Unblackboxing mediation in the digital mine

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ARTICLE INFO

ABSTRACT

As natural resource extraction moves into increasingly remote frontiers, rapidly proliferating technologies associated with digitization and automation are respatializing technical and environmental relations both on- and off-shore. Drawing on scholarship in digital geographies and media studies, we employ the concept of mediation to open up the blackbox of digital encounters in mining and extraction. The digitization of earth's lithosphere serves to physically distance the miner from the mine, while simultaneously producing novel relations between humans and more-than-human matter via granular, multi-spectral, and richly textured information that streams from the mines. Thus, the mine is reconceived as a double treasure trove, where the seams of the earth are both ore and data rich. Focusing on two iron-rich sites targeted for robotic extraction - the proposed seabed mine off Aotearoa New Zealand and the heavily-mined Pilbara region of Western Australia - the comparative findings expand theorization through an explicit focus on digital mediation and shifting relations of the human and non-human components of the extractive industry. Our analysis of the digital mine illustrates how these technologies are driving increased abstraction and decontextualization of the broader socio-ecological relations, serving to obscure the ecological, social, and cultural context within which the mine site is materially entangled. Technologies with automated and remotely-controlled manipulation and simulation capacities, such as digital twins, displace human miners from physical mine sites, increase transmission distances, and reinforce extractive ways of knowing the subterranean and subaqueous. We reveal how digital mediation amplifies a reflexive phenomenon of earth-as-mine feedback loop and how environmental manipulation-from-nowhere transforms the god's-eye-view into the hand-of-god.

1. Introduction to the digital mine

An acceleration in digitization and automation is underway in the mining industry, both on land and offshore, characterized by an extractive imaginary of replacing human bodies in subterranean and subaqueous mining sites with rapidly evolving constellations of sensing systems and autonomous robots. This trajectory in mining, designated Mining 4.0, has been described as an emerging fourth industrial revolution prefaced on the increased capabilities of digital technologies, in particular automation and machine learning (ABB, 2022). In *Digital Oil*, Monteiro (2022) details a key threefold shift enabled by digitalization focused on the objects of knowing, the modes of knowing, and the machineries of knowing as digital representations and digital mediation become more prevalent in the oil extraction industry. As over-extraction has led to depletion of traditional mineral and metal reserves, access to increasingly remote and dangerous spaces of extraction is required (Owens, 2013; Cowin, 2017; Paredes and Fleming-Muñoz, 2021). For

example, in the nascent seabed mining industry, sensors and robotics are essential due to physical extremes of pressure, temperature, and lack of oxygen under the ocean. Concomitantly, on land adoption of emerging technologies for automation and remote control associated with "smart mining" promises a new mining future that is safer for workers and significantly more efficient for extractive industries (Wang and Huang, 2017; Lööw et al., 2019).

Recognizing that extraction landscapes have long been sites of technical mediation (ie. mediated through different kinds of technologies, such as rock hammers, dynamite, drills, canaries, etc.), our argument draws specific attention to contemporary processes and imperatives of digitization and automation that seek to know and manipulate geologic matter at a distance. We follow Parikka's formulation of media materialism, which "has come to refer to technology as an active agent in the ontological and epistemological sense. In other words, media structure how things are...how things are known in the world" (2015, p. 1). Emerging techniques of extraction serve to produce

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novel relations between humans and more-than-human matter via pixelated, multi-spectral, and richly textured information that streams from mines. In this conceptualization, the mine is reconceived as a double treasure trove, where the lithospheric seams of earth are both ore and data rich.

We argue digitization of mine sites amplifies processes of abstraction and decontextualization facilitating a significant shift in relations of extraction between remote mining operations and target environments. We identify this shift as producing a self-reinforcing earth-as-mine feedback loop, where technical data selected from mines has been tailored specifically to report on mining interests. This phenomenon of reflexivity fuels an extractive imaginary of achieving complete detachment and alienation of commodifiable resources from their embedded relationality within broader socio-ecological landscapes. Further, these processes respatialize relations by producing conditions of displacement, as human miners are increasingly displaced offsite into centers of remote operations. Displacement serves to further diminish and obscure embodied and experiential knowledges of sites, as sensors capture, transduce, and transmit emanations – the constant vibrations and myriad emissions exuded through earthly media – rendering possible remote operation via digital twins enabled by machine learning algorithms and high-resolution visualizations of mine sites.

In this paper, we investigate two digitally-mediated, iron-ore extraction sites in Oceania: iron-rich sandy seafloors off Aotearoa New Zealand, and banded iron formations (BIFs) of Western Australia's heavily-mined Pilbara region. Through our analysis, we aim to illuminate processes of mediation, which may otherwise remain blackboxed in the emerging phenomenon of smart mining. Drawing explicit attention to the digital mine and its entanglements, we extend focus towards material and technological engagements of earthly extractive relations in the context of rapidly proliferating digital technologies. Our analysis sutures ongoing conversations in geography and media studies in novel ways to theoretically interrogate key processes that have received little attention to date in social science scholarship on extraction. Theorizing the intersection of processes of digital mediation and relations of abstraction reveals complex entanglements of techno-social milieus hidden behind smooth, corporate veneers of robotically-enabled mining practices. We expand the critique of Enlightenment science's disembodied *god's-eye-view*, tracing how emerging robotic technologies and advances in automation are accelerating environmental manipulation-from-nowhere via robotics operated from afar, manifesting a remotely embodied *hand-of-god*.

The next section of the paper reviews the existing scholarship in geography and media studies towards spatializing mediation and unblackboxing technical relations of the smart mine. The third section introduces the comparative case studies and describes our methods and the empirics underscoring this conceptual contribution. The fourth section traces mediation of the digital mine across multiple layers of abstraction and decontextualization. Our analysis examines relations of primitive accumulation, colonization and land theft that render earth as property for extraction, the activation of earth for data capture, subjective processes of signal–noise differentiation that reinforce the earth-as-mine feedback loop, and respatialization of relations between mine and miner via processes of automation and increasing transmission distances. Finally, we conclude with a discussion of the contributions to scholarship in geography and media studies and suggest directions for future research.

2. Mining and mediation

Increasing digitization and automation of mines draws renewed attention to concepts related to processes of technical mediation and digital communication. Latour describes the phenomenon of blackboxing in technical work, "paradoxically, the more science and technology succeed, the more opaque and obscure they become…made invisible by its own success" (1999, p. 304). In relation to the rise of automated processes, Hayles (2014) further warns of the inaccessibility and persistent blackbox related to the growing application of computational media. Attention and theorization are needed to reveal how mine site materiality is converted through multiple phases of digital mediation into data for automating and remotely controlling extractive processes.

