Political Geologies of Magma

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Meetings with Magma in the Krafla Caldera

In the spring of 2009, engineers drilling in Iceland's volcanically active Krafla region unexpectedly struck magma (Elders et al, 2011). As the centrepiece of the Iceland Deep Drilling Project, the aim of the Krafla borehole was to explore the feasibility of generating geothermal power from supercritical hydrothermic fluids: `supercritical' in the geothermal context referring to water close to subterranean heat sources that its temperature has passed over the critical point at which a fluid begins to behave at once like a gas and a liquid (around 400 °C in the case of water) (Elders et al, 2014).

Described as `one of the most demanding drilling projects undertaken anywhere in the world at this moment' (Landsvirkjun, 2008), the scheme accidently exceeded some of its own expectations. Intended to reach depths of 4-5 kilometres, close to the estimated location of a chamber of magma, drilling came to a halt when the drill-bit intersected magma at just over 2 kilometres (Landsvirkjun, 2008). As it eventuated, the magma body in the Krafla Caldera – a caldera being a large depression resulting from earlier ventings of magma – was far closer to the surface than anticipated. Only twice before – at the Puna geothermal field in Hawai'i and the Menengai caldera in Kenya - are drilling operations known to have directly encountered magma (John Hopkins University 2008, Awili 2017). On these occasions, offending boreholes quickly clogged up, but at Krafla engineers have been able to keep the well open. Steam from the wellhead later reached 450 °C, a temperature well over the supercritical threshold and reportedly a world record for a geothermal well (Landsvirkjun, 2012).

While working with extreme heat and corrosive fluids presents numerous challenges, Krafla project managers anticipate putting magma to work driving steam turbines

(Landsvirkjun, 2012). Given estimates that wells tapping magma directly could produce ten times the energy of standard geothermal boreholes (Elders et al, 2011), there is understandable interest in the project at volcanic hotspots worldwide. The Deep Drilling Project has since evolved into an international research facility – the Krafla Magma Testbed, which aims not only to develop the potential of magma as a low carbon energy source but to take advantage of the scientific opportunities of what is being described as `the first direct access to the magmatic environment of Earth' (ICDP, 2017: unpag).

Speaking of the 2008 magma strike at Puna, geologist Bruce Marsh enthused: `As scientists, we've hypothesized about the nature and behavior of magma in literally countless studies, but before now the real thing has never been found or been physically investigated in its natural habitat within the earth' (cited in John Hopkins University 2008 unpag.). But if Krafla can realise this promise, it is not just a matter of the first sustained scientific engagement with *in situ* magma or even the first *human* encounter. It would be the first time that any living being – in a history of biological life spanning at least 3.5 billion years – has broken through the earth's crust and made contact with the planet's molten interior.

What kinds of political questions might be incited by the `event' of meeting with magma? For those of us who see ourselves as `critical' social thinkers, there is a great deal going on in the quest for `supercritical' hydrothermic energy that is neither novel nor particularly surprising. As Marx put it - a century and a half ago - capital, in search of new inputs and outlets, sets about `the exploration of the earth in all directions' (1973 [1857]: 409). Today, in spite of and sometimes because of escalating concerns over human-induced change in the earth system, we are witnessing a drive both for `unconventional' energy or mineral resources and for `conventional' resources from non-traditional sites. At once on the Artic fringe and the cusp of the earth's crust, the Krafla project might well be positioned amidst a broad-fronted advance of extractive `frontiers' into the polar regions, the seabed, the deeper geological strata, and even other astronomical bodies.

The Deep Drilling Project brings together Icelandic public companies and multinational mining and manufacturing interests – fitting a profile what has recently been referred to as new Nordic extractivism (Kröger, 2016). Such a nexus of resources, state and corporate power suggests a need to interrogate the role of politics and economics in geological developments in the Iceland context. But it is equally important to keep in mind that a sovereign state that names itself `Iceland' only exists by virtue of the geological forces that

the Krafla project seeks to exploit. The island is the product of a constructive plate boundary, where new crust-forming molten rock pumps up from the inner earth – pushing apart the Eurasian and North American tectonic plates. Most constructive plate boundaries are situated on the deep seabed. But as a not-uncontested geological explanation has it, Iceland sits above one of the numerous vast upwellings in the inner earth known as mantle plumes - making it `the only example where a powerful mantle plume and constructive plate boundary happen to coincide' (Rothery, 2007: 22-23). And it is this dynamic combination that results in a visible and habitable mid-oceanic landmass.

A consideration of the earth processes that make the territorial space of Iceland possible and endow it with energetic potentiality is suggestive that, just as we need to consider how geological resources can and ought to become political issues, so too might we think in terms of the `political' itself as being geologically conditioned. With this in mind, I take the events at Krafla as an incitement to explore the role magma is playing and might yet play in new political mobilizations, and – more speculatively – to reflect on what a `magmatic' politics might look like

Political Magma, Magmatic Politics

Aside from pockets of sedimentary rock, Iceland is composed of accreted and hardened volcanic rock (Weisenberger 2010). In other words, it is mostly made of magma –the magma that had collected in a reservoir or `chamber' beneath the Krafla region being a manifestation of this at once generative and destructive process. Magma - in geological terms - is any molten rock, lava being melted rock that makes it to the earth's surface. Why volcanoes happen - how and why there are masses of molten rock powering their way up from the depths of the earth - puzzled geoscientists and their predecessors for centuries. As Icelandic volcanologist Haraldur Sigurdsson points out, it is a question that could not be satisfactorily answered until knowledge about the composition of the inner earth was combined with an understanding of crustal mobility – a synthesis that awaited confirmation of the theory of plate tectonics in the 1960s (1999: 6-7, 224-229).

