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Lithium Transformations: An Unfinished Story

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Jonas Köppel is a PhD candidate in anthropology and sociology at the Graduate Institute of International and Development Studies in Geneva. In his research he takes an ethnographic approach to the chemical element lithium, drawing on work in the anthropology of science and materiality. Focusing on how scientists in different places and times attend to lithium he seeks to enrich the picture of the currently booming mineral. In particular, he engages with scientists in both the Bolivian lithium industry and in biomedical lithium research around the world.

ABSTRACT

In this paper I explore what we can do with minerals as scholars of the human. To stay with their ambivalence, between ecological destruction and technological development, it might be worth thinking again about how humans are entangled with minerals. Here, I build on the observation that minerals make both our environment and our very selves; and I engage with debates around materiality to explore what this feature can do for us in one particular case: lithium. Through lithium I explore how minerals confront us with complex epistemological issues in interdisciplinary conversations. Based on science studies and work on scale I seek ways between social constructivism and scientific universalism, suggesting matters of scale as a way forward. Drawing on diverse histories of science, technology and medicine I perform matters of scale by telling a pragmatic story about lithium as specific material situated in scientific practice.

KEYWORDS

lithium, materiality, scale, science studies, stories

Introducing lithium transformations

Minerals matter a great deal at this juncture, confronting humanity with a far-reaching set of complex problems – the editors of this special issue made this a clear point. Using minerals makes successful human societies; and it brings about ecological destruction and social conflict. In the light of this, here I ask what we as scholars of the human can do with minerals. How are minerals entangled with humans? How do we think and talk about these entanglements in human science? And how does this shape our relationship with natural science? [1] But first it might be worthwhile to ask: what is a mineral? The Oxford English dictionary defines a mineral as "a solid, naturally occurring inorganic substance" with two meanings in everyday language: first, a mineral is "obtained by mining" and second, it is "needed by the human body for good health." In this contribution I reflect on the category of the mineral, that which is defined in contrast to life but also makes life. I do so by exploring one particular mineral: lithium. What I offer here is a reflection on my own epistemological practice as a scholar of the human who ended up working on a mineral. How do I approach lithium in my research and what stories do I tell about it?

[1] I use "human science" and "natural science" as contrasts in my discussion of minerals as issues spanning different disciplines in the humanities and social sciences, and the so-called hard sciences alike. I use "interdisciplinary" to refer to these contrasts, which I magnify to discuss the epistemological issues at stake in this paper. I use "Science," with a capital S, to point at the idea of natural science as the hegemonic form of knowledge production, in particular referring to its epistemological conflicts with the social sciences and the humanities.

Today, lithium is subject to intense transformations. Proliferating battery technologies for the emerging electric vehicles industry have induced an outright boom of lithium extraction around the world. But mining industries and modern technologies are not the only ways in which lithium matters to humans. Lithium is also a mineral in the second sense of the term; that is, it makes a difference for human bodies, affecting health as food or drug. In what follows I explore what happens when we bring these two facets of human-mineral entanglements together; and I do so by contrasting two figures that foreground different moments of mineral transformation: extraction and metabolism.

My argument goes as follows. Extraction is the dominant figure to think minerals in human science; but it is problematic because it ignores their materiality. It is not about minerals as such, but about what societies make of them. Materiality is important for two particular reasons here. First, it matters to new materialists who have called on social analysts to reconsider how they relate to material things. They hope to overcome anthropocentrism, for better politics and ethics in times of ecological crisis. Second, it matters to natural scientists whose access to the world it provides. Ignoring it makes for bad interdisciplinary conversations. Such conversations are crucial to deal with pressing issues of mineral transformation, for science has always a part in them. Thus, I offer metabolism as an alternative figure. It allows to think and talk about how both societies and bodies are entangled with minerals. This should make for better conversations, but it also confronts us with a problem: can we switch from societies to bodies and back without changing our frame of reference? Are we talking about the same matters here? Human and natural scientists have radically different answers to these questions. To avoid irreconcilable confrontations between universalisms and constructivisms I employ the figure of scale. Scale is a tool to think through connection and difference; it allows matters to differ across contexts while remaining the same. It does so by helping us notice the uneven makeup of the world, adding texture to excessively smooth stories. It is a pragmatic proposal to irreconcilable camps: instead of claiming final answers it asks odd connections as questions.

To make my argument I work on lithium as one particular case of a mineral. Case studies allow us to go on well together in difference (Verran "Engagements") by "detecting and handling difference well, case by case" (Law, "STS as Method" 45). To build my case I collect stories about lithium, noticing how they entangle it with humans. "Stories structure common sense and science alike" (Law, "STS as Method" 38), an insight that scholars in feminist science studies have long used for political intervention (e.g. Haraway "A Manifesto for Cyborgs"; Martin *Flexible Bodies*). Thus, my goal is to craft a different story about lithium, one for interdisciplinary conversations. The materials I use for this endeavour come mainly from different histories of science, technology and medicine. Putting things in historical perspective is helpful in muddling through the convoluted fields between universalism and constructivism (Daston). I also draw on ethnographic fieldwork with lithium scientists in Bolivia, and I use a TED talk to exemplify lithium entanglements in popular science. Finally, I cite literature from both human and natural science to explore how we might bring together the stories that each tells about lithium.

