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Résumé de l'article

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RED LAKE BRECCIA: ARTS-INTEGRATION TO MAP A FRACTURED RELATIONSHIP WITH GEOSCIENTIFIC KNOWLEDGE PRODUCTION NETWORKS

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Abstract: Through this work I engaged the geological process of brecciation as a metaphor in an arts-integrated critical analysis of an event that changed the trajectory of my career and initiated the transformation of my relationship with geoscientific knowledge and professional practice. I integrated personal stories from my time as an exploration geologist in Red Lake, ON, and reflections on my current role as a post-secondary geoscience educator, to specifically situate myself within this inquiry. I used mixed-media acrylic painting to analyze information and experiences across sometimes dissonant paradigms. Though common in educational research, arts-integrated practices are still extremely rare for research focused on post-secondary technoscientific training. This work provides an opportunity to think differently. It is a first step toward making visible, and challenging, some of the hidden lessons and omissions

in geoscience education that have insulated geoscientists from the effects of their knowledge production.

Keywords: breccia; geoscience; geoscience education; geoethics; geoethics education; arts-integrated research; care

Shattered Ground

Breccia is a rock type that tells a story of transformation. The existing geologic foundation is broken by slow crumbling at the surface under the force of gravity, by crustal scale tectonic stresses, by magmatic explosions, by sudden boiling and expansion of pore fluids, or even by meteorite impact. The shattered foundations are reconsolidated into a new rock through compaction or slow precipitation of minerals in the interstitial spaces. Breccias are unique to their formation conditions, as the character of each breccia depends on the composition and history of the broken rock, the geologic processes that cause the fracture, and the nature of the reconsolidation. In the course of my work as a geologist, I have described and photographed many different breccias (Figure 1), each telling a unique story of rupture.

With this work, I engaged the geological process of brecciation as a metaphor in an arts-integrated analysis of an event that changed the trajectory of my career and initiated the ongoing transformation of my relationship with geoscientific knowledge and professional practice. The foundations of this work were derived from my undergraduate and graduate educational experiences in geoscience,[1] my short-lived work as an exploration geologist at a high-grade gold mine, and my more than a decade as an undergraduate geoscience educator.

Figure 1

Field experiences of breccia

Note. a) Fault breccia, formed during brittle fracturing as two blocks of rock move past each other; Nanoose Bay, BC. b) Pillow breccia, formed when fresh lava rock fractures on contact with sea water; Nanoose Bay, BC. c) Hydrothermal breccia, formed when ground water boils explosively, in proximity to magma; Yellowstone National Park, USA. d) Volcanic breccia, formed from rock fragments ejected during volcanic eruption; Nanaimo area, BC.

Deciding where to begin telling the story of my brecciated relationship with geoscience was complicated. I am so entangled in this story that it was difficult to approach directly. This is a story that changes in the telling, with multiple entry points and exits; one that refuses disciplinary loyalty. It is a story whose truth depends on what section you encounter. At certain scales the plots may converge into a coherent narrative, but cohesion is tenuous at best. Applying a personal chronological approach, I could have begun with my own geological foundations, in the third row of the Cinecenta theatre at the University of Victoria, my first Earth Science class. A story with a disciplinary focus might begin with the artistically rendered geological maps of William Smith, which laid "the groundwork for the making of great fortunes–in oil, in iron, in coal, … in diamonds, tin, platinum, and silver–[fortunes] won by explorers who used such maps" (Winchester, 2001, p. xvi). A story told from the perspective of the rocks would have begun nearly three billion years ago with a pulse of fluids into a disrupted seafloor, precipitating gold into a network of quartz-carbonate veins (Chi et al., 2006). Or this story could have begun in 1842, following in the boot tracks of William Edmond Logan, with the formation of the Geological Survey of Canada (Vodden, 1992).

Since a breccia's defining characteristic is its brokenness, I begin this telling in the hallway of the Red Lake gold mine in mid-March 2003. I was a newly-minted Master of Science in Earth Science and I had just driven my packed station wagon east across the country, from southern British Columbia to Red Lake, Ontario, to start working as a mine-site exploration geologist. Gold mining was not a career I had imagined for myself, but jobs were scarce. After six years of post-secondary education, I was relieved to have employment in my field.

At the time, in early 2003, Saddam Hussein and weapons of mass destruction dominated the news cycle, bleeding seamlessly into coverage of the American search for Osama bin Laden in Afghanistan. I was disgusted by the narratives of The War on Terror but, for me, Iraq, Afghanistan, and even the rubble of the twin towers, were worlds away. It was easy to turn off the news. It was easy to imagine that these worlds of violence were separate from my own. And then, on March 20, 2003, the United States (US) invaded Iraq. On March 24, 2003, I came to work to learn that the CEO of the company where I was newly employed had published an open letter to then Prime Minister Jean Chrétien, criticizing the Canadian decision not to join the war (The Northern Miner, 2003). I can still feel my hot face as I stood in the office hall in confusion and disbelief trying to understand the implications of that letter. That letter illuminated previously invisible cracks in the complex fracture network connecting the dynamite-blasted gold veins in northwestern Ontario with the bomb-blasted craters in Baghdad

and Basra. I felt my own complicity intensely but struggled to understand the complex relationships of gold production networks.[2] My beliefs about the political neutrality of geological knowledge and geoscientific practice, accumulated through six years of post-secondary immersion, ruptured that day with the revelation that gold mining profits are saturated with violent conflict and human suffering.[3]