Current thinking has it that vast slow moving `convection currents' in the viscous rock comprising the earth's mantle layer interact - or are coupled - with movement of the planet's hardened outer crust (Sigurdsson 1999: 224-229). The rising, sinking and grinding together of the tectonic plates composing the crust – along with the sucking

under of seawater in the process - causes some of the mantle material to melt, not as a result of heating but through reduction in pressure as it ascends (White and McKenzie, 1989). More buoyant than the rock from which it is formed, magma tends to rise. A small proportion of this rising molten matter bursts through the surface in volcanic eruptions, but most of it stalls in fractures or collects in subsurface chambers, like the one beneath the Krafla Caldera (Rothery, 2007: 21-31)

Just as there is no organism on earth that could experience the 600 °C -1600 °C heat of magma without immediate loss of life, so too does magma quickly lose its essential and definitive characteristics when it enters `our' world. As Marsh observes: `once magma erupts, it begins cooling unusually quickly and it loses any gases that it may contain, so it really is a different animal' (cited in John Hopkins University 2008, n.p.). Until the trio of accidental strikes, geoscientists researching magma have had to content themselves with laboratory reconstructions of subterranean conditions, explorations of `fossilized' magma dykes and chambers, or quick-footed forays into freshly extruded lava (Stewart and Lynch 2007: 70).

This is why the ability to study magma *in situ* promises new insights on the physical and chemical state of subsurface magma bodies. As well as having a constant source of fresh magma, researchers anticipate placing sensors directly into magma chambers – with the potential for improved understanding of tectonic processes, oceanic crust formation and seawater chemistry. One option being considered at Krafla Magma Testbed is using access to magma chambers as a way to cool molten rock and therefore reduce volcanic hazards – a possibility which NASA scientists studying supervolcanoes had been considering independently (Cox, 2017).

Aware of the risk of mobilising toxic chemicals such as mercury or arsenic, wary of triggering the very volcanic eruptions from which they wish to keep `civilians' safe, geoscientists know they must proceed with caution in their dealings with the subcrustal world. So too, I want to suggest, do those of us who see ourselves as more-or-less social thinkers need to attend carefully to the question of how new political formations might be crafted about and through meetings with magma – for we are encountering materials and powers with which most of us have a lot less experience than our science counterparts. But the novelty of the current conjunction also suggests that a certain degree of imagination is required, for this is less a matter of `staying with the trouble' than of groping towards problems and opportunities that have yet to materialize (cf Haraway

2016). As well as being rigorous and critical, to be `careful' or `responsible' may also require us to be speculative.

To begin to make sense of these nascent meetings with magma in the Icelandic context, I suggest, we have much to learn from the interdisciplinary and often fiercely engaged field of political ecology. Forged through the painful experience of clashes between powerful modes of appropriating physical resources and the myriad other ways that communities live with and through a living earth, political ecologists from early on set their sights on the specific issues associated with the extraction of energy and mineral from the subsurface. Political ecology also articulates in productive ways with the critical study of disasters – and its definitive concern with the uneven exposure of social actors to extreme events (see Donovan, 2017).

In the course of their immersion in contested power relations, political ecologists frequently find themselves grappling with the material properties of the resources in contention. There are other modes of inquiry, however, that have chosen to specialise in the distinctive qualities of more-than-human matter and its implications for political issue formation. Attuned to the `knots' through which human collectives intermingle with nonhumans, a clutch of approaches arising out of science and technology studies and assorted `relational materialist' currents in social and cultural thought have been probing the heterogeneous composition of collective life for several decades. With its more recent focus on the circumstances under which different kinds of `stuff' may be made to matter politically, this kind of relational thinking encourages us to seek out the ways in which magma might trigger new political mobilisations – though it is wise to the fact that the timing and trajectory of any such emergent issue may be unforeseeable.

Uncertainty, however, might go deeper than this. If there is one thing that characterizes the human-magma interface, as we have seen, it is that *in situ* encounters are exceedingly rare - owing to the fact that magma forms in environments far beyond the life-worlds of social beings. It is the specificity of these conditions that brings us to a third style or genre of approaches – more diffuse and less institutionally established than either political ecology or relational materialisms. What we might loosely gather under the `geologic turn' is a relatively recent move in social and philosophical inquiry towards a full appreciation of the force of earth and cosmic processes. While frequently in conversation with the

Anthropocene thesis - the claim that human agency is now impacting on earth system and planet's lithic strata – the emergent thematization of the geologic goes beyond the human-planet interface to confront the issue of the inhuman *in and for itself*.

As we will see, exactly what such venturing into extrahuman reaches of existence – by nominally or residually `social' thinkers – means for reconfiguring the political remains to be worked out. What I will be suggesting is that new thinking with and through the geologic can help us grapple with the exteriority and anteriority of magma – or what we might call its `subtending' of human (and nonhuman) life - and in this way opens up speculative prospects for imagining a more `magmatic' politics.

In the following three sections, I take each of these approaches in turn and tease out the contribution they might make to a political geology of magma – while acknowledging that they are by no means mutually exclusive. Though it is far too early to confidently map out a politics of magma or a magmatic politics, I suggest that there are good reasons for getting in early, in advance of the shocks or crises that might trigger `actual' political mobilizations – and I conclude by starting to think about the work that a `Krafla Magma Political Testbed' might do.

Political Ecologies of Nordic Extraction

> It is natural that in the 21st century, we should search for new ways to exploit environmentally friendly energy resources. A well-balanced exploitation of Icelandic energy resources and the export of knowledge is our international contribution, and in that way do we found a modern standard of living in a responsible manner. (Agnar Olsen, Landsvirkjun deputy Managing Director: Landsvirkjun 2008)

> … as far as geothermal development is concerned, harnessing deep seated renewable geothermal reservoirs seems to us logical and perhaps inevitable. Drilling into the roots of the existing geothermal systems will permit longer-term, and more sustainable development of the resources (Elders et al 2014: 117).

