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Engaging the Underground: An STS Field in Formation

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Abstract
Rather than existing *a priori*, the underground *comes to be* through interlinked political, economic, cultural, and technoscientific practices and processes. Underlying each of these are issues of knowledge, expertise and power that STS is uniquely positioned to explore. In this thematic collection, our focus on the underground draws attention to the work, knowledge, and placemaking activities of those engaged in mining and energy development. We focus on how questions about extraction and burial are posed and deliberated through maps and models. More generally, we highlight the contributions of STS Underground, a network that in its nascent stage is helping to connect the many STS scholars who seek to use the underground as a source, site, and symbol for thinking of the future of the field, as well as their personal interventions as engaged scholars.

Keywords
underground; subterranean; mining; extraction; justice

Introduction
The underground is a space rich in natural resources as well as controversy. In 2016 the Standing Rock Sioux tribe and their supporters brought international attention to the underground with their calls to halt construction of the Dakota Access Pipeline, which was designed to bring oil from North Dakota's booming Bakken Shale field to the US Midwest to be refined. They called

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attention to the racist and colonial politics that led to the pipeline being routed through reservation land, leaving Indian people to suffer the results of a potential leak, while simultaneously making visible the country's ever-growing reliance on oil and contribution to global warming.

Questions of the responsible extraction of fossil fuels in an era of climate change play a key role in US politics, as Trump attempts to support a coal industry beleaguered by cheaper and less carbon-intensive natural gas, and as social movements increasingly oppose oil and gas development. Debates about the underground are not limited, however, to fossil fuels. Countries and companies scramble to locate and extract rare earth metals to support the growing electronics and renewable energy industries. Artisanal mining presents one of the gravest challenges to mineral rich countries in the Global South, as the miners' environmentally intensive techniques result in widespread deforestation, deterioration of water quality, and mercury poisoning. Nor are these debates limited to mining. On the one hand, severe droughts raise the specter of aquifer depletion in the American West. On the other, urban sprawl inhibits rainwater from reaching the underground, which the case of Hurricane Harvey in Houston painfully showed creates massive flooding. The underground is also home to an aging urban transportation infrastructure, and in some parts of the American West the geologic qualities of the underground makes it a target for nuclear waste disposal.

Given the central role that the underground plays in public debate, we see an important opportunity for STS scholars to inform decision making. Previous STS scholars have recognized the underground as a useful site to pursue theoretical questions about science, knowledge, and uncertainty, but little work to date has sought to theorize the underground itself. Drawing and building on existing scholarship, we seek to help define a new STS subfield focused on subterranean extraction. An STS perspective on extraction examines the technoscientific aspects of how questions about extraction are posed and deliberated, how extraction itself occurs, and how the consequences of such extraction are addressed. Underlying each of these areas are issues of knowledge, expertise, and power that STS is uniquely positioned to explore. In particular, STS research reveals the underground as a place that is populated and given meaning by diverse people and social practices. There are many kinds of people who engage the underground first-hand through their work, lifestyles, and recreation. This broad category includes construction workers, cavers, scientists, and those who routinely ride subways or live underground.[4] Yet rarely do people experience the underground with the same intimacy as miners, who read the underground environment for signs of danger and profitability, or the scientists and engineers who work in those spaces.

We propose that rather than existing *a priori*, the underground *comes to be* through interlinked political, economic, cultural, and technoscientific practices and processes. This insight resonates with scholarship at the intersection of anthropology and STS advocating a move away

[4] While the underground is primarily conceived and experienced as a place of work—leading to its central place in metaphors of industrial capitalism, as identified by Williams (1990)—there are also people such as archaeologists or cavers (Pérez 2015, 2013) who experience the underground through other frames that also include recreation.

from viewing "natural resources" as substances with essential qualities that exist ready to be extracted, toward the study of "resource materialities" as "complex arrangements of physical stuff, extractive infrastructures, calculative devices, discourses of the market and development, the nation and the corporation, everyday practices, and so on, that allow those substances to exist as resources" (Richardson and Weszkalnys 2014: 7). In our case, the underground comes to be as people study, engage, excavate, and fill it—and bring questions of science and expertise to bear in debating those practices.[5] In this thematic collection, for example, David Kneas shows that competing understandings and knowledge claims about Andean "nature" animate attempts to bolster or undermine Ecuador's status as a "mining country" open for international investment. Geologists and political figures who view the Andes through an ontological lens of uniformity and equivalence position Ecuador as a country rich in unexplored resource abundance, in contrast with those who emphasize Andean difference and heterogeneity to argue that Ecuador is an exception to the famed mineral wealth of its neighboring countries.

In contrast with conventional wisdom, the underground is not fixed, inert, or lifeless. At a basic level the physical strata of the underground are active, as was made all too clear in the September 2017 earthquake in Mexico, and organic materials come into contact and interact with each other. The biophysical characteristics of underground substances, like other resource materialities, provide affordances that shape but do not determine how they are engaged by people and industries (Barnes and Alatout 2012; Li 2015; Mathews and Barnes 2016; Richardson and Weszkalnys 2014). The stored energy of coal invites its burning for heat and energy, while the characteristics of water make it an "uncooperative commodity" that was difficult to privatize in England and Wales (Bakker 2004). The physical qualities of the underground, such as the strata themselves, produce novel political and economic orders. For example, geographer Bruce Braun's (2000) work on producing vertical materialities includes considering how the development of oil in North Dakota is about how fracking as a sociotechnical system articulates with the underground geology to produce a certain economic imperative. Braun writes about how the quickly declining production curves of "tight oil" feed the need for more and more wells to keep supplies constant (see also Gold 2015). Thus the character of the underground cannot be located

[5] These ideas are influenced by a rich area of anthropological research on mining and capitalism. The classic literature, grounded in ethnographic research in Africa and Latin America, explored transformations in labor regimes and economic development that frequently benefitted foreign capital, and the ways in which these new regimes articulated with local cosmologies (Nash 1979; Taussig 2010; Powdermaker 1962; Ferguson 1999). The competing interests and desires of capital (often but not exclusively in the form of foreign investment), state actors, and local communities also animate studies of oil, which offer a critical perspective on economic theories of the "resource curse" (Appel 2012; Mitchell 2011; Rogers 2015; Sawyer 2004). While some ethnographic studies (Ferry 2005; Finn 1998; Rolston 2013, 2014) continue to examine the experience and transformation of labor alongside larger shifts in capitalism—and critiques of it—anthropologists more often study conflicts between companies and their critics, especially the communities closest to sites of production (Li 2015; Kirsch 2014; Sawyer 2004; Welker 2014). The global mining boom of the 1990s in "greenfield" territories without established histories of extraction raised new questions, particularly surrounding conflicts among indigenous communities and their academic and NGO advocates, state actors, and major multinationals (Ballard and Banks 2003; Kirsch 2006, 2014; Bebbington 2012). Engineers and scientists rarely feature as actors in these accounts, with a few notable exceptions that engage anthropology along with STS (Kneas 2016; Li 2015; Ureta 2016).

exclusively in biophysical properties, but in how these inform and are informed by sociotechnical systems and the people acting within them.[6]

In this ESTS thematic collection, our focus on the underground draws attention to the work, knowledge, and placemaking activities of those engaged in mining and energy development. We focus on how questions about extraction and burial are posed and deliberated through maps and models. Authors in the thematic collection ask, What kinds of expertise are brought to bear on subterranean resource development, and which are marginalized? Who gets to answer the questions of where and how to dig, and how to reclaim the surface? These STS scholars also illuminate the many kinds of invisibilities that get produced in the act of mapping and modeling the subsurface.

