**Vulcan's Eye: Molten Media and the Sensing of the Earth**

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## Mediating Magma

Much of the stuff of the contemporary world – the material we use to make our appliances, our built environments, the networks through which we communicate – has at some stage been transformed using high heat. Already, over four thousand years ago, artisans had learned to fire up their kilns to temperatures that were as hot as magma rising up in a volcano. Watched over by powerful deities – Vulcan, Hephaestus, Ptah, Sethlans, Ogun – ancient craftspeople used this searing, untouchable heat to transmute the structure of inorganic matter. They had no means of measuring the temperatures they were working with, no way of deciphering the thermochemical reactions through which they were coaxing their materials – but they did have a deep, tacit and embodied understanding of transformations that were occurring within the walls of their fiery chambers.

We might say that fire was – still is in many places – the artisan's way of sensing the Earth, that the interior of the kiln is a molten medium through which creative practitioners express themselves and that heat-driven metamorphosis is an act of communication with their cosmos. Although pyrotechnic craftspeople bring a degree of consciousness to their procedures, the physical changes they affect have a lot in common with the transformations that occur at similar temperatures in volcanoes, magma chambers and other geological hotspots.[1] But if we imagine molten matter in a furnace to be a kind of medium, what should we make of the magma rising up from the inner Earth?

Today, materials and techniques gifted to us from high-heat artisans are being repurposed to help understand the Earth's own molten or igneous processes. My departmental colleague, volcanologist Hugh Tuffen, has a small kiln – not much bigger than a wristwatch – that is hooked up to a microscope. When a fragment of volcanic material is heated to around 1000 ° C, the formerly solid mineral begins to behave as if it was molten rock ascending toward the surface of the Earth. As the rock 'rises', it moves from higher to lower pressure, which causes dissolved water within it to bubble and expand. It is this gaseous expansion that drives magma, or molten rock, upwards. In the subsurface of the Earth if sufficient magma collects in the crevices or chambers in the rocky crust, it will surge or blast its way to the surface – causing a volcanic eruption. Through the reinforced glass window of the desktop furnace, with the help of considerable powers of magnification, we witness a microcosmic volcano in the making.

This technologically enabled ability to take a Vulcans-eye view of the Earth coincides with an equally novel capacity to sense magma at the larger scale of the crustal environment. Most of what geoscientists know about magma they have learned from scooping samples of lava as it erupts from a live volcano, a procedure that is as fraught as it is risky because of the speed at which magma transforms as soon as it is exposed to the air. As far as we know, contact with molten rock beneath the Earth's surface has only ever occurred four times. In each case, engineers – in the process of digging boreholes to tap geothermal energy in volcanic hotspots – accidentally breached a reservoir or chamber of magma. The first three times – once at the Menegai Caldera in Kenya, twice in the Puna geothermal field in Hawaii – a quick withdrawal was made. But in the case of a 2009 magma strike at the Krafla Caldera in Iceland, they were able to keep the drill hole open.[2]

Described as 'the first direct access to the magmatic environment of Earth'[3], Krafla is being developed as an international research facility. Here, as well as exploring the potential of superheated geothermal energy, researchers are using the window into a magma chamber as a way to gain new insights into the magmatic subsurface, tectonic processes and crustal rock formation – and are looking at the possibility of placing sensors directly into deep molten rock. But if this is the first time that human agents have accessed *in situ* magma, it is also the first time – in the four billion or so years of terrestrial evolution – that any living creature has established contact with the 'plutonic' processes of the inner Earth.

At first glance, neither the desktop kiln nor the Krafla project are directly connected with the Anthropocene. Whereas the Anthropocene thesis foregrounds human impact on the Earth system, studies of magma and volcanism draw us into geological processes upon which our species has little or no impact. But if we step back and size up the broader developments that have taken place in the study of the Earth over the last half-century or so, connections and resonances between different fields of geoscience inquiry become more apparent.

More than this, putting contemporary geological or planetary science into conversation with a deeper social history of engaging with inorganic matter also prompts us to ask how 'our' coaxing of earthy materials into novel expressions relates to the planet's own capacities to express itself. It raises questions, relevant to but in excess of the Anthropocene debate, about the ways in which the human sensing of the Earth – our practices of perceiving, communicating, remembering and forgetting planetary processes – might also serve as apertures into the Earth's sensing or mediating of itself.