Among the formative insights of political ecology is the idea that we ought to be sceptical of claims about the `naturalness' or `inevitability' of any proposed developmental pathway, that we should be especially suspicious whenever protecting the global environment is rolled out as a rationale for such developments, and doubly dubious when corporate actors and scientists make such claims in concert.

With an enviable standard of living and a relatively egalitarian social order, Iceland has been spared much of the environmental violence that political ecologists – in partnership with affected communities – have brought to light in the `developing' world. It is not easy in the Icelandic context to make a strong case for exclusion of the less privileged from the benefits of resource exploitation or to identify deeply entrenched socio-economic differentials in exposure to the country's manifold volcanic hazards. In other senses however, as a former colony historically dependent on primary and extractive industry and as a marginal economy struggling to make its way in an uncertain global environment, Iceland displays some familiar tensions between economic development and protection of the environment.

On the environmental score, paradoxes run deep as the rift valleys bisecting the country. Iceland boasts the largest area of European wilderness, while soil erosion is ranked as Europe's most severe; past governments have claimed that `Iceland is the greenest country in the world' (cited in Chapman, 2017)**,** while the nation's per capita ecological footprint has been rated second highest on earth (Olafsson et al, 2014); near 100% renewable electricity generation has been achieved, yet Icelandic negotiators cut a deal under the Kyoto Protocol for a 10% *rise* in carbon emissions from the 1990 baseline – the biggest increase in the world (Lyall, 2007; DeMuth, 2003).

Though a far cry from the `resource curse' storyline, much of Iceland's equivocal environmental record can be put down to the manner in which nominally `renewable' energy resources are being subsumed into the global economy. With hydroelectric and geothermal capacities proving more than sufficient for the local market, Icelandic public energy companies turned to energy-intensive manufacturing – most notably aluminium smelting and processing – as a way to effectively export energy. But what is officially glossed as renewable, low impact energy generation, Iceland's environmental critics insist, needs scrutinising. Geothermal developments, it is has been noted, have resulted in a 255% rise sulphur oxide emissions between 1990 and 2010 (Olafsson et al, 2014: 941), while the building and running of aluminium plants, even when fuelled by more-or-less

renewable energy, results in high carbon dioxide emissions (Olafsson et al, 2014; 942). Moreover, so thirsty is aluminium smelting for energy, that far from absorbing surplus capacity, it now drives Iceland's energy development. Most controversial has been the 690 MW Kárahnjúkur hydropower station, which required the construction of five dams and the flooding of large areas of wilderness, provoking an outburst of environmental protest. The project, carried out by Landsvirkjun and completed in 2009, increased Iceland's overall electric power capacity by almost a third – with the sole purpose of powering a single massive aluminium plant owned by the United States-based aluminium manufacturer Alcoa (Lyall, 2007).

It is no coincidence that Landsvirkjun and Alcoa are partners in the Iceland Deep Drilling Project. For it one of the original intentions of the shift toward supercritical geothermal power generation in Iceland's north east was to fuel another Alcoa smelter – this time avoiding the controversy that would likely have been sparked by any further export-oriented hydro development.

What galvanized protest was not only the perceived sacrifice of wilderness areas for large-scale energy development but also the tight hold local political elites had over decisions of lasting economic and ecological environmental significance – and the corresponding paucity of public consultation. It is revealing that of the partners in the Deep Drilling Project - Landsvirkjun, Hitaveita Sudurnesja, Orkuveita Reykjavíkur, Orkustofnun, StatoilHydro ASA, and Alcoa - all but the last are Nordic public companies. Such significant state involvement in the energy and extraction sector is a core concern of recent political ecology. For as geographer Gavin Bridge notes: ` natural resources and state power can be mutually constitutive, and highlight the importance of examining the political formations currently emerging at the resource-state nexus' (2014: 126, see also Bebbington, 2012).

The question of why extractive industries in the global South are so often implicated in political instability and spatially uneven forms of governance has been a staple of research in political ecology, with canonical work exploring the lack of fit between the `governable spaces' established around resource deposits and the imagined space of the nation (see Watts, 2004). But as global capitalism exerts its relentless pressure on resources, and as the age of easily accessed `cheap nature' seems to be waning (Moore 2015: 16-17), extractive `frontiers' and their associated governance issues are on the move. In this context, critical development scholar Markus Kröger observes, Arctic regions – including the Nordic

`global North' – are emerging as crucial sites of a new extractivism. Taking mining in Finland as his case study, Kröger notes how high levels of state support coupled with political stability make the Scandinavian nation highly appealing to global extractive industries. But on the back of reviewing some particularly calamitous metal ore extraction ventures in the far northern region, he concludes by dismantling the assumption amongst Finnish mining advocates that their own country is ` too advanced politically and technologically to repeat the errors and disasters that other countries make' (Kroger, 2016: 564-5).

It is not just its location on the Arctic fringe (or its plumbing of unprecedented depths) that has Krafla resonating with Kröger's Nordic new extractivism. It is also the prominent role of the Icelandic state in establishing a political and legal environment conducive to attracting energy-hungry manufacturing interests. Where Icelandic proponents of `big' energy developments have enjoyed an advantage over many other state-supported extractive policies is in their ability – in a context of escalating concern over climate change – to highlight the renewable side of proposed power projects. Playing the `sustainability' card has helped the resource-state alliance carve out a `symbolic space' suggestive of social and environmental responsibility (cf Kröger, 2016: 256-7) – although this has been tempered by rising opposition to hydropower projects.