Mining and extraction have long been objects of study in geography. However, the proliferation of digital technologies in mining has received less attention. Critical resource geographers have produced a body of theoretically and empirically rich scholarship across thematic and conceptual areas making significant contributions to understanding labor relations, embodiment, resource nationalism, subterranean territorialities, commodification and commodity chains, sacrifice zones, conflict, environmental degradation, water security, popular resistance, and discard studies (see Arboleda, 2020; Bebbington et al., 2008; Budds and Hinojosa, 2012; Holifield and Day, 2017; Marston 2019, 2021; Peluso, 2018). Bakker and Bridge's highly cited original intervention (2006), and more recent follow up article (2021) encourage radical reconsideration of agency in human-environment relations and invoke materiality in critical resource geography; attention to the role of sociotechnical practices in resource management has since grown significantly. Relatedly, new materialist studies provide multiple trajectories for expanded engagement with the liveliness and agency of messy materials that constitute volumetric place and space (Bennett, 2010; Peters and Steinberg, 2019; Squire, 2016; Whatmore, 2006).

The digital geography subdiscipline has extended spatial insights, particularly in urban spaces, related to the role of smart cities, platform urbanism, displacement via automation, and how rapidly expanding digital networks are altering myriad relations central to urban life (see Amoore, 2020; Ash et al., 2018; Leszczynski, 2020; Lynch, 2020). In relation to smart mining, the emphasis on displacement (Lynch et al., 2022), the epistemological effects of algorithms (Maalsen, 2023), and material aspects of digitization and automation in digital geographies scholarship are most relevant to this research (Kinsley, 2014; Bissel, 2018; Bissell, 2021). Less attention to date has been paid in digital geographies scholarship to more industrial spaces like the growing digitization of extraction landscapes, with a few important exceptions (e.g. Bissell, 2021).

Digital geographers have advanced theorization of mediation, specifically challenging false virtual-real dichotomies, expanding the conceptualization of media to include spatial media, and reorienting the ontological claims of mediation (Kinsley, 2014; Leszczynski, 2015; Rose, 2017) to "suggest that reality may be understood *in terms* of mediation, i. e. as always-already mediat*ed*" (Leszczynski, 2015, p. 731). Durham Peters further expands attention to the capaciousness of media arguing "once communication is understood not only as sending messages… but also as providing conditions for existence, media cease to be only studios and stations, messages and channels, and become infrastructures and forms of life" (2015, p. 14). Calls for digital geographers to attend to materiality have produced important theoretical and empirical insights for understanding user interfaces (Ash et al., 2018), intersections between embodied practices and datafication (Schäfer and van Es, 2017; Elwood and Leszczynski, 2018), and has spawned an emerging subfield of digital political ecologies (Lehman, 2016; Lally et al., 2019). This nascent subfield attends to how data technologies make and remake environments, infrastructures, politics, and logics of environmental governance, rejecting discourses that position data as "a neutral, objective resource…for decision-making around nature" (Nost and Goldstein, 2022, p. 4).

Collapsing distances via instantaneous signal transmission has been a major discussion in geography. Starting with Harvey's time–space compression (1989), scholars have examined implications of technology on time, space, and distance and the coincident impacts on relations of capital, difference, and the discipline of geography itself (May and Thrift, 2001). More recently, geographers' productive engagement with, and theoretical development of, the volumetric, has meant engaging

with the material excess of vertical politics and sociality (Elden, 2013; Adey, 2015; Steinberg and Peters, 2015; Gordillo, 2018; Squire and Dodds, 2020); (Sammler, 2020). Attention to volume and verticality contributes to analyses that compound metrics of distance when considering mines that are both increasingly deep and technologies that displace miners to remote operations centers. Yet, to engage volumetrics beyond just extending an empty Euclidean geometric space means contending with layers of soil, rock, water, animal, mineral, atmosphere, steel, glass, and waste that produce (and are productive of) these spaces (Billé, 2020; Nurmi, 2020). Thus, mediation is necessary to know and manipulate these vertical geographies, often inaccessible to the sensing apparatuses of human bodies (McCormack, 2018). Further, following the subterranean turn, geographers have demonstrated the political capacity of holes, caves, and mine shafts and their assemblages of relations (Bosworth, 2020; Pérez, 2021; Pérez and Melo Zurita, 2020; Chien and Chang, 2021). Similarly, in their research on geographies of the subterranean, Melo Zurita et al. (2017, p. 298) demonstrate how "[h]uman identity and practice is entangled with rock stratum, both now and in the future," recognizing "the underground as an epistemological space for economic, social, and political calculation.".

Further research is needed on how digital extraction processes mediate and enroll earth's materiality in new ways, presenting openings for perspectives that are deeply material and non-human. Here scholarship in media studies, that engages with new materialism, offers fertile terrain to explore proliferations of technologies in extraction landscapes and deep entanglement of media, society and the environment (Cubitt, 2016; Rust et al., 2015). As Gamble et al. describe, previous conceptualizations of materialism conceive matter as "essentially passive, non-performatively constituted, and discretely self-contained" (2019, p. 113), presuming the human as an external, objective observer. New materialist approaches, in contrast, embrace the generative capabilities of matter (Coole and Frost, 2010) and, as Sanzo argues, "extend the capacities of agential and vital qualities to the nonhuman and the material" (2018, n.p.). Additionally, contributions from this scholarship help us to move beyond what is often a metaphorical use of terms in new materialism to consider the agency of objects and messy entanglements of medianatures (Parikka, 2012), in particular earth's ability to act as media, to originate and communicate signals.

Refocusing attention to earth's materialities and ways they are captured and transduced into digital data, our conceptualization of the digital mine attends to new engagements at techno-material interfaces of earthly extractive relations. While geographers have made important contributions to engaging agentic capacities of objects and the imbrications of politics and geologic matter (Huber and McCarthy, 2017; Yusoff, 2018; Bobbette and Donovan, 2019; Klinke, 2021), geographic scholarship has focused less explicit attention to the role of communication in these assemblages of more-than-human relations. The technologies used to capture, store, and process data about the earth correspond to and are mapped onto our mental models and imaginaries of the earth itself. For example, Bobbette and Donovan explain how in early geological sciences,

> notions of the cabinet, box, crate, and other systems of ordering, archiving and transporting geological samples mirrored the very understanding of the earth as itself a filing system. The transformation of concepts of aesthetic serialization in the eighteenth and nineteenth centuries in the scientific and engineering disciplines informed the idea that the subsurface of the earth is also a serialized object, stacked in stratified layers (2019, p. 10).