The paper is made up of four steps. First, I explore the figure of extraction and how it structures mineral stories in human science. Building on new materialist theory I argue that we need an alternative figure, suggesting metabolism instead. Second, I tell a lithium story with metabolism. It is the story of Ben's TED talk about lithium's wonderful journey from bodies to societies, from mind to universe. Third, I explore why stories like Ben's are problematic and how we can tell them differently. I discuss issues of materiality, similarity and difference between human and natural science, suggesting scale as a way forward. Finally, I take my chances and use these insights to tell an unfinished story about lithium as a specific material situated in scientific practice. It is a story about constant transformation; a story of change and standstill in permanent oscillation; a story following lithium through different histories of different people, places and issues. In light of irreconcilable confrontation between global change and eternal continuity it looks closely at how lithium differs while also remaining the same.

From extraction to metabolism

There has recently been a resurgence of work on resource extraction in human science (Bakker and Bridge; Richardson and Weszkalnys). Minerals have come to play a particularly important role now that the age of oil is coming to an end. Alternative energy and digital technologies, requiring an ever broader range of minerals, are quickly transforming the complex landscapes of resource extraction around the world (e.g. Klinger; Bazilian). Lithium is a case in point. Quickly rising demand has extended extractive frontiers into territories such as the socially complex and ecologically fragile salt flats in the highlands of South America (cf. Sanchez-Lopez). Without any doubt, there is great need for critical reflection and public debate on these shifting realities. There is work to do for human scientists.

Indeed there is an increasing literature on lithium extraction, focusing mainly on the so-called lithium triangle of Argentina, Bolivia and Chile. It tells the stories of the lithium boom, which marks a dawning new era for producers and consumers alike, an era when energy is no longer produced from fossil fuels but stored in lithium-based batteries. It is an era that is no longer hypothetical, but necessary. The world urgently needs to transition to renewable energy in order to have a future. How much lithium will we need for this transition? Will there be enough to supply the energy industries of the future (e.g. Kavanagh et al.; Kesler et al.; Narins)? Where some fear scarcity, others sense opportunities. For countries of extraction lithium might change the fate of history, holding great potential for industrial development and geopolitical power (e.g. Barandiaran; Revette; Zicari and Fornillo). But extraction comes at a cost, and this cost is particularly high in the arid salt flats where concerns about water use for mining projects have spurred conflicts with indigenous residents (e.g. Agusdinata et al.; Göbel; Schiaffini). These stories allow thinking and talking about lithium in certain ways and not others. They tell lithium as an object of human manipulation, a resource that affords both great and terrible things once we get our hands on it. What matters in these stories is not lithium itself but what humans make of it.

What else can we do with minerals in human science? Jane Bennett, for instance, explores minerals to blur the line between living and non-living worlds (Bennett). Her work in *Vibrant Matter* is exemplary for what has been dubbed "the material turn" (Bennett and Joyce), or "new materialisms" (Coole and Frost), in its endeavour to reconceptualise the ontological foundations of the material world. The point of departure is the figure of dull matter, matter as dead, inert, passive – of matter-as-object. This conceptualisation, or so the story goes, is a thoroughly modern one, deeply rooted in hegemonic Science. Scholars of the human have uncritically accepted it, or intentionally overlooked things material altogether. They have sought refuge in the social realm of language. But, or so the new materialists object, matter matters. It should be thought of as lively, vital, active. The ontology of the material world is one of process. In it matter acts, is subject, imbued with agency.

And what ends does such a reconceptualisation of matter serve? The ethics and politics of new materialisms are diverse and defy a single direction; but much of the work comes from feminist and ecological scholarship critiquing the anthropocentrism of modern thinking. For Jane Bennett, in this case, it is about "encourag[ing] more intelligent and sustainable engagements with vibrant matter and lively things" (viii). Thus, as Andrew Barry has noted the material turn stages "an encounter between theories of material agency and post-Foucaultian accounts of political power" ("Thermodynamics, Matter, Politics" 112). The figure of active matter, irreducible to human endeavours, is set as a resistant force or essence against the all-encompassing straitjacket of Foucauldian power. It is imbued with hope that things can be different. What then if we wanted to employ lithium towards such ends? The figure of extraction no longer serves in this case. It only allows telling stories where minerals and humans are completely dissimilar things, and where the latter do all the action. To tell different mineral stories we need a figure that entangles humans and minerals differently.