Of course, not all gold mining CEOs are publicly lobbying for violent conflict. Still, it would be naïve to write this event off as the action of a bad-seed mining executive or a symptom of an isolated toxic corporate culture, given the interdependence and co-dependence of governments and different types of corporations with financial institutions and markets (Bridge, 2004; Dougherty, 2013; Geenen, 2018). All the actors in gold production networks stand to benefit from rising gold prices, along with the many other passive investors holding gold-based, exchange-traded funds (commodity ETFs[4]). In the year following the US invasion of Iraq, gold prices climbed from approximately $340 USD per ounce in March 2003 to $407 USD in March 2004, a difference of around $67 USD per ounce (Macrotrends, n.d.). Given that gold production at the Red Lake mine in 2003 was 532,028 ounces (Lichtblau et al, 2004, p. 104), profits from production alone could have increased by more than $35 million USD that year as a result of conflict-driven rising gold prices. Accumulation rates of speculative capital from trading gold futures or other types of gold-based ETFs during this same period remain much murkier and more difficult to map. And meanwhile, estimates suggest that there were more than 7,000 violent civilian deaths in Iraq in 2003 and 2004 (Iraq Body Count, n.d.).

While employed at the mine, I was not able to do much with my disillusionment. My professional training in geosciences had not equipped me to parse the nuances of moral and ethical dilemmas beyond the post-Bre-X scandal admonishment: “Don’t salt your samples.”[5] I had no tools to understand the ways that geoscientific knowledge moves through corporate hierarchies, financial exchanges, nor to consider how my work might be influenced by century-spanning geopolitical histories.

This inquiry began as a way to think differently about my early professional experience in Red Lake. Nearly twenty years later, that letter continues to open up questions about the political neutrality of geoscientific knowledge, both in relation to the Iraq conflict, and also about other invisible transformations of geoscientific knowledge through the networks of capitalism. Can the work of a geologist be ethical if their employer is lobbying for a violent conflict that will increase profitability? I started with the intent to map pathways between geological knowledge and violent conflicts like the 2003 Invasion of Iraq, but these connections have been difficult to consider without looking more broadly at the ways geoscience transforms land into capital.

In Iraq, new frontiers of *terra nullius* are opened up for mineral exploration in the landscapes laid to waste by the bombs, and, meanwhile, in Red Lake, fortunes are made extracting gold from the unceded lands of the Anishinaapek people. In Anishinaapek territory, reserve lands were specifically established under Treaty 3 to exclude valuable, known mineral deposits (Filice, 2020), and access to these contested lands for mineral exploration continues to be granted according to laws relying on the Doctrine of Discovery (Reid, 2010). Once I began to question the relationship of corporate mining profits with violent conflict, I quickly became entangled with geoscientific contributions to ongoing violent global histories of both colonialism and capitalism, particularly confronted by the critical perspectives of Yusoff (2018) and Butler (2015).[6] What is the responsibility of a geologist (or an educator) for the ways geoscientific knowledge moves through the world?

This work is an effort to make sense of the ways that I am implicated as a geologist in the effects of gold production networks, and also in replicating innocent standpoints in the classrooms where I currently teach geoscience.[7] Throughout this inquiry, visual art has been a method of analysis used to both think differently about, and to work through, my conflicted positions in relation to the subject (Loveless, 2019). *Red Lake* (2021, 24”x36”) is an original mixed media acrylic painting incorporating paper collage and gold leaf (Figure 2). The painting depicts a slice through the Earth into the subsurface, with the distinctive green and gold headframe of Goldcorp’s Red Lake mine sitting above a network of fractures that penetrate deep below the surface.