Such anachronistic ideas that presented earth's materiality as serialized layers, representing linear, stratigraphic time, accessible via processes of digging down through successive strata, have been replaced along with the technology of the file cabinet from which the analogy draws. With the introduction of computing in the 20th century, and the exponential growth of data processing power, algorithmic manipulation, and emerging AI capabilities in the current century, lithospheric imaginaries have similarly experienced a process of respatialization. Today, the proliferation of sensors and digital technologies in extractive industries allow layers of earth to inform on and transmit information about the depths below in new ways, be accessed out of order, and hence digitally remixed. In this configuration, layers of earth and ocean are at once both material archives storing rich data, and multimedia communication systems entangled in complex relations of knowledge production (Lehman, 2018; Mendelsohn, 2019; Neimanis, 2020).

Drawing from media studies, we interpret mediation as comprising "[t]he interposition of stages or processes between stimulus and result, or intention and realisation" (Chakravorty, 2021, n.p.). This includes engagement with physical properties of earth and its atmosphere that interact with data storage and transmission, such as friction, electrical resistivity, conductivity, absorption, scattering, reflection, and transmittance. Thus, we recognize there is no purely passive medium or process of mediation (Kember and Zylinska, 2012). We draw on Williams' contention that "… [mediation] is not the neutral process of the interaction of separate forms, but an active process in which the form of the mediation alters the things mediated, or by its nature indicates their nature" (1985, p. 204). Therefore, we must confront that a medium by the very terms of its existence remediates; it absorbs and reconfigures the form and content of other media. Litho-, hydro-, and atmo-spheres play various roles as conductive and resistant media - some act as signal, others as noise - at various space-times in data collection and in knowing mine sites and their diverse materials and entanglements. As geographers, we find it generative to incorporate media studies scholarship, as it provides a language for conceptualizing digital mediation as an active and agentic process of transmission predicated on geo- and eco-materiality.

In summary, we find mediation helpful for addressing rapid shifts from an analog to digital imaginary of the mine. Focusing on mediation draws together ongoing conversations in digital geography and media studies to theoretically interrogate key processes that we argue have received little attention to date in scholarship on mining and extraction. Digital mediation offers opportunities to expand communication media beyond human systems to non-human materials, landscapes, and objects that are activated through technologies of information capture, selection, transmission, visualization, and machine learning. Such a perspective offers new possibilities for unpacking processes of transforming a living landscape into various commodities that occlude earthly media from their broader eco-socio-cultural milieu. Explicit engagement with the submerged and subterranean enables us to consider unique challenges at the intersection of mediation and materiality to un-blackbox digital relations of the mine by connecting technical imaginaries and infrastructures. The next section introduces the two case studies and our methods of data collection and analysis to reveal the inner workings of blackboxed relations of mediation in the digital mine.

3. Automation in two iron mines

As case studies for this research, we chose two iron mining sites located in Oceania, both known as testing grounds and sites of experimentation for new mining technologies. The heavily mined Pilbara region of Western Australia has been called the world's autonomous technology testing ground. While the Taranaki region of Aotearoa New Zealand is one of the first seabed mining permits to be issued in national waters. The two sites also represent distinct milieus that allow us to explore processes and consequences of digitization on- and off-shore. The onshore Pilbara site, the world's largest supplier of exported iron ore, illustrates a case where experiments in new technologies of automation, robotics and advances in machine learning and AI are building upon more conventional forms of mining. The proposed offshore Taranaki mine is experimenting with both mine engineering and oceanic legal regimes by extracting iron from submerged land. Such practices are still in a proof-of-concept stage as to their viability, technologically and

economically. The fate of the Trans-Tasman Resources (TTR) mine will impact development of seabed mining across Oceania and beyond. Comparing the media milieu for the two locations offers unique insights into digital advancements in extraction technologies and their interactions with the materiality of onshore and offshore environments.

Increasing technological dependency engenders a diverse and evolving array of mediated interactions. While acknowledging that multi-stage processes of mediation is an inseparable continuum, we look to unpack "blackbox" relations that fetishize the digital mine. This aligns with Parrika's call, "to open up the machine physically and methodologically to its physics" (2012, p 0.97). To access blackbox relations of the digital mine, we collected data from TTR and Rio Tinto, two mining companies active at case study sites. We also draw on data from other mining companies and subsidiaries developing and employing these technologies, such as Caterpillar and Underwater Mining Robotics, who design and build machines, robots, and software to operate a digital 'smart mine.' Data is sourced from company reports, annual stockholder reports, promotional videos, engineer specs, industry publications, and media articles. We recognize these data provide only a partial representation of the processes involved and are largely shaped by the visions of mining CEOs and public relations personnel, often targeted for pleasing stockholders and improving public relations. However, in this research we find that these data sources are useful for revealing speculative futures of digital mining as they divulge practical details of current and future planned operations.

Through iterative stages of qualitative content analysis, informed by critical theory and textual analysis (Allen, 2017), we examine descriptions and representations presented by two mining companies and their subsidiaries to identify specific discourses that function through reductive and abstractive characterizations to transmute complex socio-ecological landscapes into objects for technological and engineering control. Descriptions of company goals in automating the industry reveal the intention to respatialize mining operations through displacement of human miners and intensification of technological experimentation and deployment. Beyond the analysis of corporate discourses, we expanded our data collection to: 1) examine the broader socio-legal relations to understand the legal statutes that permit mining operations in these landscapes in the first place, 2) explore the technical specifications and specific data collection apparatuses that facilitate the capture of sensory information from the seafloor and the Pilbara, as well as reports outlining the obstacles posed by such probing of these milieus, and 3) visually analyze video representations of the simulated 3D digital minescape, the high-resolution and immersive, yet inert and flattened, version of these lively places. In the next section, we detail the findings of our research and integrate empirical examples drawn from the comparative case studies to illustrate and enliven the theoretical insights, demonstrating the importance of understanding shifting sociotechnical entanglements in relation to the materiality and dynamism of specific places.