Here I offer metabolism as such an alternative figure. Metabolism denotes the chemical processes that occur within a living organism in order to maintain life. It describes a material relationship between bodies and their environment: an "interface between inside and outside, the space of conversion of one to another, of matter to energy, of substrate to waste, of synthesis and break down." (Landecker 193) The figure of metabolism suggests minerals not as mere objects to be extracted from the earth by humans, but as part of what makes these very humans. Metabolism makes room for non-human action without eclipsing human powers and responsibilities. It distributes agency. Hannah Landecker has described it as "the third thing … a concept with which to move across and beyond – or simply hold in permanent oscillation – polarities of all kinds" (Landecker 210). Instead of conceiving of humans and minerals as separate entities – the former as subject, the latter as object – metabolism shows us processes in which both are always already entangled with each other.

Metabolism is known in human science as a concept to think human-environment relations, but its use has been limited to theorising extraction. Ecological Marxists and environmental scientists use social metabolism to conceptualise how societies transform nature through their labour, and to grasp the material flows that enable the reproduction of industrial lives (cf. Gonzâalez de Molina and Toledo). The importance of this work notwithstanding, this use of metabolism roughly corresponds with the figure of extraction: active human labour transforming passive natural resources. What if we wanted to think through metabolism while holding on to the materiality of minerals? To dissolve the monopoly of human action, or so I suggest, we have to include a diversity of scales: from the macro to the micro, from societies to bodies. But while scholars in human science have developed ample registers to deal with extraction, they have left us with relatively few tools to critically think minerals' entanglements with bodies. And so it seems we will have to listen to what people in natural science have to say about metabolism, and develop our own registers in interactions with them. This is the path I will follow from here. And as we will see, it is anything but an easy walk, being fraught with all kinds of pitfalls.

An unexpected journey

When Ben got on stage that cold rainy November day in 2014 he must have felt the weight of the historic venue resting on his shoulders. The impressive dome in the former Williamsburgh Savings Bank, built in the late 19th century, is "one of the most monumental spaces surviving in New York." [2] A small stage had been set up for him and the other speakers who presented their stories at that TED event around the theme "Grand, central." [3] On the immense screen above him shone one simple image of a chemical element: colourful balls, some static and stuck together, others circling freely on orbitals around them. "So, this is lithium," Ben started his talk pointing at the screen.

Why would someone like Ben present a story about lithium at an event like that TED conference? Ben is a trained particle physicist "who left the ivory

[2] See https://weylin.com/spaces/main-rotunda. For more pictures of the event hall, visit https://www.google.com/search?tbm=isch&q=weylin+main+rotunda.

[3] See event website https://www.ted.com/tedx/events/9504. For a recording of the talk, visit https://www.youtube.com/watch?v=906URaAZFRw.

[4] See https://www.storycollider.org/board-bios/2019/1/9/ben-lillie.

tower for the wilds of New York's theater district." [4] He is invested in communicating science to a broader audience by telling stories about it. TED conferences are an ideal platform for his project, as they allow to spread ideas "in the form of short, powerful talks" to growing audiences around the world. Why, then, is the lithium story an "idea worth spreading?" As Ben promises in the beginning there is more to lithium than we usually think. In fact, it turns out to be "one of the strangest elements in the universe." What puzzles him, however, are not the complex physical laws that explain lithium's existence, but the fact that Nirvana and Evanescence have written songs about it. Why would these "intense emotional bands" write songs about one of the most simple chemical elements? Visibly nervous at first, he skilfully takes us onto the "unexpected journey" that follows this question.

Most people know lithium from batteries and medications. But where does it come from? Ben first tells us the physicist's origin story. As it cannot be formed in imploding stars like most elements, lithium has puzzled scientists. It turns out that most of the lithium on earth has come from the very beginning of things, formed in the hot furnace of the Big Bang. Ben then goes on to take us into the geochemical processes that have moved lithium through the earth over billions of years to deposit it in certain places and not others: "places like Bolivia, and Chile, and Argentina." And once humans found those deposits, they extracted lithium and built technologies with it, from batteries to bombs. "And because of all these technological applications, the geochemistry that deposited it gives way to geopolitics of mining ethics and colonialism."

But lithium is more for humans than technology and politics, Ben goes on to explain. We can ingest some of it by turning it into pills, for it to enter our blood stream, to cross the blood brain barrier and get inside our brain cells. And although we don't know how it works, we do know that lithium thereby becomes a highly effective medication for bipolar disorder. "It can bring down the highs of mania and lift up the lows of depression," Ben tells us gesturing lithium's balancing effect on human mood. And this is why people have written songs about lithium; and this is what makes lithium a fascinating story for Ben. "This one atom, number three, which possibly came from the Big Bang itself, has a profound effect on what we think of as our personality."

What makes lithium an intriguing element for Ben, then, are the ways in which it connects scientific knowledge with everyday experience. It brings science closer to people by "making visceral" something that we know in the abstract: "that the same forces that shape our personality, are the same as the forces that shape everything else in the universe." And this is why Ben presented the lithium story on the stage in that monumental hall on a cold rainy November day in 2014. He told this story as a "myth," a story that we keep repeating to "locate ourselves in the world," to explain "how the universe works, what our place is in it, and how we should live in that world." And thus he ended his talk with an appeal to his audience to take seriously stories about science. "If we are serious about living in a scientific world, in the world that has been revealed to us by science, then we need to be telling more of these stories. We need the story of the atom from the Big Bang that can affect our personality. We need stories that cut across all the different sciences and the humanities, stories that show us that everything out here really is deeply connected. Thank you."