Thinking With the Underground in STS

The mutual imbrication of the underground and the sociotechnical systems used to imagine, model, study, extract, and otherwise engage it, was influentially theorized by Rosalind Williams in *Notes on the Underground: An Essay on Technology, Society, and the Imagination* (1990). She argues that the underground is not just a place, but a pervasive and enduring trope for human built, highly technological environments, and dystopian environmental futures:

> The underworld setting therefore takes to an extreme the displacement of the natural environment by a technological one… The defining characteristic of the subterranean environment is the exclusion of nature—of biological diversity, of seasons, of plants, of the sun and the stars. The subterranean laboratory takes to an extreme the ecological simplification of modern cities, where it sometimes seems that humans, rats, insects, and microbes are the only remaining forms of wildlife (1990: 4, 20).

Williams reads 19th century European fictional narratives of human life underground alongside contemporary processes of excavation and extraction: during that period the mining industry formalized and grew, the growing network of railways and roads required deeper and longer tunnels, and building taller structures was only possible by digging deeper to accommodate more substantial foundations. These narratives show a fundamental ambivalence characteristic not just of extractive activities, but of science and technology in general: they represent the undermining of society and the abstract progress of civilization, a "dialectic of

[6] Here we are indebted to geographers who have helped usher in a geologic turn in social theory (Clark 2011; Bebbington 2012; Yusoff 2013). In *Capitalism and the Earth,* Kathryn Yusoff's makes a compelling case for reoccupying the strata of the earth (2014). Likewise, in his address at the Association of American Geographers meeting, Tony Bebbington stated that the flurry of new work on minerals and hydrocarbons matters greatly, because they are "constitutive of the functioning of capitalism and when they are enrolled into social life, a wide range of political imaginaries and relationships are reworked" (2012: 1153). Citing Noel Castree's work, Bebbington further argued that control over the subsoil can be deeply conflictive and signal a sort of Polanyian double movement "where attempts to expand the reach and depth of capitalist commodification are met by vocal (even violent) forms of resistance" (ibid).

progress and destruction" (1990: 54, 65). She also persuasively shows that excavation became the "dominant metaphor for truth seeking. The assumptions that truth is found by digging, and that the deeper we go the closer we come to absolute truth, have become part of the intellectual air we breathe" (1990: 49), citing intellectual currents from Freud's conceptualization of the superego, ego, and id as "strata of the mind" to Marx's invitation at the beginning of *Capital* to leave the "noisy sphere, where everything takes place on the surface" to journey down to the "hidden abode of production."

Williams' conceptualization of the underground as a metaphor for highly technological environments and environmental futures builds from Lewis Mumford's description in *Technics and Civilization* (2010 [1934]) of coal mines as the "first completely inorganic environment to be created and lived in by man… a triumph of the manufactured environment" (cited in Williams 1990: 5). Yet characterizing the underground as a "place where the organic is displaced by the inorganic" (1990: 5) risks obscuring the agentive, biophysical capacities of underground substances such as rocks and gas as well as the relationships developed among the humans and animals who do inhabit that space.

Historian Thomas Andrews, for example, richly documents underground mines as workscapes that are a "constellation of unruly and ever-unfolding relationships—not simply land, but also air and water, bodies and organisms, as well as the language people use to understand the world, and the lens of culture through which they make sense of and act on their surroundings" (2008: 125). He illustrates how miners developed loving, symbiotic relationships with mice who helped detect dangerous conditions, but cajoled the mules who hauled the ore to the surface (2008: 134). He also provides a vivid description of the miners viscerally encountering ancient history as they excavated, and how the geologic past took on new economic meaning in the context of coal mining:

> In the course of their daily work, colliers encountered impressions of seaweed and clam shells, not to mention recognizable remains of figs, palms, redwoods, breadfruit, and other tree species altogether different from scrubby junipers and piñons that grew outside the mines. The miners' craft thus bound its practitioners to a past when the dark seams in which they toiled had been teeming swamplands dappled by the sun's rays. Variations in these ancient ecosystems determined the thickness of coal seams and their character... Ancient streams and rivers had sometimes carved out channels through peat swamps, leaving behind troublesome features that miners called washouts or rolls. More uniform but equally problematic were layers of shale or other rock; these "bands" or "partings" of "bone" or "boney" had formed when volcanic eruptions, catastrophic floods, droughts, or other cataclysms deposited ash, silt, or sand on top of Cretaceous and Tertiary swamps (2008: 135-136).

These social-natural-environmental workscapes presented organic and geophysical dangers, such as potholes and water slips, moving rocks, dust and flooding, dripping and seepage. Andrews writes that "Miners butted up against earth at every turn. It butted right back, with less intention but much greater might. Try as miners would to control the powerful physical

and chemical forces that their work unleashed, they could not turn back the clock" (2008: 139). Recognizing the agentive capacities of the underground, as Andrews does, does not, however, relieve humans from their responsibilities for harms: our own politics, consumptive patterns, and economic systems bring the underground into being in particular ways that present different kinds of risk for the humans who work in it.

If Williams and Andrews provide ways to think about the underground as an inhabited––and often unjust—space, STS research has provided an array of concepts and theoretical frameworks for analyzing the construction of knowledge about what lies underground. In the mid-1980s, the estimation of oil reserves was an interesting case for researchers who probed the social construction of scientific knowledge. Bowden attempted to explain how social factors determine what is accepted as knowledge about "how much oil is in the ground." He focused on the organizational interests of the oil industry, concluding that the "validity" of resource estimates is socially constructed through an attributional process that is tied to the political economy of the oil industry (1985). Dennis came to a similar conclusion, looking at an earlier time period. His analysis considered a wider range of interests and ideas, arguing that oil reserve "[e]stimates are a product of a complex social process in which the estimate-makers' goals and multiple interests (social, economic, occupational and institutional), as well as their scientific knowledge, play an important role in shaping the final value" (1985: 242).