4. Abstraction and decontextualization

Emerging digital mines, in combining capitalist and exploitative logics of extraction and abstraction, transform geologic milieu through various processes that comprise digital mediation. Before the mine, there is a complex socio-environmental milieu, a living ecosystem from which the extraction site and targets emerge. Metal and mineral are transformed into target and then into signal, landscapes collapse into digital information parsed between signal and noise, ore and gangue, disembodied coordinates, and data bytes. Williams (1977) reveals how mediation comprises another dimension of social relations and relations of production that alienate both consumer and producer from the conditions of production. The development, deployment, and reliance on technologies for digitizing mining serves to increasingly alienate the miner from the extraction landscape. This is exacerbated by the imaginary of achieving a fully automated and remotely-controlled mine, a

goal long discussed by mining giants like Rio Tinto, where miners' information about the target site would be digitally simulated.

These subterranean and subaqueous spaces have long been known by the ancestral peoples of Taranaki and Pilbara without the assistance of western technologies. Māori geography is understood as a "relationship with the coast in ways that are holistic, intertwined and unbounded… captured in memories, ingrained in hearts and passed on in practice, stories, and song" (Greensill 2005, pp. 158-9). Māori have long known and used the foreshore and seafloor in Aotearoa for fishing, seaweed collection, battles, and burials (Hickford, n.d.). In Western Australia, Aboriginal people have co-existed with groundwater and other subterranean resources since their arrival between 40,000–65,000 years ago. Locations of groundwater, flint, and other metals and minerals figure prominently in ceremonies, oral stories, songlines, and rock wall art, communicating and passing along knowledge of resource availability and management techniques (Indigenous Knowledge Institute, n.d.).

In the subsections that follow, we trace how processes of mediation serve to blackbox relations of digital mining, revealing how earth strata come to be decontextualized from their broader earthly relations, transformed from lively subject to targeted object. We demonstrate how theoretical attention to these processes illuminates the complexity of entangled milieus hidden behind smooth corporate veneer of robotically-enabled mining practices. We begin by examining forms of mediation that render earth abstract, first as property, and subsequently as mine, the first stage in formulating earth-as-mine. Second, we explore the varied capability of landscapes to emit and transmit signals of interest for extractive industries, demonstrating how the materiality of earth itself serves an ambiguous role in facilitating or impeding the capture and transmission of information. Third, we examine how the multitudinous information streaming from earthly materials is parsed through an ontologically unstable process of differentiating desired signal from unwanted 'noise', further reducing the landscape's richness via abstraction and decontextualization. Finally, the spatial arrangements introduced by remote operations centers (ROCs) and digital twins are considered in relation to transmission and displacement. The emergence of digital twinning technologies renders the earth-as-mine feedback loop complete, as technologies of automation transform the *god's-eye-view* into the *hand-of-god*.

4.1. Rendering earth into property and mine

Even before the transformation to mine site, in Oceania, land and sea have long been alienated and abstracted from their milieu via colonial practices of territorial capture, primitive accumulation, and expropriation from Aboriginal and Indigenous peoples, and de-animation of living places. It is the breakdown of these entanglements of existence that fundamentally allows the violent extraction of resources and uneven concentrations of wealth, leaving behind toxic bodies and landscapes (Povinelli, 2021). This reorientation to "begin with the catastrophe of colonialism and racism as the location of contemporary climatic, environmental and social collapse" (Povinelli, 2021, p.3) draws attention to ancestral catastrophes, "which ground damage in the colonial sphere rather than the biosphere" (ibid, p.3). Before the mine is "the mine" it is a part of earth, a landscape, an ecosystem, a place. Yusoff draws attention to political and material relations of displacement associated with abstraction, evoking the concept of transmutation to further describe semiotic transformations of place into property and lively matter into extractable material.

> [T]he categorization of matter is a spatial execution, of place, land, and person cut from relation through geographic displacement…It is not just that geology is a signifier for extraction but that a transmutation of matter occurs within that signification that renders matter as property, that makes a delineation between agency and inertness (2018, p. 2–4).

Following Yusoff, we contend the first moment of abstraction, within

the mine's mediation, is the conversion of a relationally-embedded landscape into alienable property. We extrapolate from Elden's (2021) argument that territory is a political technology, to pose that private property, as part of a territorializing regime, spatially produces abstraction and mediation, stripping place-based meaning (Tuan, 1977).

Offshore prospecting in Taranaki exemplifies the processes of abstraction as the complex seabed milieu is alienated and transmuted into property for extraction. Black sands adorn the west coasts of Aotearoa New Zealand's north island, the color belying its metalliferous composition. Iron has been mined onshore since the 1850s, but in 2013 Trans-Tasman Resources Ltd (TTR) submitted a plan for offshore extraction. This was permitted because the seabed and foreshore were claimed as Crown property after the ratification of the United Nations Convention on the Law of the Sea (UNCLOS) and the passage of several domestic legislative acts. This transmutation from customary tribal relation to private property for extraction continues to be vigorously contested by coastal Māori Tribes that maintain tenure from mountains to sea (Author). While the original mining permit was denied by the Environmental Protection Authority in 2014, they later granted the license in 2017. A protracted legal battle continues, and it is unclear whether the extraction project will move forward. The TTR mine gives insights into one type of oceanic media-minescape under the broader guise of seabed mining.

Similarly, land acquisition for mining giant Rio Tinto's iron ore operations in the heavily-mined Pilbara region of Western Australia has followed processes of dispossession, expropriation, and denial of ancestral landholder's self-determination. Rio Tinto's presence in the Pilbara dates to the 1960s when the area was targeted for mining due to the presence of highly concentrated iron ore deposits. Western Australia's banded iron formations (BIFs), finely layered sedimentary rock formations composed of alternating layers of chert and iron oxide, represent a highly coveted geology, where most of the major iron deposits occur worldwide. In 1966, Rio Tinto opened its first Pilbara iron mine at the site that is commonly known as Mount Tom Price. Over the last half century, Rio Tinto's presence in the Pilbara has rapidly expanded to 13,600 employees and current production of 333 million tons of iron ore per year.

The Pilbara is the ancestral homeland and traditional land base of many Aboriginal communities, including the Eastern Guruma, Ngarluma, Kuruma Marthundunera, Puutu Kunti Kurrama and Pinikura (PKKP), Nylyaparli and Ngarlawangga, Yinhawangka and Yindjibarndi, and Wadjuk and Banjuma. Here echoes of Povinelli's ancestral catastrophe and Yusoff's concern with transmutation are evident, as Rio Tinto's increasing control over land and resources in the Pilbara operates through processes of privatization of lands previously held in collective ownership by ancestral custodians (O'Faircheallaigh, 2012). A dramatic recent example is when in May 2020 Rio Tinto's mine blasts destroyed the 46,000-year-old Juukan Gorge rock shelter heritage site, recognized as one of the most significant archaeological sites in Australia and key sacred cultural site for the PKKP Aboriginal community. These blasts were conducted against the stated wishes of the traditional owners, who were denied a formal seat at the decision-making table, and contradicted Rio Tinto's own commissioned archaeological report which detailed the cultural and archaeological significance of the site (Wahlquist and Allam, 2021).

