suggest that for all their affirmation of surprise and open-endedness, Deleuze and Guattari's bid `for a new earth and people that do not yet exist' (1994: 108) requires a carefully modulated play of difference and repetition, exuberance alloyed with restraint. `It is through a *meticulous* relation to the strata', they contend, `that one succeeds in freeing lines of flight' (Deleuze and Guattari 1987: 161, my italics)

This tempering of `unheard-of becomings' (Deleuze and Guattari 1987: 240) with circumspection and care - what we might see as an originary complication of inventiveness – is more explicitly analysed by Derrida. For Derrida, as for Deleuze and Guattari, a creative event implies a rupture with the known and the familiar. Thus a degree of disturbance and transgression is inevitable: `An invention always presupposes some illegality, the breaking of an implicit contract; it inserts a disorder into the peaceful ordering of things, it disregards the proprieties' (Derrida 2007: 1). At the same time, to make any real difference to its world – to have a future – an invention must also entail a certain con*vent*ionality, it must abide by the rules or habits through which new things get admitted into their social context, are passed on and disseminated:

> It will only receive its status of invention […] to the extent that th(e) socialization of the invented thing is protected by a system of conventions that will at the same time ensure its inscription in a common history, its belonging to a culture: to a heritage, a patrimony, a pedagogical tradition, a

> discipline, a chain of generations. Invention begins by being susceptible to repetition, exploitation, reinscription (Derrida 2007: 6).

While we might now trouble Wertime's assumption that pyrotechnic crafts began as *innocent* skills, his observations about their developments into *disciplines* is well taken: not just with regard to the technical aspects of controlling matter, but also in the sense of the complex customs, codes and rituals through which knowledge has been both protected and transmitted. Indeed, the very propensity of socio-material processes and techniques to transmit their effects `unfaithfully' depends, ultimately, on the presence of more-or-less effective modes of uptake, transmission, iterability.

To affirm such logics of invention – with their indissociability of eventful rupture and conventionality – is to raise questions about the distinctiveness of generative processes in the stratum that is recognizable `ours'. However much the creative involutions of other strata give rise to novel structures, assemblages, and operational possibilities, and however much the forces of the `inhuman' strata might energize, summon or provoke our own becomings, there are limits to how far we might wish to stretch the idea of conventionality. Though other sites or modes of creativity `provide( ) the ground and support for human invention,' Derrida notes, `no one has ever authorized himself to say of animals that they invent' (2007: 25); a verdict we can assume he would extend to other nonhuman creatures and to the geologic. So too do we need to recall that for all their affording of ontological dignity to the articulations of all strata, Deleuze and Guattari acknowledge specific cultural-linguistic capacities that help merit human productions a distinctive stratum of their own

Today, as evidence of intensifying planetary heating provokes increasingly urgent demands for the reinvention of human socio-material relations with the rest of the earth, the tension between the advent of the wholly new and the conventions through which novelty is re-inscribed flares with especial intensity. `Even a summit of all the nations of the earth, preceded by the most strident media campaigns, could not digest an issue so intractable and so enmeshed in contradictory interests as this one,' exclaims Latour (2011) of the current deadlock in climate change politics. On the one hand, this impasse appears to issue from the limitations of unfathomably complex and interminable deliberation. Successive global forums seem at best to generate only new conventions – but never an inventive rupture with existing socio-material orders. On the other hand, the procedural commitment to fairness, inclusion and consensus to which many climate

negotiators ascribe is increasingly haunted by the possibility of new kinds of grand scale physico-material intervention: geoengineering schemes or climate modification experiments that vaunt their inventiveness while threatening to circumvent deliberative processes (Clark 2013). In short, there appears the disconcerting spectacle of two extremes; convention bereft of invention, invention untethered from convention.

Under the current compulsion to invent – to contrive new legislation, techniques, products – Derrida detects a further paradox. In the context of political economic competition and national rivalries, it is increasingly seen as necessary to pre-order and institutionalise creative change. Not only is the logic of attempting to programme the unforeseeable inherently contrary, Derrida contends, but the demand for incessant innovation soon becomes tiresome and draining:

> A closer analysis should show why it is then the word "invention" that imposes itself [….] And why this desire for invention, which goes so far as to dream of inventing a new desire, remains, to be sure, contemporary with a certain experience of fatigue, of weariness, of exhaustion (2007: 22-3).

Climate change – a topic Derrida himself barely broached – couples the almost universal exhortation to innovate with the enervation attending interminable effort in a world of diminishing resources. As philosopher Michael Marder notes, the consequence of intensifying industrial combustion is burnout: `the breakdown and exhaustion we experience when we run out of the mental and physical resources to be expanded at an ever-accelerating rhythm of self-incineration' (2015: 94). Burnout, Marder insists, is at once a planetary and a personal predicament. Under such pressure, even the ardent affirmation of creativity in radical visions might come to seem world wearying. While broadly sympathetic to Deleuzoguattarian notions of becoming, ethical philosopher John Caputo eventually draws breath and confesses: `I find it too exhausting, all this outpouring and overflowing, all this firing away of forces night and day' (1993: 53). A lament we might imagine the earth itself echoing.