If the influence of the sociology of scientific knowledge is evident in these "interests analyses," subsequent STS research on the underground bears the marks of numerous other theoretical approaches. Indeed, the diversity of frameworks suggests that STS researchers throughout the 1980s and 1990s were not particularly committed to theorizing the underground itself, but instead found it to be a useful site to pursue theoretical questions about science, knowledge, and uncertainty. For instance, Bowker builds on insights by Pinch and Bijker, Latour, Hughes, and Callon to conduct a network analysis of the oil exploration activities of Schlumberger (a leader in the industry) (1987). This study examines "what happens when material property (oil), intellectual property (patents) and scientific properties (physical constants) enter the world of the oil network" (612). Bowker went on to publish a book on the history of Schlumberger, showing that geophysicists there capitalized on the pressing need for the oil industry to accurately characterize and access reservoirs to enable Schlumberger to become one of the world's largest corporations (1996). This work continues to inform social studies of industrial science and infrastructure, as well as oil exploration.

In subsequent decades, STS publications dealing with the underground continued to draw on a multiplicity of orientations that were prevalent in the field, including controversy studies (Cole 1996), public engagement in science (Bloor 2000), boundary organizations (Cash 2001), and co-construction of science and politics (Macfarlane 2003). Some STS work probed the perspectives and training of experts on the underground. Working in the vein of engineering studies, Constant (1989) examined the discipline and profession of petroleum engineering. The paper aimed to challenge stereotypes about engineers, revealing their social origins and identities.

Some STS research on the underground concluded with policy recommendations. For example, Hund (1986) compared how experts from different disciplines dealt with the inherent uncertainty of underground knowledge, in the case of the General Electric Test Reactor, a small nuclear reactor in California, which happens to be near a fault line. There was considerable uncertainty about where the fault was located and the likelihood of an earthquake affecting the reactor. In this context, engineers and geologists, using different ideas about what is "conservative" and "appropriate," reached different recommendations when reviewing the same geological information. Hund concluded the paper with recommendations for improving the Nuclear Regulatory Commission's policy process. Likewise, Macfarlane's (2003) research on the science and policy surrounding the proposed Yucca Mountain nuclear waste repository indicated that a new process is needed for choosing waste storage sites. She wrote, "A more successful policy—and one more acceptable to the public—would be to compare multiple sites and choose the 'best' site. But the 'best' site must be selected not only through scientific analysis. The local residents should also be given a choice" (803). Perhaps unsurprisingly, both Hund and Macfarlane went on to work in US science policy. Hund was a senior analyst at the US Congressional Office of Technology Assessment in the late 1980s, while Macfarlane served as the Chair of the US Nuclear Regulatory Commission during the Obama Administration.

Today's STS research on the underground continues to showcase theoretical diversity and engagement with contentious public issues. Using an actor-network approach, Alatout revealed how the construction of groundwater "abundance" in Palestine facilitated Zionist immigration and colonization between 1918 and 1948 (2009). Smith and Tidwell used the concept of sociotechnical imaginaries to illuminate contested understandings of coal and uranium mining as sites of blue-collar labor (2016). Wallsten and Krook applied insights from social studies of infrastructure to argue for the recovery of valuable materials from subterranean cables and pipes that remain buried after being disconnected (2016).[7]

STS ideas are particularly important in the recent debates surrounding the hydraulic fracturing techniques ("fracking") that are now used to release hydrocarbons from shale formations located thousands of feet beneath the surface. This water-intensive extraction technique, coupled with failures in the underground infrastructure used to transport it to the surface, can damage human health and wellbeing by contaminating water and air. The rapid expansion of hydraulic fracturing activity close to US communities in Ohio, Pennsylvania, Texas, and Colorado prompted scholars to track the environmental and social risks and harms, along with forms of community and political organization to mitigate them (Kroepsch 2016; Perry 2012; Jalbert et al. 2017; Espig and de Rijke 2016; Willow et al. 2014; Eaton and Kinchy 2016; Partridge et al. 2017; Zilliox and Smith 2017a, 2017b). Citizen science and other forms of public engagement

[7] Other recent STS contributions to making sense of the underground have addressed topics ranging from the interpretation of remote data sources in petroleum reservoir geology to decision making about geothermal energy to conspiracy stories about the definition of geological boundaries around protected sites, among other subjects with public relevance (Almklov 2008; Almklov and Hepsø 2011; Raman 2013; Gilbert 2015; Rahder 2015; Barandiaran 2015; Gross 2015; Pijpers 2016; Bleicher and Gross 2016; Sareen 2016; Oskarsson 2017).

in science have been key features of these controversies, as activists and concerned communities aim to fill the gaps in "undone science" (Kinchy 2017; Kinchy, Parks, and Jalbert 2016; Malone et al. 2015; Jalbert and Kinchy 2016; Wylie et al. 2016; Vera 2016; Zilliox and Smith 2018).

STS responses to fracking build on at least two strands of research. First, there is an important body of participatory research that works with and for various publics and "fence line" communities near polluting infrastructure (Ottinger 2010; Allen 1999). Second, STS scholars collaborate with scientists and engineers with aims toward making resource extraction and burial more sustainable and socially just. A recent ESTS thematic collection on "Making and Doing Politics Through Grassroots Scientific Research on the Energy and Petrochemical Industries" includes illustrations of both of the above points. Papers in the thematic collection highlight technoscientific practices that can reveal the harmful health and environmental impacts of extracting, burning, and refining fossil fuels, in order to inform debates about the justice and sustainability of subterranean resource extraction. For example, Wylie et al.'s article "Materializing Exposures" describes civic science efforts that include working with data scientists to produce environmental monitoring devices that help communities visualize the toxic releases from oil and gas wells (Wylie et al. 2017). In a similar vein, Jalbert et al.'s piece in the same thematic collection describes how the non-profit FracTracker Alliance in the northeastern US has used maps of bans, development moratoria, and crude oil train routes to help communities better visualize the risks of exposure and politically mobilize (Jalbert, Rubright, and Edelstein 2017).

Engaged STS work on the underground connects up with the lively interest in the field in addressing issues of environmental justice, climate justice, and toxic exposures. STS scholars politically engage through their public scholarship for general audiences, blogs, and op-eds that intervene in key public debates that involve regulatory decisions and industry influence.[8] As Wylie et al. suggest, STS scholar-activists are "diversifying the kinds of products that can count as STS scholarship" by "producing material interventions in addition to writing traditional papers" (2017: 413).[9]

Our efforts in establishing a subfield called STS Underground builds on this body of work, drawing out common themes to sharpen the field's ability to study and respond to pressing concerns about the underground. The above research contributions demonstrate how engaged STS research approaches can yield important insights about the underground. What

[8] This includes Naomi Oreskes' and Erik Conway's book *Merchants of Doubt,* which intervenes in the debates about climate denialism and the role of corporate lobbying. Another example is Gwen Ottinger's public writing about the importance of activist work calling for better air monitoring for oil and gas fenceline communities.