**Apprehending the Anthropocene**

The Anthropocene thematic of human geologic agency arose primarily out of Earth system science, a relatively new cross-disciplinary field that views our planet's hydrosphere, atmosphere, biosphere and lithosphere as coupled components of a single, vastly complex system. This kind of 'planetary' thinking has been traced to a critical moment from around the mid-1960s to the early 1970s in which a series of major new perspectives on the dynamics of Earth and life emerged or crystallized. This included the confirmation of the theory of plate tectonics; a new appreciation of the role of extra-terrestrial impacts in shaping Earth history; the thesis that evolution is punctuated by catastrophic bursts linked to major geophysical events; and the Gaia hypothesis about the systematic inter-relations between the living and non-living Earth.[4]

With hindsight, we can see that these developments paved the way not only to thinking about our planet as an integrated system, but to the idea that this system was capable of re-organizing itself into new operating states – the notion that out of the Earth's unity comes self-differentiation and multiplicity.[5] It's worth noting too, that although this burst of planetary-scaled thinking set the scene for the Anthropocene thesis, none of the four perspectives mentioned above centres upon human agency. Their focus is much more about how the planet operates, how it became what it is today, and what it might yet become. And in this way, these new directions in Earth and life science also raise questions about how to view the Earth in relation to other planets, and the broader issue of how different planets became what they are, and how planets in general become capable of doing different things at different times.[6]

For those of us schooled in social and cultural thought, the thematization of planetary processes and dynamics – especially when it encompasses human activity – has been a mixed blessing. Homing in on the Anthropocene, with its apparent recentring of agency on the human or *anthropos*, many social scientists and humanities scholars have chosen to take contemporary Earth science to task for its singular or univocal vision of the planet – its ungrounded, abstract and aloof 'gods-eye' vision of the Earth. As historian Christophe Bonneuil puts it, Anthropocene science offers 'a single grand narrative from nowhere, from space or from the species'.[7] Or in the words of media theorist Sarah Kember, the Anthropocene foregrounding of 'Man' enacts yet another 'god-trick of masculine disembodied knowledge'.[8]

Such reactions are understandable and unsurprising. The diagnosis of the current predicament of the planet and its translation into calls for urgent 'global change' by small groups of mostly male scientists clustered in metropolitan centres can and ought to give cause for concern. Reminding us to keep asking 'who speaks for the future of the Earth', critical social thinkers insist upon the need to situate those who would give voice to the planet in the profoundly uneven fields of knowledge production and call upon us to open up the storying of the Earth to a global multiplicity of experiences and perspectives.[9]

It's important to keep in mind, however, that back in the 1980s when Donna Haraway, Sandra Harding and other pioneers of feminist science studies drew attention to the value of situating knowledge, their intent was not to rule out any particular scale, field or object of inquiry. The aim of acknowledging the positioning of truth claims and their attendant partiality, as Haraway would have it, was to generate more objective, conjoined and encompassing accounts of 'a "real" world'.[10] So while its was considered crucial to prevent languages or truths generated in one time and place from assuming a god-like omniscience, the goal of 'situating' was from the outset one of multiplying and conjugating rather than delimiting or precluding possible vantage points.

When confronting scientific framings of the global environmental predicament, many later advocates of situated knowledge practices seem to have taken it to heart that the only viable position from which to approach the world is one of entanglement between human and nonhuman others.  Extending the idea of 'ecology' to include a full range of human collectives, other-than-human beings, and increasing life-like machines and networks, reigning conceptions of positionality tend to bind all the significant actors into a mutually-constitutive, intra-active flux of relationships.  In this regard, if Anthropocene science has anything to tell us, it is a message of '(t)he deep intertwining of natural and human systems'.[11]  The task, for progressive social thinkers and practitioners then, becomes one of teasing out these entwinings:  demonstrating how 'manifold and different socio-ecological relations' give rise to a multitude of ways of knowing and engaging with the Earth.[12]

Critical interventions in the Anthropocene debate now routinely insist on the need to subdivide and pluralize *Anthropos* – as a crucial step towards storying the geo in terms of 'a plurality of narratives from many voices and many places'.[13] The value of such approaches should not be underestimated. They commendably seek to proliferate and extend the composition of shared worlds across the surface of the Earth, to reclaim marginalized and disavowed ecological knowledges, and to put metropolitan science into conversation with a world of other sciences.  But however generative and just these imperatives might be, its worth considering that the axiom of natural-social intertwinement or socio-ecological co-enactment does not exhaust the modes of relating out of which our planet has arrived at its current state.