Another moment of abstraction, one that allows this land theft and erasure, is how earth's extractable matter comes to be activated as target for mining and actualized as profitable ore. Following Povinelli (2016,2021) and Yusoff (2018), this *desire* for differentiation is ontologically unstable and always-already political, where the parsing of mine from not-mine aligns with life/nonlife and lively/inert binaries. Thus, before this violent physical extraction of minerals and metals can even begin, a spatial execution is necessary to identify, define, and control the target area on either earth's surface or seafloor, containing the valuable material for extraction, which will become the mining site. Drawing upon Haraway's (1988) god trick of seeing everything from nowhere, D'Ignazio and Klein warn how the *view-from-nowhere* serves to "mask the people, the methods, the questions, and the messiness that lies behind clean lines and geometric shapes," (2020, p.76) while producing a deceptive sense of objectivity and neutrality, that is in fact always a partial perspective.

4.2. Activating earth for data capture

The selection of what to consider as a viable signal for sensing, collection, and analysis is a function of both operational necessity and technical capability. Necessity depends on the spatiality (ie. location, depth, concentration, territoriality) of targeted ore within its material surroundings. Whereas capability varies across the landscape's propensity to emit and transmit signals of interest, and the limited capacity of existing technology to collect and make sense of the landscape's complexity. Processes of abstraction require the paring down, generalization, and truncation of earth's almost infinite emanations. One key element in identifying targets for extraction from their larger milieu is spatial sampling. Spatial sampling is the process of selecting points or areas of information meant to represent a larger whole, necessary when a full census cannot be undertaken, or to reproduce a continuous field through selection and interpolation. Temporal sampling may stand for a snapshot in time or a series of them, like frames of an animation. Broadly, our planetary sampling is highly biased, but in particular, knowing the subaqueous and the subterranean is predicated on their extraction potential, as a result becoming most known in areas targeted for extraction. Sampling techniques are also vulnerable to error, including spatial aliasing "the appearance of distortion artifacts when representing a high-resolution image at a lower resolution, or displaying curved or irregular shapes on a raster screen" (Gaboury, 2021, p. 224). With the digitization and automation of mining, what is valuable for extraction is no longer only the material ore, but has become the mining of data itself, as machine learning and AI processes require streams of big data for algorithmic training, pattern recognition, modeling, and prediction. Further, as Hawkins (2018) warns, how we come to know and sense subterranean volumes ultimately shapes how we come to know how to control them.

In exploration of the seabed and its mineral richness, air, water, and rock are tasked with signal propagation. While each serves as a medium, they also shroud the target from most remote sensing techniques, as well as obscure easy direct measurement. Only a tiny percentage of visible light penetrates deeper than 10 m below the sea's surface, impeding many optical techniques. The extensive scale, crushing pressure, corroding composition, and freezing temperatures frustrate in situ methods. Ocean depths, and in particular the seafloor, are solely encountered via mediation (Helmreich, 2010; Lehman, 2018). Jue argues, "to be articulated as a medium is not about a stable ontological identity (this is a medium, that is not) but about being enfolded into an assemblage such that something performs the function of a medium" (2020, p. 24–25). So, for the seabed miner, the water column above the targeted seafloor is not rendered as a medium, but represents an opaque barrier obscuring information required to know the land beneath. In fact, a subsea mining equipment manufacturer considers how, "offshore resources are plentiful with high ore grades. In many cases these resources are unburied" (Soil Machine Dynamics, n.d.). They disregard the water column completely, because for their purposes its impedance is lower than earth's crust. It is submerged, but not subterranean. However, impedance depends on what is transiting the water, whether it is a machine, signal, vibration, sound, light, or body. For example, the ocean is a medium that transmits sound superlatively, its characteristics get reemployed as a bathymetric probe, bouncing sound off sunken topography, collecting enough data points to fashion the surface in abstraction. Therefore, the water column is articulated as a medium for seabed mapping assemblages, but is ignored as such for material extraction.

The materiality of earth itself serves an ambiguous role in facilitating or impeding the capture and transmission of information. Mining

sensors and networked technologies require myriad metals and minerals, themselves mined from the earth, to retrieve ever more materials. The entanglement of rock and wire produces a techno-geographical landscape characterized by the inseparability of technical and non-technical components (Gabrys, 2016). The mine milieu is activated as infrastructure and implicated in its own extraction. For example, Nurmi (2020) recounts the relationship between target ores and their apparatuses of extraction during the American Gold Rush, "minerals were more than energy stores or sources of capital. They were integral to the structural integrity of the mining technologies themselves (like rock drills, for example), which in turn laid the foundation for transportation infrastructure" (p. 163). Billé (2020) in conversation with Chambliss (2020) explains how "magnetometers and other metal detectors, electromagnetic induction, electrical resistivity, gravity measurement technology, and seismic and acoustic sensors…[each] *recruits the Earth itself as informant*" (p. 9, emphasis added). This reflexive recruitment is mirrored in the transmutation of iron ore into steel, which serves to construct the very equipment and infrastructure - trucks, shovels, bulldozers, trains, etc. - used to extract and transport the iron ore itself.

In seabed mining, considerable expense is associated with collecting high-resolution data from the ocean floor. Approximating ore location at a large-scale employs magnetic survey to identify zones for higher resolution exploration. Aeromagnetic surveys use magnetometers attached to the wings and aft of an airplane, surveilling broad offshore swaths, searching for magnetic anomalies in earth's crust. Such regional reconnaissance requires knowledge of the background magnetic field emanating from the planet's core, fluctuations from solar weather, and any perturbations from the magnetic field of the aircraft itself. Such tactics were previously developed to detect submarines in World War II, and in fact many manufacturers of heavy machinery used in mining are also military contractors (i.e. Caterpillar). TTR has invested heavily in studying the New Zealand seafloor, its iron ore concentrations, and their markets. But beyond prospecting, which determines the mine's viability, characterization of the surrounding environment is also necessary. This includes identifying benthic habitats and organisms, modeling sediment and its mobility, and determining the spatio-temporal impacts on benthic and pelagic ecosystems. TTR reports having spent more than $65 million "defining the resource potential, environmental assessment of the proposed mining areas and possible impacts of the mining, mine engineering and process design, ore marketing and the processing and shipping operations associated with the resource extraction and iron sands export operations" (Trans-Tasman Resources, 2019, n.p.). They assert this area is "New Zealand's most studied offshore environment." Therefore, the most well understood seafloor is always-already mine, where the partial knowledge propagates an earth-as-mine feedback loop.