[9] Another potential point of intervention for STS scholars is in "corporate social responsibility" initiatives and other corporate responses to critics (Benson and Kirsch 2010). Corporate social responsibility (CSR) programs are emerging in response to both community critique and the need for public buy-in of local mining operations, what the industry terms a "social license to operate." Anthropologists have shown that the discursive framework of CSR and the community engagement tools inspired in its name actually reinforce the power of corporations to solve problems that they themselves define (Appel 2012; Dolan and Rajak 2016; Kirsch 2014; Rajak 2011; Welker 2014; Li 2011). Moving from academic critique of these practices to constructive modes of public engagement can be a key contribution of STS to these debates, given the field's substantial literature on public engagement on technoscientific controversies (Phadke 2014).

then, is new about our articulation of "STS Underground"? We see an opportunity for a shared research agenda around two deceptively simple questions. These questions are framed around problems of injustice and unsustainability, giving an ethical focus to our work.

"Should we dig here?" is a question that reverberates across every region of the earth (in the Arctic, in the Gulf of Mexico, in shale formations, in aquifers, in uranium deposits, etc.) and even in space, as asteroid mining becomes a real possibility.[10] What kinds of expertise are brought to bear on questions of where to dig? Whose knowledge is marginalized, and why? Deciding where to dig involves unexpected forms of knowledge and expertise that are often not visible or accessible to the public. For example, knowledge of colonial era artisanal African coal miners was "pirated" and used by modern multinational firms operating today (d'Avignon 2015). STS scholars can also illuminate the many kinds of invisibilities that get produced in the act of digging. For example, coal seam gas extraction produces ecological damage to wetlands and rivers that gets "unseen" (Cullis 2015).[11] Urban redevelopment can erase toxic social relations in one place while creating new body burdens and potential exposures in the communities receiving the soil (Dillon 2014). STS research on these topics can make useful contributions to public policy and movements for social change.

A second question—"How should we reclaim this surface?"—is equally fraught with technoscientific questions. Will it be safe to live in a housing development located on a former waste dump? What are the consequences of living in urban neighborhoods that sit atop deep horizontal shale oil and gas wells? Can the lands devastated by artisanal gold mining be transformed back into forest? Answers to these questions are highly contested and constrained by the limits of scientific knowledge and technological design. STS research is extremely well equipped to shed light on technoscientific processes like these. But opening up these black boxes does not necessarily lead to more socially just and ecologically sustainable decisions. Thus, STS theorists should also examine the kinds of public inquiries and deliberative events that help lead to greater and better public engagement. In particular, STS investments in thinking about the "morality of mining" may present development alternatives and alternative voices enabling an examination of what "extractive justice" might mean in its fullest sense, a concept that can connect consumers (of new cities, energy forms and devices) with sites of extraction around the globe.[12]

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[10] The Colorado School of Mines has developed a new training and research program focused on "space resources." See http://space.mines.edu/

[11] The d'Avignon and Cullis papers cited here are from our 4S 2015 panel titled "STS Underground."

[12] Some dimensions of these questions are addressed by STS research on energy, climate change, water, and waste, as in the thematic collection of ESTS discussed above. Finding other STS research relevant to the underground, however, can be challenging. Many STS scholars addressing the underground are publishing research in journals dedicated to environmental studies or energy policy, such as *Energy Research & Social Science* and the *Environment and Planning* journals. Answering the questions we pose about the underground will also require sustained engagement with research outside of STS, particularly anthropology, geography, history, and environmental studies.

Mapping and Modeling the Underground

For this thematic collection, we have selected five research papers that address the processes and politics of mapping and modeling. Though the underground is a crucial source of resources and a repository for waste, it largely remains mysterious and imperceptible to people, particularly those in wealthy countries who most conscipiously but only indirectly participate in the sociotechnical systems that engage the underground by filling up their large gas tanks to wearing gemstone jewelry. By contrast, direct experience with and knowledge of the underground is limited to small circles of workers and experts. As such, most people come to know the underground vicariously through film, stories, music, and the kinds of maps and models analyzed by the authors in this thematic collection. The invisibility of the underground makes it analogous to studying other "invisible" forces like nuclear radiation (see Hecht 2012). Cultural imaginaries about the underground add to this distance, as they tend to mystify it in ways that are different from, for example, the way we think about forests. And while speculation is inherent to scientific practice, it is especially central to any efforts to work underground, given that it cannot be directly visualized, touched, or manipulated outside of excavation or sampling. These unique characteristics of the underground make it an especially fertile space for examining the practices of mapping and modeling.

Historical research on geology and mining drew our attention to the construction of this kind of underground knowledge and expertise. In the 1970s, Rudwick argued that a visual language of science was integral to the nineteenth century emergence of the discipline of geology (1976). Nystrom ties the 19th century emergence of the mining engineering profession to the emergence of a visual culture of mining in which making and reading maps of the underground was the key distinguishing feature between engineers and practical miners (2014). Mapping gave engineers the power to organize and control the mining process, displacing skilled miners, who previously had been "the most important figure in mine work… as the locus of decision-making as the new organizational and technological systems promulgated by mining engineers fragmented the traditionally wide range of skilled work performed by miners into a series of semiskilled and unskilled occupational niches" (2014: 8-9). Nystrom also shows that the two- and three-dimensional models of underground mines constructed by companies were never politically neutral, but used to further particular ends, such as claiming mineral rights or improving the public perception of mining companies. An influential curator at the Smithsonian, for example, used models to "convince visitors that massive corporations were not scary unnaturalistic monopolies, but rather were good and necessary institutions for America, because only they could create and master the complex and 'efficient' technical operations that generated resources wisely and inexpensively" (Nystrom 2014: 215).

Geographers have long argued that maps are not objective renderings of reality. In this classic volume *How to Lie with Maps*, Mark Monmonier describes in great detail the use and abuse of maps by cartographers to create the worlds they desire to depict (1996). Monmonier notes that the use of color, font, symbol, text labels and scale can all serve to distort reality. Countermapping, and critical and DIY cartography, are all important tools used by political movements to empower everyday users to depict their own lived realities. Artist and activist

collectives have generated countermaps to challenge the epistemic authority of corporate, state, and military actors. In this spirit, Hebert and Brock's work in Bristol, Alaska illustrates how counter-mapping helps create new publics who can use state data to oppose resource extraction and restore priority to subsistence hunting, fishing, and gathering activities (2017). Similarly, Phadke showed that after extended political protest against the Indian government's design for the Uchangi dam, nongovernmental engineers and social activists aided project-affected villagers in producing an alternative dam design through participatory mapping techniques (2005). These critical mapping practices form part of what Mathews and Barnes in their introduction to a special issue on prognosis and environmental futures, identify as a larger "reworking of the relationship between states, corporations, and their publics, which opens up new points for opposition or engagement on the part of the people who might be affected by governmental or corporate action." (2016: 10). They and their contributors argue that new regimes of forecasting and modeling future environments give rise to new forms of nature and modes of politics.