**Partiality/Planetarity**

What we need to remember is that the Anthropocene 'moment' of coupled human-nonhuman systems is only an episode in a much longer geo-history and that the discursive field which focuses upon human impacts on the outermost layers of the Earth is but one expression of a much broader body of research into planetary processes. As members of the Anthropocene Working Group themselves explain, the science involved is very much a collaboration between newer Earth systems science concerns with 'contemporary global change' and more conventional geological inquiry into 'ancient, pre-human rock and time'.[14]

But even the oldest, deepest, most inhuman rock – like the life-enriched outer envelope with which it interfaces – is only a slender segment of our planet. As Earth system scientist Tim Lenton puts it '(i)t is the thin layer of a system at the surface of the Earth – and its remarkable properties – that is the subject of my work'. But as he goes on to say: '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'.[15] And 'great bulk' it is. At any moment, geoscientists inform us, a mere 1 % of our planet's mass is made up of the cool, hard rock that is the Earth's crust. Of the remainder, around 15% of the Earth's volume is the metallic core, which geophysicists estimate to have a temperature range between 4400°C and 6000°C. Most of the other 84% is compromised of the mantle: a slowly churning mix of viscous rock with temperatures ranging from around 1000°C nearer the surface to 3700°C closer to the core.

When it comes to studying *in situ* mantle rock, geophysicists lack even the option of meeting superheated material halfway. The best available method is to wait for seismic waves generated by natural earthquakes to pulse through the semi-solid matter of the sub-crustal Earth. By collating signals from earthquake monitoring stations around the world, 'seismic tomographers' are able to detect variations in the timing and direction of the seismic wave-front – and in this way to identify discontinuities in the heat, structure and composition of the material through which it has passed.[16]

Scrambling after recently ejected lava before it cools, accidently drilling into misplaced magma chambers, and waiting upon earthquakes in order to chase seismic waves through the inner Earth seem like especially good examples of an objectivity that, in Haraway's words, 'makes room for surprises and ironies'; one which reminds us that 'we are not in charge of the world'.[17] In the process, these knowledge practices reveal how exceptional the zones of human-natural entanglement are on a planetary scale. But recognizing that there is an excess or remainder to socio-ecological co-presence or co-enactment, in this way, by no means implies a disavowal of context or positioning.

Like their social or humanistic counterparts, the physical sciences perform a version of contextualization – the situating of objects or processes under interrogation within a broader field. In the fast-evolving planetary sciences of the last fifty or sixty years, acknowledging and exploring 'context' has entailed opening terrestrial geology to the periodic intrusion of extra-terrestrial objects, exposing the outer Earth to inner Earth dynamics, situating the current operating state of the Earth system in relation to past or potential systemic states, confronting the prevalence of imperceptible dark matter and energy in the universe, and considering the possibility that ours is but one of multiple universes.

Just as reflexive social thinkers seek to 'provincialize' Europe or the West, we might say, so too do discerning planetary thinkers regionalize the human, the organic, our particular planet, this solar system, and even the entire perceptible universe. In short, they reveal the resounding partiality of any standpoint that takes for granted existing terrestrial conditions or that privileges 'the living gloss on the surface' of our planet of which humans are a part.[18] But we should also be mindful that scientists themselves are not always interested in pursuing the consequences of the contextual shifts, displacements and abyssal openings they inaugurate, and may not be the best placed to probe the conceptual or perceptual implications of their own situational manoeuvres.

Far from simply advancing a monocular gods-eye view, the contemporary sciences of life, Earth and cosmos have been proliferating perspectives, I am suggesting, in ways that are potentially rich in inspiration for social thought and cultural-aesthetic investigation. In the final section, I return to the relationship between the inner and outer Earth – which is just one of these incitements – drawing together insights from a range of disciplines and fields that seem to share a certain fidelity to a 'Vulcans-eye view' of our planet. Such approaches draw our attention to the ways scientists and other expert witnesses access otherwise hidden worlds. At the same time, they raise questions about how and why there is such a thing as living beings capable of apprehending their world – and whether this world is actually in need of such beings in order for knowing or sensing to take place.

## The View through Vulcan's Eye

A good re-entry point to the inner Earth are the reflections by media theorists such as Jussi Parikka and Sean Cubitt on the reliance of modern media on glass, metals and other earth-sourced matter.[19] To this we might add the observation that Western science and technology, more generally, has been congenitally dependent on 'earthy' elements and compounds – of which glass has had a special significance. 'As well as being transparent, heat-resistant, and strong enough to make thin-walled vessels, glass is also largely inert', notes science writer Lewis Dartnell, making it the ideal material for observing chemical reactions. To this he adds glasses' ability to manipulate light, the basis for magnification and teloscopy.[20]

We can push this further – or deeper. Both metallic ores and the silica that is the base material for glass ultimately derive from the Earth's mantle and find their way into the crust by travelling upwards in the molten medium of magma – as simulated in the desktop kiln. Indeed, the element of silicon – the basic ingredient of sand, quartz, feldspar and granite, and also present in basalt – is the primary material from which crustal rock is composed. Upwelling magma is also often rich in metals, which are released into the outer Earth environment as volcanic rock weathers or erodes. And these metals may well have helped reroute the evolution of biological life – along pathways that ultimately, but by no means necessarily, wend their way toward a complex, crafty and inquisitive being.