To map seafloor topography, a shockwave is emitted, reflecting back to multiple seismometers, creating a "vertical sonic cross-section of the subsurface beneath the survey line" (Lundin Group, 2019, n.p.). Höhler explains that an abstract concept like ocean depth reaches optical consistency when "enormous quantities of sounded data [are] woven into a rich graphic texture…[highlighting] the theoretical and practical unity and integrity of an abstract concept like ocean depth but also its stability in transport and translation" (2003, pp. 5–6). Once ore concentration regions are determined, spatial sampling at finer resolutions collects more precise information about content. For example in Taranaki, TTR collected "over 700 shallow drill samples … 17 deep drill holes [and] processing and assaying of over 3,700 samples" (Trans-Tasman Resources, n.d.). With the goal of approximating a continuous field of sedimentary iron knowledge, TTR uses two different submersible rig drilling systems to obtain sediment samples to determine iron grade, grain size, chemistry, and resource depth. Together these soundings and samples, collected at different scales, utilize ocean and sediment as media to create layers of data compiling a partial archive of the selected area.

Onshore in the iron-rich Pilbara, the mining of data drives the mining

of ore. Rio Tinto's Mine of the Future™ program aims to "precisely identify the size, location and quality of ore in real time by retrieving data from automated trucks and drills operating in its mines" (International Mining, 2014, n.p.). Sensors and electronic geo-tags capture increasingly vast volumes of data - more than 30 million geo positions each day (Winterford and Caruana, 2014) equivalent to 2.4 terabytes of data every minute, which are coded and decoded, often via algorithmically enabled AI processes. A Rio Tinto promotional video proudly states, "Satellites stream oceans of data, telling us everything from the position of a truck to where our next discovery might be…We then use AI to make the best use of our systems" (Rio Tinto, n.d.). Massive real-time data sets feed an integrated mining processing and logistics system and enable construction of digital twins that can be utilized in remote decision making, allowing operators located 1,500 km away in ROCs in Perth to communicate and control real-time operations at physical mine sites (Barbaschow, 2018). Yet, these technological advancements rely on coding "messages into signals, which are subjected to medium-specific modes of noise, then decoded by receiving devices for delivery to destinations" (Mitchell and Hansen, 2010, p. 134). Given the lack of transparency in algorithmically-enabled processes of data analysis, attention to data codification provides another point of entry into attempting to unblackbox these digitally-mediated relations (Paßmann and Boersma, 2017).

4.3. Parsing signal from noise and mine from earth

Mining technologies not only capture electromagnetic (EM) waves and sound vibrations, but have advanced to also include a wider range of sensorial complexity, including textures, tastes and smells. While recognizing that earth emanates without desire for interpretation or representation, emanations can however represent a mode of communication, insofar as they transmit information sent through and received by earthly media. Yet earth's emanations are not inherently signals as although they communicate information, they precede semiotic meaning-making. The difference being a directed signal infers an intentional sender, while a non-directed emanation transmits information that may intentionally or unintentionally be captured through active or passive sensing systems. We are interested in how earth's multiplicitous emanations are made perceptible, captured, attenuated, and then processed for meaning-making through human-devised sensing apparatuses and algorithmic logics that serve to differentiate emanations into rich sources of information that feed the earth-as-mine into digital renderings and simulation models, such as the digital twin. One objective of this research is to better understand how environmental objects come to be known in relation to sensors and technology (Gabrys, 2019) through which the identified target becomes recognizable and abstracted, through the capture and transduction of earth's emanations into data.

The process of meaning-making in the sensing of the world begins with emanations, before their truncation and formation into the shape of a sensor, parsing signal into data, and processing data into information. Emanations, once extracted out of their original context of earthly materials, become signals, digitally coded with specific metadata assigning signifiers. As the amount of digital data collected proliferates, the need to differentiate signal from noise is a paramount concern. In information processing, signal-to-noise ratio (SNR) represents the proportion of desired to undesired input, as "what we consider to be information must be carved out from noise, which is expected to add nothing but spurious 'uncertainty'" (Malaspina, 2018, p. 110). In mining extraction, the differentiation of signal and noise is inherently a political and subjective process that is always-in-the-making, determined by powerful interests, global metal demands, and profit motivation. In other words, SNR is ontologically unstable, "a subjective relation, rather than an analytical fact. It is our desire to listen, to receive and transmit that sculpts signal and meaning out of the noise" (Heinonen, 2017, p. 10). As with spatial sampling, which attenuates earthly emanations geographically, spectral

differentiation between emanations considered useful for extraction, and those that are not, further forecloses the infinite potential of earthly relations.

Models of signal and noise processing in environmental geophysics, widely used to get information about earthly structures, distinguish between coherent and incoherent (random) noise. Noise encompasses disturbances and fluctuations, thus interfering with or obscuring the targeted signal. Information theorist Heinonen explains the malleability of the concept of noise itself, "the noise in the system is defined as a relation to the signal, and vice versa…a subjective relation, rather than an analytical fact" (2017, p. 5). Further examining the epistemological implications of identifying, typologizing, and parsing signal from noise, Malaspina (2018) writes "everything that is not selected, is in principle considered as noise, the earth's atmosphere, no less than the thermal radiation of all things and people around us, the noise of our activity, of our observation interfering with what is being observed" (p. 110). Expanding upon Malaspina, the digitization and automation of mining illustrates how logics that underpin the selection process and differentiation of signal from noise separate the narrow conceptualization of which emanations are valuable for the digital mine, from earth's expansive emanations. Thus, this transformation serves to cement particular desires, imaginaries, and meanings at the expense of broader relations embedded in the socio-environmental milieu.

The plume disrupts and obscures underwater visibility. Plumes can arise naturally, but are also produced as a byproduct of extraction machinery operating on the seafloor, as the process of capturing iron sands is never fully complete, releasing particles into the surrounding water. A plume is the culmination of fine sediment particles suspended in the water column, creating two fluids of different momentums, densities, and viscosities. It is part of the gangue, or commercially valueless materials within which ore is found. Even with bright lights attached to crawlers and shipboard operators viewing real-time imagery, they mostly drive in blackout conditions. Sediment plumes quickly create a blizzard of suspended particles obscuring the largely featureless plane. These iron sands, while the target of extraction, upon entering this disordered state adrift in the water column, become noise, physically blocking optical signals, like snow or TV static. The process of differentiating SNR determines which information reports mine, while categorizing anything else as undesirable, excess. Beyond the plume, sound waves emitted by the mining equipment pose their own issue for signal reception. Within the mining area, but not considered part of the mine, marine mammals' communication and navigation can be interrupted by both the decibel levels and frequencies produced during extraction.