Building on this scholarship on mapping and modeling, the papers in this thematic collection turn on several central themes vital to an engaged STS. The authors delve into how natural resources are socially constructed through processes of visualization and speculation. Several papers describe how both expertise and technologies of extraction translate material resources into economic assets. Finally, several papers discuss the need for epistemic and economic justice for communities near sites of extraction. The articles span continents and resources, from the Andes to west Africa, and from gold to groundwater. Across the articles, the authors are grappling with how we come to know the underground, and the relationships between subsurface and above ground expertise.

Drawing on the rich STS scholarship on how climate and environment modeling is simultaneously world building, Adrienne Kroepsch's article "Groundwater Modeling and Governance: Contesting and Building (Sub)Surface Worlds in Colorado's Northern San Juan Basin" describes how subsurface spaces are still zones of political contention in the American West. Using computer based groundwater models as her case, Kroepsch assesses how a more expansive underground view has not "generated epistemic consensus about the inner workings of subsurface systems." She argues that the "inscrutability" of subsurface water resources has resulted in a lack of shared understanding of the underground. On the theme of epistemic justice, Kroepsch describes how regulators' reliance on groundwater models has "delimited who spoke for the subsurface and buoyed the privatization of hydrologic knowledge in ways that reinforced mistrust among stakeholders and generated further legal battles."

Jessica Smith and Nicole Smith's article analyzes one group of people who, in speaking for the subsurface, bring it into being: the engineers and applied scientists who work for oil and gas companies. They argue that ethnographic attention to engineers illustrates the "contested politics of how resources 'become' as these actors produce and transgress distinctions between the subsurface and surface." They describe how community conflicts have prompted engineers and applied scientists to "view the subsurface and surface as interlinked, mutually dependent and, in some cases, mutually constitutive." In particular, they argue that maps and models help

make social concerns visible and actionable, at the same time as these techniques raise questions about how residents' concerns are translated and come to matter to project decisions.

Daniel Cumming's article describes how hydrocarbon extraction in the petro-suburbs of Los Angeles is connected with a racially segregated housing market. His article, "Black Gold, White Power: Mapping Oil, Real Estate, and Racial Segregation in the Los Angeles Basin, 1900-1939," examines the interlocking technologies of oil production and racial segregation that were created by capitalists, geologists, real estate agents, and federal appraisers. Cumming argues that mining, speculating, and mapping subsurface resources was crucial to the engineering of "residential apartheid" in metropolitan Los Angeles. Cumming describes how highly specialized technologies and scientific knowledge merged with the legal technologies that underwrote racist and predatory regimes for property rights, through maps, deeds, and land use policies, to co-produce the Los Angeles landscape.

Robyn d'Avignon also explores how racialized extractive regimes produce injustice, shifting our attention toward the grievances and expectations of so-called "artisanal miners" whose knowledge has been vital to gold prospecting in much of the Global South. d'Avignon's article, "Shelf Projects: Exploration Geology on Senegal's Gold Mining Frontier," describes how state map-making technologies serve as instrumental forms of power to lay claim over knowledge, resources, land, and people in the "under-explored mining frontiers" of West Africa. In recounting competing histories of how gold deposits were first discovered in this region, her goal is to ask the legal and ontological question of when a resource becomes an economic asset. She argues that while knowledge making about mineral wealth was "radically collaborative" in the French colonial era, the contribution of artisanal miners to discovering deposits currently exploited by corporations has no legal standing in the post-colony. d'Avignon argues for the need for multi-vocal histories of discovery and production of subterranean knowledge.

Similar to d'Avignon, David Kneas examines the framing of Ecuador's subsoil as "unexplored abundance." Kneas describes the ontological natures and epistemological scales that inform assumptions of resource potential. Kneas records how a notion of abundance is embodied in diverse sources—from 19th century landscape paintings to plate tectonic models of subsoil copper. Like d'Avignon, Kneas also touches on how contemporary claims of Ecuadorian mineral wealth are contingent upon "silencing histories." In his case, contemporary claims of Ecuadorian mineral wealth are also "presumptions of Andean difference, and Ecuador's own history of marginal mining and the knowledge of Ecuadorian subsoil that it engendered."

Together, these articles bring us rich stories from across the globe of how extractive industries work across models, fields, and areas of expertise. The final commentary in this thematic collection, by geographer Trevor Birkenholtz, draws out major themes across the articles, with reference to cartographic and model production and representation, particularly in the ways that they render the landscapes partially knowable and contestable. Whether our example is the discovery of oil in Ecuador or the extraction of groundwater in Colorado, Birkenholtz highlights how the power struggles over representation and modeling described

across regions have implications for "justice, political representation, and the distribution of environmental and material harms and benefits."

A Subfield in Formation

These elucidating studies came to us through a series of exciting scholarly meetings over the last three years that have been part of our effort to shape a new subfield we've come to call STS Underground. In 2015, Phadke and Kinchy organized an open session for the annual meetings of the Society for Social Studies of Science (4S), which we subsequently blogged about in 4S's *Backchannels*. Our aim was to discover and highlight interesting new research on the science, technology, and politics of the subsurface. The nine presenters at that conference were the beginning of the STS Underground Network. Two further sessions at the 2016 4S meetings, which were organized by Abby Kinchy and Jessica Smith, expanded this research network.

We received a grant in 2016 from the National Science Foundation to organize a workshop called *STS Underground: Investigating the Technoscientific Worlds of Mining and Subterranean Extraction*.[13] The workshop was held at the Colorado School of Mines in February 2017. We received nearly 50 abstract submissions for the conference, indicating the high level of interest in this topic. We selected 15 authors and three discussants, who workshopped papers over three intensive days. Gabrielle Hecht gave a keynote lecture about the human impacts of radioactive exposure to mining in South Africa. Hosting the workshop at the Colorado School of Mines (CSM) opened up opportunities to directly engage with scientists, engineers and practitioners in the extractive industries. CSM researchers, students, and faculty brought important perspectives to the workshop by participating in our opening session, a fieldtrip to the university's experimental underground mine, and a closing public panel.

Our workshop encouraged participation from graduate students, postdoctoral fellows, and junior faculty from an array of fields. After the workshop, we received many notes of gratitude from participants about the planning of the event and the impact on their professional development. In post workshop evaluations, we learned that participants most valued sharing resources and creating new relationships with other junior scholars with similar interests, and more senior scholars who helped reinforce and validate emerging interests and questions.