Figure 2

Red Lake

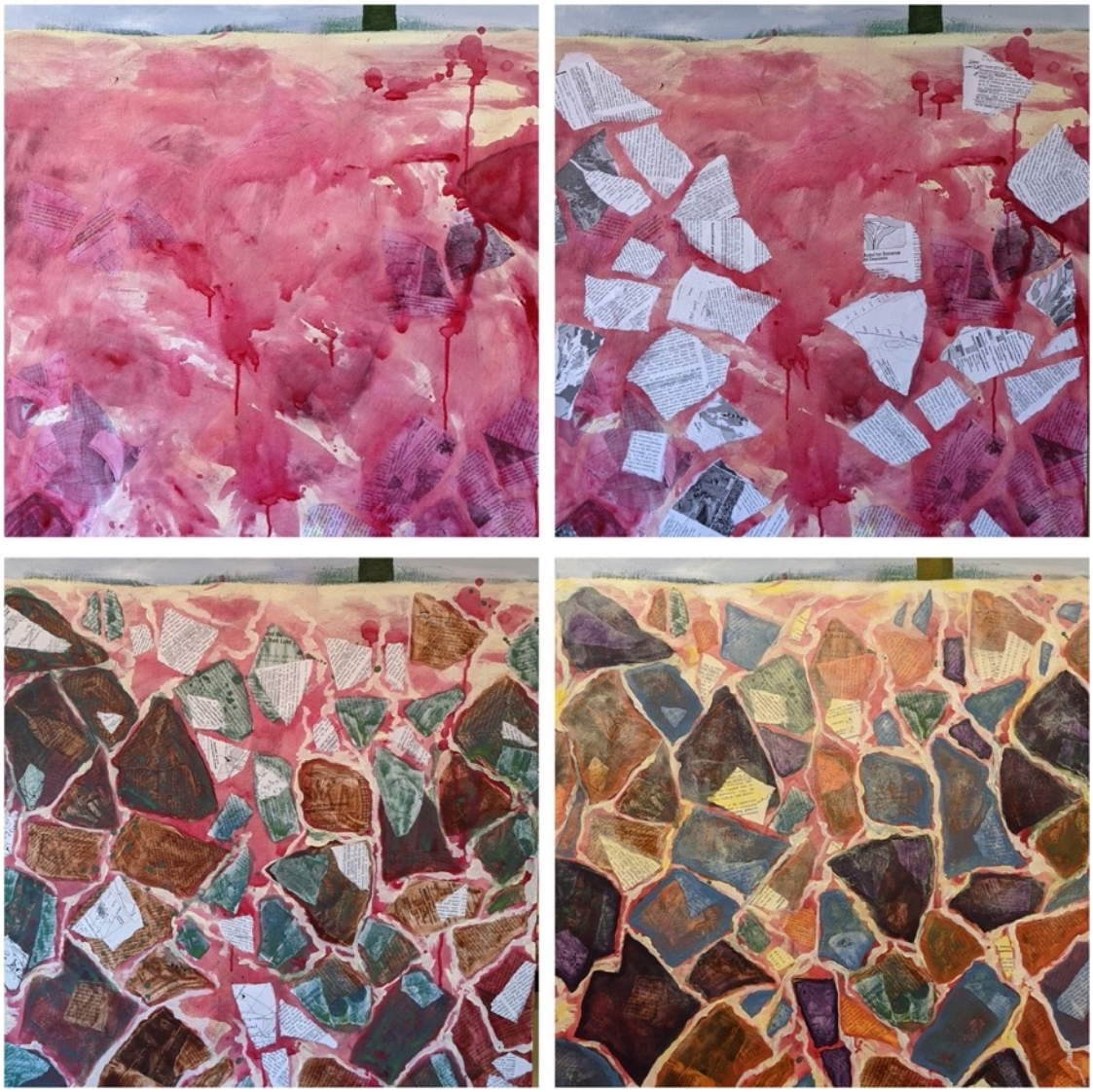
Note. (2021, 24”x36”). Mixed media acrylic painting, collage and gold leaf. Author’s original work.

Both the artwork and the text from this project emerged through an iterative and mutually informed process of writing and painting. But while the painting flowed, writing this accompanying text has been incredibly difficult. The words are sharp, clumping together into unwieldy blocks. My sense has been that the text has replicated its broken and disrupted substrate, stubbornly refusing coherence. A significant part of this work has been considering the ideas and actions that can bring these dissociated fragments together to begin the repair.

I began the creation process by immersing myself in the technical literature on the geology of the Red Lake gold camp. I purposefully selected papers that spoke to my own experiences: those that were authored by acquaintances, listed former colleagues in their acknowledgements, and/or focused on topics related to my expertise as a geologist, especially structural geology, geochronology, or geochemistry. I read the selected papers with a dual purpose. I was looking to see what stories the authors were telling about the origins of the gold in the Red Lake area, and also how they framed the purpose of their work in a broader social context. I underlined, made notes, and otherwise marked up my physical copies of the papers. The brecciated foundations of my *Red Lake* landscape are formed from these papers, layered with paint (Figure 3). As I developed the fragmented imagery, I considered both events that could break up and challenge geoscientific knowledge production, and what actions might repair the broken foundations. The 24K gold leaf deliberately ties the painting to real gold production networks, but also alludes to a *kintsugi*-inspired conception of repair (Keulemans, 2016; McLaren, 2018).[8]

Figure 3

Red Lake, process details



Note. This work was created through an iterative process of paint and collage.

Foundations

There can be no mistaking the distinctive yellow colour and bright metallic lustre of gold. One of the first lessons I was taught as an inexperienced geologist scanning the drill core for visible gold was: *If you have to wonder, it's not gold*. Gold is both a chemical element (Au) and a naturally occurring crystalline material, meeting all the criteria to be classified as a mineral in the class native elements.[9] In addition to its alluring colour and lustre, gold is prized for its adaptable mechanical properties. This metal is highly malleable, ductile and sectile. It can be stretched into fine wires, hammered into sheets as thin as a few micrometres, or carved with tools. It is electrically conductive and chemically inert at the Earth's surface. Pure gold has a very high density of 19.3 g/cm^3, owing to the tight packing of atoms in its crystalline structure and high elemental mass (196.97 g/mol). Crustal concentrations of gold are rare, since gold is a siderophile (iron-loving) element that is not compatible in the silicate minerals that make up most of the Earth's crust. This means that accumulations of gold occur only in specific geologic settings and are therefore tied to specific places and geographies.