On land, growing demand to mine deeper underground introduces new challenges for capturing data in areas inaccessible to humans due to reduced ground stability and heightened dangers of mine collapse. In particular, voids, stopes, and other subterranean cavities have long presented difficulty for mapping and measurement. Stopes - the dugouts that contain the ore being mined - are both necessary and dangerous spaces as they provide direct access to the orebody, but are at risk of deformation and collapse. The multi-dimensionality of subterranean voids and the unique challenges posed by measuring negative space have long plagued traditional mapping methods, such as handheld mobile scanning platforms. As Chambliss describes "a void betrays itself: an absence confessing its presence in space–time to anyone who can measure it accurately enough" (2020, p. 68). Traditional methods of stope detection and mapping reliant upon surveyors manually inserting poles fitted with sensors into voids have historically been unable to produce complete scans. Without the ability to scan from multiple perspectives, these tools have failed to capture the full spatiality of signals and to meet the goal of obtaining "an accurate picture of what is happening in those voids" (Australian Mining, 2021, n.p.).

In the digital mine, new technologies, such as Emesent's Hovermap™, seek to increase the ability to "see" underground to more precisely determine messy boundaries between ore and gangue and improve remote monitoring of mining environments. Hovermap, an omni-directional LiDAR-enabled system is advertised as capable of ultra-deep mapping underground through its ability to fly autonomously beyond-the-line-of-sight in GPS-denied environments using sensors that capture precise position, orientation, and velocity information. Yet, the workflow from LiDAR data capture to final interpretation introduces signal–noise differentiation issues. Increased precision of Hovermap's sensors return high-resolution, big data point clouds that require complex post-processing algorithms to attenuate noise through point thinning to create maps with smooth contours and reasonable slope estimates (Jones et al. 2020). Seeing the void through the noise produces another moment of simplification, abstraction and decontextualization as feature reduction methods are employed to more efficiently derive ore from the noise of the broader geologic context. The focus on SNR processes in this section exemplifies a key part of the earth-as-mine feedback loop, where emanations that are not beneficial to the extraction industry are classified as noise.

4.4. Transmission, displacement, and distance

Media studies draws geographers' attention to the need to critically examine how media impact the transmission and exchange of information and signals (Mitchell and Hansen, 2010; Thomsen, 2012). Transmission describes processes of sending and receiving information, which relies on signal conveyance through a medium. In media studies, transmission has been defined as a "process in which meanings, packaged in symbolic messages, like bananas in crates, are transported from sender to receiver" (Craig, 2001, p. 125). However this model of transmission is overly simplistic, as Parikka argues it is necessary to attend to the materiality of the transmission process as it produces messy networks, "otherwise we are going to miss a lot of the material ephemerality of technical media cultures as well as the long, messy networks in which one materiality is transformed into another one" (2012, p. 98). The materiality of earth's media further complicates transmission processes, as each medium is characterized by its own unique transmission openings (ie. windows) and closures, creating a textured media space of topographical ambiguities.

Focusing on the messy materiality of media directs attention to the inherent loss of signal strength as transmission distance increases due to the attenuation of EM energy as it travels through the transmission line. This reduces the SNR and impacts the fidelity of data used to digitally replicate the mine environment. While any model is a drastic simplification of the world, limitations on the data once it has left the mine site are further constricted by compression and loss, leading to greater decontextualization. Broader 'situational awareness' of the mine site is lost in transmission. The trend of displacing humans from the mine site in favor of robotic systems and sensors further diminishes and constrains the contextual information captured, as humans' multisensory and haptic capabilities for perceiving and processing information are replaced by manufactured sensor systems designed with narrow specifications. This lossy and cherry-picked data that streams from the mines to the distant miners, digitally constructs the earth-as-mine model.

Associated with contemporary trends in automation, digitization, and remote control, the design and utilization of digital twins for decision-making is gaining in popularity. Digital twins are virtual representations of a physical world that can be stored on cloud data platforms and utilized through user interfaces for remote visualization, planning, and manipulation. The digital twin creates a fully abstracted and idealized simulation of the extraction site with limited capability to incorporate real-world social-ecological complexity. Hu et al. draw attention to the "lack of consideration of environmental coupling" in digital twins "which results in the inaccurate representation of the virtual components in existing models" (2021, p. 1). Further, the design of digital twin replicas utilizes the principle of parsimony to balance competing interests of complexity, scope, feasibility, and cost. VanDer-Horn and Mahadevan (2021) argue that while "digital twins may theoretically be used to represent the chosen system to an atomistic level

of resolution, the intended application and desired outcomes determine the rationale by which to select the appropriate scope and abstraction level of the digital twin" (p 0.7). Thus, while increasingly detailed and robust, the digital reconstructions utilized by surface support ships and ROCs are inherently incomplete and highly decontextualized. Designed to enhance extraction efficiency, these digital replicas archive a landscape of extraction-for-extraction, obscuring the ecological, social, and cultural context within which the real-world mine site is materially entangled. Or, in Gaboury's words, "this quest operates under the tacit assumption that total simulation is possible and a belief that we might one day produce a perfect image of the world" (2021, p. 29).

The emergent digital twin suite of technologies can be distinguished from earlier models and simulations by increased computer processing power, incorporation of dynamicity and autonomy, integration of machine learning capabilities, and bidirectional data flow that allows for automated manipulation at a distance (Hazrathosseini and Afrapoli, 2023). Davey (2022, n.p.) explains how digital twinning of a seabed mine differs from other simulation technologies,

> Firstly, digital twins benefit from real-time data from suites of sensors on the physical object, a two-way information flow. Secondly, there is a difference in scale – simulations tend only to analyze a single process, whereas a digital twin provides information on an entire system…Physical assets can also be controlled remotely due to the interconnection between the asset and its twin. Algorithms that govern all the aspects of the operation of an asset can be used to automate processes, replace manual workers, improve safety, and reduce costs.