Our Colorado School of Mines workshop also served to launch an expanded STS Underground Network, which now includes over seventy scholars from across the world. We also now maintain a google group to serve as an online platform for communication about new publications, conferences, and news events. The STS Underground community will meet again in a pre-conference for 4s 2018 in Sydney and another series of panels at the annual meeting. This time we are interested in exploring the research methods and analytical strategies we use to observe and make sense of human interactions with subterranean materials and places. By focusing on method, we hope to better understand and share the ways in which we come to

[13] The 2017 workshop was generously funded by the Science, Technology and Society Program at the National Science Foundation (SES 1632651) (https://www.mines.edu/stsu/).

know and mobilize the underground spaces and places that are so difficult to see, explore and develop.

This thematic collection is an opportunity for us to share the emerging work from the STS Underground network, a network that in its nascent stage is already helping to connect the many STS scholars who seek to orient to the underground as a source, site, and symbol for thinking through the future of the field and meaningful interventions. As a collective, we seek to explore how our research can advance justice, sustainability, and equity through engaged scholarship.

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References

Alatout, Samer. 2009. "Bringing Abundance into Environmental Politics: Constructing a Zionist Network of Water Abundance, Immigration, and Colonization." *Social Studies of Science* 39 (3):363–94.

Allen, Barbara L. 1999. *Uneasy Alchemy : Dissonance, Resistance, Justice, and Change in Louisiana's Industrial Corridor*. 1999. http://libproxy.rpi.edu/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=cat02306a&AN=rlc.1376741&site=eds-live&scope=site.

Almklov, Petter G. 2008. "Standardized Data and Singular Situations." *Social Studies of Science* 38 (6):873–97.

Almklov, Petter G., and Vidar Hepsø. 2011. "Between and beyond Data How Analogue Field Experience Informs the Interpretation of Remote Data Sources in Petroleum Reservoir Geology." *Social Studies of Science* 41 (4):539–61.

Andrews, Thomas G. 2008. *Killing for Coal: America's Deadliest Labor War*. Cambridge: Harvard University Press.

Appel, Hannah. 2012. "Offshore Work: Oil, Modularity, and the How of Capitalism in Equatorial Guinea." *American Ethnologist* 39 (4):692–709. https://doi.org/10.1111/j.1548-1425.2012.01389.x.

Appel, Hannah C. 2012. "Walls and White Elephants: Oil Extraction, Responsibility, and Infrastructural Violence in Equatorial Guinea." *Ethnography* 13 (4):439–65.

Bakker, Karen J. 2004. *An Uncooperative Commodity: Privatizing Water in England and Wales*. 1 edition. Oxford ; New York: Oxford University Press.

Ballard, Chris, and Glenn Banks. 2003. "Resource Wars: The Anthropology of Mining." *Annual Review of Anthropology* 32 (1):287–313. https://doi.org/10.1146/annurev.anthro.32.061002.093116.

Barandiaran, Javiera. 2015. "Chile's Environmental Assessments: Contested Knowledge in an Emerging Democracy." *Science as Culture* 24 (3):251–75. https://doi.org/10.1080/09505431.2014.992332.

Barnes, Jessica, and Samer Alatout. 2012. "Water Worlds: Introduction to the Special Issue of Social Studies of Science." *Social Studies of Science* 42 (4):483–88. https://doi.org/10.1177/0306312712448524.

Bebbington, Tony. 2012. *Social Conflict, Economic Development and Extractive Industry: Evidence from South America*. London: Routledge.

Benson, Peter, and Stuart Kirsch. 2010. "Capitalism and the Politics of Resignation." *Current Anthropology* 51 (4):459–86. https://doi.org/10.1086/653091.

Bleicher, Alena, and Matthias Gross. 2016. "Geothermal Heat Pumps and the Vagaries of Subterranean Geology: Energy Independence at a Household Level as a Real World Experiment." *Renewable and Sustainable Energy Reviews* 64 (Supplement C):279–88. https://doi.org/10.1016/j.rser.2016.06.013.

Bloor, M. 2000. "The South Wales Miners Federation, Miners' Lung and the Instrumental Use of Expertise, 1900-1950." *Social Studies of Science* 30 (1):125–40. https://doi.org/10.1177/030631200030001005.

Bowden, G. 1985. "The Social Construction of Validity in Estimates of United-States Crude-Oil Reserves." *Social Studies of Science* 15 (2):207–40. https://doi.org/10.1177/030631285015002001.

Bowker, Geof. 1987. "A Well Ordered Reality: Aspects of the Development of Schlumberger, 1920-39." *Social Studies of Science* 17 (4):611–55.

Braun, B. 2000. "Producing Vertical Territory: Geology and Governmentality in Late Victorian Canada." *ECUMENE* 7 (1):7–46.

Cash, David W. 2001. "'In Order to Aid in Diffusing Useful and Practical Information': Agricultural Extension and Boundary Organizations." *Science, Technology, & Human Values* 26 (4):431–53.

Clark, Nigel. 2011. *Inhuman Nature: Sociable Life on a Dynamic Planet.* London: Sage Press.

Cole, Simon A. 1996. "Which Came First, the Fossil or the Fuel?" *Social Studies of Science* 26 (4):733–66.

Constant, Edward W. 1989. "Cause or Consequence: Science, Technology, and Regulatory Change in the Oil Business in Texas, 1930-1975." *Technology and Culture* 30 (2):426–55. https://doi.org/10.2307/3105111.

Dennis, Michael Aaron. 1985. "Drilling for Dollars: The Making of US Petroleum Reserve Estimates, 1921-25." *Social Studies of Science* 15 (2):241–65.

Dillon, Lindsey. 2014. "Race, Waste, and Space: Brownfield Redevelopment and Environmental Justice at the Hunters Point Shipyard." *Antipode* 46 (5):1205–21. https://doi.org/10.1111/anti.12009.

Dolan, Catherine, and Dinah Rajak. 2016. *The Anthropology of Corporate Social Responsibility*. Berghahn.

Eaton, Emily, and Abby Kinchy. 2016. "Quiet Voices in the Fracking Debate: Ambivalence, Nonmobilization, and Individual Action in Two Extractive Communities (Saskatchewan and Pennsylvania)." *Energy Research & Social Science*, Risks, the Social Sciences, and

Unconventional Hydrocarbons, 20 (Supplement C):22–30. https://doi.org/10.1016/j.erss.2016.05.005.

Espig, Martin, and Kim de Rijke. 2016. "Unconventional Gas Developments and the Politics of Risk and Knowledge in Australia." *Energy Research & Social Science*, Risks, the Social Sciences, and Unconventional Hydrocarbons, 20 (Supplement C):82–90. https://doi.org/10.1016/j.erss.2016.06.001.