The geological story of the Red Lake gold begins somewhere between 2.73 and 3 billion years ago, when the central Canadian Shield, known as the Superior craton, was assembled through collisions of smaller bits of crust (Fensome et al., 2014). Through these tectonic collisions, the rocks were subjected to intense compression and heating, as well as injections of magma and mineral-saturated fluids (Fensome et al., 2014). Strips of ancient seafloor, composed of iron- and magnesium-rich lava rocks, basalt and komatiite, were caught up in the collisions between these blocks of crust. The gold in present-day Red Lake occurs in one of these slices of seafloor, formed from interlayered lava rocks and muds, with most of the gold mineralization occurring in a package of rocks known as the Balmer assemblage (Twomey & McGibbon, 2001). Further tectonic movements continued to cause stretching and compression, flowing and fracturing, of these rocks, creating conduits (shear zones) to channel mineral-bearing fluids (Zhang, 1997).[10] Considerable effort has been made by geologists to characterize the chemistry of the fluids and the pressure-temperature regimes that resulted in precipitation of the gold, with the hope that the specific geological and geochemical indicators of Red Lake mineralization may be generalized for both local and regional prospecting purposes (Harris et al., 2006). Because the gold-bearing veins parallel minerals in the shear zones, it is believed that fluids were injected under high pressure (Zhang, 1997). The age of the mineralization is thought to be approximately 2,700 million years, based on isotopic uranium-lead ages of microscopic titanite crystals extracted from the gold-bearing quartz veins (Gallagher et al., 2018). The chemistry of

small liquid bubbles trapped in the vein minerals show that these veins were likely injected from crustally-derived fluids at depths greater than 7 km (Chi et al., 2006; Liu et al., 2011).

Here it is easy for me to get lost in the details. Before everything broke apart, the foundations of my career were built on the stories that coalesce from systematic empirical analysis of atoms, molecules, minerals, rocks, and fossils. These stories are written in the languages of their analytical tools—the compass and rock hammer, the polarizing light microscope, the thermal ionization mass spectrometer—and they move across dizzying spatial and temporal scales, from nanometers to thousands of kilometres, from instantaneous events to incremental transformations over thousands of millions of years. As a student I spent innumerable hours examining trays of mineral specimens, learning their particular languages: their characteristic lustres, hardnesses, and cleavages; their preferred mineral kin; the temperatures and pressures for crystals to flourish. I pored over geological maps and then, eventually, created my own. I learned the ways geoscientific knowledge is foundational to addressing environmental challenges ranging from climate change to industrial contamination, providing the means to understand baseline data, technologies for real-time monitoring, and the principles upon which to model possible Earth futures (IPCC, 2021). Geoscientific knowledge provides empirical measures of constraints in the availability of Earth materials upon which we can base plans for sustainable use (Rockström et al., 2009). Geoscientific principles and technologies are used as well to predict and plan for natural hazards that threaten human lives including volcanoes, earthquakes, and landslides (USGS, n.d.). Knowledge of geological time provides a macro-context for human existence, positioning humans as a geological force to define the present moment (Crutzen, 2002; Gradstein et al., 2012; Zalasiewicz et al., 2015).

The cracks were already showing by the time I began to scrutinize the ground beneath my feet more carefully, considering the foundational lessons that were invisible, along with those that were absent altogether. If lessons on the entanglements of gold mining with conflict-driven commodity pricing were absent, what other consequences of translating land to data had I missed in my education? In mapping these foundations, I have considered the ways content and culture were taught during my own professional training, and how I may be replicating these lessons in my own teaching. I am trying to be alert to the practices and stories that geoscientists rely on to establish culture and connection, as well as those that may obscure the sociomaterial effects of geoscientific knowledge production.

Transforming people and things into commodities requires alienating them from their life-worlds (Tsing, 2017). Geologists are often far from home, working on lands to which they have little connection. They act as translators, using observations of the land to create maps that can be read and interpreted by other geologists in urban office towers, then used to fuel the imaginations of executives and speculative investors who will never visit the lands themselves. During my own education, most of my knowledge of geological materials came from mineral, rock, and fossil specimens that were separated from their lands and people. In most cases the connection between a specimen and its origin are long broken, with only passing reference to the country where it was collected: “Corundum; India” or “Native sulphur; Iraq”. Braun (2000) proposes that this process of alienating rocks and minerals from their people and places, both through sample collection and translation of geological information onto maps, was a key method of, and then motivation for, expanding territory during British colonization in present-day western Canada. In gold production networks, the complex hierarchies of corporate relationships, with increasingly isolated and specialized professional roles, may also have the effect of alienating geologists from the consequences of their work (Ayeh & Bleicher, 2021; Dougherty, 2013).

The Red Lake technical papers, though primarily focused on characterizing the rocks and geological setting, situate the purpose of their work in terms of production capital, using past extracted tonnages from the 14 mines that have operated in the area since the Howey mine began production in 1930 as the primary research rationale (Zhang, 1997). The geoscientific knowledge moves to transform the gold found in narrow quartz veins into capital. None of these papers makes mention of the uses of the gold once it has been extracted, giving the impression that the mining itself is the end goal and rendering the social effects of gold production further invisible.