In minute quantities, 'bioessential' metallic elements play a vital role in sustaining biological life by serving as catalysts for a slew of enzyme-driven metabolic processes, including photosynthesis, respiration and digestion. Around two billion years ago there was an exceptionally large extrusion of metal-rich magma across the Earth's surface. As these granite lava flows gradually eroded, geologist John Parnell and his colleagues have recently proposed, they provided a surge of bioessential metals into the ancient environment which gave multicellular life the boost it needed to compete with simpler unicellular life-forms – and from there to evolve and diversify.[21]

The hypothesis that a massive outburst of mantle-derived magma during the Proterozoic eon helped trigger the ascent of complex life has arisen out of close conversations between geologists, biogeochemists and biologists. Like the Anthropocene concept, this collaborative research is ultimately an offshoot of the surge of interest in planetary dynamics in the 1960s and 70s. When scientists working at planetary or cosmic scales engage with unequivocally nonhuman or extra-social realms – as is routine for them – they still tend to this by projecting a hypothetical human observer into an inhuman locus.

But rather than a slur on socio-cultural construction or positionality, this is important, for it helps open up the perplexing philosophical question of how human subjects might think through and with worlds untethered from our presence or influence.[22] And one way of doing this – signaled by the scientific concern with tracking the flow of metals through the planetary body and exploring their role in catalytic processes – is to turn our attention to the issues of how the planet senses or knows itself.

This is in line with current cognitive research that is moving away from assumptions that sensing or cognition requires a self-conscious subject or even a living being – and opening up categories of information reception, processing and transfer to see how they might pertain to nonhuman and abiotic domains.[23] In their collaborative writing in the 1970s, philosophers Gilles Deleuze and Félix Guattari not only anticipated this kind of approach but took the probing, explorative and conductive role of metals in the material world as their exemplar.[24] Deleuze and Guattari went so far as to suggest that metallic elements functioned as a kind of 'consciousness' of the inorganic domain – a point that was clearly intended to stretch and destabilize conventional understandings of what it means to be conscious.

Today, taking cues from literary theorist Katherine Hayles, we might consider the catalytic and transmissive role of metals more in terms of a cognitive nonconscious. Whatever the terminology we chose, what a focus on the metallic elements brings into relief is the possibility of modes of mediation or informatic transmission that bridge the human and the nonhuman, the organic and the inorganic. If we want to think on a truly planetary scale, however, there are other divides where the intermediation of magma and its metallic payload might play a part.

There has been a lot of earlier speculation about the way that the interconnectedness of life – or more specifically, technologically networked human life – brings a new level of self-awareness to the Earth.[25] Such thinking, however, has rarely ventured beneath the life-sustaining sphere that envelops the Earth. But perhaps more than any other aspect of terrestrial existence, it is the great structural divide between the inner and outer Earth that raises questions about how the planet holds itself together, how it mediates between its component parts.

This partitioning itself is best seen not simply as the given condition of the Earth, but as the outcome of a vastly scaled self-differentiating process, an event in geohistory that redirected the development of the Earth and radically transformed the possibilities open to the planet. If on the one hand, the cooling of rock to form a crustal layer provided a platform that is sufficiently insulated from the heat of the inner Earth to support life, on the other, the ceiling provided by the shell of the lithosphere is believed to have played by a crucial role of the gradual self-organization of heat rising from the Earth's core through the mantle into massive, slow-moving convection cycles.[26] It is the interaction of these inner dynamics and outer layers that mobilizes the great slabs comprising the lithosphere, driving the process of plate tectonics that in turn constantly re-sculpts the Earth's surface and generates the exceptionally rich strata that have come to characterize the crust.[27]

Along with the mobile, fluid processes occurring at the surface of the Earth, we can view the rigid, congealed rock of the crust and the churning, superheated rocky material of the mantle as major structural components of the mature Earth. But as sociologist Bronislaw Szerszynski suggests – in a creative rereading of geophysics – we can also conceive of these differentiated layers as relatively distinct information systems. Just as the life that makes up the biosphere can be viewed as a kind of coded memory so too, he suggests, can we see the lithic strata of the crust acting as a sort of solid or 'conformational' memory.[28]