Ferguson, James. 1999. *Expectations of Modernity: Myths and Meanings of Urban Life on the Zambian Copperbelt*. University of California Press.

Ferry, Elizabeth Emma. 2005. *Not Ours Alone: Patrimony, Value, and Collectivity in Contemporary Mexico*. Columbia University Press.

Finn, Janet L. 1998. *Tracing the Veins: Of Copper, Culture, and Community from Butte to Chuquicamata*. University of California Press.

Gilbert, Paul Robert. 2015. "Trouble in Para-Sites: Deference and Influence in the Ethnography of Epistemic Elites." *Anthropology in Action* 22 (3). https://doi.org/10.3167/aia.2015.220307.

Gold, Russell. 2015. *The Boom: How Fracking Ignited the American Energy Revolution and Changed the World*. Reprint edition. New York: Simon & Schuster.

Gross, Matthias. 2015. "Journeying to the Heat of the Earth: From Jules Verne to Present-Day Geothermal Adventures." *Engineering Studies* 7 (1):28–46. https://doi.org/10.1080/19378629.2014.997738.

Hebert, Karen, and Samara Brock. 2017. "Counting and Counter-Mapping: Contests over the Making of a Mining District in Bristol Bay, Alaska." *Science as Culture* 26 (1):56–87. https://doi.org/10.1080/09505431.2016.1223112.

Hecht, Gabrielle. 2012. *Being Nuclear: Africans and the Global Uranium Trade*. MIT Press.

Hund, Ge. 1986. "The Fault of Uncertainty - Geologic Information in Regulatory Decision-Making." *Science Technology & Human Values* 11 (4):45–54.

Jalbert, Kirk, and Abby J. Kinchy. 2016. "Sense and Influence: Environmental Monitoring Tools and the Power of Citizen Science." *Journal of Environmental Policy & Planning* 18 (3):379–97. https://doi.org/10.1080/1523908X.2015.1100985.

Jalbert, Kirk, Samantha Malone Rubright, and Karen Edelstein. 2017. "The Civic Informatics of FracTracker Alliance: Working with Communities to Understand the Unconventional Oil and Gas Industry." *Engaging Science, Technology, and Society* 3 (0):528–59. https://doi.org/10.17351/ests2017.128.

Jalbert, Kirk, Anna Willow, David Casagrande, and Stephanie Paladino. 2017. *ExtrACTION: Impacts, Engagements, and Alternative Futures*. New York: Routledge.

Kinchy, Abby. 2017. "Citizen Science and Democracy: Participatory Water Monitoring in the Marcellus Shale Fracking Boom." *Science as Culture* 26 (1):88–110. https://doi.org/10.1080/09505431.2016.1223113.

Kinchy, Abby, Sarah Parks, and Kirk Jalbert. 2016. "Fractured Knowledge: Mapping the Gaps in Public and Private Water Monitoring Efforts in Areas Affected by Shale Gas Development." *Environment and Planning C: Government and Policy* 34 (5):879–99. https://doi.org/10.1177/0263774X15614684.

Kirsch, Stuart. 2006. *Reverse Anthropology: Indigenous Analysis of Social and Environmental Relations in New Guinea*. Stanford: Stanford University Press.

———. 2014. *Mining Capitalism: The Relationship between Corporations and Their Critics*. Berkeley, California ; Los Angeles, California ; London: University of California Press.

Kneas, David. 2016. "Subsoil Abundance and Surface Absence: A Junior Mining Company and Its Performance of Prognosis in Northwestern Ecuador." *Journal of the Royal Anthropological Institute* 22 (S1):67–86. https://doi.org/10.1111/1467-9655.12394.

Kroepsch, Adrianne. 2016. "New Rig on the Block: Spatial Policy Discourse and the New Suburban Geography of Energy Production on Colorado's Front Range." *Environmental Communication* 10 (3):337–51. https://doi.org/10.1080/17524032.2015.1127852.

Li, Fabiana. 2011. "Engineering Responsibility: Environmental Mitigation and the Limits of Commensuration in a Chilean Mining Project." *Focaal* 2011 (60):61–73. https://doi.org/10.3167/fcl.2011.600106.

———. 2015. *Unearthing Conflict: Corporate Mining, Activism, and Expertise in Peru*. Duke University Press.

Macfarlane, A. 2003. "Underlying Yucca Mountain: The Interplay of Geology and Policy in Nuclear Waste Disposal." *Social Studies of Science* 33 (5):783–807. https://doi.org/10.1177/0306312703335006.

Malone, Samantha, Matthew Kelso, Ted Auch, Karen Edelstein, Kyle Ferrar, and Kirk Jalbert. 2015. "Data Inconsistencies from States with Unconventional Oil and Gas Activity." *Journal of Environmental Science and Health, Part A* 50 (5):501–10. https://doi.org/10.1080/10934529.2015.992678.

Mathews, Andrew S., and Jessica Barnes. 2016. "Prognosis: Visions of Environmental Futures." *Journal of the Royal Anthropological Institute* 22 (S1):9–26. https://doi.org/10.1111/1467-9655.12391.

Mitchell, Timothy. 2011. *Carbon Democracy: Political Power in the Age of Oil*. Verso Books.

Mumford, Lewis. 2010. *Technics and Civilization*. University of Chicago Press.

Nash, June C. 1979. *We Eat the Mines and the Mines Eat Us: Dependency and Exploitation in Bolivian Tin Mines*. Columbia University Press.

Nystrom, Eric C. 2014. *Seeing Underground: Maps, Models and Mining Engineering in America*. Reno: University of Nevada Press.

Oreskes, N. and E. Conway. 2010. *Merchants of Doubt*. New York: Bloomsbury Press.

Oskarsson, Patrik. 2017. "Diverging Discourses on Bauxite Mining in Eastern India: Life-Supporting Hills for Adivasis or National Treasure Chests on Barren Lands?" *Society & Natural Resources* 30 (8):994–1008. https://doi.org/10.1080/08941920.2017.1295496.

Ottinger, Gwen. 2010. "Buckets of Resistance: Standards and the Effectiveness of Citizen Science." *Science, Technology & Human Values* 35 (2):244–70. https://doi.org/10.1177/0162243909337121.

Partridge, Tristan, Merryn Thomas, Barbara Herr Harthorn, Nick Pidgeon, Ariel Hasell, Louise Stevenson, and Catherine Enders. 2017. "Seeing Futures Now: Emergent US and UK Views on Shale Development, Climate Change and Energy Systems." *Global*

Environmental Change 42 (Supplement C):1–12. https://doi.org/10.1016/j.gloenvcha.2016.11.002.