Matters of scale

Ben's story is both a wonderful and a problematic story. It is fascinating how lithium connects different worlds, how it bridges deeply entrenched divides between body and mind, between nature and culture, between science and everyday experience. To achieve this fascination Ben skilfully draws on different scales of human-mineral entanglements: his story elicits wonder because lithium is not only an industrial resource we extract from our environment, but it also reaches into the innermost regions of our bodies and minds, making us who we are as persons. And thereby it comes alive. We should ask, however, what he puts this wonder to work for. In fact, Ben is quite explicit here: it is about "living in a scientific world, in the world that has been revealed to us by science." It is, in other words, about extending the scientific frontier into the realm of culture. Now, I do not intend here to embark on a fundamental critique of scientific reductionism; many much more skilled scholars have been devoted to this important task (e.g. Martin, Bipolar Expeditions; cf. Wilson). Rather, I want to continue exploring what different ends mineral stories can serve and how we might tell such stories accordingly.

Ben is not the only one invoking the problematic authority of Science to tell stories about how humans are entangled with lithium. Technology enthusiasts and commodity investors have proclaimed the dawning age of lithium, a new stage of human development where we liberate ourselves from the shackles of dirty oil thanks to lithium's astonishing chemical properties (e.g. Kohl). Dedicated psychiatrists and health materialists have found a magic mineral in lithium, a simple but neglected substance that promises to almost miraculously relieve us of all sorts of complicated bodily and mental pains (e.g. Greenblatt and Grossmann). In all of these stories lithium is understood to hold great potential for humanity writ large. In other words, minerals are universal objects, here imbued with a definite existence by unquestionable scientific knowledge. Human scientists are not telling these particular stories, but as in Jane Bennett's example above, some of them have drawn on natural science in similar ways to extend the political frontier to the realm of matter itself (cf. Abrahamsson et al.). Fitzgerald and Callard have called this kind of interdisciplinary engagement "ebullience" because experimental results and theoretical statements are taken as "more-or-less true." The urge to rethink materiality in critical human science, in other words, paradoxically implies a rather uncritical engagement with natural science.

An alternative strategy for interdisciplinary engagements is to focus on scientific practice instead, thereby changing again the conceptualisation of matter. Rather than making substances come alive this strategy brings out the relationality of material things, for in practice "scientific research has little to say about matter itself. Instead, it explores matter engaged in relations and, crucially, helps to practically mediate such relations" (Abrahamsson et al. 10). Foregrounding the specificity of materials enmeshed in scientific practice prevents the social analyst from slipping into universal claims of Science while enabling interdisciplinary conversations (cf. Stengers). Such engagements are crucial for living in times of ecological crisis (Alaimo; Haraway *Staying with the Trouble*; Latour *Facing Gaia*). Thus, Ben is certainly right: minerals are helpful objects to tell the important stories that cut across deeply entrenched disciplinary boundaries. But we need to think more carefully about ways to connect human and natural science, ways that do not surrender to a homogenous world in which we can effortlessly move from mind to universe.

We are getting into difficult territory here. Debates have been fierce between natural and human science, between positivism and its universal aspirations on one hand, and constructivism and its relativist stance on the other. It is a fight between two irreconcilable camps about what this strange world is that we all live in; a fight in which human scientists have tried to turn universals into particulars by placing seemingly definite things into context. Rooted in diverse politics of difference – from feminist to postcolonial to science and technology studies – scholars have used this repertoire to critique the universalism of scientific knowledge as the bedrock of the modern project (e.g. Haraway "Situated Knowledges"; Latour *We Have Never Been Modern*; Verran *Science and an African Logic*). More recently, it has resurged in debates around ontology, creating an opening for a multiplicity of material realities – for a world of many worlds (e.g. Blaser and De la Cadena; Mol; Law, Aircraft Stories). And it has not spared mineral worlds. Scholars in resource studies have explored the multiple socio-material realities making up the seemingly singular and definite minerals waiting in the ground to be extracted (e.g. Davidov; De la Cadena; Freiburger; Li). By creating room in public debates for views and worlds that diverge from political consensus they have made crucial contributions in often conflictual scenarios of mineral extraction.