The World Gold Council (2019), asserted that:

> gold plays a unique role in the global economy in protecting the financial security of nations, communities, and families, and in enabling advances in medical, environmental and communication technologies. Public trust is fundamental to the many positive roles that gold plays in society. (p. 1)

In financial markets gold acts as a hedge against inflation, held as a physical commodity, and also traded as Exchange Traded Funds (commodity ETFs; Corcoran, 2021). In 2019, only 7.4% of all global gold demand was used for technologies, while most was consumed by the jewelry sector (48%), purchased as bars or coins (20%), held by central banks (15.2%) or traded as ETFs (9%) (World Gold Council, n.d.). The above statement from the World Gold Council obscures the ways gold mining is

inextricably tied to specific places and specific peoples, obviously in terms of production (for example, Red Lake), but also through events around the globe that influence commodity trading prices (for example, the 2003 invasion of Iraq). In noting that gold prices tend to rise with the onset of violent conflicts, Guidolin and La Ferrara (2010) concluded that "there may be significant incentives for investors to exploit conflict related information" (p. 682).

The influences of commodity trading on geoscience work, along with the networks connecting global conflicts to commodity pricing, were hidden in my own experiences of geoscience education. Like many geoscience programs in Canada, my own education closely followed the academic requirements laid out by the organizations that govern professional registration, reflecting the fact that geoscience work is a regulated profession, like engineering or practicing medicine.[11] The core compulsory knowledge requirements for professional registration continue to be mineralogy, structural geology, sedimentation and stratigraphy, and field techniques (Geoscientists Canada, 2019). Some claim that the focus of geoscientific study has recently shifted from mineral extraction toward conservation (Bjornerud, 2018; Frodeman, 2003), and national surveys of US undergraduate programs in geoscience confirm that, between 1972 and 2007, trends in program-level curricular changes saw an increase of non-traditional specialized courses including scientific writing, Geographic Information Systems (GIS), geochemistry, and hydrology (Tewksbury et al, 2013). Despite signs that disciplinary aspirations may be changing toward a focus on sustainability and hazards, my observation is that undergraduate curricula at Canadian post-secondary institutions remain substantially similar to my own studies, and that the most readily available employment opportunities for new graduates continue to be in the mineral exploration and mining sectors. Additionally, it has been predicted that, in coming years, there will be increased need for geoscientific expertise, as demand grows for metals and other raw materials necessary to access renewable energy (Mining Watch, 2020). How do the structures and practices of undergraduate geoscience education continue to obscure the potential harms of translating land into capital through geoscience knowledge production?

Repair

Repair is not a word a geoscientist would usually use to describe the reconsolidation of brecciated material, but here I feel compelled to resist more passive process-oriented terminology like *cementation or lithification*. To repair these fractured foundations requires a decision that the fragments are worth salvaging, and, further, it requires rejecting the option of razing the whole project to start fresh. Repair is

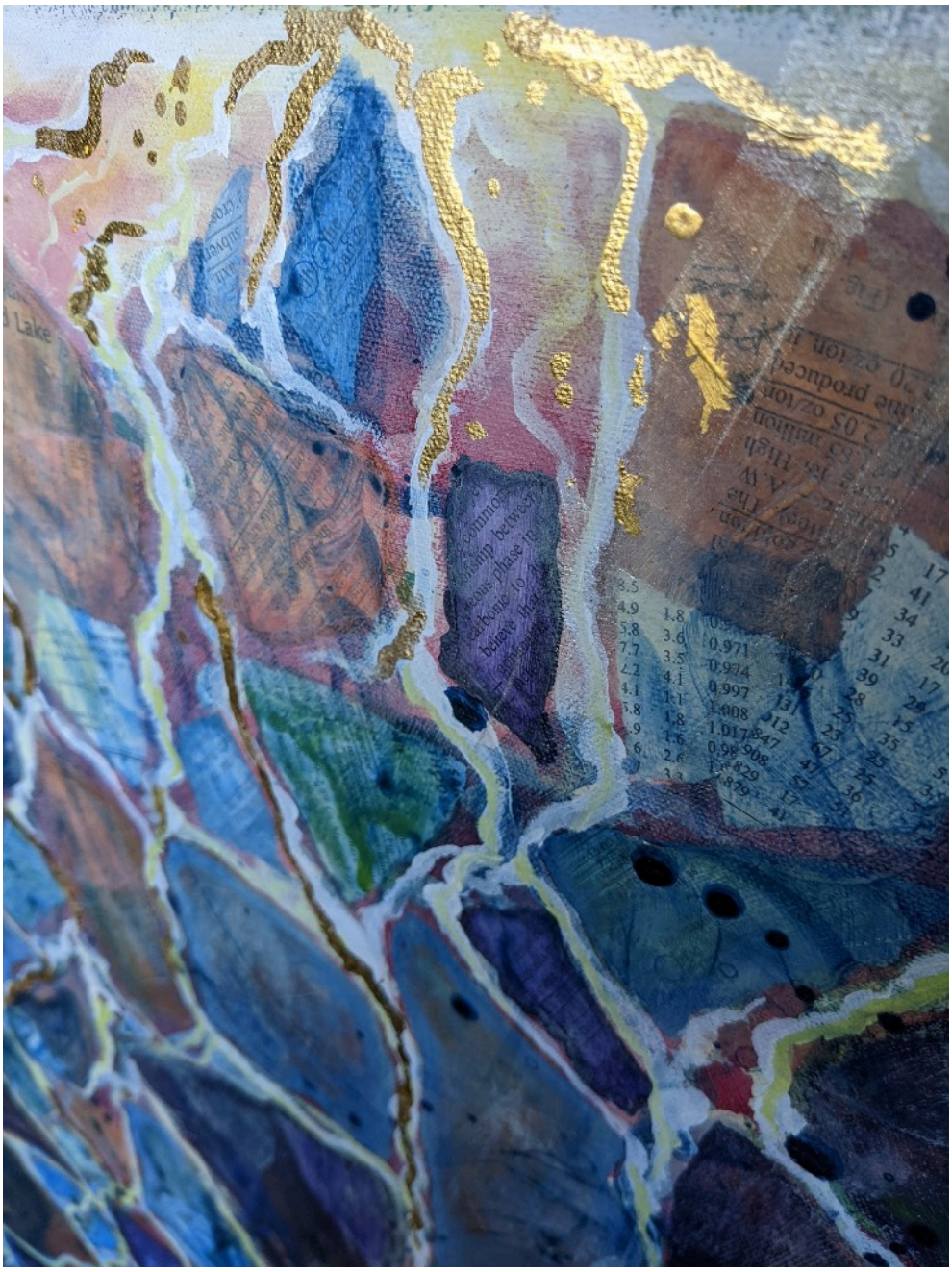
situational, specifically tied to materials, relationships, and intended uses. Depending on the context, it may encompass some or all of reconstruction, remediation, restoration, reconfiguration, or reconciliation (McLaren, 2018). Transformative repairs, whether in kintsugi pottery, naturally-formed breccias, or those I have represented in the painting Red Lake, alert us to our vulnerability and link to "perceptions of threat, urgency, catastrophe, risk, but also care, amelioration or hope" (Keulemans, 2016, p. 17). It can take a long time before minerals begin to heal the fractures. My comfortable relationship with geoscience was broken nearly two decades ago, and this arts-integrated inquiry marks one of my first formal steps toward repair.