In tandem with concerns over migrating extractive frontiers, scholars in political ecology and allied fields have been reviewing the more general implications for governance of extending the reach of the state into the subsurface. Theorists have noted that, along with a growing tendency to secure airspace, states are attempting to assert greater control over subterranean mineral and energetic resources. If `territory' is defined as that space which can be visualized, ordered and administered by governing bodies, then new techniques to probe and manipulate the subsurface can be viewed as ways of vertically extending the reach of political power (Elden, 2013; Bridge, 2013; Braun, 2000). In this light, more than a quest for energy resources, Iceland's Deep Drilling Project can be seen as a means for the Icelandic state to extend its sphere of influence. `Territorially' modest relative to larger state actors in the global context, Iceland gains political heft by opening its borders to the inner earth: an advance not just conceived as an energy fix but, in the words of Landsvirkjun management with which I opened this section, as a potential `international contribution'.

Along these lines, recent critical work on the vertical dimensions of territory has sought to

demonstrate how the subsurface can be seen as an *effect* of particular governance imperatives strategies and their associated knowledge practices. In significant ways, this inherits and develops an imperative of `denaturalization' that has characterized political ecology from the outset: the idea that specific, power-laden social practices have `produced' the nature in question as an exploitable object (Smith, 2010: ch. 2; cf Bakker and Bridge, 2006: 8). Though mindful that the natural world has properties of its own and a certain recalcitrance in the face of its exploitation, the priority of much critical scholarship has been to reveal the work that goes into converting `nature' into a form that can be known, manipulated, and uploaded into circuits of value.

While concerted attention to *any* aspect of physical reality ought to raise questions about the extent to which it has actually been shaped by social processes, geological phenomena, I claim, have a special capacity for foregrounding the irreducibly nonhuman (Clark 2017). Arguably, the rise of new modalities in accounting for the properties and agencies of the nonhuman in the constitution of social life has been one the major transformation in social thought over the last few decades. I now turn to the `relational materialist' approaches that have been at the forefront of these developments – and consider how they might help us come to terms with the `stuff' of magma and its potential `materialization' as a political issue.

Material Politics of the Geologic

With more than a whiff of censure for critical thinkers who reduce the substance of the world to the dim receptacle of social agency, science studies scholar Andrew Barry observes that: `metals and other inorganic materials …have an objectivity and an immalleability that cannot be explained away as an expression of political ideology or economic interest (2010: 90). He is, however, just as keen to remind us that `(t)here is no necessary reason why the behavior or properties of specific materials should be considered a political matter' (2010: 109).

The idea that under certain circumstances nonhuman things can play a significant role in politics – or become controversial - has emerged as a pillar of actor-network theory and other now not-so-new materialisms. Just as these self-professed `relational' styles of thought have long insisted that the so-called ``social' is composed of heterogeneous ingredients, so too are they impressing upon us that politics is an activity that is constitutively comprised of the actions or agency of nonhumans as well as humans (see

Latour, 2005; Stengers 2010; Braun and Whatmore, 2010)

In order to apprehend those moments at which matter is given political import, or impresses itself into the political domain, researchers typically set out in pursuit of the things themselves. As sociologist Mimi Sheller asks, in a case immediately relevant to the Krafla story, `What can we learn by thinking with aluminum, following its material forms around the world? (2014: 129). By virtue of its intrinsic lightness and conductive properties, she contends, aluminium came to embody a particular energy culture, emerging in the early 20th century that privileges speed and mobility. But at the same time, as we have already seen, the lightweight metal is decidedly heavy in its energy demands. Thus: `Aluminum in effect freezes electricity in metallic form, and then releases that energy in its material capacity to enable things to move more lightly, hence efficiently (2014: 141). Fortuitously for us, Sheller shows how these paradoxical properties are at the heart of Iceland's recent energy policy, and in this way served as a trigger for the environmental controversies that have rocked the small nation since the early 2000s. Still more cogently, she reveals how the potential contribution of aluminium's lightness to reducing greenhouse gas emissions has been deployed by Alcoa management to justify the Iceland Deep Drilling Project (2014: 144).

We have not yet fully arrived in the world of magma, for reasons I am coming to. For Sheller, no less than for political ecologists, questions of who benefits and who misses out matter a great deal in the Iceland energy context, though for her this theme is perplexed through the crediting of mobile metals and immobilized rivers with the power to divide or congregate people. Actor-network theorist Bruno Latour makes an analogous point by way the thousand year-old `Althing', in Iceland - reputedly the world's first parliament. In his words: `the ancient "thingmen" – what we would call "congressmen" or MPs – had the amazing idea of meeting in a desolate and sublime site that happens to sit smack in the middle of the fault line that marks the meeting place of the Atlantic and European tectonic plates …'. (2005a: 23). Today, in a world of ever more tortuous and complex entanglements between humans and nonhumans, Latour goes on to ask `(a)re not all parliaments now divided by the nature of things…?' (2005a: 23).

By this logic, things do not simply burst into readymade political constituencies or catch the attention of a preformed public lying in wait of an animating spark. Rather, publics – plural – need to be convened and mobilised around each new object of concern, just as the object itself must be identified, made visible or `materialized' (Marres 2007). More so

than the routines of party and parliamentary politics, it is this procedure of `making things public' that inaugurates and animates contemporary political life (Latour 2005a).

So, in the contemporary world, as a theory of material politics would have it, what kinds of things most often provoke us into mobilizing politically?

Latour's reference to Iceland's tectonic fault lines, it turns out, is more of a rhetorical flourish than an exemplar. Most relational materialist research has chosen to focus on less conspicuous and more mundane objects, the proliferation of more-than-human things that mediate and enable our lives but often pass unnoticed until something goes wrong. Or, rather, it focuses on the nodes or knots where the lives of people and things knit together – or unravel. Consequently, neither nature nor culture, humans nor nonhumans, on their own tend to be seen as helpful categories. Rather it is their intersection, the venues and events of mutual constitution, that matter most.