Multiplicity enables critical interventions into debates around the intricate realities of resource use, but it will only partially do here. In particular, it does not describe accurately how scientists experience minerals. In the realm of scientific practice minerals are not only theoretical objects and political projects but also substances: materials with certain properties that are indifferent to human endeavours (cf. Barry, "Materialist Politics"). Thus, following scientists into mineral worlds makes for odd connections – connections we are not used to think about in human science. Does it make sense to connect brain cells with mining projects and human mood with the Big Bang? Are we really still talking about the same lithium here? These odd connections, however, are what we were looking for when following the call to rethink materiality in human science and introducing the figure of metabolism to tell different mineral stories. Thus, we will somehow have to mediate between the irreducibility of matter and the risk of universal aspirations. We will have to find different repertoires than the ones we are used to think with in human science; repertoires that allow for things to be different while staying the same; "odd commonalities" that while being "common across distinctions [are] always already entangled in a heterogeneous logic of difference" (Anderson and Wylie 319).

Here I offer the figure of scale to do this mediating work. Thinking materiality with scale is what I call matters of scale. My understanding of scale is informed in particular by Anna Tsing's work (Tsing *Friction*; Tsing *The Mushroom at the*

End of the World) who employs the concept to think through both connection and difference, and thus provides us with tools to think minerals as odd commonalities. In most general terms scale describes the relationship between the small and the large, and thus conceives of the world as a hierarchy. This is why some people have argued that we stop using it (cf. Marston et al.) but there is also a point to be made for staying with the trouble of hierarchical scale. Scale constantly reminds us that the world is heterogeneous and that making it seem uniform is an achievement. Tsing calls this achievement scalability, that is, "the ability of a project to change scales smoothly without any change in project frames" (*The Mushroom* 38). Scalability, in her understanding, is a characteristic feature of the modern project and countering it is a political intervention. She offers us "nonscalability theory" as a tool for such intervention, that is, "an analytic apparatus that helps us notice nonscalable phenomena" (Tsing, "On Nonscalability" 509). "We need nonscalability theory to tell a different story, a story alert to the awkward, fuzzy translations and disjunctures" (ibid 522).

What does this mean for our concern with minerals here? It means that minerals might well be excellent at travelling from extractive landscapes to human brains; but they never do so without friction. A story that follows lithium's unexpected yet effortless journey from universe to mind is too modern. Thus I want to try and tell a different story about lithium, one that might not fit easily into a neat TED talk but is hopefully still worth telling – for slightly different reasons. My unfinished story is not about extending the reach of Science, but about fostering interdisciplinary conversations. Such conversations are crucial for times when minerals increasingly matter, confronting humans with the contradictory realities of resource use. How to enable such conversations? The well-known registers in human science will no longer do. Countering universalism with constructivism ends the conversation before it even started. New materialisms offer openings: at least we are talking about the same things now. But their ebullience towards natural science is equally problematic, for it uncritically reproduces universal aspirations. To find ways in between I tell lithium neither as a human project nor as a universal object, but as a specific material situated in scientific practice. In my story I walk with the irreducibility of matter, accompanied by theories of scale to notice nonscalable phenomena in mineral worlds. Where does lithium differ? What does it take to make it the same? My story allows me to follow the odd connections that mineral transformations make on different scales without resigning to scientific universalism. It tells lithium as a matter of scale, an odd commonality for interdisciplinary conversations.

An unfinished story

"There was nothing in La Palca before we got here," Benigno assured me. Together with a handful of other chemists and engineers they were sent to an abandoned patch of land outside the infamous city of Potosí, the Bolivian symbol of colonial exploitation (cf. Lane). The place was once a tin refinery built by the Soviets and has been out of service for decades. An impressive tangle of rusty pipes sticks out from the red barren hills and up into a steel-blue sky; a visibly alien object that somehow blends in with the rough landscape of the Bolivian highlands. Benigno and his colleagues came to La Palca with a mission: to build up a cutting edge research facility for the emerging national lithium industry. And so they did, from scratch and within only a few years.

Bolivia has a somewhat peculiar history with lithium. Since the government declared it a strategic resource, and announced a state project for its exploitation in 2008, promises have been big. The country intends to industrialise its huge lithium resources without the treacherous help of transnational companies to finally benefit its own people. Colonial history shall not repeat itself; this time it will be different (Revette). "One hundred percent Bolivian" has become the rallying cry over the last ten years, echoing through public discourse, and resounding in the minds of those who are charged with implementing the ambitious plans. Bolivian scientists and engineers should develop their own technology to turn the white treasure into riches for an impoverished people. But things have moved slowly. Extracting lithium from the brines of the Salar de Uyuni is no easy matter; not to speak of producing the lithium-ion batteries the government has promised.

Knowledge and skills for building a lithium industry are scarce in Bolivia. This is why the government has been vividly advertising lithium at universities across the country to convince an entire generation of young scientists of its promising future. "We have struggled to find qualified personnel to staff our research centre," Benigno tells me. Receiving students and showing them around La Palca has thus been one of their priorities. And the tours have not failed to impress. The government has been generous with the centre, investing millions of its gas rents into the emerging industry that will fuel the country's modern future (cf. Barandiaran). The lab is well equipped with state-of-the-art machinery from all over the world. Ending our tour Benigno shows me one of their most important acquisitions: an electron microscope worth over a million dollars alone. It is crucial equipment for the development of lithium-ion batteries because it allows making visible their makeup down to a single atom.