For Szerszynski, this is more than a matter of rocky strata constituting an 'archive' for human observers to interpret. It is about how the stretching, faulting and other stress-driven deforming of rock actually stores information, and how this storage or 'memory' both helps the crust maintain its shape and enables it to move along novel pathways.[29] Likewise, the convection currents of the mantle can be read as a form of long term, slow-moving fluid memory: 'a memory of energy, stored in motion and intensivity' that translates the likewise 'remembered' radioactive energy pulsing in the planet's core into a great continuous, cyclical motion.[30]

Such an approach raises questions about how different informational media or repositories communicate with one another. This is especially important when we consider the current geoscience model of an Earth that holds itself together as a more-or-less integrated system while remaining flexible enough in its togetherness to pass through overall changes of state – which may also entail the planet changing its behavior or 'learning' to do new things.[31] In this regard, as Szerszynski proposes, the contact zones between different modes of planetary memory play a special role – in the case of the Earth or any other planet. As he puts it: '(p)lanets are bodies where the combination of fluid motion and solid durability creates information-rich pockets, where correlated states and motions can arise, endure and become more elaborate'.[32] And so just as materially-minded social thinkers now stress the crucial importance of the entanglement between social and ecological systems, so too should we look to other critical junctures between different planetary systems or mediums to begin to understand how planets at once persist through time and periodically transform themselves.

While the Anthropocene thesis directs our attention to the planet-shaping interface between the lively flows of the Earth system and the relatively solid geological strata, no less important is the contact zone between the slowly churning matter-energy of the mantle and the rigid rocky shell that encompasses it. Here we need to consider the role of subducting (or sinking) chunks of crustal rock, and in the other direction, the constant intrusion of mineral-rich magma from the mantle into the crust as the means by which information moves across the inner-outer Earth divide. Taking cues from Deleuze and Guattari as well as from Parnell and his interdisciplinary team, we might give special attention to the role of metals in negotiating the boundary that separates the planet's preeminent bodies of viscous and solid media. For, as we have seen, it is mantle-derived metals – that tend to collect and concentrate as they pass through the rocky crust – that gift the biosphere with catalytic capacities. And without this boost, life's constitutive informational exchanges would be a great deal slower, cruder, and less accurate, if they could function at all.

This brings us back to the work of metallurgists and other high heat artisans. Just as the Earth transformed its capabilities through the formation of a solid shell around itself – a barrier between the seething, high-pressure interior and the cool, life-sustaining exterior – so too does the skilled human operator open up a raft of possibilities by constructing a robust 'firewall' between their world and the raging heat within the kiln.[33] Pyrotechnicians, in this way, furnish themselves with an 'information-rich pocket' in which to extend and elaborate upon the expressive potentialities of the planet itself – including, or especially, the molten media of the inner Earth. In turn, the objects and materials they produce have helped to complexify and accelerate human social life, ultimately enabling new ways of observing and experimenting with the Earth itself.

And so we might see the kiln or furnace, in this regard, as a vital juncture in the sensory apparatus of our planet: a kind of focal point of different modes of mediation – recalling that 'focus' is the Latin term for fireplace. The high heat chamber, I am suggesting, marks a moment at which the Earth's own inorganic self-sensing capabilities are captured and intensified by an organic being – and then turned back upon Earth itself in ways that extend planetary capacities to generate, store and transmit information. To put it another way, the human harnessing of molten media is the first real way that biological life takes hold of – and reverses – the monstrous informational flux between inner and outer Earth – whose primary mechanism for the first 4.6 billion years has been the upwelling of mantle-derived magma and the subduction of crustal slabs.

But such a defraction through Vulcan's eye is just one of many ways that social thought and cultural-aesthetic practice might play upon the perspectives that planetary science has been proliferating for the last half century or more. We can of course devote our energy to disciplining the geosciences for their insufficient attention to the social positioning of expert witnesses. And/or we might chose to pursue what I have termed 'speculative geophysics' and Szerszynski refers to as 'speculative planetology': a vision of the Earth and cosmos that at once acknowledges the partiality of any or all human standpoints and tries to imagine how sensing or knowing might work in thoroughly inhuman contexts.[34] In the process, as the limits of socio-centric optics prompt us to renew our acquaintance with Vulcan and other ancient gods, we might just find that speculative planetary thinking is a route towards rather than away from the embrace of a broader panoply of Earth beings.

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