This privileging of in-between spaces, of sites of entwining and acts of intermingling reflects assumptions about relationality that underpin most new materialisms: it manifests an ontology in which the very idea of a `relation' is most often taken to mean a reciprocal encounter involving the transformation of each of the participants (see Clark, 2011: 30-34). At the same time, the prioritizing of `networks' and `entanglements' conveys a more empirical sense that the world itself is increasingly an expression of complex infrastructural linkages and novel ad-mixings – the idea, as Latour puts it, that `the very extension of science, technologies, markets, etc. has become almost coextensive with material existence' (2008: 7).

There is nothing in the material politics literature that preempts certain kinds of objects from participating in political life. In practice, however, some things have proven more amenable to material politic thematizing than others. Organisms, ecologies, and technological devices have fared well, but until very recently minerals, geological phenomena and geophysical process have attracted much less attention (see Clark and Yusoff, 2017). In relational materialist inquiry what seems to grate about the geologic, at least in its more expansive registers, is its stubborn inhumanness: its resistance to the `inter' in interaction or the mutual presence implied by co-enactment. This is not a matter of insisting that all `stuff' of significance must always already be partaking in the tangled webs of social existence. Latour, for one, proffers the figure of `plasma' to depict the `not yet formatted, not yet measured, not yet socialized' outside of any discernible social order

(2005b: 244). But Latourian plasma still feels like it is some conceptual distance from magma or any other deep-seated geological matter: for plasma is decidedly `*in between*' rather than beneath, beyond or before (Latour, 2005b: 244 authors italics).

We should not be too hasty to pigeonhole relational materialisms, however, for they are nothing if not vibrant and adaptable. As the earth itself emerges as a troubling object, and as questions of what is becoming of our planet materialize as matters of contention, so too are the concerns of relational thought stretching and morphing (see Conway, 2016). And in the process it is not just the scope of things open to inquiry that seem to be shifting - but the very idea of what counts as relating.

Most notably, Latour has begun to supplement his older concern with associations and networks not merely with notions of in-between-ness, but with the issue of what lies beneath or prior to the world of recognizable objects and their interactions. This is bound up with an explicit thematization of the geologic – expressly in his recent engagements with the Gaia thesis and the Anthropocene concept. As Latour puts it in the paper `Agency at the Time of the Anthropocene': `The prefix "geo" in geostory does not stand for the return to nature, but for the return of object and subject back to the ground —the "metamorphic zone"' (2014a: 16). In more detail:

> Why does it seem so important to shift our attention away from the domains of nature and society toward the common source of agency, this "metamorphic zone" where we are able to detect actants before they become actors … where "metamorphosis" is taken as a phenomenon that is antecedent to all the shapes that will be given to agents? (Latour, 2014a: 13).

It is the earth itself that seems to have lured Latour into engagement with the `ground' – a region that is both prior to the human and the condition of our possibility – in ways that his previous encounters with laboratories, technological systems and living creatures never quite managed. This comes through clearly in the compendious *Modes of Existence* (with its telling volcano jacket illustration). Here, in the context of the modes of `reproduction' and 'metamorphosis' – Latour introduces us to a generative domain of existents that `*precede* the human infinitely' (2013: 203). This protean zone or field, he recounts, serves as `a sort of matrix or kneading process from which the "human" can later take nourishment … but will never be able to replace, engender, or produce' (Latour, 2013: 203). With this stress

on the temporal asymmetry of antecedence and the unilateral supporting of `latecomers' like our own species, I would argue, Latour has brought into relief a kind of subtending mode of relating quite distinct from the reciprocal or mutual relations prevalent in his own actor-network theory or in most other relational ontologies (see Clark, 2016).

We should not underestimate the importance of this new willingness to grapple with geological processes that vastly exceed any measure of human, and to open up the question of what this means for politics. To be clear, for Latour, this is not just a matter of recognizing that humans have become geological agents. It is as much an acknowledging of geologic agency in and for itself: an affirming that `the Earth has now taken back all the characteristics of a full-fledged *actor'* (Latour 2014a: 3). The metaphoric fault-line beneath the Icelandic parliament, we might say, has materialized into a literal, tectonic rift.

There is a persistent theme in Latour's political – or rather, `cosmopolitical' - thinking that the preeminent task before us is one of how best to collectively compose a common, meaningful and coherent cosmos (2004: 182-3; 2014a: 14). For all the allure of the idea of `living with Gaia', there are questions which remain for me about the extent to which we can posit an antecedent or preconditional geologic reality and at the same time make this a realistic object of political action. Or to put it another way, I am left wondering what radical asymmetry in the relationship between humans and the earth means for the very idea of the political. These are questions, I would suggest, that become clearer and sharper if we dig deeper into the unlivable domain of magma.

Geopower and Molten Rock

Deftly conveying the relational materialist view of the way worldly goings-on prompt political mobilizations, geographer Sarah Whatmore speaks of 'moments of ontological disturbance in which the things on which we rely as unexamined parts of the material fabric of our everyday lives become molten and make their agential force felt' (2009: 587–588). But what is this `everyday' and what happens at its extremities, or far beyond its reach? And what are we to do, collectively, when those phenomena that sway to epochal or eon-long rhythms burst into our life-worlds? Or when we intrude into their worlds?

For human beings, I noted earlier, to be intimately entangled with magma is to cease to

be. Indeed, for any earthly creature, interaction with the vast majority of the planet's rock would prove fatal. Some 84% the Earth's volume is comprised of the mantle –that slowly churning mix of more-or-less solid rock whose temperatures range from around 1000° C closer to the surface to 3700° C nearer to the core. The planet's metallic core, which geoscientists estimate to have a temperature range between 4400 °C and 6000 °C, makes up another 15% of the earth's mass. That leaves, at any moment, a mere 1% of the planetary body – mostly rocky material of the mantle that has made it to the outer earth, degassed, cooled and hardened – that is anywhere near life-supporting.