Producing batteries far off in the Bolivian highlands is in fact quite a bold endeavour. Battery science is becoming a highly competitive field that attracts major capital investment around the globe. The rapidly increasing importance of battery technologies would not have been possible without the remarkable rise of the lithium-ion battery. Conceptually, it was born in the labs of the infamous US oil corporation Exxon where Michael Stanley Whittingham developed the basic mechanism that still underlies the technology today. This mechanism is based on the principle of chemical intercalation, meaning that lithium ions are sort of squeezed into the molecular spaces of another material – a bit like a very small sponge. Since the beginning, understanding and manipulating how lithium ions move in and out of these molecular spaces has been the crucial factor for improving the technology.

Whittingham's battery never made it to the market, however. In the 1970s, research on batteries was booming because Peak Oil was looming on the horizon. What should power cars after oil had run out? But Peak Oil never happened and the oil glut following the oil crisis buried the battery at the end of the decade. It took another generation for it to re-emerge, in the age of the Walkman and the mobile phone; and yet another one for it to find its way back into the electric car (cf. Fletcher; Yoshino). Today, governments are investing billions to ready their car industries for a future beyond fossil fuel. Thanks to rapidly falling prices batteries no longer power only mobile phones and computers, but also bikes, cars and buses; and they increasingly buffer the irregular flows of sun and wind energy.

> *Pause I: Lithium scales*
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> *We begin to see what scale can do for materiality. Lithium is anything but a singular object. It is a resource carrying hopes and dreams, an industry providing futures and opportunities, a material requiring production and enabling technology, an ion moving in and out of molecular spaces. But we are still talking about the same lithium: the one Whittingham used to develop the battery that now fuels extraction in Bolivia. Lithium travels across times and spaces, telling stories about different people, places and matters. But it does not do so easily. Attending to lithium requires very specific knowledge and quite heavy machinery. To release its great potential both have to come along.*

The lithium-ion battery is abruptly transforming the industries producing raw materials for the proliferating technology. The lithium industry in particular is booming. Around three years ago, global production started to grow exponentially, but future demand is expected to grow even faster. As a consequence, lithium extraction projects are mushrooming around the world, driven by companies and governments trying to secure access to future supply. Within these dynamics lithium is again becoming a geopolitical issue. During the Cold War it was a strategic raw material, globally policed and stockpiled for national security, because it was used to make fuel for nuclear bombs. In those days, mining lithium in Latin America, in the backyard of the hegemon, was virtually impossible. After lithium had lost its geostrategic value the salt flats in the so-called lithium triangle of Argentina, Bolivia and Chile quickly emerged as the major source of global production. Extraction here was much cheaper than in the US and the salt flats contain a major part of global reserves.

Since then, there has been increasing conflict around the salt flats. In Bolivia people defended lithium as a national resource against foreign companies, although most had hardly ever heard of it before (cf. Daza; Argento). In Argentina and Chile, in contrast, indigenous residents have defended their territories against the states' claims to the metal of the future (cf. Göbel; Schiaffini; Gundermann and Göbel; Fornillo). Salt flats and their surroundings are highly arid zones, housing fragile ecosystems. Life has settled in a fine balance here, getting easily disrupted by an industry that consumes large amounts of water. Social movements and engaged scientists are challenging the imaginary of the salt flat as a desert, empty of life, and thus of lithium as exploitable without consequence. [5] And while the political discourse in Bolivia has thus far been missing a proper debate on socio-environmental impacts, these are very likely to haunt the project once it finally starts.

[5] For an example of science activism visit the microorganism database from the Atacama desert https://www.atacamadb.cl.

Pause II: Matter as process

If we hold on to lithium at one particular scale for a moment we get a glance at what it takes to make it the same. Lithium is anything but a definite object here but changes depending on context. It constantly draws in different people, places, things and issues. Thus, separating lithium as a stable object requires work. Let us call this work purification. Purification is what chemical experts do in the lab, and extractive industries in the field. It is also what traders and bureaucrats do. It is ridding lithium of its place of extraction to make it travel around the world. But something always comes along, from the geopolitical ambitions of hegemonic governments to the territorial politics of social movements.

Before lithium was found in salt flats it was mined from rocks. In fact, in its very name lithium carries the environment from which it emerged. In 1817 Johan August Arfvedson named it after the Greek *líthos*, meaning stone, because it had not been found in organic matter first but in mineral ore from a little island in Sweden (Arfvedson). At first sight lithium seemed rather unimportant during the century that followed its discovery. A German company first produced it industrially in the 1920s only and aside from the weapons industry it was of little societal import. The age of lithium, it seems, is only just starting now, two centuries after it was first named.