I have been trying to identify processes of repair, both inside and outside disciplinary discourses on professional and corporate ethics, following the fracture lines to also consider critical perspectives from the fields of education, cultural studies, science and technology studies (STS), and feminist research. Following Alaimo and Hekman (2008), I have found that my troubles[12] at the confused interface between geology, politics, history, discourse, ethical practices, art, technology, and the Earth, have both challenged and opened up generative possibilities for what might bring transformative repair to my relationship with geoscience. Personal storytelling and visual art have been my preferred methods of analysis across the sometimes dissonant perspectives. These dissonances are likely the reason that arts-integration, though common in educational research (Barone & Eisner, 2011; Holm et al., 2017; Irwin, 2008, 2013), remains extremely rare in research focussed on post-secondary technoscientific training. Using art as a way to work with, to challenge, and to transcend disciplinary conventions, I consider the frictions[13] made visible through my experience at the Red Lake mine. I have relied on visual art to "disrupt common [disciplinary] understandings" (Sameshima et al., 2019, p. 36), and hope that the arts-integrated analysis has produced "objects that work not only across discursive fields but challenge the norms of those fields" (Loveless, 2019, p. 37).

Creating the art piece *Red Lake*, began as a way for me to analyze the causes and consequences of my disillusionment with the images of damage and brokenness occupying my attention in the early phases of creation. As the work emerged, however, I began to focus on the openings, the gaps between the now dissociated fragments, and my attention shifted toward processes of transformation. I began asking: *What could heal this broken landscape?* In the final phases of creation I applied 24K gold leaf to the fractures, replicating the occurrence of gold in the geological formations of the Red Lake area, while specifically tying this piece to gold production networks. The addition of the gold also serves to bind the fragments together, at the same time adding emphasis and embellishment to the fractures (Figure 4).

Figure 4

Red Lake, gold leaf detail



Encouragingly, since 2003, the perception of the geosciences as a value-neutral discipline has begun to shift. Communities of discourse have emerged around both geoethics and responsible mining to address growing concerns around sustainability, as well as socioenvironmental justice in geoscientific and extractive industries (Ayeh & Bleicher, 2021). The sociocultural dimensions of geoscientific practice, research, and training have begun to be problematized in more varied and nuanced ways, especially around gender disparities (Gries, 2019; Nentwich, 2010; Thornbush, 2016), racism (Bernard & Cooperdock, 2018; Bush & Mattox, 2020; Dutt, 2020; Mattheis et al., 2019), and colonialism (Liboiron, 2021). Geoethics integrates philosophical and practical approaches to address ethical relationships between the geoscientist and self, the profession, society, and the Earth (Peppoloni & Di Capua, 2017). Within geoethics discourse, geoscience is positioned as an important knowledge framework to inform decision-making around socioenvironmental issues including sustainability, water, energy, and environmental hazards (Metzger & Curren, 2017; Mogk et al., 2018). In my readings of the geoethics literature, however, I have not found perspectives that adequately address the moral and ethical complexities of producing minerals as commodities for trade, where wealth and corporate profits may be generated by violent conflicts, or where end material uses may be demonstrably unsustainable. Integration of geoethical training into undergraduate education has been identified as a key opportunity to improve sociocultural and ethical decision-making for geoscientists (Mogk et al., 2018; Mogk & Bruckner, 2020; Ryan & Bank, 2017), and teaching modules are available from the National Association of Geoscience Teachers website Teach the Earth (Mogk, n.d.) and GeoContext (Pico et al., n.d.). But despite broad recognition of the local, regional and global implications of geoscientific research and professional practice, with some suggesting that geoscientists have a responsibility to act as “spokespeople for an unstable Earth” (Castree, 2017, p. 54; see also Bjornerud, 2018), geoscientists continue to be socialized and educated to avoid value judgements in their work (Castree, 2017). Acknowledging this contradiction in educational settings seems an important first step in developing more nuanced conversations around extractive ethics in geoscience.