While Latour has certainly warmed to the larger scale geologic forces, he is frank about his preference for the uppermost layers of the earth where life and rock are indeed vitally enmeshed, which is to say `the envelope of the biosphere (Gaia's skin in Lovelock's parlance) which extends vertically from the top of the lower atmosphere down to the so-called sterile rocks' (2014b, 2–3). In support of this predilection he cites earth system scientist and Gaia theorist Timothy Lenton, who sets forth:

> For many Earth system scientists, the planet Earth is really comprised of two systems -the surface Earth system that supports life, and the great bulk of the inner Earth underneath. It is the thin layer of a system at the surface of the Earth -and its remarkable properties- that is the subject of my work (cited in Latour, 2016: 8, see Lenton 2016: 17).

But Lenton himself, if we put the passage cited by Latour in context, is actually a lot more equivocal. For he also submits:

> What is less clear is whether and where to put an inner boundary on the Earth system…. The longer the timescale we look over, the more we need to include in the Earth system … material in the Earth's crust becomes part of the Earth system, and we must recognize that the crust also exchanges material with the Earth's mantle (2016: 15-16).

It is this other side – or inner side - of the `geostory' that philosopher Manuel De Landa foregrounds, in a passage that seeks to unsettle the taken-for-grantedness of the `living' outermost layers in so much thinking about the earth. He writes:

> In terms of the nonlinear dynamics of our planet, the thin rocky crust on

> which we live and which we call our land and home is perhaps the earth's least important component. The crust is, indeed, a mere hardening within the greater system of underground lava flows which, organizing themselves into large "conveyor belts" (convective cells), are the main factor in the genesis of the most salient and apparently durable structures of the crusty surface (De Landa, 1997: 257-8).

Though we might quibble about the use of the term `lava' here, De Landa is taking us into reaches of earthly `materiality' into which few relational materialist thinkers have ever ventured. Years before the emergence of the Anthropocene idea and the geologic turn, he was advocating that humanities scholars had much to learn about social processes - both directly and laterally - from the study of geophysical processes. As De Landa ventured in 1992: `The geologic strata teach us that even the seemingly most rigid strata can flow (however slowly), mutate (metamorphic rocks) or even be reincorporated into self-organizing processes (convection flows of lava)' (1992: 155).

There is a deep-seated philosophical point rumbling beneath these geo-centric ruminations. Though he tenders his appreciation of the `rich and complex biosphere', De Landa avers that western thought has long been biased towards the thematic of biological life – what he refers to as `organic chauvinism' - at the expense of more inclusive materialisms (1997: 103-4). Literary theorist Claire Colebrook makes the closely related point that `vitalism is …*the* dominant motif in Western philosophy in general' (2010: 43) - referring here to a lineage lasting over two thousand years.

Much of the inspiration for both De Landa and Colebrook is the `stratigraphic' thought of philosophers Gilles Deleuze and Felix Guattari. In answer to their own question of `*What is Philosophy?',* Deleuze and Guattari propose that there is no philosophy that is not in some sense also a *geo*philosophy, stating their preference for an orientation to the world `that puts thought into a direct relationship with the earth' (1994: 85, see also 1987: 39-45). For them, our planet is not the stable platform of sensible experience posited by the phenomenologists or any of their foundation-seeking philosophical predecessors, but a seething, shifting bundle of potentiality - more of an `ungrounding' ground (1994: 84-5; see also Deleuze, 1994: 229-231). In short: `the earth constantly carries out a movement of deterritorization on the spot' (Deleuze and Guattari, 1994: 85).

But as in the work of De Landa or Colebrook, there is more going on here than simply

translating earth science into a program of philosophical or social inquiry. When Deleuze, in the early *Difference and Repetition* writes: `Something of the ground rises to the surface, without assuming any form but, rather, insinuating itself between the forms… (t)his ground which is now on the surface is called depth or groundlessness' (1994: 275), he is neither being metaphorical nor restricting himself to the geological structuring of the earth. `Depth', in this sense, refers not only to a discernible zone or defined geological layer, but to any region of existence where multiplicities or as-yet-unrealised potentialities lie. So while Deleuze, and later Guattari, indeed take inspiration from the scientific study of the earth, this is part of a more generalized interest in the way that any existing structuring of matter, energy or information can – without `divine' assistance – give rise to entirely new forms or structures.

A lot of attention has been given to Deleuze and Guattari's notion of an interplay between processes of `stratification' – the settling of matter-energy of any kind into relatively stable, self consistent layers – and processes of `destratification' or `deterritorialization' through which the stuff of strata is released into flows, admixtures and – potentially – new organizational forms (see 1987: 39-45). Unsurprisingly, the prominence of the concept of `assemblage' in their work – the coming together of heterogeneous materials into new articulations - has attracted comparisons with, and directly contributed to, relational materialist thinking. But it is important to keep in mind that for all the affirmation of open-ended recombinance and self-organization in Deleuze and Guattari's work, their thought has a profoundly hierarchical dimension. `The assemblage', they remind us, `is between two layers, between two strata' (1987: 40).

So while it is possible – even desirable – to bring the contents of different strata into new conjunctions, Deleuze and Guattari view this as risky and unpredictable precisely because of the deep, irreducible differences between these compositional layers (the main strata for them being the physicochemical/geological, the organic/biological and the human/cultural). What this also means is that they are not only concerned with mutual or reciprocal modes of relation: their geophilosophy is also thoroughly committed to what I have been describing as the radically asymmetrical relations of antecedence and subtending. When they move from thinking `horizontally' to thinking `vertically', Deleuze and Guattari provide a quite systematic depiction of 'hierarchies of order between groupings … a succession of framing forms, each of which informs a substance and in turn serves as a substance for another form' (1987: 335).