But there are other ways for a chemical element to matter than industry. Lithium was insignificant for industry in particular because for decades there was no way to produce it in quantities worth mentioning. Indeed, Arfvedson never managed to completely isolate the substance. Lithium is highly reactive and does not exist in its pure form without human intervention. It was only in 1855 that Robert Bunsen found out how to use electrolysis to isolate lithium metal from its salts (Bunsen). By then, however, chemists had already described many properties of the element, by experimenting with different reactions between lithium salts and other substances.

One of these chemists was Alexander Lipowitz, who in 1841 was concerned with the solubility of uric acid (Lipowitz). Uric acid is a product of normal human metabolism, but at consistently high levels it crystallises in the body, causing health issues such as gout. Lipowitz was looking for ways to prevent the formation of urate crystals by mixing uric acid with various alkaline substances; and he found lithium carbonate to be by far the most effective one. "Nomen et Omen," he proclaimed in light of lithium's extraordinary capacity to dissolve urinary stones. And he thereby laid the foundation stone for lithium's use in medicine.

The medical history of lithium is often told starting with John Cade, the Australian psychiatrist who wrote a highly influential paper in which he reported on the astonishing efficacy of lithium salts in treating acute mania (Cade). Being the first effective drug in mental illness lithium marked the starting point for psychiatry as part of modern medicine. The lithium story is important for psychiatrists because it tells about the "birth of modern psychopharmacology" (Schioldann). And this is what doctors and patients know lithium as today: a cheap and effective drug to treat manic depression; and arguably the only one, in psychiatry altogether, that is specific to a particular illness (e.g. Malhi and Gershon). To get there, or so the story goes, lithium had to walk a stony path, struggling with psychiatric dogma and pharmaceutical industry. Lithium is a true hero, here, an orphan drug that has never really got the recognition it deserved. But hope is last to die and the story might well end as gloriously as that of Cinderella (Fels).

Alternatively, we might start telling this history with Eduard Trautner, "the forgotten hero in the lithium story" (De Moore and Westmore). Trautner was a German doctor and writer with leftist ideas and an interest in human sexuality and drug use. His last book is entitled "God, the present and cocaine." Fleeing from the rising threat of fascism in the 1930s he settled in England but was later incarcerated and expelled for fear of being a German spy. He was sent to Australia aboard a ship with thousands of other unwanted migrants. A stroke of luck and a new friend got him out of prison and straight into the physiology department at the university of Melbourne. Here, Trautner read Cade's work, teamed up with a psychiatrist at a nearby mental hospital and shortly thereafter started treating manic patients with lithium salts (Noack and Trautner). The problem that he was mainly concerned with as a physiologist was the following: how could doctors know how much lithium to prescribe? Like Cade he showed that the right amount of lithium could curb mania, but if the dose was too high patients showed symptoms of acute toxicity or even died from the treatment.

The fact that lithium can be toxic, of course, was not new to Trautner. Lithium toxicity has a pre-modern history. In late nineteenth century lithium was regarded "a normal constituent of the body, and essential to its well-being." (Garrod 370) It increased the solubility of uric acid, which was held responsible for all sorts of health conditions, from gout to general indisposition. Lithium springs across Europe and the US courted their wealthy customers with on-site relief in luxurious resorts. Soon, they also started bottling their waters and selling them to ordinary people in the city. Each was touted for being the richest in lithium, but they were later found to contain only tiny amounts of the precious mineral. This gave rise to an outright scandal, as consumers had paid for basically nothing but water (Leffmann). Luckily, convenient tablets soon allowed people to prepare their own healing waters at home. The popular use of lithium salts reached its climax when US doctors started recommending them as a substitute for table salt (Talbott). Several people died and just about when Cade published his now famous paper the headlines in US media proclaimed lithium as "dangerous poison" (The New York Times).

Pause III: Historical matters

We have shifted from societies to bodies, but things do not seem that different at all. In historical perspective lithium tells rather similar stories on different scales. Not only do knowledge and machinery act as mediating factors between humans and minerals, but so do related issues of production and consumption. Again we see that lithium does not have an existence on its own but is always already entangled within historically shifting configurations. It is hard to see a singular moment of origin as lithium has been discovered time and again, from a magical mineral to a toxic substance to a neglected cure. How these histories are arranged into stories matters for practitioners of different kind. What purposes do these stories fulfil?

A story in Cade's line would tell of how this "toxicity scare" (Johnson) prevented lithium's grandiose breakthrough in the US for decades. Following Trautner, in contrast, tells of lithium toxicity within a longer trajectory in which humans have tinkered with lithium in different ways. Maybe it is Trautner's slightly edgier personality – the immigrant, the dissident, the stray – that lends itself to such a story. In fact, both Trautner and Cade experimented extensively with lithium on different bodies, including their own. But whereas we know very little about what the dedicated Catholic Cade tinkered with in his lab – he did not even tell his wife when he tried lithium on himself – the "mischievous, and more than a little salacious" Trautner (De Moore and Westmore) left us with rich descriptions of his experiences. He measured lithium levels in blood plasma with the help of a flame photometer, which to this point had only been used in sheep rearing. It enabled him to probe lithium's effects on human bodies in unprecedented ways:

> Doses of lithium below 20 milliequivalents did not cause unpleasant sensations, but only a few of us tolerated without discomfort 30 milliequivalents, and none 50 to 60 milliequivalents. The symptoms were as follows: dysfunction of the central nervous system, vertigo, impairment of mental function and concentration (though not necessarily sleepiness); diminished cutaneous sensation and impairment of proprioception (despite objectively accurate motion, the legs "seem to drag behind and not to do what they are told"); diminished motor coordination and visual accommodation; and a feeling of muscular heaviness and weakness.... The symptoms increased in intensity throughout the time of these high plasma lithium values (one to one and a half hours), and faded so rapidly over ten to fifteen minutes that we could eat a full meal with a good appetite, only half an hour after feeling as if we would never want to eat again. (Trautner et al. 282)

Trautner was one of many who have been puzzled by lithium's efficacy in psychiatric patients. How is it possible that such a simple substance can have such a specific effect on something as complex as a human being? The potential of finding lithium's mechanism of action has driven numerous researchers because it has promised medicine what it has long longed for: a handle on mental illness; a final answer to what phenomena such as mania really are (cf. Malhi). Trauter had his own explanations but in retrospect they seem to lack sophistication. Contemporary neuroscience explains lithium's effects within a dynamic web of neuronal networks and signalling cascades of such complexity that we have only just begun to understand. Powerful imaging techniques, genetically engineered animal models, and stem cells that reproduce an individual person's brain cells in a Petri dish, allow for ever more ingenious experimental setups (cf. Malhi et al.). And still, after more than half a century of systematic lithium research, after thousands of publications and countless experiments, science has still not found a final answer. Instead, it has merely added possible explanations to others, according to the latest neuroscientific fashion (Belmaker and Agam).

Pause IV: Tinkering

We get a sense of what it means to do lithium research. Humans know lithium through science, from toxicity levels to mechanisms of action. But we should not forget the materiality of things. Knowledge does not come from nowhere, but is produced by bodies in experiments. Here lithium is also a substance affording multiple things for humans, many of which remain unknown. And so the promise of knowing endures, keeping scientists at work. Histories of lithium in scientific practice do neither tell stories of human projects nor of universal objects; but of different people in different times and different places tinkering with matters that are somehow, yet never really, the same.

But the promise remains, and it has been productive in other ways. Around twenty years ago researchers found that lithium has a neuroprotective effect at doses much lower than those prescribed in clinics (Nonaka et al.; Chen and Chuang). As a consequence, it now matters again far beyond psychiatry. It is hoped to prevent and even cure neurodegenerative diseases such as dementia and Parkinson's, and in general to lead to longer and healthier lives (e.g. Kerr et al.). This finding has brought back some of the magical qualities lithium was once thought to have (e.g. Greenblatt and Grossmann). Some lithia waters are still sold today, imbued with the novel authority of molecular neuroprotection. [6] Some prominent enthusiasts even want to make all of us drink it, by adding lithium salts to water supply (e.g. Fels). And a much broader question is opened for renewed scrutiny: what role does lithium in general play in biological systems? (e.g. Jakobsson et al.) Researchers are adapting their methods to the shifting scales of this question, following lithium ions as they move through the body to settle in certain places and not others (e.g. Lichtinger et al.). At a moment when quickly increasing amounts of lithium are brought into circulation through extractive industries and battery technologies, new ways to approach this question seem just about in time.

[6] For an impression of remaining lithia springs visit http://lithiaspringwater.com.

To conclude

What can we as scholars of the human do with minerals? In this paper I have approached one of the intricate epistemological issues that minerals confront us with by performing matters of scale through stories. The result was an unfinished story about lithium, an indeed rather strange mineral in constant transformation. At this particular moment, it would seem, lithium is again subject to remarkable change. What will become of the booming mineral? What worlds will it enable, what others foreclose? Natural scientists, or so I tried to show, have a big say in these questions. We would be well advised in human science not to ignore their part in defining a future that is still in the making. Rather, we should look for ways of resolving together the issues constantly emerging in interdisciplinary collaborations, case by case. Here I have worked through one particular issue, namely the materiality of minerals. Materiality confronts us with irreconcilable epistemological enemies: universalism and constructivism. In light of this I have used stories to develop languages that do not end the conversation before it even started. Stories structure common sense and science alike. How can we tell mineral stories well – stories where neither side is forced to the other? Maybe, as John Law has remarked, "in the end, the enemy is hubris" and to confront it we might be well advised to cultivate a sensibility for mess (Law, "STS as Method" 49; cf. Law, *After Method*). Thus, I have tried to tell a pragmatist story where lithium is neither a universal object nor a human project. In pragmatist stories all we have got are experiments; and experiments are never confined to the lab but constantly draw in, and leak into, all kinds of spaces. They are unfinished stories, which do not have a clear direction, but ask the unexpected connections they make as questions.

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