Facing criticism on social and environmental records, corporations in extractive industries are adopting principles of corporate social responsibility. I find it easy to agree with The Responsible Gold Mining Principles listed by the World Gold Council (2019). Of course, corporations should conduct business with integrity and oppose corruption. Yes, corporations should understand the impacts of their business on stakeholders and should protect the health and safety of the people they employ and contract. Obviously, corporations should respect human rights, protect fragile ecosystems, and make

efficient use of materials. I am left wondering, however, if these principles, like the principles of geoethics, establish arbitrary boundaries on responsibility that oversimplify and obscure the complex global effects of gold production networks, further rendering some of these effects invisible. The list of principles specifically addresses human rights and conflict in Principle 5.4: “We will ensure that when we operate in conflict-affected or high-risk areas our operations do not cause, support or benefit unlawful armed conflict or contribute to human rights abuses or breaches of international humanitarian law” (World Gold Council, 2019, p. 5). I continue to have a difficult time understanding how this principle can address flows of speculative capital generated by wars or prevent executives lobbying for a conflict like the 2003 invasion of Iraq.

Ayeh and Bleicher (2021) consider the relationship between the principles of geoethics for geoscience professionals and those of responsible mining for corporations. They conclude that there are gaps and tensions between professional and corporate codes of ethics, in that neither adequately accounts for the structural complexities inherent in the mining industry. Technical specialization, the short-term contracting and sub-contracting of specialized work, and the flow of properties and projects between different corporate entities (junior, mid-level, and senior mining companies) may all act to make it difficult for people to care about the effects of their work. Not to mention that these codes of ethics do not address deeper issues of how the end uses of a mined material, whether held in a bank vault or manufactured into gold leaf for crafters, might determine whether mining can be considered “responsible.”

The question of care has been seeping down into all my cracks. I first began to wonder about the relationship between scientific knowledge and care, provoked by a question posed by Kimmerer (2013): “For what good is knowing, unless coupled with caring? Science gives us knowing, but caring comes from someplace else” (p. 345). Kimmerer’s question opens up a possible antidote to the cultures of alienation that seem to pervade industries that convert land to capital (Tsing, 2017). This question prompted me to consider what it means to care, and, more specifically, what an ethic of care might look and feel like in geoscience. Caring seems to be both a prerequisite for repair, and the means through which it can be accomplished. Care is “everything that we do to maintain, continue, and repair our ‘world’ so that we can live in it as well as possible” (Tronto, 1993, p. 103). Puig de la Bellacasa (2017) argues for a multi-dimensional ethic of care in technoscience–affective, practical, and ethico-political. An ethic that is relational, founded in doing, attends to “neglected things” (p. 27), is specifically situated, non-innocent, and practiced as an affective concern. There is no room for alienation in this kind of care ethic, which requires “thick, impure, involvement

in a world where the question of how to care needs to be posed" (Puig de la Bellacasa, 2017, p. 6).

To repair my relationships with geoscientific knowledge and practice, there is no way for me to avoid being present in the act of caring, despite my discomfort. Mediating this story through my own artistic work, and sharing this analysis as a first-person account, are deliberate strategies to position myself responsibly and to be accountable for my partial perspectives, within the networks of geoscientific knowledge production (Haraway, 1988). After twenty years of passive-voice invisibility, I will admit to getting some small satisfaction from revealing myself through this work; however, my personal entanglements with the places detailed here have complicated this feeling. This process has also raised feelings of ambiguous grief as I have engaged critical perspectives on the relationships of geoscience with violent conflict, extractivism, neoliberal economic policies, and neo-colonialism (Butler, 2004). In order to practice care from a non-innocent standpoint, I have to take critical perspectives seriously, and I have found the intersectional principles of data feminism presented by D'Ignazio and Klein (2020), with the anticolonial science methodologies of the Civic Laboratory for Environmental Action Research (CLEAR, n.d.) particularly useful in this regard. In their spirit, I hope to engage critical perspectives with care, while avoiding adding "fresh ruins to fields of ruins" (Latour, 2004, p. 225). Here I embrace Haraway's (1997) ethical position to "critically analyze or 'deconstruct' only that which I love and only that in which I am deeply implicated" (p. 151). Arts-integration is used here as a way to turn careful attention to the difficult knowledge, as a way to both deconstruct and rebuild. This work is a first step toward making visible, and challenging, some of the hidden lessons and omissions in geoscience education that have insulated geoscientists from the effects of their knowledge production. I share my own transformation from broken fragments to breccia, as just one example of the ways that thinking differently about disrupting experiences can open up opportunities and possibilities for repair that did not exist before.