Given conditions of compounding emergency and exhaustion, it's small wonder that the planet-scaled task of reinventing the social threatens to overwhelm. Faced with the daunting prospect of crafting what we might refer to as new `geosocial formations' (Clark and Yusoff 2014: 224), the deep history of pyrotechnology offers no answers –

though it may offer hints, clues, prompts about how we might `learn to be affected' by the matter-energy of the earth (see Latour, 2004). The key to the success of the emergent pyrotechnic complex seems to have been the ability to corral, enclose and insulate; to downsize vast and intimidating forces to an intimate level; to sublimate inhuman forces into everyday spaces. Attuned to accidents, perhaps enamoured with chance and surprise, pyrotechnic knowledge was also enframed in lore and convention, though its inscription into the social frequently took forms we would hardly wish to revisit.

That the work of reinventing the social in a turbulent world might respond to the allure of matter and flame, that critical practice might coalesce around palpable workings with the grit and grain of proximate materials, points toward social sciences with a sensuous touch and an expanded toolkit. Our focus on the *longue durée* of artisanal practice serves as a reminder that metaphors of forging, shaping, molding or constructing social worlds have literal traces, and in turn hints at the distance that has opened up between modern social thought and what was once the everyday work of manipulating matter-energy to make useful and beautiful things (see Ingold 2013; Guggenheim et al. this volume). More than simply admonishing would-be earth system engineers for their circumvention of socio-political procedurality, it might be time for social thinkers to seek out modes of geotechnics and material-energetic experiments more to our liking. And to keep in mind that there are likely many more pathways along which the materials of the earth might be coaxed than have yet been pursued. Though neither should we downplay looming doubts about whether we still have time or energy enough to craft whole new social worlds out of the intransigent forces of the earth

References

Aitchison, L., *A History of Metals, Volume 1,* (London: MacDonald & Evans, 1960).

Bachelard, G., *The Psychoanalysis of Fire,* (London: Quartet, 1938).

Biringuccio, V., *The Pirotechnia*, (New York: Dover Publications, 1990).

Bergson, H., *Creative Evolution*, (Mineola, NY.: Dover Publications, 1998).

Caputo, J., *Against Ethics,* (Bloomington, IN.: Indiana University Press, 1993).

Childe, G., *What Happened in History*, (Harmondsworth: Penguin, 1942).

Clark, N., `Rock, Life, Fire: Speculative Geophysics and the Anthropocene', *Oxford Literary Review,* 34.2 (2012): 259–76.

--------`Geoengineering and Geologic Politics', *Environment and Planning A,* 45 (2013): 2825-32.

-------`Geo-politics and the Disaster of the Anthropocene', *The Sociological Review*, 62.SI (2014): 19-37.

-------`Fiery Arts: Pyrotechnology and the Political Aesthetics of the Anthropocene', *GeoHumanities,* 1.2 (2015): 266-84.

Clark, N., and K. Yusoff, `Combustion and Society: A Fire-Centred History of Energy Use', *Theory, Culture & Society,* 31.5 (2014): 203–26.

Crutzen, P., `Geology of Mankind', *Nature,* 415 (2002): 23.

De Landa, M., *A Thousand Years of Nonlinear History*, (New York: Swerve, 1997).

Deleuze, G., and F. Guattari, *A Thousand Plateaus: Capitalism and Schizophrenia*, Minneapolis: University of Minnesota Press, 1987).

------- *What is Philosophy?* (London: Verso, 1994).

Derrida, J., *Cinders*, (Lincoln, NE. and London: University of Nebraska Press, 1991).

------- *Psyche: Inventions of the Other,* (Stanford, CA.: Stanford University Press, 2007).

Forbes, R. J., *Metallurgy in Antiquity*, (Leiden: E. J. Brill, 1950).

Foucault, M., *The Order of Things: An Archaeology of the Human Sciences,* (London: Routledge, 1989).

Goudsblom, J., *Fire and Civilization*, (London: Allen Lane the Penguin Press, 1992).

Grosz, E., *Chaos, Territory, Art: Deleuze and the Framing of the Earth,* (Durham, NC.: Duke University Press, 2008).

------- *Becoming Undone: Darwinian Reflections on Life, Politics, and Art*, (Durham, NC. & London: Duke University Press, 2011).

Guggenheim, M., B. Kräftner, and J. Kröll, `Inventing the Social: A Recipe for Incubations' in Marres, N., M. Guggenheim and A. Wilkie eds. *Inventing the Social* (tbc)

Ingold, T., *Making: Anthropology, Archaeology, Art and Architecture*, (Abingdon, Oxon.: Routledge, 2013).