Pérez, María Alejandra. 2013. "Lines Underground: Exploring and Mapping Venezuela's Cave Environment." *Cartographica: The International Journal for Geographic Information and Geovisualization* 48 (4):293–308. https://doi.org/10.3138/carto.48.4.1696.

———. 2015. "Exploring the Vertical: Science and Sociality in the Field among Cavers in Venezuela." *Social & Cultural Geography* 16 (2):226–47. https://doi.org/10.1080/14649365.2014.973438.

Perry, Simona L. 2012. "Development, Land Use, and Collective Trauma: The Marcellus Shale Gas Boom in Rural Pennsylvania." *Culture, Agriculture, Food and Environment* 34 (1):81–92. https://doi.org/10.1111/j.2153-9561.2012.01066.x.

Phadke, Roopali. 2005. "People's Science in Action: The Politics of Protest and Knowledge Brokering in India." *Society & Natural Resources* 18 (4):363–75. https://doi.org/http://dx.doi.org/10.1080/08941920590915260.

———. 2014. "Green Energy, Public Engagement and the Politics of Scale." In *The Handbook of Science, Technology, and Society, Edited by D. Kleinman and K. Moore.* New York: Routledge.

Pijpers, Robert J. 2016. "Mining, Expectations and Turbulent Times: Locating Accelerated Change in Rural Sierra Leone." *History and Anthropology* 27 (5):504–20. https://doi.org/10.1080/02757206.2016.1222524.

Powdermaker, Hortense. 1962. *Copper Town: Changing Africa: The Human Situation on the Rhodesian Copperbelt*. Harper & Row Publishers.

Rahder, Micha. 2015. "But Is It a Basin? Science, Controversy, and Conspiracy in the Fight for Mirador, Guatemala." *Science as Culture* 24 (3):299–324. https://doi.org/10.1080/09505431.2015.1007034.

Rajak, Dinah. 2011. *In Good Company: An Anatomy of Corporate Social Responsibility*. Stanford University Press.

Raman, Sujatha. 2013. "Fossilizing Renewable Energies." *Science as Culture* 22 (2):172–80. https://doi.org/10.1080/09505431.2013.786998.

Richardson, Tanya, and Gisa Weszkalnys. 2014. "Introduction: Resource Materialities." *Anthropological Quarterly* 87 (1):5–30. https://doi.org/10.1353/anq.2014.0007.

Rogers, Douglas. 2015. *The Depths of Russia: Oil, Power, and Culture after Socialism*. Cornell University Press.

Rolston, Jessica Smith. 2013. "The Politics of Pits and the Materiality of Mine Labor: Making Natural Resources in the American West." *American Anthropologist* 115 (4):582–94. https://doi.org/10.1111/aman.12050.

———. 2014. *Mining Coal and Undermining Gender: Rhythms of Work and Family in the American West*. New Brunswick, New Jersey: Rutgers University Press.

Sareen, Siddharth. 2016. "Seeing Development as Security: Constructing Top-Down Authority and Inequitable Access in Jharkhand." *South Asia Multidisciplinary Academic Journal*, no. 13 (April). https://doi.org/10.4000/samaj.4146.

Sawyer, Suzana. 2004. *Crude Chronicles: Indigenous Politics, Multinational Oil, and Neoliberalism in Ecuador*. Duke University Press.

Smith, Jessica M., and Abraham S. D. Tidwell. 2016. "The Everyday Lives of Energy Transitions: Contested Sociotechnical Imaginaries in the American West." *Social Studies of Science* 46 (3):327–50. https://doi.org/10.1177/0306312716644534.

Taussig, Michael T. 2010. *The Devil and Commodity Fetishism in South America*. Univ of North Carolina Press.

Ureta, Sebastian. 2016. "Caring for Waste: Handling Tailings in a Chilean Copper Mine." *Environment and Planning A* 48 (8):1532–48. https://doi.org/10.1177/0308518X16645103.

Vera, Lourdes. 2016. "Community Health Impacts from Oil and Gas Development in Texas: The Perspective of Sharon Wilson." *NEW SOLUTIONS: A Journal of Environmental and Occupational Health Policy* 26 (3):496–507. https://doi.org/10.1177/1048291116665073.

Wallsten, Bjorn, and Joakim Krook. 2016. "Urks and the Urban Subsurface as Geosocial Formation." *Science Technology & Human Values* 41 (5):827–48. https://doi.org/10.1177/0162243916634866.

Welker, Marina. 2014. *Enacting the Corporation: An American Mining Firm in Post-Authoritarian Indonesia*. 1 edition. Berkeley: University of California Press.

Williams, Rosalind H. 1990. *Notes on the Underground: An Essay on Technology, Society, and the Imagination*. MIT Press.

Willow, Anna J., Rebecca Zak, Danielle Vilaplana, and David Sheeley. 2014. "The Contested Landscape of Unconventional Energy Development: A Report from Ohio's Shale Gas Country." *Journal of Environmental Studies and Sciences* 4 (1):56–64. https://doi.org/10.1007/s13412-013-0159-3.

Wylie, Sara, Kim Schultz, Deborah Thomas, Chris Kassotis, and Susan Nagel. 2016. "Inspiring Collaboration: The Legacy of Theo Colborn's Transdisciplinary Research on Fracking." *NEW SOLUTIONS: A Journal of Environmental and Occupational Health Policy* 26 (3):360–88. https://doi.org/10.1177/1048291116666037.

Wylie, Sara, Elisabeth Wilder, Lourdes Vera, Deborah Thomas, and Megan McLaughlin. 2017. "Materializing Exposure: Developing an Indexical Method to Visualize Health Hazards Related to Fossil Fuel Extraction." *Engaging Science, Technology, and Society* 3 (0):426–63. https://doi.org/10.17351/ests2017.123.

Yusoff, Kathryn. 2013. "Geologic Life: Prehistory, Climate, Futures in the Anthropocene." *Environment and Planning D: Society and Space* 31 (5):779–795.

Zilliox, Skylar & Jessica M. Smith. 2017a. Memorandums of understanding and public trust in local government for Colorado's unconventional energy industry. *Energy Policy* 107: 72–81. https://doi.org/10.1016/j.enpol.2017.04.032

Zilliox, Skylar & Jessica M. Smith. 2017b. Supraregulatory Agreements and Unconventional Energy Development: Learning from Citizen Concerns, Enforceability and Participation in Colorado. *Extractive Industries & Society* 4(1): 69–77. http://dx.doi.org/10.1016/j.exis.2016.11.008

Zilliox, Skylar & Jessica M. Smith. 2018. Colorado's Fracking Debates: Citizen Science, Conflict and Collaboration. *Science as Culture* https://doi.org/10.1080/09505431.2018.1425384