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ENDNOTES

1. Here I use the term geoscience synonymously with earth science and geology, though there is some perception that *geology* relates specifically to the solid Earth—or may be tainted by its association with exploitative mining practices—and earth or geo-sciences can broadly encompass earth materials, with a more environmental focus (Frodeman, 2003). Frodeman (2003) challenges this idea, bringing the term geology back to its Greek etymological origins, *geo* (earth)–*logos* (study), claiming *geology* is broad enough to encompass geoscience, along with geopoetry, geopolitics, and geotheology. In my experience this integrative perspective is typical neither in training nor practice of geology, geoscience, or earth science. Here I use the term *geoscience* to indicate a discipline inclusive of earth materials and based on empirical study of earth materials.

2. Gold production networks encompass the web of actors and processes through which gold is produced and consumed (Geenen, 2018). Geologists are most active at the front end of the gold production network, though geological knowledge continues to move through corporate hierarchies making possible extractive production, but also fueling the imaginaries of speculative investing.

3. Guidolin nd La Ferrara (2010) tested the correlation between asset market reactions (including gold) and onsets of violent conflicts, concluding that wars could be exploited to produce abnormal investment profits. Of particular interest here, they found that gold prices were particularly sensitive, and likely to rise, during conflicts in the Middle East.

4. There are several types of commodity exchange-traded funds that depend on the price of gold, including equity ETFs, exchange-traded notes, futures funds, and those based on the physical commodity. See Corcoran (2021) for a more detailed explanation of each type.

5. In her book *Friction: An Ethnography of Global Connection* (2005), Tsing discusses the conditions that led to the infamous Bre-X mining scandal of the late 1990's. On the basis of favourable geological reports, Bre-X, a junior mining company, claimed to have discovered a huge gold deposit in the Kalimantan region of Indonesia, sparking a rush in both speculative investment and in corporate competition for rights to mine the deposit. Ultimately the geological data was shown to be fraudulent and geologist Michael de Guzman was dead after falling from a helicopter into the jungle. This scandal continues to be used as a cautionary tale on professional ethics for geoscience students.

6. Both Yusoff (2018) and Butler (2015) apply a critical paradigm to geoscientific knowledge production networks, especially considering the ways modes of classification have allowed racist logics to permeate the scientific decision-making and ethical practices in geoscience. Butler summarizes a series of narratives used by geologists and other mining professionals to secure innocence in their exploitation of mineral deposits in Africa. One of these stories that I find particularly problematic, and that continues to move through geoscientific practice with the effect of dispossessing peoples of their homelands, is the myth of terra nullius (empty land), which sometimes masquerades as exploring the wilderness. Terra nullius has been one of the principal logics in European colonization practices and continues to undergird Canadian property laws (Reid, 2010). It has been identified specifically by the United Nations Declaration on the Rights of Indigenous Peoples (United Nations, 2007) and, closer to home, by the Truth and Reconciliation Commission of Canada (Truth and Reconciliation Commission of Canada, 2015) as a false concept that needs to be repudiated by all levels of governments. Considering this narrative has me thinking about the ways that war may move the colonial-era myth of *terra nullius* into the present by opening up bomb-shattered lands to future mineral exploration.

7. Here I use *innocent* in the sense of Haraway (1988), who contends that “a commitment to mobile positioning and to passionate detachment is dependent on the impossibility of innocent ‘identity’ politics and epistemologies” (p. 585). Puig de la Bellacasa (2017) extended the work of Haraway to encompass non-innocent relationships to both humans and others, as essential to caring involvements. A non-innocent approach requires engaging difficult knowledge and critical perspectives from a specific position.

8. *Kintsugi is* a Japanese technique used to repair broken pottery with lacquer resin, mixing in gold dust to draw attention to both the damage and the repair. Keulemans (2016) draws on Deleuze and Guatteri to position *kintsugi* as a transformative repair process by which the care and attention to the repair gives the repaired object an affective power, with broader cultural implications.

9. The mineralogical properties and geologic occurrence of gold are described in detail in innumerable rock and mineral guides, as well as geology and mineralogy textbooks. Here I follow Johnsen (2002), Bishop et al. (2005), Nesse (2017), Wenk and Bulakh (2004), and Perkins (2001).

10. Early barren carbonate and quartz veins in the shear zones are overprinted by gold-bearing quartz veins, with sulphide minerals that could include arsenopyrite, pyrite,

sphalerite, chalcopyrite, and/or stibnite (Gallagher et al, 2018; Twomey & McGibbon, 2001).

11. In Canada, geoscience is a provincially-regulated profession, with educational requirements following those laid out by Geoscientists Canada (Geoscientists Canada, 2019). Those meeting the educational and practical requirements of the pertinent provincial regulatory body are granted the status of Professional Geoscientists (P.Geo.). Four foundational courses continue to be compulsory for professional registration: Field Techniques, Mineralogy & Petrology, Sedimentation & Stratigraphy, and Structural Geology.

12. See Haraway's *Staying with the Trouble* (2016).

13. Tsing (2005) describes frictions as the awkward engagements that happen across cultural contexts in global production networks "where words mean something different across a divide even as people agree to speak" (p. xi). I see this trouble-making character of arts-integrated research as particularly suited to mapping difficult fields of knowledge that may be filled with frictions. Loveless (2019) advocates for research-creation beyond disciplinary boundaries, driven by "curiosity that gets one into (methodological/ontological/epistemological/disciplinary) trouble" (p. 23).