Jasanoff, S., `A New Climate for Society', *Theory, Culture & Society*, 27.2/3 (2011): 233–53.

Joseph, G., *Copper: Its Trade, Manufacture, Use, and Environmental Status*, (Novelty, OH.: ASM International, 1999).

Kant, I., *Critique of Judgement*, (Mineola, NY: Dover Publications, 2005).

Latour, B., `On Interobjectivity', *Mind, Culture, and Activity,* 3.4 (1996): 228-45.

------- `Morality and Technology: The End of the Means', *Theory, Culture & Society,* 19.5/6 (2002): 247-60.

------- `How to Talk About the Body? The Normative Dimension of Science Studies', *Body & Society* 10.2/3 (2004): 205–29.

------- `The Year in Climate Controversy', *Tehelka*, 15 June (2011). <http://archive.tehelka.com/story_main48.asp?filename=Ws040111CLIMATE_CHANGE.asp> [accessed 15 June 2016].

McGuire, W., R. Howarth, C. Firth, A. Solow, A. Pullen, S. Saunders, I. Stewart, and C. Vita-Finzi, C., `Correlation between Rate of Sea-Level Change and Frequency of Explosive Volcanism in the Mediterranean', *Nature*, 389 (1997): 473-6.

Marder, M., *Pyropolitics: When the World is Ablaze*, (London: Rowman & Littlefield: 2015).

Nunn, P., `Understanding and Adapting to Sea Level Rise', in F. Harris, ed., *Global Environmental Issues,* 2nd edn, (Chichester: John Wiley & Sons, 2012), pp. 87-107.

Montaigne, F., `Leaving Our Descendants A Whopping Rise in Sea Levels', *Environment 360* (2013), <http://e360.yale.edu/feature/leaving_our_descendants_a_whopping_rise_in_sea_levels/2675/> [accessed 15 June 2016].

Pyne, S., `Maintaining Focus: An Introduction to Anthropogenic Fire', *Chemosphere* 29.5 (1994): 889–911.

------- *Vestal Fire*, (Seattle, WA.: University of Washington Press, 1997).

------- *Fire: A Brief History*, (Seattle, WA.: University of Washington Press, 2001).

------- `The Fire Age', *Aeon*, 5 May (2015), <http://aeon.co/magazine/science/how-our-pact-with-fire-made-us-what-we-are/> [accessed 15 June 2016].

Rehder, J. E., *The Mastery and Uses of Fire in Antiquity*, (Montreal & Kingston: McGill-Queens University Press, 2000).

Roberts B., C. Thornton C., and V. Pigott, `The Development of Metallurgy in Eurasia', *Antiquity* 83 (2009): 1012–22.

Schmitt A., M. Danišík, E. Aydar, E. Şen, I. Ulusoy and O. Lovera, `Identifying the Volcanic Eruption Depicted in a Neolithic Painting at Çatalhöyük, Central Anatolia', Turkey, *PLoS ONE* 9.1 (2014), <http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0084711> [accessed

15 June 2016].

Serres, M., `Turner Translates Carnot' in *Hermes: Literature, Science, Philosophy*, (Baltimore, MD.: John Hopkins University Press, 1983).

------- `Science and the Humanities: The Case of Turner', *The Journal of the International Institute* 4.2. (1997), <http://quod.lib.umich.edu/j/jii/4750978.0004.201?view=text;rgn=main> [accessed 15 June 2016].

Smith, C. S., *A Search for Structure: Selected Essays on Science, Art, and History*, (Cambridge, MA.: MIT Press, 1981).

Urry, J., `A Low Carbon Economy and Society', *Philosophical Transactions of the Royal Society* A, 371 (2013): 1-12.

Wertime T., `Man's First Encounters with Metallurgy', *Science,* 146 (1964): 1257–67.

------- `Pyrotechnology: Man's First Industrial Uses of Fire. *American Scientist,* 61.6 (1973): 670-82.

Yener, K., *The Domestication of Metals: The Rise of Complex Metal Industries in Anatolia*, (Leiden: Brill, 2000).

Yusoff, K., `Geologic Life: Prehistory, Climate, Futures in the Anthropocene', *Environment and Planning D: Society and Space* 31.5 (2013): 779–95.

Zalasiewicz, J., M. Williams, A. Smith, T. L. Barry, A. L. Coe, P. R. Bown, P. Brenchley, D. Cantrill, A. Gale, P. Gibbard, F. J. Gregory, M.W Hounslow, A.C.Kerr, P. Pearson, R. Knox, J. Powell, C. Waters, J. Marshall, M. Oates, P. Rawson and P. Stone. `Are We Now Living in the Anthropocene? *GSA Today,* 18 (2008): 4-8.