For all that has subsequently been said about `flat', `networked', `tangled' and `knotty' ontologies, it is important to recall that for Deleuze and Guattari, any assemblage is positioned on or between specific strata. This means that there is always, for them, a two-fold relationship in any event or becoming: a kind of downward-facing relation to the stratum from which materials are derived, and an outward-facing relation to the more mobile, shifting, intermixing world of relatively unstratified matter (Deleuze and Guattari: 1987: 40-41, 335-7; see also De Landa, 1997: 57-61). So while there is much in common between `Deleuzoguattarian' and relational materialist affirmations of the generativity of novel couplings, it is rare that the latter follow Deleuze and Guattari in viewing this in the broader context of hierarchical or nested layers of reality (see Clark 2017).

But what does this mean for politics? What are the implications of thinking with and through a geologically layered earth for our understanding of the political?

In what is also a strongly Deleuze-inflected account, philosopher Elizabeth Grosz has recently introduced the term geopower as a way to set out and explore the relationship between the dynamism of the earth and the collective strivings constitutive of the political (2012, see also Grosz et al, 2017). As Grosz would have it, most conventions of critical political thought fail to acknowledge the 'primordial interface' where the stratum of life articulates with the earth and cosmos:

> What we understand as the history of politics – the regulations, actions and movements of individuals and collectives relative to other individuals and collectives – is possible only because geopower has already elaborated an encounter between forms of life and forms of the earth (2012: 975).

As is the case in actor-network theory and other relational materialisms, Grosz recognizes the perturbing force that inhuman events and processes import into everyday social existence. Geopower, for her, provokes, excites, and lures collective life in new directions But Grosz's stress is on the excess that inheres in the geologic and cosmic strata – the superfluity of possibility over any actualized biological or social expression. `Power—the relations between humans, or perhaps even between living things' she contends `—is a certain, historically locatable capitalisation on the forces of geopower' (2012: 975). And it is this unabashed prioritization of the `generative force of the universe itself' (Grosz, 2011: 94), that unsettles both the conventional critical stances that have socio-political forces `producing' material existence and relational ontologies that posit always

already intermingled `socio-natures'.

There is however, much in common between the idea of a primordially indeterminate and excessive earth in the work of Grosz, De Landa, Colebrook and other Deleuze-inspired theorists, and Latour's recent formulation of metamorphosis as a mode of existence. Indeed in the Latourian positing of prehuman, antecedent metamorphic zone we might well detect the trace of Deleuze and Guattari's affirmation of `perpetual metamorphosis, the song of the universe, the world before or after man' (1994: 189).

None of this, it hardly needs to be said, provides firm guidelines for to how to conduct ourselves in the presence of magma or how best to convene a public to deliberate over any future human-magma interface. For as Deleuze and Guattari conclude their discussion of the generative relationship between the order of strata and the processes of destratification: `this work requires…the forces of a *people,* which is what is still lacking' (1987: 337). What ontologies that are really committed to thinking through the geologic do for us, I would hazard, is to help us *frame* the political, more specifically to bring into relief the asymmetrical relation between collective human action and its cosmic-terrestrial conditions of possibility. Which is to say, the geophilosophical and stratigraphic thought we have been looking at suggests that, while the domain of politics is inescapably open to the deep, reverberating potentially of the earth, there are still momentous geologic forces that are beyond the sway of political influence. This brings us to the final section, and the question of what sort of politics we might need in order to grapple with the unprecedented articulation between the life-infused stratum of the outermost earth and the magmatic environment of the inner earth.

Toward a Krafla Magma Political Testbed

The magma with which geothermal engineers have recently established contact, I have been suggesting, is a good test case because of the way that it draws us both into and beyond political issues, mobilizations, and formation with which we are familiar. In this regard, I have identified three main genres or styles of contemporary social thought that can help us think about the conjunction of the political and geologic - though my three-fold distinction, like most categorizations, cannot do justice to the many overlaps, subdivisions and cross-fertilizations in its constituent parts.

Political ecologists exhort us to ask what interests are driving political decision-making and knowledge production, whose knowing and doing counts, and how the benefits or detriments of any development are being distributed. They make convincing arguments that the imperatives of the global capitalist economy are vast and forceful drivers of relations with the subsurface - to such an extent that the dynamics of capital have attained geological significance. In this regard, the trajectory being taken by Iceland's Deep Drilling Project – with its nexus of capitalist, state and scientific actors – is neither innocent nor inevitable. But the closer we examine the implication of powerful social agents in geological process, the more we are compelled to ask from where and what `social' power gains its force – and what part the properties and potentialities of the earth itself play in the making of these powers. Or might yet play.

What relational materialist approaches layer into these concerns is a more explicit engagement with the role played by heterogeneous materials in the composition of social agency and in the emergence of novel political issues. They help us to see how the properties of aluminium and the affordances of `renewable' energy, in an economically unstable and climatically volatile world, are being made to matter in Icelandic development strategies - and in their contestation. By the same logic we can see how magma power is beginning to be enmeshed in agential networks and ensembles, if in ways that are yet to fully `materialize'.

The deeper we follow magma, however, the more we encounter a forcefulness and potentiality that seems to exceed our capacity to make it matter, to meaningfully enroll it in any composition of a common world. As signaled by Latour's conceptualizing of an metamorphic zone – an *igneous* zone might have suited us better – we find ourselves drawn into relationships of a radical asymmetry, of antecedence and subtending. If not conventionally political in itself, thinking with and through the geologic body of the earth in this way opens the question of the conditions of possibility of a polity - and about the limits of the political.