The digitization of these landscapes achieves the quintessential *view-from-nowhere* and reinforces the idealized *god's-eye-view*. Prodigious emanations are pared down to earth-as-mine data points fed into the sterile digital twin, allowing distant miners the "seeming neutrality and objectivity of data and their visual display" (D'Ignazio and Klein, 2020, p. 76). The *view-from-nowhere* positionality on which western scientific "objectivity" is based has long created an imagined distance between subject and object, colonizer and colonized landscape (Sammler and Lynch, 2021). This can be rendered via digital transformation and pixelization of place, but also via increasing spatial distances introduced through transmission.

Development of the autonomous mine is a centerpiece of Mining 4.0. Such remote mining allows the observer to impose a physical change on the earth from afar. This relationship transforms the encounter with the *god's-eye-view* into a position to perform what we argue is the *hand-of-god*, an extension of purported objectivity that breaches the presumed separation of subject and object through mechanical ability for manipulation from increasingly far away. The *hand-of-god* abstraction recalls Yusoff's argument that "[e]xtractable matter must be both passive (awaiting extraction and possessing properties) and able to be activated through the mastery of white men" (2018, p. 2). The suturing of an epistemological position of neutrality and objectivity with the digitization and automation of extraction landscapes activates a *hand-of-god* relationality of remote master to distant submissive earth.

In Rio Tinto's Perth-based ROC, a nerve center of interconnected control rooms, located hundreds of kilometers from the physical mine site, mine operators use consoles to manipulate autonomous drills, trucks, and blasters in a virtual space made possible by the mine's digital twin. Remote control is enabled through digital transmission of remotely sensed data and technological advances that provide hyper-visibility underground. The ability to produce 3D, and even 4D, images and simulations of ore bodies and mine pit activities, and increasingly advanced transmission and connectivity capabilities serve to construct idealized models of the lithosphere that can be "acted upon" remotely. This sensory feedback loop circulates and transmits digital information from mine to distant ROCs and back, producing material impacts at sites of extraction. For example, Rio Tinto's RTVis™ software is advertised as providing remote ability "to predict, prevent and optimize activities by

applying software to the challenges of the physical world" (Rio Tinto, n. d.). Head of Innovation, John McGagh, describes how these simulations "quickly and easily view, compare and evaluate data to paint a picture of what's under the ground – it's like an ultrasound image of the deposit delivered in real time, something that we could never do before" (Mining Global, 2020, n.p.). Rio Tinto's promotional materials further describe the capabilities of these digital tools,

> We can fly over a site and dive down to the detailed information we need. We can hover over an excavator, follow a haul truck, or examine an orebody. The software brings together geology, geotechnical, drill and blast, production and planning, and visualises surface and subsurface features. (Rio Tinto, n.d..)

These tools provide a basis for integration and remote management of mine operations from one central location, enabling decision-making powered by machine learning and AI components. Yet, the digital twin's replication of the mine's materiality necessarily removes contextual specificity, transmuting a complex socio-environmental milieu into a simplified, pixelated terrain for extraction.

Similarly, in submerged mines, virtual and automated technologies integrated with sensors, cables and pipes connect surface support vessels to robotic mining machines located on the seafloor. These umbilical cord-like structures, which contain electrical cables and optical fibers for power and signal transmission, are connected to the ship along with fluid conduits, like riser pipes, that suck up mineral slurry. While in the deepest mines these umbilical cords can be miles long, TTR plans to operate in comparatively shallow realms where cables first penetrate 30 m of water column and then excavate 10 m into the seabed. Even though the high resolution representations of the mine are intended to improve performance, a general technical report on Underwater Mining Robotics outlines how "removing operators from the vicinity of worksites introduces many technical challenges: low situational awareness in unknown environments, complexity of operated machines, and the need for high bandwidth real-time communication" (Jasiobedzki and Jakola, 2008, p. 1). While sonar, gyros, accelerometers, and position sensors are used to help operators maneuver the giant machinery on the seafloor and provide remote operators with enormous amounts of digital input, their dearth of in situ awareness hinders their efficiency. To be "iterative and predictive," Gerard Barron, Chairman and CEO of The Metals Company explains, "the Digital Twin will give us visibility — that's the first critical step…This is a mission-critical system for us" (quoted in Moore, 2021, n.p.). This system includes incorporating machine learning to improve efficiency and reduce environmental impact, all towards realizing an imaginary of optimized remote operation.

5. Conclusion

As many accessible mine sites are depleted, mining companies are moving extraction into more dangerous and difficult locations. Pledging safer and more efficient operations through development and deployment of digital and autonomous extraction technologies, mining companies are increasingly experimenting with displacing human miners offsite into ROCs. In these remote environments, some mining operators may never interact with physical mine sites except through fully digitized replicas, such as a digital twin. This re-spatialization of relations between miner and mine site is producing emergent relationships between human and more-than-human landscapes, materials, and machines, that have need further exploration in digital geographies and media studies scholarship. Beyond corporate discourses espousing increased efficiency, safety, and new capacities to know and more precisely target ore with digital technologies, in practicality mining operations in both subterranean and subaqueous spaces remain coarse, imprecise, and dangerous.

This paper makes two primary contributions to scholarship on extraction in geography and media studies. First, this research contributes to nascent theorizations of the digital mine, as it undergoes new

forms of mediation. The impetus toward automation and digitization serves to reinforce and reify relations of abstraction and decontextualization, further diminishing and obscuring embodied and experiential knowledges of the site. With mining companies, both on land and offshore, promoting future imaginaries of the fully automated mine, the digital twin becomes the dominant representation of the target site. Our analysis highlights how displacement interacts with digital mediation to collapse the lively relations of the material environment into earth-as-mine.

Second, this paper contributes to understanding how relations of digital mediation and increased distances of transmission in the digital mine produce a self-reinforcing feedback loop, where data are intentionally selected and tailored to report on and for mining interests and extraction endeavors. This phenomenon of reflexivity aligns with an extractive imaginary of achieving complete detachment and alienation of commodifiable resources from their embedded relationality within the broader landscape. We argue that the digital *view-from-nowhere,* paired with abilities to remotely manipulate mine sites, completes a data feedback loop that produces the reflexive mine. Not only does the *god's-eye-view* transform into the *hand-of-god* when paired with automation, but as digital recreations of the target environment are abstracted and compressed into a digitally mediated mine site, it becomes an always-already extractive landscape reducing its capacity to be known as anything else than as mine. The emergence of digital twins and their manipulation via haptic and tactile interfaces is one of many new directions for theorizing mining technologies and more-than-human relations in the 21st century.

CRediT authorship contribution statement

Katherine G. Sammler: Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing. **Lily House-Peters:** Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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