There is no necessity to follow magma beneath or beyond its forgathering into specific sociomaterial projects or political mobilizations. To be alert to its possible problematizing or to join with others in teasing out its troublesome implications does not require us to appreciate how much of the earth's rocky surface has welled out of the inner earth. Nor is it vital to know that much of the rock, metal and concrete from which `civilizations' have been constructed were once molten rock, or that the glass which has been so central to

science and other visual practices is a product of solidified and granulated magma (see Clark, Gormally, Tuffen 2018). As we go about our shaping and sharing of knowledge, we are not compelled to consider that the silicon at the core of integrated circuits and fibre optic cabling was the stuff of the mantle layer before it was extruded into our world. Not least, we ourselves can function happily as political beings without any sense that our own ascendance as multicellular macro-organisms may well owe a great debt to bioessential minerals derived from massive effusions of magma in a distant geological era (see Parnell et al, 2012).

None of these insights are essential elements of the political. But if we are interested in following the things themselves, it feels unwise to draw a line in the body of the earth: to falter at the junction with our planet's fearsome interior. And if we want to get even a hint of how human beings and our social formations might enter into new assemblages with magma, it seems judicious to take as long and as broad a run-up as possible.

What is so vital about volcanoes and other sources of magma, insists science writer Simon Winchester, `is their role in the process of bringing from the secret storehouses of the inner earth the elements that allow the outer earth, the biosphere, the lithosphere, to be so vibrantly alive' (2004, 302). To get a glimmering of just how much of the fabric of human and other forms of life has magmatic origins, in this way, is to begin to grasp that the geologic does not anchor life so much as nourish and incite it. It is to start to see the mineral interior of the earth less as the biosphere's infernal and barren `other', and more as a wellhead of possibility - a reservoir so vast and deep that even the exuberance of life cannot exhaust its potential.

There are times when contestation is crucial, as Icelandic environmental and social activists have recently demonstrated, just as they have shown how political mobilization can draw on and give rise to creative expressions (see Dibben 2009). This should serve as a reminder that as well as involving a succession of conflicts and disgruntlements, progressive politics is also an occasion for experimentation, for collective exploration of new structures and permutations. And it is in this sense, Grosz has insisted, that the earth itself offers `the excess of colors, forms, materials' upon which creative productions can elaborate and play variations (2008: 9). The people of Iceland, it hardly needs to be said, have long and deep experience of dwelling in the midst of geothermal and volcanic activity. What we might call a localized `becoming with magma' ranges from the sonic and visual imagery of musician Björk's 2011 song `Mutual Core', artist Olafur Eliasson's

2012-13 photographic and installation series `Volcanoes and Shelters', through to the remarkable practical efforts at the town in Heimaey, in Iceland's Westman Islands, to cool and reroute lava flowing from the volcano Helgafell during its 1973 eruptions (see Palsson and Swanson 2016).

Yet neither these lively engagements with lavas and magmas, nor anything else in the previous eleven and half centuries of igneous co-existence quite prepares Icelanders for the encounter with *in situ* magma. For although upwelling magma has been shaping conditions for earthly life for over three and half billion years, as I suggested earlier, never before have humans or any other creature reversed the traffic with the inner earth in order to confront magma in its `natural environment'. By this logic, the broaching of Krafla's magma chamber –and its predecessors at Puna and Menengai - may be as much the crossing of a threshold in geohistory as a juncture in human history. All of which means that viewing magma primarily as substitute for fossil hydrocarbons or hydropower – however successfully this is realized falls some way short of a full-bodied `speculative' apprehension of the potentiality of inner earth forces (see Clark, Gormally, Tuffen 2018).

Magma, then, has long been inflaming, fuelling, luring life in new directions – though it makes no more sense to refer to molten rock as `lively' as it does to call biological life `magmatic'. As Palsson and Swanson's account of the Helgafell eruption reminds us, and many other volcano stories corroborate, cohabiting with magma is much more than an opportunity for creative experimentation. To conceive of earth processes as subtending rather than simply inter-mingling with social life is to be wary of the possibility that these supporting conditions are subject to withdrawal – it is to avow their ineluctable power to undermine or overwhelm any and all of our productions (Clark 2011: xx-xxii). It is understandable that the prospect of releasing the pressure of magma chambers to reduce the likelihood hazard risk of volcanic eruption is twinned with the risk of triggering the selfsame eruptions. More to the point, we must concede that any sociotechnical intervention in magmatic processes, for the foreseeable future, is unlikely to advance further than the chambers and dykes of molten rock that have already come some way to meet us, and that the great mass of magma-generating processes will remain indifferent to human influence.

For all the current commotion about a human imprint in the earth's operating system, the radical asymmetry between the social and earth that meetings with magma brings into relief is a reminder that there are limits to collective negotiation and the will of a polity.

While the borderlands of the political may be nebulous and shifting, to take geology seriously is to come up against what Colebrook refers to as the `monstrously impolitic': (2011: 11). In this regard, rather than reducing what matters about the earth to a slender envelope, it may be more helpful to acknowledge the full depth of our astronomical body while conceding that the political is a thin skin, a fragile skein that flails across a rifting, upheaving planetary surface. If Krafla is to be a Magma Political Testbed as well as a place of engineering and scientific experimentation, it is likely that it will sooner or later find itself confronting experiments that fail, fall short or succeed too well, though where `our' experiments with magma end and where magma's experiments with `us' begin may be difficult to decide. And while we researchers should be alert to the emergence of new publics who are agitated or aroused by magma, and attentive to their demands, the beauty of a speculative approach to the geologic is that we are not obliged to wait.

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